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Soil science and fertilizer use

PODUCTION AND USE OF POTASSIUM FERTILIZERS – THE MODERN VIEW IN EUROPE

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Abstract

The consumption of fertilizers and productivity of agricultural land had been strongly declined in Central and Eastern European countries since 1988/1989. The renewed increase in fertilizer use is observed at last decade during the transition to market economy. But fertilizers applied are unbalanced to replenish the nutrients removed with crop yields from the soil. It is very important to prevent a reduction of soil fertility level, especially soil K status. In this paper the consequences of the different fertilizer applications for crop yields and quality of production are discussed.

Key words: soil testing, fertilizers, efficiency, crop response, production quality

Introduction

It is a necessity to maintain the land productivity on the appropriate high level, due to the important role of agriculture in economy of many European countries. The fertilizer consumption has been strongly increased in Central and Eastern Europe (CEE) since the beginning of the 60's to the end of the 80's. This period was characterized by significant crop production growth and build up of soil fertility. Part of soils with very high nutrient concentration provides environmental concern in several countries. But the agriculture production sharply decreased by about 20 to 40% since the beginning of the 90's, as the result of decline in fertilizer consumption. Since 1993/94 a renewed slow increase in fertilizer consumption is evident. But the present insufficient and unbalanced fertilization leads to unstable agriculture production, poor crop quality and soil fertility depletion. Poor financial status of farmers is the major obstacle for efficient use of fertilizers and manure. Still there is a need for development of helpful agricultural politics and relevant fertilization strategies.

Materials and Methods

Yield and fertilizer consumption data of selected countries were collected from official statistics FAO, IFA and from publications of scientists. Typical tendencies were analyzed and needs for future development discussed.

Examples of crop responses to fertilizes were taken up from BRISSA long-term field experiments conducted by conventional methods on different textured Podzoluvisol soils. Economic efficiency parameters of fertilizer application in this paper were calculated using the crop response data and current prices of fertilizers and crop production. The values are given in US dollars according to official transfer rate of National Bank of Belarus. In the soil samples mobile P_2O_5 and K_2O was determined by extraction in 0.2 M HCl in 1:5 ratio with following determination by calorimetric and flame emission spectrophotometer methods correspondingly. Soil reaction pH was determined with a glass electrode in an aqueous suspension of 10 g of dry soil and 25ml of 1 M KCl, stirred and left to stand overnight. Concentration of ^{137}Cs in plant and soil samples was measured by gamma spectrometry with a HP-Ge detector Canberra GC4019.

Results and Discussion

Global fertilizer consumption increased during period from 1950 to 1988/89 from 14 to 145.4 million tons $N+P_2O_5+K_2O$, or almost 6% annually. After 1988/89 the world fertilizer use decreased continuously until 1993/94 when it reached 120.5 Mt (Table 1). The sharp reduction of fertilizer consumption was observed mostly in countries of Central Europe and Former Soviet Union (Eastern Europe and Central Asia). It has been caused by political and economic reforms and disintegration processes. Policy changes related to production subsidies, ecological considerations and set-aside programs in Western European countries also caused some reduction (23%) in fertilizer use. However continuous increasing of crop yields has been observed in Western countries at the same period due to the technical and management improvements.

Table 1. World fertilizer use by regions, Mt, 1988/1999–2002/2003 (derived from IFA, 2004)

Fertilizer	Region	1988/1999	1993/1994	2002/20033
Total $N+P_2O_5+K_2O$	Western Europe	22.4	17.2	15.4
	Central Europe	9.8	3.1	3.5
	Eastern Europe &Central Asia	27.2	7.6	3.9
	World	145.4	120.5	142.0
Nitrogen	Western Europe	11.3	9.3	9.1
	Central Europe	4.6	2.0	2.3
	Eastern Europe &Central Asia	11.6	4.0	2.5
	World	79.5	72.4	85.2
Phosphorous	Western Europe	5.1	3.7	3.0
	Central Europe	2.6	0.6	0.6
	Eastern Europe &Central Asia	8.6	2.0	0.6
	World	37.7	29.0	33.4
Potassium	Western Europe	5.9	4.2	3.4
	Central Europe	2.6	0.5	0.6
	Eastern Europe &Central Asia	7.0	1.7	0.8
	World	28.0	19.2	23.4
Ratio K_2O:N	Western Europe	0.52	0.45	0.37
	Central Europe	0.56	0.25	0.26
	Eastern Europe &Central Asia	0.60	0.44	0.32
	World	0.35	0.27	0.27

During the last period from 1993/94 to 2002/2003, world total nutrient consumption increased from 120.5 to an average of 142 Mt. Consumption in West Europe and Central Europe stabilized while demand in the FSU fell again. Increment of global fertilizer consumption at last period was achieved mainly in developing countries of Asia and Latin America. Future fertilizer requirements have been related to FAO's latest forecasts of worldwide crop yields and areas. In order to provide the feeding over 8 billion of people in 2030, it is forecast that fertilizer consumption will have to increase to 188 million tones of nutrients $N+P_2O_5+K_2O$ (Bruinsma, 2003). This represents an annual growth rate of between about 1 percent per annum, which compares with an average annual increase of 2.3% p.a. between 1970 and 2000. Presently world nitrogen consumption had exceeded its 1988/89 level, with stabile level in Europe and further fall in the FSU. However, world phosphate consumption remains below its 1988/89 peak, as does that of potash.

The current relative level of fertilizer application per hectare of arable land in 2002/2003 represents a great difference between the countries of Western and Eastern Europe (Table 2).

Table 2. Fertilization and productivity of agriculture in some European countries

Country	NPK kg ha^{-1} of arable land (2002/2003)	Ratio N: P_2O_5: K_2O	Cereals yield, t ha^{-1} (2002-2004)	Livestock production, tons per 100 ha (2002-2004)	
				Milk	Meat
Germany	220	1:0.18:0.27	6.3	165.5	39.2
Belarus	147	1:0.28:1.15	2.7	58.7	7.2
Lithuania	113	1:0.38:0.31	2.8	51.6	4.8
Poland	109	1:0.36:0.45	3.0	66.5	17.2
Estonia	44	1:0.24:0.38	2.2	95.9	8.8
Latvia	27	1:0.17:0.29	2.3	34.0	2.7
Ukraine	18	1:0.12:0.06	2.5	34.1	4.1
Russia	12	1:0.35:0.20	1.9	14.8	2.3
Moldova	5	1:0.11:0.11	2.7	24.2	3.7

In Germany the comparable mineral fertilizer input amounts to 220 kg ha^{-1} NPK and correspondingly high yields of cereal crops (6.3 t ha^{-1}) and livestock production are being achieved in average for 2002–2004. Ukraine, Russian Federation and Moldova are characterized by very low levels of fertilizer consumption and rather low agricultural output, especially of livestock production. Belarus, Lithuania and Poland have medium level of fertilizer consumption. It is clear that differences in the level of fertilizer input between the countries could only partly explain the differences in the output of main agriculture production.

The most important problem for countries of Eastern Europe is the mining of nutrients and depleting the potential level of soil fertility. The use of phosphate and especially of potash fertilizers is far below the level of nutrient removed by crops. The fertilizer usage is unbalanced in many countries. The NK ratio in fertilizer use strongly varies in different countries from a roughly balanced value of 1:1.15 in Belarus to 1:0.06 in Ukraine. The high level of potassium application in Belarus could be partly explained by decision of Belarusian Government to 50% subsidizing of K-fertilizer price for domestic use. The unbalanced ratios contrasts with the ratio in which plants absorb N and K. Cereals for example take up nitrogen and potassium in almost equal quantities, vegetables and root/tuber crops absorb even more potassium than nitrogen.

Germany keeps acceptable K balance in agriculture because of high level of manure application. However, results from 650 field trials in Germany showed that, at the lowest level of exchangeable K, cereals lost 18% and leafy crops like potato or sugar beet almost 40% of yield opportunity (Krauss, 2000). The level of farmyard manure application in Belarus and Poland nowadays is about of 6 tons per hectare of arable land. Estonia and Lithuania have the medium level of manure application, about 4.5 tons per hectare. The lower husbandry production is observed in Latvia, Moldova and Ukraine. The average level of farmyard manure application in Ukraine is about 1.3 tons per hectare of arable land. Recently (1999–2000) the soil surface phosphorus balance in Poland was sustainable, while the potassium balance was negative in most of regions (Igras, Kopinski, 2003). Negative potassium balance was reported in Lithuania but phosphorus showed a very slight surplus (Lazauskas, 2000).

Since 2001 there is a positive trend of a renewed increase in K fertilizer consumption in Lithuania and Ukraine (Fig. 1). Belarus has showed a drop in K fertilizer use because of build up of K soil reserves during continuous positive potassium balance in agricultural land at last period.

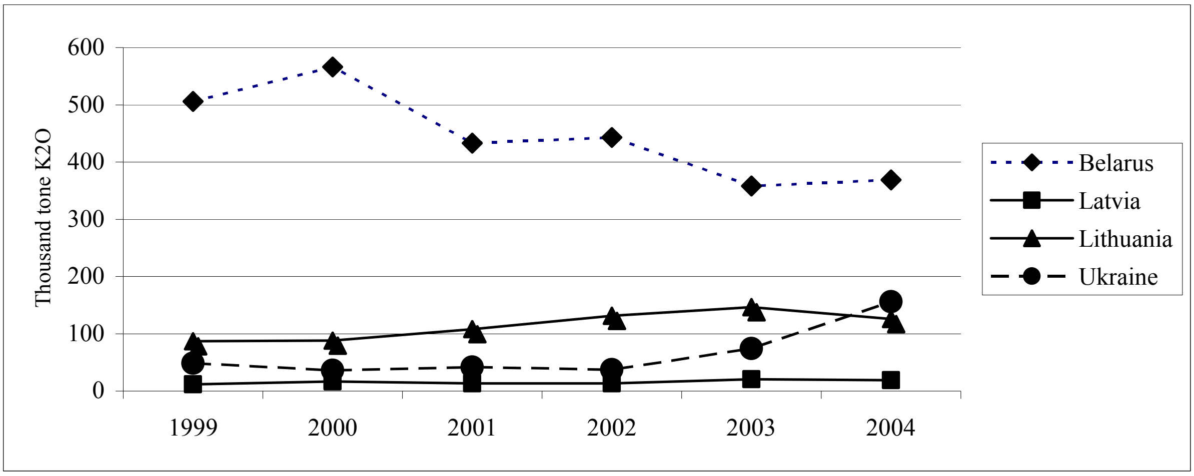

Figure 1. Dynamics of total K fertilizer used in Belarus and neighboring countries in 1999–2004

But the problems of required agriculture production output and soil fertility maintenance still are not settled. For instance, the negative P balance in arable soils is observed in 82 from 118 districts of Belarus. It is evident that in the most of Eastern European countries agricultural production is mainly done at the cost of soil reserves.

Long intensive cropping with low rates of potassium fertilizer decreases the level of available K in the soil. It could be seen from results of BRISSA long-term field experiment conducted on Podzoluvisol loam soil in Minsk district, Belarus (Table 3). Agrochemical parameters of soil arable horizon were as follows: humus 2.0%, pH (KCl) 5.7–6.0, mobile P_2O_5 341-381 mg kg^{-1}, K_2O 265–317 mg kg^{-1}, total N content – 0.11–0.13%. Crop rotation: vetch-oat mixture (green mass), winter triticale + clover, 1^{st}-year clover, 2^{nd}-year clover, spring wheat, oat. During crop rotation complex fertilizing ($N_{68}P_{32}K_{59}$) resulted in crop productivity 10.32 t ha^{-1} of cereal units (c.u.) and response – 13.3 c.u. per 1 kg of NPK and maximal net return from fertilizer use – 78 USD per ha. The mentioned treatment of fertilizer system provides the maintenance of achieved level of phosphorus and humus in tested soil. However annual application of 59 kg ha^{-1} K_2O is not sufficient in order to keep up achieved level of potassium content in soil. Effective potassium dose, which need for the maintenance of initial K-content in Podzoluvisol loam soil, is about 120 kg ha^{-1} of K_2O. At this K fertilizer rate crop rotation productivity is increased by 0.26 t ha^{-1} c.u. with minor reduction of net return. The unbalanced use of N-fertilizer resulted in relatively high crop productivity (9.70 t ha^{-1} c.u.) but was accompanied with significant reduction of mobile fractions of phosphorus and potassium in soil – by 48 and 98 mg kg^{-1} respectively. This experimental treatment shows typical picture for many countries. For instance, Karklins (2003) reported that unbalanced fertilizer use is still a problem for many farmers in Latvia. Tendency for fast and short-term economic returns is a reason to give preference to nitrogen application.

Table 3. Fertilizer efficiency in crop rotation on Podzoluvisol loam soil (1995–2003)

Treatment	Annual yield, t ha^{-1} c.u.	Response, c. u. per 1 kg of NPK	Net return, USD per ha	Soil P_2O_5, mg kg^{-1}		Soil K_2O, mg kg^{-1}	
				2003	+/– to 1995	2003	+/– to 1995
Control	7.40	–	–	229	–25	102	–18
FYM 10 t ha^{-1}	8.21	–	3	238	–22	140	–37
N68	9.70	21.9	65	284	–48	196	–98
N68P32K59	10.32	13.3	78	340	–1	241	–34
N68P64K119	10.58	9.4	72	352	21	265	2
$LSD_{0.05}$	0.18						

Efficiency of K fertilizer strongly depends on the soil supply with available potassium for growing plants. Four levels of exchangeable potassium supply (104-167-209-299 K_2O mg kg^{-1}) of Podzoluvisol loamy sand soil were prepared for study in the field experiment (Table 4).

Table 4. Effect of K-fertilizer on the yield of winter rye depending of K-supply of loamy sand soil (2004)

K_2O mg kg^{-1} of soil (F_A)	Grain yield at fertilizer treatment, t ha^{-1} (F_B)		Response of yield to K fertilizer		
	N90P30	N90P30K120	t ha^{-1}	%	per 1 kg of K_2O
104	2.01	2.79	0.78	39	6.5
167	2.32	3.02	0.70	30	5.8
209	2.59	2.98	0.39	15	3.3
299	2.72	3.03	0.31	11	2.6
LSD_{05} for grain yield: F_A	0.17	0.17			
LSD_{05} for grain yield: F_B			0.19		

Winter rye (cultivar Igumenskaya) was grown in 2004 in this experiment at farm Druzhba, Minsk region. Arable horizon was characterized by favorable agrochemical parameters: pH (KCl) 6.0–6.2, contents of P_2O_5 300–350 mg kg^{-1}, humus 2.64–2.71%. The studying treatments include two factors: K-fertilizer and K-content in soil. The increase of soil K-supply from 104 up to 209 mg kg^{-1} accompanied with significant enhance of grain yield on NP treatment. On the NPK treatment the yield response to soil K supply level was observed only up to 167 mg K_2O per kg of soil. Further increase of potassium content in soil did not followed by yield increase. Application of K120 provided yield increase from 39% on first soil K supply level to 11% on fourth level. Grain response to 1 kg K_2O fertilizer applied was related to K content in soil. At lower levels K-supply of soil (K_2O 104-167 mg kg^{-1}) the grain responses to 1 kg of K_2O were higher, accordingly 6.5–5.8 kg.

K fertilizer positively affected on amino acid composition of winter rye grain. Positive effect on grain quality was observed because of K90 application at low and medium K content in soil (Table 5).

Table 5. Influence of K fertilizer on amino acid content in winter rye grain, %

Treatment	Lysin	Thre-onine	Methio-nine	Iso-leucine	Leucine	Phenyl-alanine	Total critical	Total irreplaceable
N90P30	4.02	3.50	1.50	5.00	7.03	5.49	31.8	9.0
N90P30K90	4.29	3.78	1.69	5.37	7.6	5.90	34.2	9.8
Response to K90	0.27	0.28	0.19	0.37	0.57	0.41	2.39	0.8

The increase of biological quality indices of rye grain was also observed during the K supply increment from 104 to 167 mg K_2O kg^{-1} of soil.

It is well known that crops with adequate supply of potassium also have a better resistance to unfavorable weather conditions. Long-term field investigations with spring triticale, potatoes and sugar beet in Poland showed that adequate K fertilization practice may be one of the cheapest ways to diminish the negative effect of naturally occurring, short-lasting drought on crop growth and yield (Grzebisz, 1998). Our experiment on oat showed badly damaged germinations by night frost (–10–16 °C) in mid May 2000. During the vegetation period there was visible difference in plants growth on N90 P60 treatment with different levels of K soil supply. The mean grain yield at harvest was 2.3 t ha^{-1} on plots with low K_2O content (94 mg kg^{-1} of soil), while on the plots with high K supply (194 mg K_2O kg^{-1}) the grain yield made 3.6 t ha^{-1}, or 56% higher.

Numerous field trials prove the beneficial effect of balanced fertilization with potassium on the quality of the harvested product. The review of 2450 references (Perrenoud, 1990) showed that correct balanced fertilization with potash resulted in a greater than 50% reduction in disease and pest incidence, and at the same time considerably higher yields. The nutrition affects the yield, growth pattern and morphology of plants, that is especially important for crops grown for fiber (Table 6).

Table 6. Effect of balanced nutrition of on yield of flax fiber on Podzoluvisol clay loam soil

Treatment	Yield of fiber	Long fiber,%	Response, t ha^{-1}	Profit, USD ha^{-1}
Control	2.15	50	–	–
N25P87K132	3.05	53	0.90	292
N25P87K132 + B, Zn	3.21	51	1.06	354
N25P87K132 + B, Zn, S	2.75	63	0.98	321

Compound fertilizers designed for flax by scientists of BRISSA provide balanced nutrition of flax plants with required ratio of macro and micro nutrient, as well as increase the yield and improve the quality of fiber. The experiment shows that expenses for compound fertilizer application and for harvesting of additional yield are well paid. Therefore about 67% of farms growing flax in Belarus used compound fertilizers in 2004.

Potassium fertilizer play significant ecological role because higher yields at balanced fertilization leave less residual N in soils which could pollute the environment. Even greater role of K fertilizer could be seen on radioactive polluted land of Belarus and Ukraine. Potassium, as a chemical analogue of caesium, could effectively inhibit the transfer of radiocaesium from soil to plants. However, the inhibitory effect is strongly dependent of K status of soil, which will determine the effect of K fertilization as countermeasure to reduce the Cs concentration in crop production. The genotypic differences in ^{137}Cs uptake between the various crops are very important; however these also depend on exchangeable potassium content in soil (Bogdevitch, 1999). The example of experiment with potatoes is shown in Fig. 2.

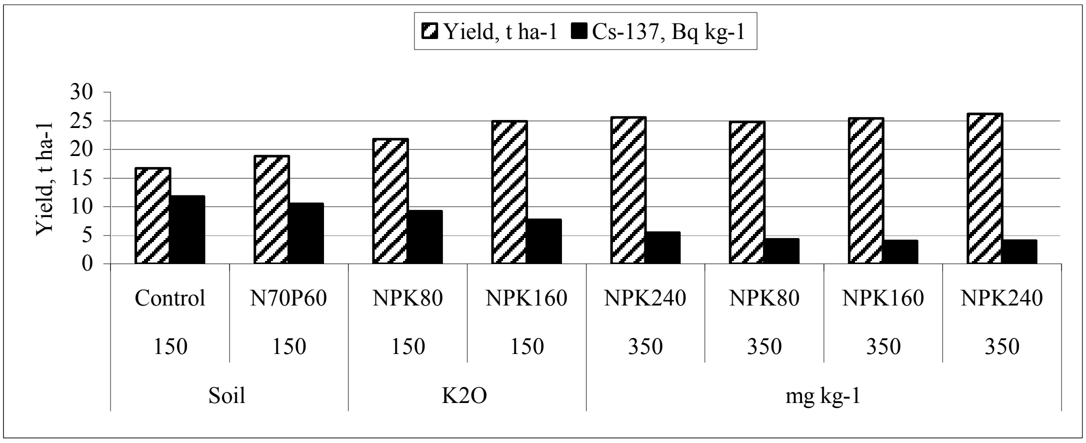

Figure 2. Efficiency of K fertilizer for yield and ^{137}Cs activity of potatoes tubers in dependency on K status of Podzoluvisol loamy sand soil

It was found that improvement of K supply level of Podzoluvisol loamy sand soil from exchangeable K_2O 150 to 250–350 mg kg^{-1} allowed to increase significantly yields and to reduce of radionuclide ^{137}Cs transfer from soil to potato tubers by factor 2. High K-fertilizer rates up to 160–240 kg K_2O per hectare are effective for potatoes cultivation on loamy sand soils with low potassium content. Only moderate potash fertilizer rates are needed for rich K-supplied soils (K_2O 250–350-mg kg^{-1}) to replace of the crop K-removal

Conclusions

The current relative level of fertilizer application per hectare of arable land represents a great difference between the countries of Western and Eastern Europe. Fertilizer application in most of countries of Eastern Europe is low and unbalanced. The lower input of fertilizers in addition with reduced livestock and smaller amount of manure leads to depletion of soil reserves.

Farmers and decision-makers prefer nitrogen fertilizers because of its evident effect. Saving on phosphorus and especially on potassium supply leads to soil fertility decline and therefore to the restricting of the yield potential in future.

Experimental information on the potash effect on yield and quality of production, including the economics of K fertilizer use provides the basic information for the extension of K-fertilizer consumption and for enhancing the efficiency of balanced fertilizer use.

References

1. Bogdevitch I. (1999) Soil conditions of Belarus and efficiency of potassium fertilizers. Proceedings of Workshop organized by International Potash Institute at the 16 World Congress of Soil Science, Montpellier, France, 20–26 August 1998. IPI, Basel, Switzerland, 21–26.
2. Bruinsma, J., ed. (2003) World agriculture: toward 2015/30. An FAO Perspective. Earthscan, London on behalf of FAO, Rome.
3. FAOSTAT (2004): FAO statistical database. Food and Agriculture Organization, Rome, Italy.
4. Grzebisz W. (1999) Interrelationship between water and nutrient supply and response to potassium. Proceedings of Workshop organized by International Potash Institute at the 16 World Congress of Soil Science, Montpellier, France, 20–26 August 1998. IPI, Basel, Switzerland, 39–46.
5. IFA data bank (2004) International Fertilizer Industry Association, Paris, France.
6. Igras J., Kopinski J. (2003) Regional differentiation of the soil surface phosphorus and potassium balance in Polish Agriculture. Proceedings of the Latvia University of Agriculture, LLU Raksti 8(303), 29–32.
7. Karklins A. (2003) Fertilizer recommendation to meet objectives for Good Agriculture Practice approach. Proceedings of the Latvia University of Agriculture, LLU Raksti 8(303), 13–17.
8. Krauss A. (2000) Balanced fertilization, integral part of sustainable soil management. Global Dialogue EXPO 2000, Science in Dialogue, Hanover, Germany.
9. Lazauskas S., Masauskas V. (2000) Prospects of balanced potassium and phosphorus fertilization in Lithuania. Potassium and phosphorus: fertilization effect on soil and crops. Proc. Of the regional IPI Workshop, Dotnuva-Academija, 206–211.
10. Perrenoud, S. (1990) Potassium and plant health. IPI-Research Topics No. 3, International Potash Institute, Basel, Switzerland.

EFFECTS OF K-FERTILIZER AND SOIL REACTION ON YIELD AND RADIONUCLIDES ACCUMULATION IN SPRING WHEAT AND CLOVER

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Abstract
The primary aim of agrochemical countermeasures on radio-polluted lands is to reduce the radionuclide transfer into the human food chain. The productivity and uptake of ^{137}Cs and ^{90}Sr by spring wheat and red clover depending on potassium fertilizer rates and acidity of Podzoluvisol loamy sand soil were studied in field trials in Belarus. A balanced plant nutrition resulted both in the increase of red clover productivity and in the reduction of radionuclides concentration per unit of mass. The application of balanced fertilizer including 120 kg K_2O per hectare in comparison with unfertilized control increased the productivity of spring wheat grain at pH 5.9 on 44% and pH 6.8 on 62% and red clover 58 and 72% respectively. The extent of ^{137}Cs and ^{90}Sr accumulation by spring wheat grain and clover differed significantly. Soil-to-plant transfer factors of radiocaesium and radiostrontium for spring wheat and red clover may be predicted based with consideration on pH tests of Podzoluvisol loamy sand soil. The optimization of soil reaction combined with application of balanced K fertilizer allowed the expansion of the area of spring wheat and clover cultivation on radio-polluted soils for production acceptable food and feedstuff.

Key words: wheat, clover, potassium, ^{137}Cs and ^{90}Sr accumulation

Introduction

The primary aim of agrochemical countermeasures on contaminated lands is to reduce radionuclide transfer into the human food chain. The liming, extra rates of potassium and phosphorus fertilizers are basic elements of the plant production technology in radioactive contaminated zone, which result in essential change of the soil agrochemical properties and radionuclides behavior in soil-plant chain.

There is considerable variation in the soil to plant transfer of radionuclides. This is due to differences in pH, potassium status, clay and organic matter content (Absalom *et al.,* 1995; Arapis and Perepelyatnikova, 1995; Sanzharova *et al.,* 1996).

Exchanges of K-nutrition of plants result in essential change of intensity of accumulation both ^{137}Cs, and ^{90}Sr in plants. Insufficient K supply in soil leads to the intensive involvement of radiocaesium in biological chain on contaminated soils (Waegeneers *et al.,* 2001; Bogdevitch *et al.*, 2002; Ehlken and Kirchner, 2002).

The application of extra rates of potassium fertilizer as a countermeasure is designed to reduce the plant uptake of radionuclides, especially for radiocaesium. Addition of potassium to soils with a low K status significantly increases the pool of available potassium. This lowers the ratio of Cs to K in the soil solution and thus reduces radiocaesium uptake by plant roots. The relationship between radiocaesium uptake and external K level could be described by a negative power function (Massas *et al.*, 2002; Zhu, 2001).

Weather-climatic conditions of southern areas of Belarus are the most suitable in republic for cultivation food-grade wheat. However in connection with high density of contamination of arable lands by ^{90}Sr there is a problem of production of a grain meeting the requirements of permitted levels (Bogdevitch *et al.,* 2003).

Pastures grasses, hay or ensilaged crops are often important contributors to radionuclide intake by animals (Bogdevitch *et al.*, 2001). After Chernobyl accident due to high concentration of radionuclides in leguminous crops the structure of sown areas was changed towards reduction of legumes on contaminated lands. Such feeding practice leads to decrease of productivity and impairment in the quality of the animal-based food products. The introduction of leguminous plants to crop sequence is also very important for the increase of protein yield and for the soil fertility improvement.

The objective of this research work has been done to determine parameters of radionuclide transfer to plants of spring wheat and clover depending on soil fertility status and potassium fertilizer rates. These parameters are the basis for development of protective measures in the long-term post accidental period to decrease the transfer of ^{137}Cs and ^{90}Sr in food chain.

Materials and Methods

Tested crops in the experiments were spring wheat (*Triticum aestivum)* and red clover (*Trifolium pratense).* Research on studying of rates influence of K-fertilizers on a background of changes of soil properties on sod-podzolic loamy sand soil (Podzoluvisol) on ^{137}Cs and ^{90}Sr accumulation by clover was conducted in 2000–2002, by wheat in 1995, 2003. Agrochemical parameters of soil: pH_{KCl} – 4.9; P_2O_5 – 152 mg kg^{-1}, K_2O – 146 mg kg^{-1}, Ca – 521, Mg – 42 mg kg^{-1}, humus 2.1%. Treatments included different levels of soil acidity created by dolomite application and the increasing K-fertilizer rates (Tables 1, 2). Soil deposition of ^{137}Cs – 407 kBq m^{-2}, ^{90}Sr – 41 kBq m^{-2}. The number of clover cuttings: in 2000 – 1, in 2001 – 3, in 2002 – 2. The number of repeated plots was four. Registration area of plots was 16 m^2. Plant samples of clover were collected in budding stage, spring wheat – in full maturity.

In the soil samples the following physic-chemical parameters were measured by conventional methods (Peterburgskiy, 1963), pH was determined with a glass electrode in an aqueous suspension of 10 g of dry soil and 25ml of 1 N KCl, stirred and left to stand overnight. Organic matter was measured on a 1 g soil sample by a calorimetric method based on the reduction of 0.4 N chromic acid. Moveable P_2O_5 and K_2O was determined by extraction in 0.2 N HCl in 1:5 ratio with following determination by calorimetric and flame emission spectrophotometer methods correspondingly. Exchangeable Ca and Mg were determined by extraction in 1 N KCl in the ratio 1:2.5 with following determination by AAS.

^{137}Cs concentration was measured by gamma spectrometry with a HP-Ge detector Canberra GC4019 (IAEA-TECDOC-1092, 1999). Plant and soil samples were put into Marinelli beakers (1.0L) and results were calculated for individual samples both as Bq $kg^{-1}$and as kBq m^{-2} by using the apparent density data for soil.

^{90}Sr concentration was determined by the oxalate method by separation of ^{90}Y. Plant and soil samples were ashed at 600^0 C. ^{90}Sr concentration by beta activity was measured in the liquid scintillation counter (CANBERRA Tri-Carb 2750LL). Results were expressed as activity concentration in Bq kg^{-1}, and recalculated as kBq m^{-2} for soil.

Conventional, variance statistical procedures for data treatment were made with the STATISTICA Program, StatSoft, Inc. (2001).

Results and Discussion

Application of rates of K-fertilizers on background N70P60 promoted increase of wheat yield. At the initial level of soil acidity and N70P60K60 application the crop response of grain was 0.75 t ha^{-1} for two years on the average (Table 1). Increasing of K-rates of fertilizers up to 180 kg ha^{-1} K_2O resulted in the further growth of yield up to 3.68 t ha^{-1} at pH 4.9, up to 4.29 at pH 5.9 and up to 4.58 t ha^{-1} at pH 6.8.

Table 1. Yield of spring wheat grain depending on K-fertilizer rates

Treatment	Yield, t ha^{-1}	Response	
		t ha^{-1}	%
	pH 4.9		
Control	2.79	–	–
N_{70} $P_{60}K_{60}$	3.54	0.75	27
N_{70} $P_{60}K_{120}$	3.60	0.81	29
N_{70} $P_{60}K_{180}$	3.68	0.89	32
	pH 5.9		
N_{70} $P_{60}K_{60}$	3.87	1.08	39
N_{70} $P_{60}K_{120}$	4.02	1.23	44
N_{70} $P_{60}K_{180}$	4.29	1.5	54
	pH 6.8		
N_{70} $P_{60}K_{60}$	4.22	1.43	51
N_{70} $P_{60}K_{120}$	4.51	1.72	62
N_{70} $P_{60}K_{180}$	4.58	1.79	64
LSD_{05}	0.275	–	–

There was the increase of red clover yield at all studied soil acidity levels due to the application of K-fertilizers (Table 2). On each applied kg of potassium (K_2O) have been received 23.8–28.4 fodder units in addition, increase of rates of potassium fertilizers from 60 up to 180 t ha^{-1} K_2O resulted in the further growth of a crop yield without decrease of fertilizers recoupment.

Table 2. Yield of clover green mass depending on K-fertilizer rates

Treatment	Yield, t ha^{-1}	Response	
		t ha^{-1}	%
		pH 4.9	
Control (P60)	28.7	–	–
P60K60	36.4	7.7	27
P60K120	42.5	13.8	48
P60K180	50.7	22	77
		pH 5.9	
P60K60	38.6	9.9	34
P60K120	45.4	16.7	58
P60K180	55.8	27.1	94
		pH 6.8	
P60K60	42.6	13.9	48
P60K120	49.4	20.7	72
P60K180	58.9	30.2	105
LSD_{05}	2.3		

Balanced plant nutrition resulted in both the rise of crops productivity and the reduction of radionuclides concentration per 1 unit of mass. The extent of ^{137}Cs and ^{90}Sr accumulation by spring wheat grain and clover differed significantly (Fig. 1, 2).

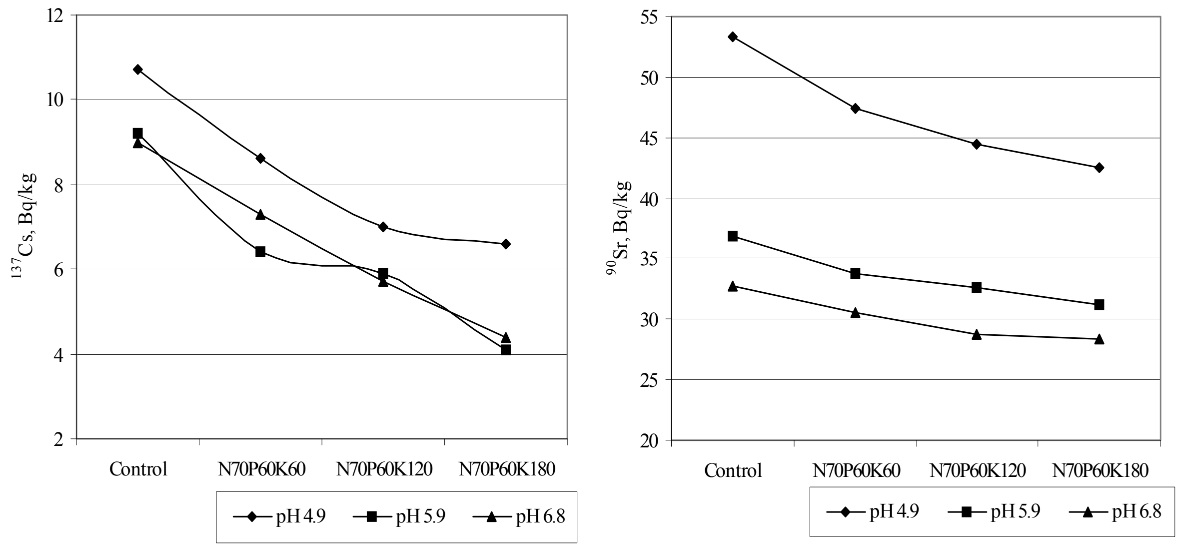

Figure 1. Effect of K-fertilizer on accumulation of ^{137}Cs and ^{90}Sr in spring wheat grain depending on the level of soil acidity at the density of contamination with ^{137}Cs 370 kBq m^{-2} and with ^{90}Sr 37 kBq m^{-2}

In a subacidic interval the further neutralization of soil acidity with the purpose of reduction of radionuclide transfer in grain is less effective. Liming of soil with pH_{KCl} 4.9 up to 5.9 reduced accumulation of ^{90}Sr by grain up to 31% and by red clover up to 22%. The minimal accumulation of ^{137}Cs by spring wheat was observed at N70P60K180 application on pH_{KCl} 5.9 of soil, while minimal ^{90}Sr concentration in grain was at pH_{KCl} 6.8 with the same fertilizer treatment. The minimal accumulation of ^{137}Cs and ^{90}Sr by red clover was found at pH_{KCl} 6.8 and P60K180.

Application of full mineral fertilizer (P60K60-120-180) has allowed to lower ^{137}Cs uptake by clover green mass at an initial level of soil acidity (pH 4.9) in 1.4–2.0 times, at the level with pH 5.9 – in 1.5–2.2, at pH 6.8 – in 1.2–1.8 times (Fig. 2).

Each applied 10 kg K_2O per hectare provided decrease in accumulation ^{137}Cs by green mass of red clover on a background pH 4.9–5.9 – on 1.8 Bq kg^{-1}, on a background pH 6.8 – on 1.1 Bq kg^{-1}; ^{90}Sr – on a background pH 4.9 – on 2.5 Bq kg^{-1}, on a background pH 5.9 – on 2.2 Bq kg^{-1}, on a background pH 6.8–on 1.9 Bq kg^{-1}on average.

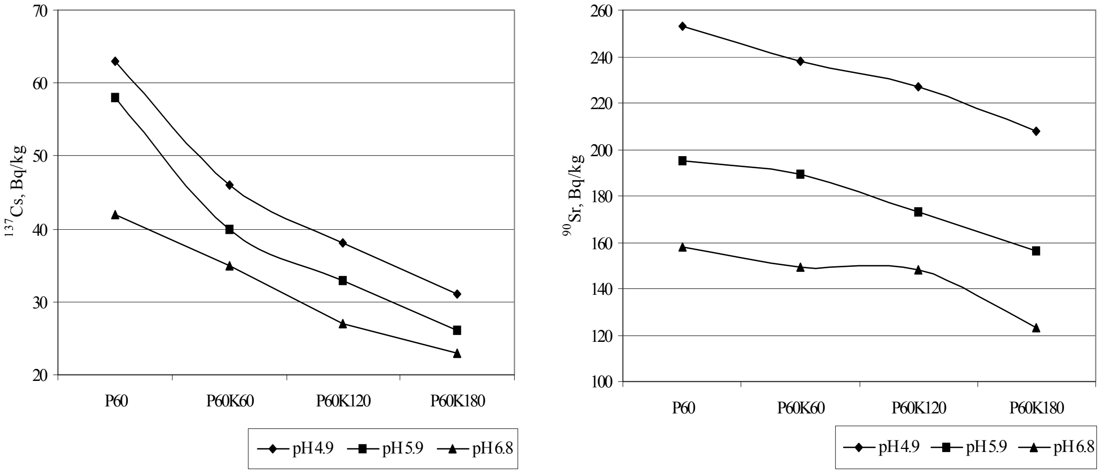

Figure 2. Effect of K-fertilizer on accumulation of ^{137}Cs and ^{90}Sr in green mass depending on the level of soil acidity at the density of contamination with ^{137}Cs 370 kBq m^{-2} and with ^{90}Sr 37 kBq m^{-2}

Decrease of soil acidity on 1 unit in an interval with 4.9 up to 6.8 pH reduced ^{90}Sr transfer from soil to clover plants on 31%. Application of 180 kg ha^{-1} K_2O on background P60 at pH_{KCl} 4.9 decreased specific activity of ^{90}Sr in green mass on 18%, at pH_{KCl} 5.9 – on 20%, at pH_{KCl} 6.8 – on 22%.

Results of researches permit to draw a conclusion that rational application of potassium fertilizer allows expanding an area of crop cultivation on the soils contaminated by radionuclides and product the acceptable feedstuff on soils with density of contamination in 2 times higher in comparison with soils where countermeasures are not applying.

Conclusions

Balanced plant nutrition resulted both in the rise of crops productivity and in the reduction of radionuclides concentration per unit of mass. Soil-to-plant transfer factors of radiocaesium and radiostrontium for spring wheat and red clover may be predicted based with consideration on pH tests of Podzoluvisol loamy sand soil. The optimization of soil reaction combined with application of balanced K fertilizer allowed the expansion of the area of spring wheat and clover cultivation on radiopolluted soils for production acceptable food and feedstuff.

References

1. Absalom J. P., Young S. D., Crout N. M. J. (1995) Radiocaesium fixation dynamics: measurement in six Cumbrian soils. European Journal of Soil Science, 46: 461–469.
2. Arapis, G., Perepelyatnikova, L. (1995) Influence of Agrochemical countermeasures on the yield of crops grown on areas contaminated by Cs-137. In: Aspects on Environmental Toxicology. Kotsaki-Kovatsi, Vafiadou (Eds.), Thessaloniki-Greece: 228–232.
3. Bogdevitch I., Shmigelskaya I., Efimova I., Putyatin Yu. (2001) The volumes of ^{137}Cs and ^{90}Sr accumulation per species and variety of agricultural plants. // Proceedings of Academy of Agrarian Sciences of the Republic of Belarus. 2, Minsk: 40–45 (in Russian).
4. Bogdevitch, I., Tarasiuk, S., Shmigelskaya, I., Putyatin, Yu., Dovnar V. (2002) Influence of soil K-supply and K-fertilizer on the radionuclides uptake by crops. „Radioecology of Chernobyl Zone", Proceedings of International Scientific Workshop, Slavutych, Ukraine: 111–113.
5. Ehlken S., Kirchner G. (2002) Environmental processes affecting plant root uptake of radioactive trace elements and variability of transfer factor data: a review Journal Environmental Radioactivity 58: 97–112.
6. INTERNATIONAL ATOMIC ENERGY AGENCY (1999), Generic procedures for monitoring in a nuclear or radiological emergency, IAEA-TECDOC-1092, Vienna.
7. Massas I., Skarlou V., Haidouti C. (2002) Plant uptake of ^{134}Cs in relation to soil properties and time, Journal of Environmental Radioactivity, 59 (3): 245–255.
8. Sanzharova N. I., Fesenko S. V., Kotik V. A., and Spiridonov S.I. Behaviour of radionuclides in meadows and efficiency of countermeasures. Radiation Protection Dosimetry. – 1996. – 64. No 1/2: 43–48.
9. Waegeneers N., Camps M., Smolders E., Merckx R. (2001) Genotypic effects in phytoavailability of radiocaesium are pronounced at low K intensities in soil Plant and Soil 235(1): 11–20.
10. Zhu Y.G. (2001) Effect of external potassium (K) supply on the uptake of ^{137}Cs by spring wheat (Triticum aestivum): a large-scale hydroponic study Journal of Environmental Radioactivity, 55 (3), 303–314.
11. Петербургский А.В. (1963) Практикум по агрономической химии. Анализ почв. Сельхозиздат, Москва, Наука: 592.
12. Богдевич И.М. и др. (2003) Рекомендации по ведению агропромышленного производства в условиях радиоактивного загрязнения земель Республики Беларусь, Минск, 72.

THE INFLUENCE OF DIFERENT NITROGEN AND POTASSIUM FERTILIZER RATES ON SEED YIELD AND QUALITY OF SPRING OILSEED RAPE

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Abstract

It was for the first time under soil and climatic conditions of Latvia when the Research institute of Agriculture in Skriveri carried out field trials with spring oilseed rape "Olga" on optimization of nitrogen and potassium nutrition in 2001–2003. The influence of nitrogen (N) and potassium (K) fertilizer rates 60, 80 (60+20), 100(60+40), 120 (60+60), and 140(60+80) kg ha^{-1} on the formation of spring oilseed rape yield and quality of seed was tested on phosphorus fertilizer background P_{70}. The fertilizer was split into two applications. The first dose of fertilizer $N_{60}K_{60}$ kg ha^{-1} was applied before sowing while the second – as additional NK fertilizer 20–80 kg ha^{-1} at the stage of stem formation. The results of 2001–2003 show that nitrogen and potassium fertilizers on background P_{70} provided seed yields 2.06–3.15 t ha^{-1}. Introduction of nitrogen 60–100 kg ha^{-1} and potassium 60–100 kg ha^{-1} resulted in yield increase 0.75–1.09 t ha^{-1} ($LSD_{0,05}$= 0.22 t ha^{-1}). The increase of seed yields is significant in comparison with the control. The highest increase of the seed yield – 1.09 t ha^{-1} was obtained in treatment $N_{100}K_{100}$. The seed yields showed tendency to decrease when increasing NK fertilizer rates to 120–140 kg ha^{-1}. The highest seed yield increase with 1 kg of applied NK fertilizers (6.25, 6.0 kg) was observed in treatments $N_{60}K_{60}$ and $N_{80}K_{80}$ kg ha^{-1}, but the lowest (3.36 kg) – in treatment $N_{140}K_{140}$ kg ha^{-1}. The use of NK fertilizers promoted the accumulation of crude protein (22.12–24.13%) but decreased the content of oil (47.06–43.72%) in the seeds. The economic optimal rate of nitrogen and potassium in the sowings of spring oilseed rape `Olga` was $N_{88}K_{88}$ kg ha^{-1}, providing the highest seed yield 3.07 t ha^{-1} and yields of oil 1286 kg ha^{-1}.

Key words: spring oilseed rape, mineral fertilizer, seed yield, yield of oil

Introduction

It takes less time for spring oilseed rape to develop assemblage of rootlets in comparison with winter oilseed rape. Therefore spring oilseed rape needs to be abundantly supplied with nutrients in spite of its lower seed yields and uptake of nutrients. Deficient nutrient supply quickly results in growth interruption and yield inhibition (Шпаар и др., 1999). Phosphorus is necessary for the formation of strong assemblage of rootlets, increase of seed yields and maturation acceleration. Oilseed rape plants are supplied with phosphorus mainly at the expense of its reserves in soil (70–80%) as oilseed rape well assimilates background phosphorus from soil (Schroder, 1992).

There is no consensus of opinion in reference literature regarding the influence of potassium on the spring oilseed rape yield and quality of seed. According to Savenkov V.P. (2000), application of potassium fertilizers has not led to substantial increase in the seed yields and has made just a slight influence on protein content and oil content of oilseed rape seeds. The tests carried out in Germany show that full-value nutrition increases both the seed yields by 0.02–0.03 t ha $^{-1}$ and oil content in seeds.

Like winter oilseed rape, spring oilseed rape requires nitrogen fertilizer. Provided that a correctly set dose is applied, nitrogen increases the seed yields while overdosage can promote lodging of plants, outbreak of fungi diseases and reduction of oil content in seeds (Шпаар и др., 1999). In order to achieve sufficient formation of the seed yield components, splitting of the introduced doses of nitrogen fertilizer is recommended. The first dose of fertilizer 60–80 kg ha^{-1} was introduced before sowing or immediately after it while the second – 40–60 kg ha^{-1} – at the stage of stem formation (Beer *et al.*, 1990; Cramer, 1990; Feger, Orlovius, 1995; Finck, 1991; Fruchtenicht *et al.*, 1993; Sturm *et al.*, 1994).

It was for the first time under soil and climatic conditions of Latvia when Research institute of Agriculture in Skriveri carried out field trials with spring oilseed rape `Olga` on optimization of nitrogen and potassium nutrition in 2001–2003.

The field trials were aimed at both determining the role played by nitrogen and potassium fertilizers in the increase of the spring oilseed rape yields and quality of seeds, and finding optimal nitrogen and potassium nutrition for the purpose of use of oilseed rape biological potential in a more complete way under specific conditions.

Materials and Methods

Field trials were conducted on sod-podzolic sandy clay soils: pH – 6.2, organic matter content 33 g kg^{-1} (Tyurin′s method), high plant available level of P (P_2O_5 – 195 mg kg^{-1}) and medium high K (K_2O – 147 mg kg^{-1}) (DL method). The clay parameters were fit for oilseed rape cultivation. Pre-crop was autumn fallow. Conventional farming techniques were used. Prior to sowing mineral fertilizers P_2O_5 70 кg ha^{-1} in the form of superphosphate, K_2O in the form of potassium chloride and N in the form of ammonium nitrate were applied. The following NK doses were studied: 0, 60, 80 (60+20), 100 (60+40), 120 (60+60), 140 (60+80) kg ha^{-1}. $N_{60}K_{60}$ was introduced as pre-plant fertilizer and at the stage of stem formation 20–80 kg ha^{-1} were applied according to treatments. All the treatments were arranged by randomization method in four replications. The area of a trial plot was 35 m^2 in size, total trial area was 0.15 ha.

The yield was calculated at 8% moisture level. Data processing was performed by the method of single-factor analysis of variance as well as using MS Excel program for straight-line regression and second-degree polynomial regression (Arhipova, Baliņa, 2003). Optimization of NK fertilizers was calculated using computer program developed by experts of the Danish agricultural advisory center. They determined economically optimal rate for nitrogen and potassium fertilizer in seeds of spring oilseed rape considering the increase of harvest from the use of fertilizers as well as fertilizer cost and that of the seed of oilseed rape.

500–700 mm of precipitation per year is required so as to obtain a good harvest of spring oilseed rape. Humidity is especially crucial within the period of formation, budding and blossom of plants. It is only from the beginning of blossom until maturation when oilseed rape already requires 300 mm of water (Шпаар и др., 1999). Provision of oilseed rape with moisture was different within different years of research (Table 1).

Table 1. Weather conditions in 2001–2003

Month	Daily average temperatures, °C				Total of precipitation, mm			
	2001	2002	2003	long-term averages	2001	2002	2003	long-term averages
April	7.9	7	4.3	4.9	94	33	49	45
May	11.5	14.2	12.5	11.4	61	22	51	54
June	14.2	15.9	14.1	15.0	137	169	69	70
July	20.7	19.3	19.8	16.6	120	51	68	89
August	16.8	18.8	15.8	15.9	40	12	136	78
September	11.9	11.8	11.9	11.3	71	25	38	78

Total precipitation from blossom until maturation was only 160 mm in 2001. Freezing exerted a negative influence on the harvest during blossom of oilseed rape.

The growth of oilseed rape under unusually hot and arid weather conditions in the first half of vegetative season in 2002 had negative effect on the growth of plants and especially on the formation of their productive part. Total of precipitation during the critical period (blossom-maturation) was even less – 131 mm. Maturation of oilseed rape took place in enhanced temperature range.

Rainfall exerted a negative influence on ripening of seeds in 2003 at the time of maturation. Spring oilseed rape ripened slowly and unevenly while lower pods run to seed thus negatively affecting harvest.

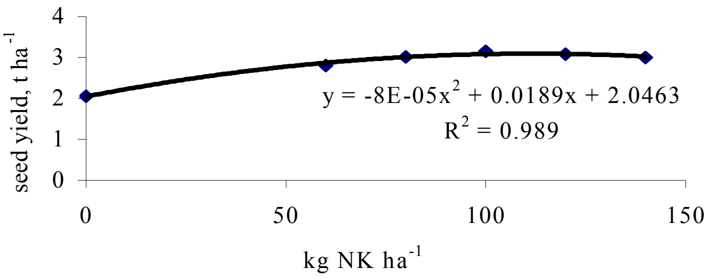
Results and Discussions

Obtained results showed that mineral fertilizers exerted a positive influence on the growth and development of spring oilseed rape plants contributing to yield and quality of seeds. The seed yields were in the ranged of 2.06–3.15 t ha^{-1} in three trial years. Use of nitrogen and potassium fertilizers at the rates of 60 kg ha^{-1} to 100 kg ha^{-1} substantially increased the harvest of oil seeds. Further increase of nitrogen and potassium rates did not lead to rise of seed yields. The highest seed yields were obtained with $N_{100}K_{100}$ – 3.15 t ha^{-1}. The yield increase obtained with the application of N-fertilizer 60–100 kg ha^{-1} and K-fertilizer 60–100 kg ha^{-1} was 0.75–1.09 t ha^{-1} ($LSD_{0,05}$ = 0.22 t ha^{-1}). The seed yields showed tendency to decrease per 1 kg NK applied (from 6.25 to 3.36 kg) when rates of fertilizer were increased from $N_{60}K_{60}$ to $N_{140}K_{140}$ (Table 2).

Table 2. The influence of different rates of NK fertilizers on yield and quality of seeds in spring oilseed rape (2001–2003)

Treatments	Yield of seeds	± to control	Addition of harvest	Yield of oil	Protein content	Oil content
	$t\ ha^{-1}$	$t\ ha^{-1}$	in kg per 1 kg of NK	$kg\ ha^{-1}$	%	%
N_0K_0	2.06	–	–	881	22.12	47.06
$N_{60}K_{60}$	2.81	0.75	6.25	1173	22.61	46.09
$N_{80}K_{80}$	3.02	0.96	6.00	1268	22.82	45.54
$N_{100}K_{100}$	3.15	1.09	5.45	1295	22.95	45.01
$N_{120}K_{120}$	3.09	1.03	4.29	1254	23.70	44.02
$N_{140}K_{140}$	3.00	0.94	3.36	1199	24.13	43.72
$LSD_{0,05}$	0.22				0.62	1.22

The average change in the spring oilseed rape seed yields under the influence of adding different rates of nitrogen and potassium fertilizers within 2001–2003 can be represented with the equation for the second degree polynom $y = -8E - 05x^2 + 0.0189x + 2.0463$ ($r = 0.99$). In this case the equation reflects 98.90% of the cases at coefficient of determination $R^2 = 0.9890$ (Fig. 1).



* Optimum of the yield 3.07 $t\ ha^{-1}$, NK optimal $N_{88}K_{88}$ $kg\ ha^{-1}$

Figure 1. Polynomial regressive interrelation between the harvest of seeds and the rate of NK fertilizers (2001–2003)

Regression equation shows that increase of oilseed rape seed yield is determined by the nitrogen and potassium fertilizers what is connected with the increase in number of pods on the plant. Owing to the NK fertilizer, the number of side branches increased on average by 2–3, the number of legumes on a plant by 26–84, the number of seeds per legume by 2–4, 1000-grain weight (TGW) by 3.5–4.2 g (Table 3).

Table 3. The influence of different NK rates on yield formation of spring oilseed rape (2001–2003)

Treatments	Height of plant, cm	Branching height, cm	Number of first grade branches	Number of legumes per plant	Number of seeds in legumes	1000-seed, weight, g
N_0K_0	116	52	3	49	21	3.5
$N_{60}K_{60}$	131	59	5	75	23	3.8
$N_{80}K_{80}$	136	61	5	90	24	3.8
$N_{100}K_{100}$	139	63	5	103	24	3.9
$N_{120}K_{120}$	142	69	5	106	25	4.0
$N_{140}K_{140}$	145	68	6	133	26	4.2

Mineral fertilizers contributed to a considerable increase of seed protein content. As a result of the introduction of nitrogen and potassium fertilizers, crude protein content increased by 0.49–2.01% in 2001–2003 while oil content decreased by 0.97–3.34%. The change of crude protein content in seed under the influence of different rates of NK fertilizers can be represented with straight-line regression equation $y = 0.0139 + 21.894$. The value of coefficient of correlation ($r = 0.94$) points to a close linear relationship existing between the factors in equation while coefficient of determination ($R^2 = 0.8841$) points to 88.41% of the observed cases (Fig. 2).

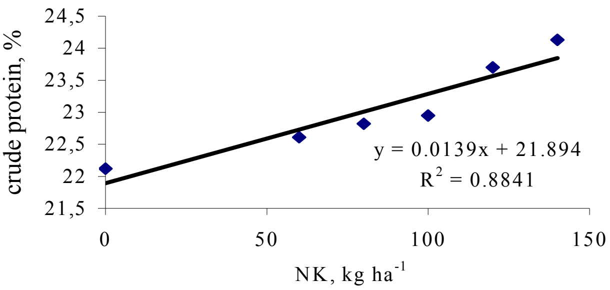


Figure 2. Linear regression interrelation between the content of crude protein in the seeds of spring rape and the rate of NK fertilizers (2001–2003)

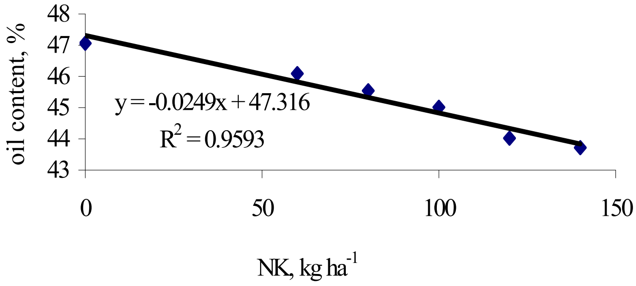


Figure 3. Linear regression interrelation between the seed oil content and NK fertilizer rate (2001–2003)

Oil content decreased and a close correlation inverse relationship ($r = -0.98$) is observed at the increase of the NK fertiliser rate. The change in oil content is reflected in regression equation $y = -0.0249x + 47.316$ which reflects 9593% of the cases at coefficient of determination $R^2 = 0.9593$ (Fig. 3).

In spite of reduction in seed oil content, total yield of crude fat was 881–1295 kg ha^{-1} depending on mineral fertilizer rates. The highest yield of crude fat – 1295 kg ha^{-1} was obtained with 100 kg ha^{-1} of N and 100 kg ha^{-1} of K fertilizers what was ensured by higher seed yields in this treatment (Table 2).

The economic optimal rate of N and K fertilizers after autumn fallow on sandy clay soil was N_{88} K_{88} kg ha^{-1} with the produced seed yields 3.07 t ha^{-1} at the cost of 130 LVL per kg t^{-1} and the cost of reactant nitrogen and potassium amounting to 0.50 LVL.

Conclusions

Application of nitrogen and potassium fertilizers at the rates from $N_{60}K_{60}$ to $N_{140}K_{140}$ kg ha^{-1} considerably increased the yield of spring oilseed rape. A significant increase of yield 0.75–1.09 t ha^{-1} was obtained with applied fertilizer rates $N_{60\text{-}100}$ $K_{60\text{-}100}$ kg ha^{-1}.

The economic optimal rate of nitrogen and potassium in the sowings of spring oilseed rape \`Olga\` was $N_{88}K_{88}$ kg ha^{-1} providing the highest yields of seed (3.07 t ha^{-1}) and oil (1286 kg ha^{-1}).

Application of mineral fertilizers exerted a considerable influence on the quality of seed. Increase of N and K fertilizer rates increased protein content and decreased oil content in the seed of spring oilseed rape.

References

1. Arhipova I., Bāliņa S. (2003) Statistika ekonomikā. Datorzinību Centrs, 349.
2. Beer K., *et al.* (1990) Organische und mineralische Düngung.. – Berlin: Deutscher Landwirtschaftsverlag, 480.
3. Cramer N. (1990) Raps. Zuchtung, Anbau und Vermarktung von Kornerraps. – Ulmer-Verlag Stuttgart, 147.
4. Feger G., Orlovius K. (1995) Wichtige Nährstoffe für den Raps. Ratgeber für die Landwirtschaft 10, 19.
5. Finck A. (1991) Düngung – ertragsteigernd qualitatsverbessernd, umweltgerecht. Stuttgart: Eugen Ulmer Verlag, 310.
6. Fruchtenicht K., *at al* (1993) Pflanzenernnahrung und Düngung. In: Faustzahlen fur Landwirtschaft und Gartenbau. Hydro Agri Duhnen GmbH. Landwirtschaftsverlag Münster-Hiltrup. 12 Aufl., 254–275.
7. Schroder G. (1992) Raps hat hohe Anspruche. Neue Landwirtschaft., 7, 43–45.
8. Sturm H., *et al.* (1994) Gezielter düngen. Integriert wirtschaftlich, umweltgerecht. 3. überarb. Aufl. – Frankfurt: DLG-Verlag, Verlags-Union Agrar, 471.
9. Савенков В. П. (2000) Роль минеральных удобрений в повышении урожайности и качества семян ярового рапса. В кн. Артемов И.В. Научное обеспечение отрасли рапсосеяния и пути реализации биологического потенциала рапса. – Липецк, 110–113.
10. Шпаар Д. и др. (1999) Рапс. – Минск, 204.
11. Шпаар Д., и др. (1999) Яровые масличные культуры. – Минск, 283.

USE OF LIQUID COMPLEX FERTILIZERS AND GROWTH ACTIVATORS FOR ADDITIONAL FERTILIZATION OF SUGAR BEETS

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Abstract

The investigations were carried out in the Experimental Station of the Lithuanian University of Agriculture in the period of 2003–2004. The attention was focused on the influence of additional foliar fertilization with growth activator 'penac$_p$', liquid complex fertilizers 'Atgaiva-1', produced at Joint-Stock company 'ARVI', and growth regulator Stilit-123, synthesized at the department of Organic Chemistry of the Kaunas University of Technology, and their mixtures on the productivity of sugar beet variety 'Kassandra'. Exact field experiments were sown at the end of April with pneumatic seeding-machine at distances between rows – 50 cm and applying the seed norm of 1.4–1.5 s/u per hectare. Tillage and care of crops followed the requirements of sugar beet growing technology applied in Lithuania. Sugar beet seedlings were sprayed with solution of liquid complex fertilizers (40 l ha^{-1} diluted with 300 l ha^{-1} H_2O), and solutions of 'penac$_p$' – 100 ml ha^{-1} and Stilit-123 100 mg ha^{-1} in the phase of 5-6 real leaves.

Results of the investigations showed that additional fertilization with solutions of growth stimulating complexes increased sugar beet yield and sugar content of roots. The highest yield was received in the variant where sprouts had been sprayed with liquid complex fertilizers 'Atgaiva-1'. Additional fertilization increased root-crop yield by 3.7 t ha^{-1} or 6%. Growth activators and their mixtures with complex fertilizers increased sugar beet yield by 2.5–3 t ha^{-1} or 4–5% on average. The highest sugar content of root crop was obtained having sprayed the sprouts with solution of Stilit-123. In this variant sugar content of sugar beets increased by 1% unit, the amount of white sugar – 1 t ha^{-1} or 12.6% in comparison with the control. Application of the mixture of Stilit-123 and Atgaiva-1 solutions increased sugar content of root-crops by 0.85% unit, the amount of white sugar – by 0.95 t ha^{-1} or 12% if compared with the control, in which sprouts had been sprayed with water.

Key words: liquid complex fertilizer 'Atgaiva-1', growth activators, sugar beets, productivity, sugar content

Introduction

At present all areas under sugar beets are sown with the seeds of productive and high quality varieties from West European countries, however, rich yield and root crops of high technological characteristics are not always the case. Creation of favorable conditions for growth and development is important to enable comprehensive realization of potentials existing in the plant's genotype. Regulation of plant's hormone system plays an important role next to application of the main agro technical measures such as proper soil preparation, sowing time, balanced fertilization, plant protection, timely and quality harvesting [1]. Search and synthesis of the compounds that regulate physiological processes of growth and development, investigation of the possibilities of their application in plant growing are carried out both in our country and in the world. Exogenous phytohormones – growth regulators are increasingly used in field plants' growing technologies. Thanks to these compounds biochemical and physiological changes take place at the level of plant cells and organs; very low concentrations of these compounds are necessary to start and regulate physiological and morphogenetic programs [2]. Stimulation of roots formation, stem growth, flowering time, fruit ripening, and plant maturity depends on the concentration and conditions of application of growth regulators and on physiological condition of the plant. Growth regulators can change speed of ontogenesis but the direction of ontogenesis remains unchanged as it is determined by genetic information [3, 4]. Having entered the plant the exogenous growth regulators stimulate activity of natural (endogenous) phytohormones by this changing the intensity of physiological processes that naturally take place in the plant [5]. Physiological activity of growth regulators is revealed by their ability to influence any particular component of phytohormone system: to increase amount of the particular phytohormone, having introduced its synthetic analogue into the plant organism to stimulate or inhibit biosynthesis of natural phytohormones, to block movement of phytohormones, etc. [6].

When growth regulators are used in sugar beet growing technologies it is purposeful to mix them with liquid complex fertilizers. In this case metabolism processes in the plant are more intensive and at the same time plants additionally get and assimilate nutrients and microelements [7]. This opens new possibilities to regulate plants' growth, to increase their productivity and yield quality.

Aim of the investigations – to determine the influence of growth regulators and their mixtures with liquid complex fertilizers on sugar beet growth, productivity and sugar content of root crops.

Materials and Methods

The investigations were carried out in the Experimental Station of the Lithuanian University of Agriculture in the period of 2003–2004. The influence of growth regulator stilit-123, synthesized at Organic Chemistry department, Kaunas University of Technology, growth activator penac$_p$ and liquid complex fertilizer Atgaiva-1 on sugar beet productivity was investigated.

Stilit-123 N-(4-metoxi-2-nitrofenil)-β-alanine sodium salt – it is an ecologically clean compound of high physiological activity that is used in the form of water soluble salts. Having applied very low concentrations of this compound (100 H_2O – 9–10 g of regulator) the plants grow more intensively, quicker form maximum assimilative surface of leaves, processes of photosynthesis are more intensive, photosynthates are quicker transported from leaves to root crop, which results in plant productivity increase [8].

Growth activator penac$_p$ – it is an ecological and harmless compound. It increases plants' resistance to diseases, stimulates more intensive growth of root system, and improves assimilation of nutrients. Plants' resistance to environmental factors increases [9].

Still higher effectiveness is produced when growth regulator is used in mixture with liquid complex fertilizer for additional fertilization through leaves Atgaiva-1 that is produced in the firm ARVI. The fertilizer Atgaiva-1 has not only nutritional but also curative effect. It decreases the stresses experienced by plants or tiredness in the period of intensive growth. It can also be used to increase the efficiency of pesticides or growth regulators [10]. The composition of nutrients in this complex fertilizer has been enriched with the microelement zinc.

The fertilizer Atgaiva-1 contains the following amounts of nutrients:

Total nitrogen (N) – 14%
Amide nitrogen (NH_2 N) – 11,9%
Ammonium nitrogen (NH_4 N) – 2,1%
Phosphorus (P_2O_5) – 7%
Potassium (K_2O) – 7%
Zinc (Zn) – 0,2%

Sugar beets of Kassandra variety were grown on *Calcari – Endohypogleyic Luvisol*. Soil pH was 6.5–7.2. The works of soil tillage, sowing and care of crops were carried out following the sugar beet growing technology applied in Lithuania. Sugar beets were sown at the end of April with pneumatic seeder PTO MAX-540, spaces between rows – 50cm, depth – 2–3 cm, 1.4–1.5 s/u (sowing units) per one hectare. The experiments were done in three replications, the initial size of plots – 32 m^2, the registered size – 29 m^2. Distribution of plots was systematic. The following herbicides were used during vegetation of sugar beets: pyramin turbo, bethanal progress OF and lontrel. The seedlings were sprayed with water (control) and solutions of growth regulators and fertilizers with knapsack sprayer when sugar beets were in the phase of 6 pairs of real leaves.

Solutions of the following concentrations were used in the experiment:

Stilit – 123 90 mg l^{-1},
Penac$_p$ 10 ml l^{-1},
Atgaiva-1 - 13 ml l^{-1}.

Sugar beets were harvested in the end of September manually and using tractor driven lifter of root crops. Samples for laboratory analyses were taken during harvesting time. Sugar content of the root crops was determined in Marijampole Sugar factory.

Results and Discussion

Seedlings of Kassandra variety sugar beets that in the phase of 6 pairs of real leaves had been sprayed with solutions of the tested growth regulators and liquid complex fertilizers grew more intensively and more rapidly formed maximum assimilative surface of leaves. More rapid growth at the beginning of vegetation directly influenced productivity of sugar beets. The experimental results presented in Table 1 show that liquid complex fertilizer Atgaiva-1 increased productivity of sugar beets the most significantly. In these variants of the experiment the yield of root crop reliably increased by 3.73 t ha^{-1} or 6.1% in comparison with the control where no fertilizers had been used. Under the influence of growth activator penac$_p$ productivity of sugar beets increased by 3.15 t ha^{-1} or 5.2%, while the influence of growth regulator Stilit-123 reliably increased the yield of root crops by 2.59 t ha^{-1} or 4.3% in comparison with the control.

Table 1. Influence of liquid complex fertilizers and growth regulators on productivity of sugar beets (2003–2004)

Treatments	Yield, t ha^{-1}	Difference when compared with control		Number of plants, thou. t ha^{-1}	Average weight of one root crop, kg	Difference when compared with the control, kg
		t ha^{-1}	%			
Control	60.62	–	100	84	0.722	–
Atgaiva-1	64.35	3.73	106.1	85	0.757	0.035
$Penac_p$	63.77	3.15	105.2	86	0.742	0.020
Stilit-123	63.21	2.59	104.3	87	0.726	0.004
Atgaiva-1+$penac_p$	63.22	2.60	104.3	84	0.753	0.031
Atgaiva-1+Stilit-123	63.73	3.11	105.1	88	0.724	0.002
R_{05}/LSD_{05}	2.357			0.630	0.017	

The growth regulators and complex fertilizers investigated in this experiment had no significant difference on crop density and size of root crops.

The highest sugar content was determined in the root crops that grew in the experimental variants where seedlings of sugar beets were sprayed with the solution of growth regulator Stilit-123 of 90 mg l^{-1} concentration and with mixture of this regulator and complex fertilizer Atgaiva-1 (Table 2).

Table 2. Influence of liquid complex fertilizers and growth regulators on sugar content of sugar beet root crops (2003–2004)

Treatments	Sugar content, %	Difference when compared with control, % units	Amount of biological sugar, t ha^{-1}	Amount of white sugar, t ha^{-1}	Difference when compared with control,	
					t ha^{-1}	%
Control	17.33	–	10.50	7.91	–	100
Atgaiva-1	17.80	0.47	11.45	8.70	0.75	110.0
$Penac_p$	17.67	0.34	11.27	8.54	0.65	107.9
Stilit-123	18.37	1.04	11.61	8.91	1.00	112.6
Atgaiva-1+$penac_p$	17.68	0.35	11.18	8.47	0.56	107.1
Atgaiva-1+Stilit-123	18.18	0.85	11.59	8.86	0.95	112.0
R_{05}/LSD_{05}	0.163		0.357	0.249		

In these variants a reliable increase of sugar content of the root crops by 1.04–0.85% units was observed, and the obtained amount of white sugar was higher by 1–0.95 t ha^{-1} or 12–12.6% in comparison with the control. The growth activator $penac_p$, liquid complex fertilizer Atgaiva-1 and mixtures of these solutions increased sugar content of sugar beet root crops by 0.34–0.47% units, the amount of white sugar – by 0.56–0.75 t ha^{-1} or 7–10% in comparison with the control.

Liquid complex fertilizer Atgaiva-1 and growth activator $penac_p$ and mixtures of these solutions effectively stimulated intensive growth of sugar beets only for a certain period during intensive growth of root crops. In these variants of the experiment the yield of sugar beets reliably increased on average by 3 t ha^{-1} or 5–6%, root crops grew bigger in comparison with control but contained less sugar content in comparison with those in the variant where growth regulator Stilit-123 had been used. Spraying of sugar beet seedlings with solution of Stilit-123 of 90 mg l^{-1} concentration and with mixture of this solution and liquid complex fertilizer had less effective but longer lasting stimulation of intensive growth of sugar beets. In these variants yield of sugar beets was lower, root crops – smaller in comparison with yield in the variant where activator $penac_p$ had been applied. However, longer lasting impact of Stilit-123 provided more intensive stimulation of physiological processes of metabolism, transportation of photosynthates to the root crop and accumulation of dry matter. In these variants roots of sugar beets had more sugar content than the roots grown under the influence of growth activator $penac_p$. Having sprayed seedlings of sugar beets with solutions of growth regulator Stilit-123 and mixture of this regulator and complex fertilizer Atgaiva-1, sugar content of root crops, in comparison with control, reliably increased by 1.04–0.85% units, the amount of white sugar was higher by 1–0.95 t ha^{-1} or 12.6–12%.

Conclusions

Experimental variants show that additional fertilization of sugar beets through leaves with liquid complex fertilizers and growth activators is expedient.

Spraying sugar beet seedlings of Kassandra variety with 13 mg l^{-1} concentration solution of liquid complex fertilizer Atgaiva-I in the phase of 56 real leaves increases yield of root crops by 3.73 t ha^{-1} or 6% in comparison with control. In this variant saccharinity reliably increases by 0.47% units, the amount of crystal sugar is by 0.75 t ha^{-1} or 10% higher in comparison with control.

The influence of growth regulator Stilit-123 reliably increases the yield of root crops by 2.69 t ha^{-1} or 4%, saccharinity – by 1.04% units, crystal sugar – by I t ha^{-1} or 12.6% in comparison with control.

Growth activator penacp has the weakest influence on the increase of sugar beets' productivity. Having sprayed seedlings of sugar beets with solution of penacp of 10 mg 1^{-1} concentration, the yield of sugar beets reliably increases by 2.59 t ha^{-1} or 4.3%, saccharinity – by 0.34% units, crystal sugar – by 0.63 t ha^{-1} or 7.9% in comparison with control.

Optimal variant is received having sprayed seedlings of sugar beets with mixture of liquid complex fertilizer Atgaiva-1 and growth regulator Stilit-l23 in the phase of 5–6 real leaves. In this experimental variant yield of root crops reliably increases by 3.11 t ha^{-1} or 5.1%, saccharinity – by 0.85% units, crystal sugar – by 0.95 t ha^{-1} or 12% in comparison with control.

References

1. Augimo aktyvatoriaus Penac$_p$ naudojimas žemės ūkio auginamoms kultūroms. UAB VYRYBALT, (2004) 16–19.
2. Čaikauskas V., Jakienė E. (1994) Augimo reguliatorių mišinių įtaka cukrinių runkelių derlingumui. LŽŪU Mokslo darbai. Kaunas-Akademija, 34–39.
3. Novickienė L. (1994) Augalų augimą, vystymąsi ir produktyvumą reguliuojančių fitohormonų ir retardantų analogų kūrimo fiziologiniai pagrindai. Vilnius, 74–80.
4. Merkys A., Miliuvienė L., Novickienė L. (1993) Nauji augimo reguliatoriai ir jų fiziologinio aktyvumo įvertinimas. Ketvertinių amonio druskų analogai. Biologija, Nr. 4, 45–53.
5. Stašauskaitė S. (1995) Augalų vystymosi tiziologija. Vilnius, 62–74.
6. Vaikutis V. (2002) Lietuvos cukraus ūkis ir jo plėtra. Cukrinių runkelių auginimas Lietuvoje integruojantis į Europos Sąjungą. Mokslinės-gamybinės konferencijos pranešimai. Rumokai, 46–56.
7. Voskienė A., Jakienė E., Mickevičius V. (2002) N-(4-acetilfenil)-ß-alanino kondensacijos su aromatiniais aldehidais produktai. Cheminė technologija. Nr. 2 (23), 68–75.
8. UAB ARVI katalogas. (2004) 16.
9. Кефели В.И. (1984) Рост растений. Москва, 131–144.
10. Лебедев С. И. (1988) Физиология растений. Москва, 112–125.

SOIL RESEARCH IN LATVIA WITHIN THE FRAMEWORK OF EU ACTIVITIES: RITUATION AND ACTUALITIES

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Abstract

Soil is the natural body, finite and hardly renewable resource that is under pressure from many activities, mostly human induced. Our existence fully depends from ability of soil to maintain their ecological functions. Awareness about threats and damages to soil possibly came with some backwardness but still we should react adequately and immediately to solve the problems which might impair or even endanger our existence. As soils have not national boundaries and factors affecting them also cross any man-made borderlines research for better understanding the processes that led to soil degradation, investigation of possible remediation techniques and evaluating policy impact and changes on soil resources should be performed collectively. Therefore soil research and information acquisition about Latvia soils need to be strongly coordinated within the world-wide soil information framework following the standards set up internationally. Current situation and future prospects are discussed focusing on EU Thematic Strategy for Soil Protection which is core activity currently in Europe.

Key words: soil, soil information, acquisition methods, EU Thematic Strategy

Introduction

Soil research and systematic collection of soil information in Latvia has relatively long–lasting history starting in the late of 1800s after the opening of Riga Polytechnical School. At the beginning the main interest was inventory of agricultural soils, its fertility assessment and the development of criteria for fertilizer use. Later on research topics were expanded and now it already covers almost one and a half of century with developments of many aspects of applied soil science as well as contributions for theoretical knowledge in different branches related to formation and genesis of soil, their properties, evaluation etc.

The genetic approach of soil science was introduced by Professor J. Vitins, a scholar and collaborator of the Russian soil scientist K. Gedroits in 1920ies. Soil science moved through different periods with different intensity. The main areas of research and data applications were genesis and mapping of soil parent material and topsoil, chemical composition, soil classification, soil evaluation, soil improvement, degradation (especially erosion) control, soil fertility testing. Institutes involved in soil research and data processing also changed within the history. Currently the main institutions in soil research and knowledge transfer are University of Latvia, Latvia University of Agriculture, State Land Service and Agrochemical Research Center.

As a result our knowledge about soils of Latvia is comparatively large. Materials showing spatial distribution of major soil properties (general and special soil maps, land evaluation including soil assessment, etc.) are available at least for agricultural land (40% of territory) at the scale of 1:10 000. It is good parameter comparing with other countries of Europe, although soil information requirements, scope and standards are shifted during the last decades. Environmental consequences became the major concern. In relation to that new approach, parameters, information acquisition methods, interpretations became actual. Soil research and data standards moved out from their traditional national boundaries and became very internationalized. To find the appropriate niche into the world-wide soil information flow to meet the national, regional and global needs, to identify the actual status, to balance situation analysis not under– nor overestimate the real state and processes, to monitor its and more. This might be the short formulation of soil research and data acquisition needs for Latvia at the nearest future.

EU Soil information strategy

Commission of the European Communities in its Communication named **Towards a Thematic Strategy for Soil Protection** (2002) summarized current situation and announced political goals for measures aimed to soil protection. Commission recognizes that soil is a vital resource increasingly under pressure and for sustainable development, it needs to be protected. In particular, the concept of sustainable development was agreed in 1992, at the Rio summit and legally binding conventions on climate change, biological diversity, desertification were adopted. The participating states (including Latvia) also adopted a series of declarations of relevance to soil protection (Communication… 2002).

EU **Thematic Strategy for Soil Protection and Sustainable Use**, which was elaborated within 2004, is planned to be adopted together with a **Directive on monitoring of soils** by the mid of 2005 and it is considered as a core document for the next decades. Thematic Strategies[1] are envisaged as a way to tackle key environmental issues which require a holistic approach. This is necessary to the complexity of problem, the diversity of actors involved and the need to find coordinated and innovative solutions to the challenges.

Thematic Strategy draw up its vision for realization of this challenge and the main tasks were scheduled as follows.

- Formulation of soil functions to clearly understand its vital role in ecosystem and our livelihood dependency from it.
- Identification of the main soils' threats.
- Development and realization of relevant Community policy.
- Soil information and monitoring to identify the status and follow up the processes.
- Steps towards soil protection.

Soil functions, which are crucial for environment as well as social and economic development were formulated as follows.

- Food and other biomass production.
- Storing, filtering and transformation, which play a central role in the protection of water and food chain and exchange of gases with the atmosphere.
- Habitat and gene pool.
- Physical and cultural environment for mankind – the element of landscape and a cultural heritage.
- Source of raw materials.

Thematic Strategy identified the main threats to soil of Europe, which led to the weakening or even the loss of soil functions.

- Erosion.
- Decline in organic matter.
- Soil contamination (local and diffuse).
- Soil sealing – decrease of fertile soil area due to the urbanization, construction, mining etc. activities.
- Soil compaction and other physical deterioration.
- Decline in soil biodiversity.
- Salinization.
- Floods and landslides.

All defined threats except salinization (accumulation of soluble salts in soil) are applicable to Latvia situation. Therefore several relevant Community policy measures should be taken at the EU and national scales. The first step of policy measures was large scale activities organized through five Technical working groups, Advisory forum, Stakeholders meetings and Commission which resulted on the draft of detailed reports and associated documents (Reports of the Technical…, 2004). In these documents current situation is described, priority areas and actions identified and step-by-step measures proposed. The next step, if it will be decided, might be some binding measures which could be presented either as a Council Decision, as a Directive or as a Framework Directive.

Current soil information needs

What we need to know about our soils? The short answer could be – to be able to monitor all soil functions and development of threats and keep a check about measures taken in both – local and international dimensions. More extensively – numerous tasks for addressing the challenges of the future need to be answered through basic and targeted research. To do that a concept for integrated research in soil protection and soil resource management was developed, recognizing that only collaborative research, including the co-operation of national programmes and the development of new research infrastructures and using all available human and technological resources is possible (Table 1).

[1] European Council and the European Parliament on 2002 adopted seven Thematic Strategies: soil, marine, air, pesticides, urban, waste and resources.

Table 1. Concept for integrated research in soil protection and soil resource management (W. E. H. Blum and J. Busing, 2004)

Main research goals	Research clusters	Sciences involved
To understand the main processes in the eco-subsystem soil underlying soil quality and soil functions, in relation to land uses and soil threats	Analysis of processes related to the threats to soil and their interdependency: erosion, loss of organic matter, contamination, sealing, compaction, decline in biodiversity, salinisation, floods and landslides	Inter-disciplinary research through cooperation of soil physics, soil chemistry, soil mineralogy, and soil biology
To know where these processes occur and how they develop with time	Development, harmonization and standardization of methods for the analysis of the **State** of the threats to soil and their changes with time = **soil monitoring**	Multi-disciplinary research through cooperation of soil sciences with: ▪ geographical sciences, ▪ geo-statistics, ▪ geo-information sciences (e.g. GIS)
To know the driving forces and pressures behind these processes, as related to policy and decision making on a local and regional basis	Relating the threats to **Driving forces** and **Pressures** = cross-linking with cultural, social and economic drivers, such as policies (agriculture, transport, energy, environment, etc.) as well as with technical and ecological drivers, e.g. global and climate change	Multi-disciplinary research through cooperation of soil sciences with political sciences, social sciences, economic sciences, historical sciences, philosophical sciences, and others
To know the impacts on the eco-services provided by the sub-system soil to other environmental compartments (eco-subsystems)	Analysis of the **Impacts** of the threats, relating them to soil eco-services for other environmental compartments: air, water (surface and ground water), biomass production, human health, biodiversity, culture	Multi-disciplinary research through cooperation of soil sciences with geological sciences, biological sciences, toxicological sciences, hydrological sciences, physio-geographical sciences, sedimentological sciences, and others
To have strategies and operational tools (technologies) at one's disposal for the mitigation of threats and impacts	Development of strategies and operational procedures for the mitigation of the threats = **Responses**	Multi-disciplinary research through cooperation of natural sciences with engineering sciences, technical sciences, physical sciences, mathematical sciences, and others

Methods of soil resources inventory

Acquisition of soil data is time and resources consuming process. No one country is able to afford very extensive, advanced, long-lasting and numerous soil research programs. Therefore several actions are proposed to use. First of all: to identify and to structure the existing information on soil available in Europe as well as in single countries. The next: to identify barriers that prevents the full use of existing information for policies and to make recommendations how to improve the transfer of information. And finally to identify research gaps and needs, indicating, in which time spans these can be closed (short-, medium, and long-term activities). Based on this concept the best available methods (which are able reasonable compromise between provision of data quality and eligible costs) for soil research should be chosen.

Recognizing the complexity of issue it is obvious that multidimensional soil resources inventory methods should be used. But we should take into account that besides the data quality and economical considerations future-targeted needs are also very important. Soil resources inventory programs need to include the parameters which might be important for future technologies. Use of modeling approach for environmental research, development of forecast programs, etc. in many cases require for detailed and specific soil information. If these issues might be important for the nearest future we need to start information acquisition immediately, because it takes some time for data collection and also to follow the standards applicable for these modern technologies.

In Fig. 1 some aspects of information sources and its suitability is displayed. Soil information could be collected through several activities and channels. To make it useful for current and future soil information users, e.g. researchers, decision makers, developers, extension specialists etc, some actions should be taken and some specific framework followed. First of all to set up clear vision what we need and why we need. Secondly, how to realize our needs moving forward on an ongoing basis. And finally, well motivated data acquisition methods and data standards must be set up and followed without indention.

Unfortunately very little progress in this field is reached in Latvia within the period after 1990ies. Despite of several documents developed, monitoring programs with soil component started there is no specific soil resources inventory vision and even public coordination institution. Soil information still is not considered as something important at least not on the level of other compartments of environment: atmosphere and water. It seems that soil is still as a low priority component within the monitoring of other segments of environment (land, forest). As a result this component usually is eliminated or not monitored properly for the sake of resources economizing.

Chaotic soil data collection and processing approach seems to be dominating instead of systematic planning and realization activities. We are pending somewhere between preferable actions and program statements and its realization, between old and new data standards. Data ownership is another tricky problem and sometimes information what we actually already have is hidden and not available for public use.

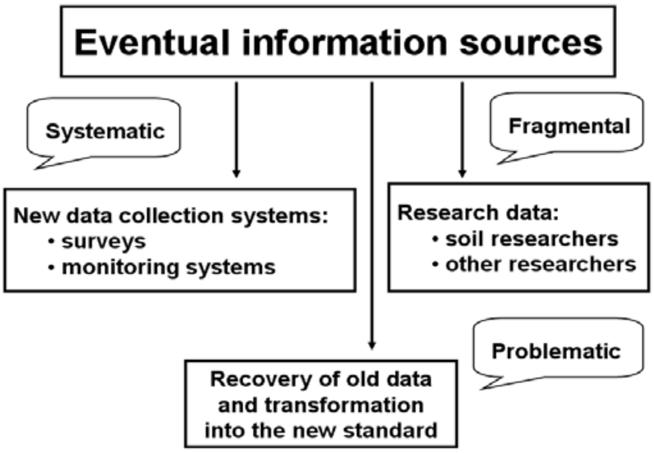

Figure 1. Diversity of soil information and its suitability

State Monitoring Program was accepted by the Latvia government in 2002. It consists of 5 blocks and one of that – monitoring of terrestrial components, in chapters “Forest monitoring” and “Agricultural land monitoring” include also soil monitoring. Unfortunately Agricultural land monitoring is not launched yet, but in Forest monitoring soil component also is not practically started. We have already experience with previous Agricultural land monitoring program which lasted from 1992 until 2000 and where soil component was important issue. Due to the lack of program consistency, institutional collisions etc. very small scope of information was obtained which could really be useful for proposed targets (Karklins, Livmanis, 2004).

Looking from the present point of view and analyzing modern approaches and soil information needs, previous soil survey which was realized in Latvia until 1990, also was not possible to proceed without substantial reorganization. On the other hand monitoring approach for soil research is very preferable, giving possibility to follow processes in their development. Using this approach we are able to accumulate large data sets but characterizing mainly research sites with very approximated applicability to the adjacent areas. Only good compromise should be as a solution taking into consideration particularities of both methods of information acquisition (Table 2).

Table 2. Comparison of soil information acquisition methods

Soil survey	Soil monitoring
Spatial data, changes of soil properties in space	Point based data. Lack of spatial dimension
Limited number of parameters	More extended number of parameters
Registration of *status quo*	*Status quo* and changes in time
Information mainly about soil/land parameters, no direct connection with other segments of ecosystem	Information about soil, other ecosystem segments, anthropogenic impact
Methodical framework should be kept as unchangeable as possible for whole survey cycle	More easy to incorporate new parameters and to change methods
High realization costs	Expenses depend on monitoring intensity and parameters selected but could be less
No need for data generalization. Covers all territory that it refers to	Data should be generalized for adjacent area. Research network plot density should be sufficient to cover all variations within the area of concern

The main steps to soil information harmonization

Monitoring and other soil research programs are growing in both scales, nationally and regionally (globally). Soil information is acquired in several of the programs, but parameters, their analytical methods could differ significantly. Heterogenity of soil related information is growing. It becomes a problem, how to associate data from different sources including monitoring programs which use to change in time and also from programs running parallel, but especially how to combine and provide the succession of new produced data with those accumulated within the period of soil surveys and early monitoring programs. Probably these aspects are important for many soil information users who are more interested in soil as real polypedons rather than several representative pedons.

If we add that several countries for a long period use to make use of different methods for soil characterization and international cooperation in information use are growing much more faster as success to agree on and implement in certain standards we are facing situation that there is no lack of soil data rather than its heterogenity. Any mutual efforts to improve situation are very desirable which also will give certain contribution in sustainable development of biosphere.

Looking for possible solutions in Latvia level presumably we need to develop our own Soil Thematic strategy where several issues should be amalgamated.

- Realization of already established monitoring programs without economizing on soil component.
- Soil mapping using new EU approach (soil, topography, hydrology, geology) – at least in medium scale 1:250 000 (Georeferenced…, 2001).
- Modeling – to transfer advanced information from monitoring research plots to the mapping units.
- Acceptance of internationally used standards for soil analytical methods and data interpretation and its use for all segments of information flow.
- Development of soil information databases open for public use.
- Establishment of institution responsible for coordination of soil information acquisition and provision.

Conclusions

Issues discussed before probably need to be solved first of all using political measures rather than technical. We have technical capacity to realize above mentioned approach if society's awareness will consider its importance. Therefore our priority action is to raise it up to a certain level of understanding.

References

1. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the regions "Towards a Thematic Strategy for Soil Protection". – Brussels: Commission of the European Communities, COM (2002) 179 final: 36.
2. Scientific Basis for the Management of European Soil Resources / Research Agenda (2004). – BOKU, ECSSS, SCAPE, JOINT, 16.
3. Reports of the Technical Working Groups established under the thematic strategy for soil protection. (2004) / *Ed. by:*L. Van-Camp, B. Bujarrabal, A. R. Gentile, R. J. A. Jones, L. Montanarella, C. Olazabal, S. K. Selvaradjou. – European Commission, European Environment Agency, EUR 21319 EN, 872.
4. Karklins A., J. Livmanis. Soil survey versus soil monitoring – are we able to get the same knowledge? (2004) // Доклады Международного экологического форума "Сохраним планету Земля" / Под ред. Б. Ф. Апарина. – Санкт–Петербург: Центральный музей почвоведения им. В.В. Докучаева, 64–67.
5. Georeferenced Soil Database for Europe: Manual of Procedures, version 1.1. (2001) / *Ed. by*: P. Finke *et al.* European Soil Bureau Scientific Committee, 163.

ESTIMATION OF SOIL MICROBIOLOGICAL PROPERTIES IN RELATION TO SOIL ACIDITY AND FERTILIZATION

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Abstract

The study was carried out to investigate the spread and efficiency of *Rhizobium* and other soil microorganisms physiological groups depending on soil acidity and fertilization. It was established that *Rhizobium leguminosarum bv. trifolii* and *Rhizobium leguminosarum bv. viciae* were most spread at soil pH_{KCl} 5.6–6.0. In acid soils (pH_{KCl} 4.1–5.0) *Rhizobium galegae* wasn't found and *Sinorhizobium meliloti* was hardly detected. Activity of nitrogenase by *Rhizobium leguminosarum bv. trifolii* in acid soil was 12.3 times lower than in neutral (pH_{KCl} 6.2–6.7) soil. *Rhizobium*, depending on species and strains, fixed symbiotic nitrogen from 142 to 289 kg N ha^{-1}. Liming increased the nitrogen fixation at 40–88 kg N ha^{-1}. Ammonifying and mineral N assimilating microorganisms were spread most at the soil pH_{KCl} 5.2–5.7 and in crop rotation fertilized with $N_{45}P_{30}K_{45}$. The increase of fertilizer rates in acid soil inhibited amounts of microorganisms. The highest activity of organic matter mineralization was identified in neutral soil ($pH_{KCl}>6.7$). However, favourable conditions for micromycetes occurrence were observed in acidic soils ($pH_{KCl}<4.7$).

Key words: *Rhizobium*, microorganisms, nitrogen fixation, nitrogenase, soil pH, fertilizers

Introduction

The symbiotic nitrogen fixation depends on occurrence and survival of *Rhizobium* in the soils and also on their efficiency (Adamovich, Klasens, 2001; Del Papa *et al.*, 2003). Soil reaction is one of the most important factors influencing legumes and *Rhizobium* symbiosis. The greater concentration of H^+ ion increases the solubility of Al, Mn and Fe, and these elements may become toxic to plants. *Sinorhizobium meliloti* and *Rhizobium galegae* are highly sensitive to acid pH and soluable Al when critical soil pH is 4.8–5.0 (Kelner *et al.*, 1997; Kloppel *et al.*, 1997; Staley, 1993). *Rhizobium leguminosarum bv. trifolii* and *Rhizobium bv. viciae* in comparison to alfalfa rhizobia are more tolerant to soil acidity. However pH lower than 4.6 inhibit their activities. The legumes and *Rhizobium* have formed efficient symbiosis and fix high amounts of biological nitrogen, when soil pH is not lower than 5.6–6.1 (Hamdy, 1982; Lapinskas, 1998). Soil acidification inhibits the root-hair infection process and nodulation (Ambrazaitienė, 2003; Hartwig and Soussana, 2001).

According to many publications on soil liming, fertilization with PK fertilizers and organic manure, as well as legumes inoculation with effective strains of *Rhizobium* are important factors for increasing efficiency of symbiosis (Vassileva, Kostov, 2001; del Papa *et al.*, 2003; Watkin *et al.*, 1997).

Poor composition of microorganisms is occurring in acid soils. None or insignificant amounts of *Azotobacter chroococcum* and *Trichoderma lignorum* are found. Nitrification process begins only at pH 5.2 and reaches highest intensity when soil acidity is diminished to pH 6.7 (Arlauskienė, 1995).

Long-term investigation shows, that formation of microorganisms in cenosis is prolonged and complex process. Systematic and repeated liming is a principal means of soil improvement (Tang, 1998; Watkin *et al.*, 1997).

The purpose of this study was to define the spread and efficiency of different species of *Rhizobium* and other physiological groups of soil microorganisms depending on soil acidity and fertilization.

Materials and Methods

The spread of main species of rhizobia (*Rhizobium leguminosarum bv. trifolii* F., *Rhizobium leguminosarum bv. viciae* F., *Sinorhizobium meliloti* D. and *Rhizobium galegae* L.) had been established in 400 different soil samples in Lithuania. There was employed a dilution method for legume inoculation in sterile conditions (Андреюк и др., 1988). Red clover, alfalfa and fodder galega were grown in big biological tubes (200 mm × 20 mm), vetch – in 500 ml capacity glass in 5 replications. Out of nodule formation amount of *Rhizobium* was determined in soil (Lapinskas, 1998). The biological nitrogen fixation in field experiments was established through the method of growing legume and cereal plants (Трепачев и др., 1991). The soil according FAO-UNESCO modified classification is Dystri-Endohypogleyic Albeluvisols (Abg-n-w-dy). Soil pH_{KCl} was 4.1–7.1, organic C – 1.06–1.80%, available P_2O_5 and K_2O – 85–220 and 137–322 mg kg^{-1} soil respectively.

Nitrogenase activity *Rhizobium leguminosarum bv. trifolii* was determined according to the described method (Hamdy, 1982; Ambrazaitienė, 2002).

The occurrence of different physiological groups of soil microorganisms was established in field experiments conducted by D. Čiuberkienė. Numbers of ammonifying, mineral nitrogen assimilating microorganisms, micromycetes and spore-forming bacteria were determined according to standard methods (Андреюк и др., 1988).

Results and Discussion

Rhizobium spread and symbiotic efficiency. The results show that *Rhizobium leguminosarum bv. trifolii* was widely spread in acid soil with pH_{KCl} 5.6–6.0. The average amount of rhizobia was $540.0 \cdot 10^3$ g^{-1} of soil (Fig. 1). Less *Rhizobium leguminosarum bv. viciae* and significantly less both *Sinorhizobium meliloti* and *Rhizobium galegae* were found. *Rhizobium* significantly declined in acid soils (pH_{KCl} 4.1–5.0).

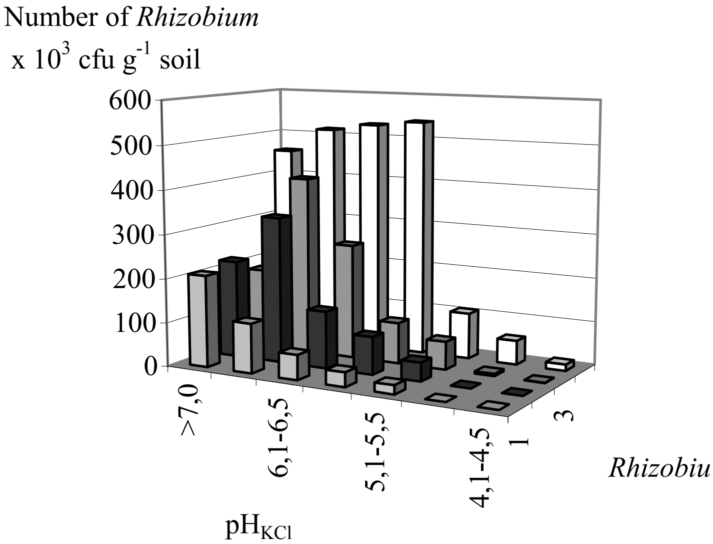

Figure 1. Impact of the soil pH on *Rhizobium* spread

1 – *Rhizobium galegae* (R_{05} 12.6)
2 – *Sinorhizobium meliloti* (R_{05} 27.4)
3 – *Rhizobium leguminosarum bv. viciae* (R_{05} 23.5)
4 – *Rhizobium leguminosarum bv. trifolii* (R_{05} 37.8)

The optimal soil pH for different species of *Rhizobium* was different. It was established that rhizobia of clover had best growth at pH 5.6–6.0, rhizobia of *viciae* and alfalfa at pH 6.6–7.0 and rhizobia of fodder galega – at pH above 7.0.

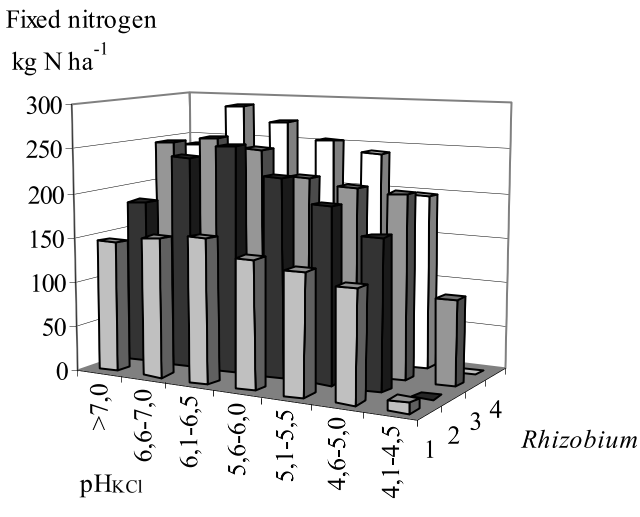

Figure 2. Impact of the soil pH on biological nitrogen fixation by different *Rhizobium* species

1 – *Rhizobium leguminosarum bv. Viciae* (R_{05} 5.1)
2 – *Sinorhizobium meliloti* (R_{05} 7.2)
3 – *Rhizobium leguminosarum bv. Trifolii* (R_{05} 9.4)
4 – *Rhizobium galegae* (R_{05} 7.8)

The most of biological nitrogen *Rhizobium* was found at soil pH from 6.1 to 7.0. *Rhizobium galegae* had fixed biological nitrogen from 196 to 289 kg N ha^{-1}, when rhizobia of alfalfa and clover were less and it depended on strain efficiency and soil pH (Fig. 2).

According to scientific literature data, *Sinorhizobium meliloti* has distinguished highly symbiotic efficiency compare to other *Rhizobium* (Hamdy, 1982; Kelner *et al.*, 1997). Prevailing acid soil in the West of Lithuania does not create optimal conditions for cultivating alfalfa and their rhizobia. When soil acidity decreased from pH 5.5 to 6.5, the amount of fixed nitrogen increased from 40 to 88 kg N ha^{-1}. When liming was not applied, legume inoculation with local efficiency and adapted strains to ecological conditions were effective means (Fig. 3).

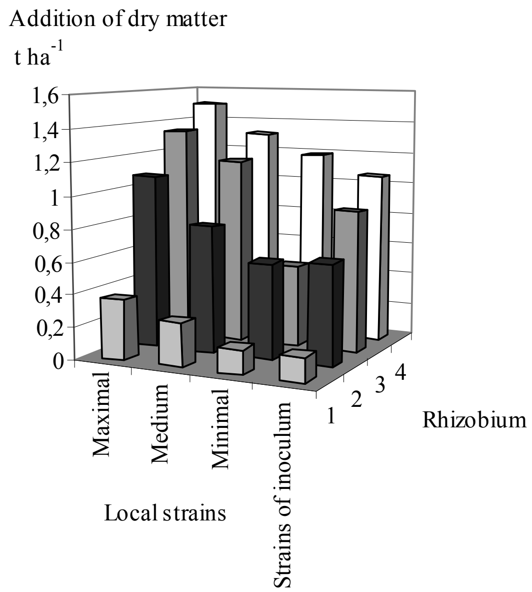

Fig. 3. Symbiotic efficiency of different *Rhizobium* strains

1 – *Rhizobium leguminosarum bv. viciae* (R_{05} 0.14) 2 – *Rhizobium leguminosarum bv. trifolii* (R_{05} 0.36)
3 – *Sinorhizobium meliloti* (R_{05} 0.30) 4 – *Rhizobium galegae* (R_{05} 0.65

Depending on both plant and *Rhizobium* properties, the addition from inoculation of dry matter yield made from 0.15 to 1.50 t ha.

Nitrogenase activity. Our study showed that nitrogenase activity in acid soils reduced, if control treatment received no fertilizers (Table 1). Fertilizing at the rate $N_{90}P_{60}K_{90}$ increased the biological nitrogen fixation by 2-4 times in comparison with non-fertilized treatment.

Table 1. Impact of the soil pH and fertilizers on nitrogenase activity by *Rhizobium leguminosarum bv. trifolii*

Soil pH_{KCl}	Fixed nitrogen μ *M* N_2 g^{-1} roots h^{-1}			
	$N_0P_0K_0$		$N_{90}P_{60}K_{90}$	
	1997 autumn	1998 summer	1997 autumn	1998 summer
4.0-4.3	0.30	2.93	0.73	18.73
4.3-4.9	0.30	10.90	1.33	26.80
5.2-5.4	0.27	36.93	0.83	19.57
6.2-6.7	0.91	36.13	0.93	10.50
R_{05}	0.89	11.37	0.89	11.37

The soil liming had a positive impact on nitrogenase activity. In limed soil it was fixed 36.93 μ *M* N_2 g^{-1} roots h^{-1}, when in acid soil it was 2.9 μ *M* N.

According to the correlation-regression analysis, significant connection between numbers of clover nodules and their nitrogenase activity was established (r = 0.41*). The increase of total nitrogen in the soil as well as *Rhizobium* virulence and nitrogen fixation was inhibited.

Table 2. Impact of the soil pH and fertilizers on spreading of microorganisms

Treatment		Ammonifying microorganisms (M)	Mineral nitrogen assimilating microorganisms (H)	Coeffi-cient M/H	Spore forming bacteria	Micromy-cetes
pH_{KCl}	fertilizers	$\times 10^6$ cfu g^{-1}			$\times 10^3$ cfu g^{-1}	
< 4.7	No fertilizers	6.40	2.12	3.02	3.06	17.57
	N_{45} P_{30} K_{45}	4.18	1.38	3.03	1.78	25.27
	N_{135} P_{90} K_{135}	3.52	0.64	5.50	0.26	32.02
5.2-5.7	No fertilizers	5.22	5.12	1.02	3.05	14.57
	N_{45} P_{30} K_{45}	15.06	18.53	0.81	12.51	15.47
	N_{135} P_{90} K_{135}	4.16	3.57	1.16	7.90	23.26
> 6.7	No fertilizers	5.09	2.58	1.97	2.80	13.53
	N_{45} P_{30} K_{45}	4.96	2.63	1.88	34.10	8.69
	N_{135} P_{90} K_{135}	4.24	4.71	0.90	9.17	6.96
R_{05}		1.32	0.89		3.41	4.92

Spread of microorganisms. The ammonifying and mineral nitrogen assimilating microorganisms mostly occurred in less acid soil (pH_{KCl} 5.2–5.7) at fertilizer rate $N_{45}P_{30}K_{45}$ (Table 2). Relatively high amount of ammonifying and the best amount of mineral nitrogen assimilating microorganisms was found in acid soil at the fertilizer rate $N_{135}P_{90}K_{135}$. In this case intensity of organic matter decomposition was 3.0–5.5 times higher than its synthesis. The optimal reaction on spore-forming bacteria was pH_{KCl} >6.7. In highly acid soil fertilized with mineral fertilizers the activity of spore forming bacteria was inhibited. The highest number of micromycetes was determinated in highly acid soil of pH_{KCl} <4.7. Increased rates of NPK fertilizers increased amount of micromycetes as well. Between micromycetes species, the *Penicillium* is genus of which about 50% are known as antagonists to valuable soil microorganisms. *Trichoderma lignorum* and *Mucor,* which are important in humic, vitamin and phytohormone synthesis, were spread the least (Андреюк и др., 1988).

Conclussions

Our study showed, that soil acidity was a decisive factor in spread and symbiotic efficiency of *Rhizobium leguminosarum bv. trifolii* F., *Rhizobium leguminosarum bv. viciae* F., *Sinorhizobium meliloti* D. and *Rhizobium galegae* L.

Rhizobium leguminosarum bv. trifolii was mostly spread and tolerant in acid soils. In slightly acid soil the average amount of rhizobia found was $540.0 \cdot 10^3$ cfu g^{-1} soil. In highly acid and medium acid soils (pH_{KCl} 4.1–5.0) *Rhizobium galegae* and *Sinorhizobium meliloti* were not found.

Optimal pH_{KCl} values for nitrogen fixation were 6.1–7.0. In this case legumes accumulated 142–289 kg N ha^{-1} per vegetation time. The soil liming increased nitrogen fixation by 40–80 kg N ha^{-1}.

Nitrogenase activity was only 2.9 μM N_2 g^{-1} roots h^{-1} in highly acid soil and 36.13–36.93 μM N_2 g^{-1} roots h^{-1} in slightly acid–neutral soils.

If soil reaction was not adjusted then the effective mean for symbiosis improvement was legume inoculation with efficient strains resulting in increased dry matter yields 0.15–1.5 t ha^{-1}.

Both soil reaction and application of NPK fertilizers determined the spread of ammonifying and mineral nitrogen assimilating microorganisms. The highest numbers of their microorganisms was found in slightly acid (pH_{KCl} 5.2–5.7) soil with the lowest rate of fertilizers – $N_{45}P_{30}K_{45}$. The highest intensity of organic material decomposition was observed in neutral soil (pH_{KCl}>6.7) at the fertilizer rate $N_{135}P_{90}K_{135}$.

In acid soils (pH_{KCl} <4.7) the activity of spore-forming bacteria was weak. Their greatest number was established in neutral soil at a low rate of fertilizer $N_{45}P_{30}K_{45}$ applied. On the other hand, amounts of micromycetes were mainly found in acid soil (pH_{KCl} < 4.7).

References

1. Adamovich A. and Klasens V. (2001) Symbiotically fixed nitrogen in forage legume-grass mixture. Grassland Science in Europe. 12.
2. Ambrazaitienė D. (2002) Activity of symbiotic nitrogen fixation in different soils. Agricultural Sciences, 82, 3, 3–11 (in Lithuanian).
3. Ambrazaitienė D. (2003) Activity of symbiotic nitrogen fixation in the Dystric Albeluvisols differing in acidity and fertilization. Agriculture, 83, 3, 173–186 (in Lithuanian).

4. Arlauskienė E. A. (1995) Influence of long-term fertilization with manure and NPK on the biological activity in acid and limed soils. Agriculture, 48, 72–77 (in Lithuanian).
5. Del Papa M. F., et al. (2003) Amicrocosm study on the influence of pH and the host-plant on the soil persistence of two alfalfa-nodulating rhizobia with different saprophytic and symbiotic characteristics. Biology and Fertility of Soils, 39, 2, 112–116.
6. Hamdy Y. A.(1982) Application of nitrogen-fixing systems in soil improvement and management. Soils Bulletin. FAO. Rome. Italy, 49, 1–190.
7. Hartwig U. A. and Soussana J.F. (2001) Ecophysiology of symbiotic N_2 fixation in grassland legumes. Grassland Science in Europe, 6, 1–10.
8. Kelner D. J., et al (1997) The nitrogen dynamics of 1-. 2- and 3-year stands of alfalfa in a cropping system. Agriculture Ecosystems and Environment, 64, 1, 1–10.
9. Kloppel H., et al (1997) Behaviour and ecotoxicology of aluminium in soil and water. Chemosphere, 35, 1–2, 353–363.
10. Lapinskas E. (1998) Biological nitrogen fixation and nitragin. LIA. Academia, 218 pp. (in Lithuanian).
11. Staley T. E. (1993) Growth of perennial forage legumes in acidic soils of the Appalachian hill-lands after liming. Journal of Plant Nutrition, 16, 12, 2577–2590.
12. Tang C. (1998) Factors affecting soil acidification under legumes. Effect of potassium. Plant and Soil, 199, 2, 275–282.
13. Vassileva V. and Kostov O. (2001) Effect of mineral and organic nitrogen on nodulation and production of lucerne *Medicago sativa* L. under imposed drought conditions // Grassland Science in Europe, 6, 23–26.
14. Watkin E. L. J., et al (1997) Calcium and acid stress interact to affect the growth of *Rhizobium leguminosarum bv. trifolii.* Soil Biology and Biochemistry. 29. 9–10. 1427–1432.
15. Андреюк Е. И., и др. (1988) Почвенные микроорганизмы и интенсивное землепользование, Наукова думка, Киев, UA, 189.
16. Трепачев Е. П., Ягодина М. С. (1991) Симбиотический азот и органическое вещество бобовых в земледелии нечерноземной зоны РСФСР: вклад в плодородие почвы и урожайность озимой пшеницы, Сельскохозяйственная биология. сер. биология растений, 1, 18–34.

EFFECT OF NITROGEN RATE AND VARIETY ON BARLEY GRAIN YIELD AND PROTEIN CONTENT

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Abstract

Increasing local malt production in Lithuania has boosted the demand for barley grain, meeting specific market requirements. Varieties with a high malting quality potential have been recently introduced in Lithuania and this study is aimed at their response to nitrogen fertiliser rate. Field experiments were conducted during 2000–2002 on a loamy soil at the Lithuanian Institute of Agriculture, Kedainiai district, Lithuania. Experimental plots were sown with the varieties Ottis, Scarlett and Barke and were applied with different rates of ammonium nitrate (0, 30, 60, 90 and 120 kg ha^{-1} of N). The growing seasons 2000 and 2001 could be characterized as normal and 2002 as dry. The varieties showed a rather similar yield level and protein content in grain, and the interaction between varieties and nitrogen rate was non significant in most cases. The only exception was found in 2001, when the variety Scarlet produced a significantly higher yield than Ottis and Barke (by 0.32 and 0.62 t ha^{-1}, accordingly). The effect of nitrogen rate on grain yield was highly significant in all three experimental years, with much higher increases in the yield in the years with normal precipitation and lower – in a dry the season of 2002. The yield was closely correlated with the number of grains per m^2 and in a dry season was much lower than in normal moisture conditions, because of the lower number of ears per m^2. The effect of nitrogen on the number of grains was positive and close to linear in the range of N rate up to 90 kg ha^{-1}. Protein content in barley grain was below 115 g kg^{-1} with the application of nitrogen rates up to 90 kg ha^{-1} in 2000 and up to 60 kg ha^{-1} in 2001. In the dry growing season 2002 grain had too high protein content (above 130 g kg^{-1}) in all treatments. In droughty years growers must take appropriate marketing measures to alleviate negative effects on income, since technological practices have rather limited effect.

Key words: malting barley, fertiliser rate, grain quality, number of grain

Introduction

Increasing local malt production in Lithuania has boosted the demand for barley grain, meeting specific market requirements. Choice of variety is important in this respect, because spring barley varieties have a broad variation in malting quality and grain traits (Bertholdsson, 2004). Varieties with a high malting quality potential have been recently introduced in Lithuania, but the interactions of these varieties with local environmental and management conditions have not been adequately studied to secure optimum agronomic and market performance.

For malting barley nitrogen management is especially important, because insufficient nutrition can result in a yield reduction, and excessive nutrition in a quality and premium price loss because of too high protein content. Optimum nitrogen rate can vary with soil and climatic conditions (Богомазов *et al.*, 1997, Petr and Wicke, 1987). A few attempts to simulate yield and quality of malting barely have been made and the models developed, which can be useful as an aid for crop risk assessment and evaluation of crop performance in water and N-limiting environments (Ruiter *et al.*, 1993, Ruiter, 1997). Simulations can provide some guidelines for improved N management, but still there is a need of further studies in the context of local soil conditions and especially site N fertility. Soil mineral nitrogen is an important factor affecting growth of spring barley and efficiency of nitrogen fertilisers (Mattson L., 1990). In our previous studies 77 field experiments were conducted with the variety Roland and a significant correlation was found between grain yield increase and nitrate content as well as mineral N content in the soil layers 0–40 and 0–60 cm (Lazauskas *et al.*, 1995). These studies were not further developed and the effect of soil N on grain quality was not assessed.

Because of the temperate climate, Lithuania belongs to the best areas for barley production (FAO/EBRD, 1999). However, shortage of moisture during the growing season occurs rather often and affects negatively the efficiency of nitrogen fertilisers and finally results in a lower yield and a lower malting grain quality. Varieties also can show a different response to the nitrogen rate with regards to malting barley performance (Лепайыэ, 1980, Oscarsson *et al.*, 1998). Until now there have been no attempts in Lithuania to study the interactions between year and variety as well as between year and N rate regarding malting barley yield and quality under field conditions.

This study was aimed at the effect of variety and nitrogen rate on the yield and protein content of the malting barley varieties recently introduced in Lithuania.

Materials and Methods

A three-year study was conducted during 2000–2002 at the Lithuanian Institute of Agriculture, Kedainiai district, Lithuania. The soil was sod gleyic (Endocalcari-Endohypogleyic Cambisol) light loam, with arable layer's pH_{KCl} – 5.7–6.8, available P 0.064–0.081 g kg^{-1}, available K 0.110–0.141 g kg^{-1} (AL-method), and 0–40 cm layer's mineral N – 6.7–12.6 g kg^{-1}.

Spring barley (*Hordeum vulgare* L.) varieties Ottis, Scarlett and Barke were chosen for this study, as the ones are preferred by the Lithuanian malting industry, and studied at five levels of N fertiliser rate (0. 30, 60, 90, 120 kg ha^{-1}) applied before drilling as ammonium nitrate. Barley was drilled of close to the optimum date (21 April 2000, 1 May 2001 and 18 April 2002) at a rate 400 seeds per m^2. Complex fertiliser (containing 65 g kg^{-1} P and 125 g kg^{-1} K) was band placed at a depth of 6–8 cm at drilling and at a rate of 400 kg ha^{-1}. One herbicidal application and one or two fungicidal and insecticidal applications were made to control weeds, pathogens, and insects in spring barley.

Samples for counts of ear number per m^2 and grain number per ear were taken from each plot before harvesting in four places 0.5 m^2 per plot. Grain was harvested with a plot combine harvester and grain samples from each plot were taken for moisture (yield corrected to 15% of moisture), protein content (Kjeldahl N × 6.25), and a thousand grain weight.

The experiment design was 3 (variety) × 5 (N rate) factorial split-plot in three replications. A combined analysis was used as a preliminary tool to test the effect of year x variety and year × N rate interactions (Petersen, 1994). In the case of significant interactions, analysis of variance for each season was preformed. Means separation was done by using the least significant difference (LSD) at 0.05 probability level. Calculations of linear regression and correlation were performed in a conventional in crop science way (Clewer A. G. and Scarisbrinck D. H., 2001).

Growing seasons 2000 and 2001 could be characterized as normal and 2002 as dry.

Results

Analyses of variance for all years combined showed that significant effects for grain yield were attributed to year, variety, and N rate and also to year x variety and year x N rate interactions (Table 1). Thus there was a significant difference in grain production from one season to other and treatment differences varied among seasons. Interactions variety x N rate, and year x variety x N rate were non significant, so the results were averaged over varieties, when the effect of N rates was analysed and vice versa. Effects for grain yield components were non-significant for year x N rate interactions, so it was possible to analyse results as a 3-year means. However, it was not in the case of varieties.

Table 1. Analyses of variance of grain yield, and yield components and protein content in grain for all years combined

Source of variation	DF	Mean squares of				
		grain yield	number of ears per m^2	number of grains per ear	1000-grain weight	protein content
Year	2	30.41**	307.270**	134.1**	956.8**	6082.2**
Replications	6	0.67**	16.233*	1.6	5.5**	69.3
Variety	2	0.99**	8.230	15.4**	76.5**	38.2
Year x Variety	4	0.52**	13.334	3.6*	26.9**	14.2
N rate	4	17.84**	153.154**	5.7**	10.4**	1669.4**
Year x N rate	8	0.52**	4.266	2.1	2.7	217.4**
Variety x N rate	8	0.03	3.992	0.6	2.1	26.3
Year x Variety x N rate	16	0.06	8.269	1.4	1.2	21.1
Error	84	0.113	7.089	1.3	1.4	33.1

*, ** Significant at 0.05 and 0.01 probability levels.

Significant differences in grain yield and yield components were found among years. In 2001 spring barley produced the highest number of ears and the highest yield of grain, but a 1000-grain weight was the lowest. Conversely, in 2002 the number of ears and grain yield was the lowest, but a 1000-grain weight was the highest. The grain yield was closely correlated with the number of grains per m^2 (R = +0.89*;

R = +0.96**, and R = +0.97** in 2000, 2001, and 2002 respectively). Correlation between grain yield and 1000 grain weight was non-significant.

The varieties showed significant differences in yield only in 2001 (Table 2), when the variety Scarlet produced a higher yield than Ottis and Barke (by 0.32 and 0.62 t ha^{-1}, accordingly). A higher yield probably resulted from a higher number of ears per m^2 in Scarlet, but the difference between the varieties regarding this trait was statistically non-significant. The effect of varieties as well as the effect of interaction between varieties and nitrogen rate on the number of ears and grain number per m^2 was non-significant.

The effect of nitrogen rate on grain yield was highly significant in all experimental years, with much higher yield increases in 2000 and 2001 with normal precipitation and lower in the dry season of 2002. The effect of nitrogen on the grain yield was positive and close to linear in the range of N rate up to 90 kg ha^{-1} with the slope of linear regression line for dependence of grain yield (y, t ha^{-1}) on N rate (x, kg ha^{-1}) rather similar in 2000 (b = +0.022±0.004) and 2001 (b = +0.025±0.005), and much lower in 2002 (b = +0.015±0.002).

Nitrogen fertilisers increased number of ears per m^2 and number of grain per ear, but higher rates of N reduced a 1000-grain weight. The effect of nitrogen on the number of grains was highly significant and positive (Fig. 1). The relationship was close to linear in the range of N rate up to 90 kg ha^{-1} (R = +0.96*, R = +0.95* and R = +0.99* in 2000, 2001, and 2002 respectively) with the slope of linear regression line for dependence of number of grain (y, 1000 grains per m^2) on N rate (x, kg ha^{-1}) higher in 2000 (b = 0.054±0.011) and 2001 (b = 0.044±0.010), and lower in 2002 (b = 0.036±0.003).

Table 2. Grain yield and protein content in grain as affected by variety and nitrogen rate

Treatment	Grain yield			Protein content		
	2000	2001	2002	2000	2001	2002
Variety		t ha^{-1}			g kg^{-1}	
Ottis	4.14	5.35	3.40	108	113	130
Scarlet	4.19	5.66	3.91	111	112	132
Barke	4.11	5.04	3.69	111	112	132
LSD_{05}	0.81	0.34	0.40	4.9	4.9	4.5
N rate						
0	2.80	3.67	2.71	104	98	127
30	3.80	4.93	3.19	105	100	128
60	4.48	5.58	3.43	106	108	131
90	4.79	5.92	4.11	114	118	131
120	5.01	5.91	4.31	119	129	137
LSD_{05}	0.45	0.24	0.33	5.0	8.0	5.7
Source of variation			Analysis of variance			
Variety	NS	*	NS	NS	NS	NS
N rate	**	**	**	**	**	**
Variety x N rate	*	NS	NS	NS	NS	NS

*, ** Significant at 0.05 and 0.01 probability levels.

For grain protein content significant effects were attributed to year, N rate and also to year x N rate interactions (Table 1). Effects of variety, interactions variety x N rate, and year x variety x N rate were non-significant, so the results were averaged over varieties.

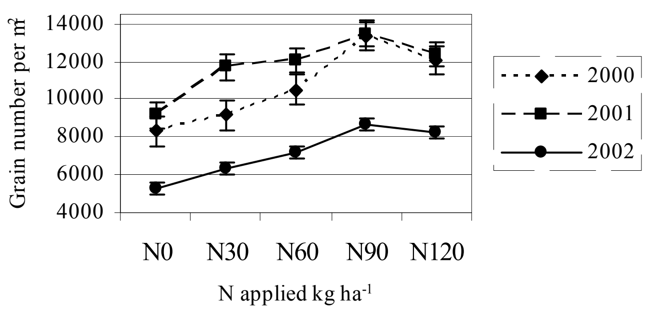

Figure 1. Grain number produced per m^2 as affected by nitrogen rate. Error bars represent SE of means

The effect of nitrogen fertilisers on protein content was positive and rather similar in 2000 and 2001. Protein content in barley grain was below 115 g kg^{-1} with the application of nitrogen rates up to 90 kg ha^{-1} in 2000 and up to 60 kg ha^{-1} in 2001. In the dry growing season of 2002 grain had very high protein content (above 130 g kg^{-1}) in all treatments.

Discussion

Low effect of variety on protein content in grain and, in most cases, on the grain yield could be partly explained by too narrow differences in genotypes studied in our experiments. The varieties chosen were those preferred by industries and with good preliminary results of agronomic performance under Lithuanian climatic conditions. Nevertheless, our results are in a good agreement with those found in studies in Latvia with barley varieties/lines with increased protein content (Belicka *et al.*, 2004). There were no significant differences found in mean yield or protein content among the genotypes originated from Europe, America, Australia and New Zealand.

Spring barley in plots without N fertilisation were able to produce as few as 5.3 thousand grains per m^2 in 2002, partly due to the rather low content of Nmin in soil (6.7 10^{-3} g kg^{-1}) and, probably, because of limited possibility to uptake from soil organic nitrogen pool in dry season. In 2001 the content of available Nmin in the soil was high (12.6 10^{-3} g kg^{-1}) and conditions for mineralization of soil organic nitrogen were more favourable, consequently spring barley in the plots without N fertilisation produced 9.2 thousand grains per m^2. Qualitative effect of N fertilisation on the number of grains was rather similar in different years, and close to linear in the range of N rate up to 90 kg ha^{-1}. Quantitatively in dry season 2002, one kg of N produced lower number of grain, than in normal season 2000 or 2001. However, we agree with opinion (Oscarson, 2000), that considering linear relationship between N availability and the total number of grains in the plant it is tempting to single out grain number as the most important character responsible for the plasticity in production with respect to N availability. Instead, there are many individual processes that, integrated, are responsible for increased yield.

The effect of nitrogen fertiliser rate on protein content in grain in 2000 and 2001 was in agreement with unpublished results from our earlier experiments with the varieties Alsa, Ula, Aidas and Baronesse. Thus general N management advice for malting barley growers could be extended also to new malting barley varieties. However, in 2002 protein content in grain was high even in the plots without N fertilisation. The lower number of grains per m^2 and lower yield of grain probably required a lower amount of nitrogen to produce it and more N was available to transport to grains for storage in 2002. High temperatures during grain filling can be an important reason of high protein content in malting barley grain (Petr and Wicke, 1987). However, results from our experiment suggest that moisture regime was also quite important. The mean temperature in July in 2001 (21 °C) was higher than in 2002 (20.3 °C), but the amount of rainfall was also much higher – higher than normal for July in Dotnuva. Our results support the opinion (Ruiter, 1997), that benefits of N application for yield and partly malting barley quality enhancement should be evaluated within the context of soil moisture information and data on site N fertility. In droughty years, improved grain could be achieved if soil moisture was managed to reduce soil water deficit. However, such management measures are not practiced in Lithuanian; therefore growers must take appropriate marketing measures to reduce the negative effects on income, since technological practices have a rather limited effect in such years.

Conclusions

Varieties showed a rather similar level of yield, and yield components and protein content in grain. Effect of nitrogen rate on grain yield was highly significant in all three experimental years, with much higher increases in yield in the years with normal precipitation and lower in dry season. The effect of nitrogen rate on the yield and number of grains per m^2 was positive and close to linear in the range of N rate up to 90 kg ha^{-1}. Protein content in barley grain was below 115 g kg^{-1} with the application of nitrogen rates up to 90 kg ha^{-1} in 2000 and up to 60 kg ha^{-1} in 2001. In dry growing season grain had too high protein content (above 130 g kg^{-1}) in all treatments. In droughty years growers must take appropriate marketing measures to reduce the negative effects on income, since technological practices have a rather limited effect in such years.

References

1. Barley, Malt, Bier. (1999) Agribusiness Handbooks. FAO/ERBD, 1, 5–15.
2. Belicka I., Briedis U., Liepa A. (2004) The Characteristics of Barley Germplasm with Increased Crude Protein Content under Latvian Conditions. Research Papers of the Lithuanian University of Agriculture, Vagos, 64 (17), 13–19.
3. Bertholdsson N. O. (2004) The use of environmentally stable grain characteristics for selection of high extract yield and low β-glucan in malting barley. European Journal of Agronomy, 20, 3, 237–245.
4. Clewer A. G. and Scarisbrick D. H. (2001) Practical statistics and experimental design for plant and crop science. John Wiley and Sons, LTD, 331.
5. Mattsson L. (1990) Effect of inorganic soil nitrogen level on fertilizer nitrogen requirements by spring barley on regularly manured soils. Swedish Journal of Agricultural Research, 20, 141–145.
6. Lazauskas S., Vaisvila Z., Matusevicius K. *et al.* (1995) Effect of mineral soil nitrogen and rate of nitrogen fertilisation on spring barley. Scientific works of the Lithuanian institute of agriculture, Zemdirbyste, 50, 41–53. (in Lithuanian).
7. Oscarsson M., Andersson R., Aman P., Olofsson S,. Jonsson. (1998) Effects of cultivar, nitrogen fertilisation rate and environment on yield and grain quality of barley. Journal of the Science of Food and Agriculture, 78 (3), 359–366.
8. Oscarson, P. (2000) The strategy of the wheat plant in acclimating growth and grain production to nitrogen availability. Journal of Experimental Botany, 51/352, 1921–1929.
9. Petersen R. G. (1994) Agricultural field experiments. Design and analyses. Marcel Dekker, Inc., 409.
10. Petr J., Wicke H. J. (1987) Vliv pocasi na kvalitu sladovnickeho jecmene. In: Petr J. (eds) Pocasi a vynosy, Statni zemedelske nakladatelstvi, Praha, 219–231.
11. Ruiter J. M., Stol W., van Keulen H. (1993) Simulation of yield and quality of malting barley. Proceedings Agronomy Society of N. Z., 23, 11–19.
12. Ruiter J. M. (1997) Prediction of effects of nitrogen management on barley quality for malting. Proceedings Agronomy Society of N.Z., 27, 67–72.
13. Богомазов Н., Шильникова И., Нетребенко Н. (1997) Влияние удобрений и погодных условий на урожай и качество пивоваренного ячменя на черноземие выщелогенном в Белгородской области, Агрохимия, 2, 60–65.
14. Лепайыэ Я. (1980) Пивоваренный ячмень в Эстонии, Валгус, Таллин, 246.

SIGNIFICANCE OF COLOUR IN MORAINES STRATIGRAPHIC CORRELATION

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Abstract

The origin of colour and its possible use in stratigraphic correlation was studied. Genesis of moraine colour was clarified, methodical recommendations for colour identification in the studied deposits were given and estimation of the necessary studies for colour use in stratigraphic correlation was done.

Results of studies showed that moraine colour could be used as geochemical environment and material transfer indicator. Three different by colour moraines (Latvia Q_{3ltv}, Kurzeme Q_{2kr}, Letiza $Q_{2ltž}$) and their most characteristic geological sections in seven outcrops in South-west of Kurzeme, on the river Letiza banks and eight outcrops on the Baltic sea coast were included in this study. Colour consistency of Latvia′s glacigenic deposits in geological plan and geological section was estimated. In total, 52 moraine samples of different colour were investigated.

Key words: morane, stratigraphy, colour

Introduction

Colour is to begin with when conducting geological research. Along with composition, colour is a trait characterizing distinction and peculiarity of the deposit. It is easy recognized but inconsistent, and of descent origin. Therefore colour differences, stability, reasons for heterogeneity, characteristics and its role as well as possibilities and limitations for use in stratigraphic correlation were studied.

In Latvia, little information is available in the literature concerning moraines genesis and its stratigraphic significance. In Latvia, A.Stinkule (Стинкуле А., 1963) has given the most significant contribution in this field. Origin of colour in Devonian classical rocks has been studied by V. Kuršs (Kuršs V., 1999, Курш В., 1992) V. Seglins (Segliņš V., 2002), (Ozols D., 1990) and other researchers also have contributed to moraines colour.

Research findings documented in the scientific literature show insufficient data amount regarding genesis and role of moraines colour in stratigraphic geology.

Research on the role of colour in sedimentary rock stratigraphy has been conducted worldwide, however little information is available on the role of colour in glacigenic deposits stratigraphy.

The research goal was analysing the use of moraines colour in stratigraphic correlation, estimation and preparation of methodical instructions for colour identification and the necessary investigations to be conducted on colour use in stratigraphic correlation.

Research on genesis and role of moraines colour in stratigraphic correlation was conducted using different methods and their interpretations.

Research task included literature studies on estimation of objective and partial field and laboratory methods used and do the following:

- Distinguish and estimate moraines colour change in geological plan and geological section.
- Estimation of the law-governed nature of moraines colour and mineralogical composition.
- Diagnostics and analysis of colour in moraine samples of different moisture and granulometric fractions.
- Moraines surface morphology investigations.
- Experimental part.
- Hypothesis propound on genetic origin of colour: primary, secondary or primary–secondary.

Three moraines of different glaciation occurring maximum close to the earth surface in the South-west Kurzeme – Letiza, Kurzeme and Latvia – were selected for the research. Research goal was to clarify possibilities and limitations for colour use in their inter-correlation. In these moraines colour inconsistency was well observed both in geological plan and geological section of the chosen territory where moraines of different age were outcropping. The investigated territory is located in South-west Kurzeme including the Baltic shore from Saraiki to Jurkalne as well as outcrops on Letiza river banks from Vibini-Meldzere road bridge 2 km down stream.

In field experiments in the investigated territory 15 outcrops were established and 6 boreholes were done from which samples were taken for laboratory analyses. Samples were taken from all moraine layers differing in colour. To obtain more precise and inter-correlated data, all laboratory analysis were done using samples, which were stored and transported in similar conditions.

Materials and Methods

Extended literature studies allowed optimal analyses complex necessary for this particular investigation. X-ray diffraction method and mineralogical petrographic analyses in light microscope are suitable for analysing moraines mineralogical composition. Different analytical reagents used for clay minerals determination were estimated as un-precise and were not included in the research (Веденеева Н., Викулова М., 1952) .According to internationally recognized practice Munsell colour chart was used in colour diagnostics.

With the purpose of labour quality improvement the following analytical methods were added to those mentioned above: qualitative and quantitative analysis of Fe (II, III) and Mn (II), and determination of iron cement formation using skannering electronic microscope.

In the first stage of research laboratory testing methods for further research were chosen, and experimental stage of laboratory tests with practical estimation of the chosen methods was done conducting experiments with separate investigated samples.

According to research plan the following experiments were made:

- Colour diagnostics in moraine samples of different moisture content.
- Colour diagnostics in moraine samples of different granulometric composition.
- Analysing different moraine fractions in light microscope.
- Light brightness and glittering inconsistency analysis during drying.

A part of experiments were estimated as proper and suitable and were used in further research.

Geological field experiments were next stage of the research. Observations sites were chosen.

In geological field experiments in South-west Kurzeme the following work was performed: locations of outcrops and bore-holes were defined and co-ordinates were fixed in GPS (Global Positional system), outcrops were cleared, sedimentary deposits identified and defined, colour diagnostics, outcrop description, graphical presentation of a geological section, sampling were done.

The third stage of research was devoted to laboratory activities, which included versatile moraine colour interpretation methods: piromorphological and granulometric analysis, colour diagnostics, chemical testing of samples and investigations in light microscope, X-ray diffraction analysis and investigations in skannering electronic microscope.

In analytical part of the research moraine samples were prepared according to each method used. In estimation of samples, subjective factor was lessened by ciphering samples prior to field research. Samples with a numbered name were used. Deciphering of samples was done in the final stage of research when obtained results were analysed and conclusions were made.

Results

Obtained results were analysed and evaluated by several factors: usefulness, interpretation possibilities, inter-correlation and novelty. Within the framework of data interpretation, methods were selected for further colour studies. Summarization of these methods resulted in preparation of methodical instructions for moraine colour use in stratigraphy.

Summarizing resources used in the research and obtained results led to conclusion regarding genesis of moraine colour and regularities of its establishment.

Results obtained by X-ray diffraction analysis could be explained by the fact that moraine basic mineralogical composition was not connected with glacigenic deposits colour though it was not deniable that origin of colour had been dependent on the mineralogical composition of moraine.

As confirmed by the obtained results different shades of the brown colour observed in moraines are due to trivalent iron compounds, which in Letiza and Latvija glacigenic deposits mainly occur in the form of hydroscopic oxides and hydroxides around quartzite grains (Alksnis U., Kļaviņš., Kūka P., Ruplis A., 1990, Hammer J., 2003) and in the moraine matrix. These results are in agreement with literature data on brown colour origin in sedimentary rocks.

Formation and stability of secondary trivalent iron compounds in samples of Kurzeme glacigenic deposits could be explained with external environment factors and moraine chemical composition interaction as in borehole samples secondary iron compounds were not observed.

Age of glacigenic deposits, and distribution of iron compounds, which is the decisive factor in moraines of different colour is delineated schematically. The concentration of iron compounds is closely connected with moraines colours (Fig. 1).

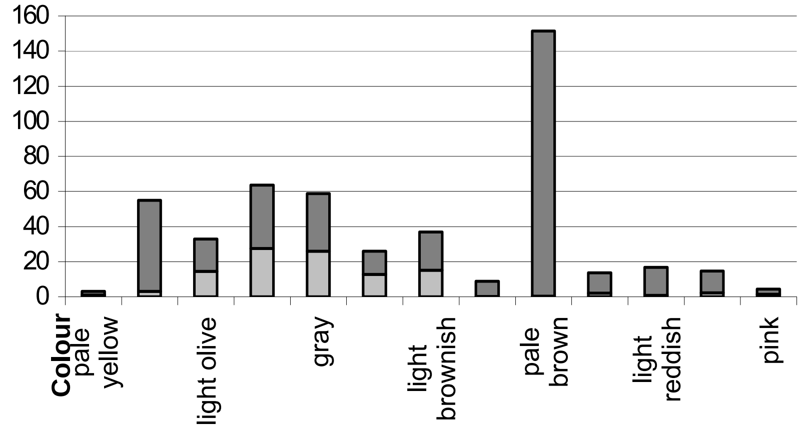

Figure 1. Mean Fe^{2+} and Fe^{3+} amounts in moraines of different colour (100^{-1} g) (Luse I.)

Moraine colour allowed determination of approximate amount of bivalent and trivalent iron compounds and vice versa knowledge of approximate amount of bivalent and trivalent iron compounds allowed estimation of a deposit colour.

Data obtained by electronic microscopy analysis did not allow conclusion in advance about cement formation in moraines. Iron compounds in combination with other minerals occurring in aleurite and clay fractions form cohesive substance of moraine frame (carcass) in which new formations of minerals (see Figs. 2, 3) are observed on separate mineral grains, which would possibly contribute to the formation of cement in future.

In its turn, the origin of grey colour in Kurzeme glacigenic deposits was somewhat different compare to brown colour moraines. The grey colour is formed by the predominance of bivalent iron compounds (see Fig. 1), which do not loose stability due to organic material enclosed in the moraine thus preserving reducing environment, which is necessary for bivalent iron. Organic material, which is enclosed in the moraine, is humificated. Determination of its genesis is burdened because determination of humus amount and composition is complicated (James B., 2002, Орлов Д., 1997).

Comprehension about origin of grey colour is to be searched for in genesis of the primary material enclosed in moraine or in genesis of the colour of sea deposits. The sea deposits or Ulmale sea layers group are distributed between Pavilosta and Jurkalne (Ozols D., 1990). The sea deposits had formed in the zone of the upper and lower submarine coastal slope but in the final stages of formation during basin regression within the beach and lagoon. This environment had been suitable for decomposition of different microorganisms and bacteria resulting in trivalent iron compounds reduction into bivalent iron compounds.

In spite of the oxidizing environment prevailing in the sea coastal outcrops, the reduced iron is not fully oxidized. It could be explained with erosion processes occurring in places where the moraine in different shades of grey is outcropping. These erosion processes are “clearing” outcrop in a natural way, exposing new moraine deposits, which have never before been subjected to active oxidation environment. A layer subjected to oxidation environment has only a partial oxidation possibility because much more time is needed for full layer oxidation. It could be explained with weak air capacity and air percolation in glacigenic deposits. As a result of exogenous processes moraine material is partly transformed − loosened, dried, moistened, etc. For that reason oxidation processes are much more rapid in upper layers of the moraine being subjected to processes mentioned above.

Results of granulometric analysis show maximal distribution of iron compounds among fractions of fine sand, aleurite and clay. It could be explained with the fact that iron compounds, which have an influence on moraines colour, are formed determining iron compounds formation under the influence of weathering processes.

In future colour diagnostics in moraine samples of different moisture will be equally interpreted if it is done in naturally dry, non-grind samples (colour becomes more faded with colour of minerals powder), in the same lighting, indirect sunbeams and if one person is doing it for the whole collection of samples. All these conditions provide comparatively precise reflection of moraine colour.

Grain topography. In all suspended samples, which were morphologically analysed using scannering electronic microscope, there was observed expressed angularity of mineral grains. It indicates that glacial material was transformed and mechanically crumbled and cut up into small bits. It in its turn indicates, that initial material was not transferred and transported under the force of active water environment (Figs. 2, 3).

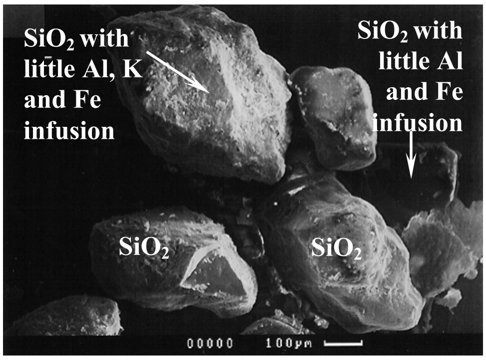

Figure 2. Quartzite grains with angular morphology

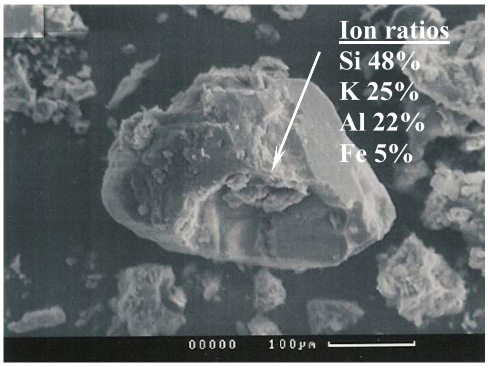

Figure 3. Feldspar grain

Crystalline matrix. In split off samples, in mineral grains there is well observed very fine lamellar cohesive substance of crystalline matter, which possibly is matrix of iron compounds and clay minerals, which has resulted due to transformation of mineralogically-petrographic material in the process of weathering. This hypothetic statement is partly affirmed by the results obtained in analytical analysis and microanalysis using scannering electronic microscope.

Ion ratios. Changes in ion ratios were observed in moraine samples of different age. Distribution of Si, Al, Fe, K, Ti, P, Ca, s, Mn, and Na amounts was somewhat different in each sample. However it cannot lead to conclusion regarding moraine chemical inequality due to shaft of electrons running into one of the selected points for which spectrum “is built” with numbers of obtained impulses. Scannering of a sample surface is possible giving a picture of total chemical elements distribution. However such an approach does not characterize precise chemical composition of moraine without analysing twenty or more samples of moraine different age.

Discussion

Obtained data indicate that moraine colour is inconsistent and not always distinguishable in geological plan. This is a limiting factor for a wide use of colour in stratigraphic correlation. Though the visual sight of colour is explained by “values”, which are used in physics or optics, yet it is of chemical origin. At a definite wavelength light is falling on retina and we see a definite colour, which is connected with an object's luminescence (Шаронов В., 1961), which in its turn is connected with molecular composition of matter formed by chemical elements. This statement is substantiation to colour-forming components diagnostics when colour visual parameters are to be identified. Obtained results confirm connection between colour and chemical composition of moraine.

In stratigraphic correlation, moraine colour could be partly used when determining geo-chemical conditions of glacigenic deposits formation.

Colour used as additional component in glacigenic deposits stratigraphy should be identified both by Munsell colour chart and analytical analysis. In that way these methods might be inter-correlated and credible results could be obtained. Such an approach might be helpful in determining material of moraine origin and influence of geo-chemical processes on moraine deposits. Comprehension of these criteria and analysis of primary and secondary origin of colour in material allow rather wide discussion regarding genesis of glacigenic deposits being the most significant criteria for colour partial use in stratigraphy.

When identifying distribution and genesis of colour, research is recommended in the following succession: moraine samples taken in field conditions should be placed in tightly sealed polyethylene bags to preserve natural moisture level. In the laboratory, material from common sample is taken for dry sample colour identification using Munsell colour chart and for analysing in scannering electronic microscope. The rest of the sample is recommended to be stored in temperature similar to that at the moment of sampling thus maintaining its initial state. Material used for colour diagnostics and analysis in scannering electronic microscope should be dried in natural air-moist conditions. Chemical-quantitative amounts of elements were determined colorimetrically. Prior to analytical analysis chemical vessels and reagents should be prepared, and moisture content in moraine samples should be determined. Samples should be numbered in a definite succession, and after moisture determination quantitative analysis was completed. Obtained results were summarized and inter-correlated with colour codes for naturally dry samples. Morphology was analysed and microanalysis was done separately in scannering electronic microscope. Obtained results should be considered in distribution of colour definable elements in samples of moraine deposits. Results were graphically delineated in a colour pyramid or in colour profile considering changes both in geological plan and geological section where colour shades of moraine layers of different age would sooner get covered, as distribution of colour was not connected with the age of deposits but with geo-chemical conditions.

Conclusions

Colour is a significant geo-chemical value, which could be used when analysing conditions and environment of glacigenic deposits transfer.

Colour of glacigenic deposits is closely connected with geo-chemical processes going on in moraine material. Colour is an indicator of geo-chemical conditions.

Moraine colour is better distinguished in geological plan rather than in geological section, it is dynamic and inconsistent value.

In Latvia and Letiza moraines the brownish colours are due to predominance of trivalent iron compounds, but in grey moraines (Kurzeme moraine in the investigated territory) due to concentrations of bivalent iron compounds.

Iron compounds are like cohesive substance of crystalline matter as amounts of clay minerals in moraine are comparatively small – up to 15%.

There is possible only a partly use of moraine colour in stratigraphic correlations, i.e. indirectly (see above) using it parallel to other stratigraphic methods.

Strictly defined criteria for moraine colour use are necessary in stratigraphic correlations.

A partly use of colour is recommended in stratigraphy applying it in reconstructions and interpretations of geo-chemical conditions, which would limit tactless use of colour in stratigraphy when considering particular colour layers as geological values of different age.

References

1. Alksnis U., Kļaviņš., Kūka P., Ruplis A., (1990). Fizikālā un koloidālā ķīmija. Rīga, Zvaigzne, 425.
2. Hammer J., (2003). Quartäre Sedimente als Geologische Barrieren. Berlin/Heidelberg/New York/ HongKong/Lonndon/ Mailand/ Paris/Tokyo, Springer, 499.
3. James B. R., (2002). Redox phenomena. Encyclopedia of Soil Science, ed: Lal R., New York/Basel, Marcel Dekker, 1098–1100.
4. Kuršs V., (1999). Devona klastisko nogulumu krāsa un tās izmaiņas: novērojumi Lodes mālu karjerā. Referātu tēzes, Latvijas Universitātes 57. Zinātniskā konference, Zeme/Daba/ Cilvēks. Rīga, Latvijas Universitāte, 164.
5. Ozols D., (1990). Apledojuma pēdas Kurzemē. Zinātne un mēs №3. Rīga, 18–20.
6. Segliņš V., (2002). Glacigēno nogulumu sastāvs un tā izmaiņas Rietumlatvijā. Referātu tēzes, Latvijas Universitātes 60. Zinātniskā konference, Ģeogrāfija/Ģeoloģija/ Vides Zinātne. Rīga, Latvijas Universitāte, 242.
7. Wichmann P., Bronger., July 10–16, 1994. Efficiency of Weathering in Tropical Climates: Genesis and Mineralogy of „Red Soils" in SW-Nepal. 15th World Congress of Soil Science, Volume 8b, Commission VII: Poster Sessions. Mexico, International Society of Soil Science, 91.
8. Веденеева Н. Е., Викулова М. Ф., (1952). Метод исследования глинистых минералов с помощъю красителей и его применение в литологии. Москва., Государственное издателъство геологической литературы, 44.
9. Курш В. М., (1992). Девонское терригенное осадонакопление на главном девонском поле. Рига, Зинатне, 208.
10. Орлов Д. С., (1997). Гуминовые вещества в биосфере. Соровский образователъный журнал №2, 56–63.
11. Стинкуле А. В., (1963). Цветовая характеристика моренных отложений Летижского разреза. Вапроси четвертичной геологии II. Рига, 87–95.
12. Шаронов В. В., (1961). Свет и цвет. Москва, Физико-Математическая литература, 311.

EFFECT OF INCREASED NITROGEN FERTILISER RATES ON YIELD AND GRAIN QUALITY OF WINTER WHEAT VARIETIES

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Abstract

Winter wheat was cultivated in the field at the State Stende Plant Breeding station in 2002–2004 on a podsolic sand loamy soil. A field experiment of nine varieties of winter wheat was designed to study the influence of variety choice and the effects of additional top dressing (up to N_{90}) of N fertiliser rates to grain yield and quality data such as grain protein content, Zeleny index, falling number, and volume weight. The mathematical analysis of the data was applying the analysis of variance. The meteorological conditions in 2002–2004 were different compared to average long-term observations and this difference influenced plant development and yield. The results showed that differences in agro-meteorological conditions and variety choice influenced the grain quality parameters significantly more than N fertilisation given additionally to N_{90}.

Key words: winter wheat varieties, grain yield, grain quality, nitrogen fertiliser

Introduction

It was ascertained in field experiments that the plant reaction does not always correspond to the particular anthropogenic influence, the amount of fertiliser used and other scientific farming measures. Sometimes a measure gives positive effect in long term, but at the same time the effectiveness of this particular measure in particular years can be low (Лазарев, 1997).

The analyses of climatic and anthropogenic factors show that the yield capacity of winter wheat is by 47% influenced by agro-climatic conditions, by 16% – by the usage of fertilisers, and by 15% – by the choice of the pre-plant. When increasing the intensity of agriculture, the influence of climatic factors does not diminish, as the potential productivity of different varieties is growing, their endurance for biotic and abiotic factors does not increase. The influence of those environmental factors, which are not always possible to optimise in field conditions by technogenic measures, increases considerably (Лазарев, 1997).

It has been proven in a lot of scientific researches that the moisture provision during critical periods of plant growing and development (shooting into ears, flowering and grain formation) noteworthy influences the yield capacity of winter wheat (Nielsen and Halvorson, 1991; Лазарев, 1997). There has been noted direct and close connection between the yield capacity of winter wheat and precipitation in the following periods: germinating – clustering – shooting into ears – flowering (Лазарев, 1997).

The N-fertiliser is an important factor that stabilises the grain yield of winter wheat. However, the nitrogen effect is small compared to climatic (Teesalu and Leedu, 2001) and variety influences (Gooding *et al.*, 1997; Livmanis *et al.*, 2003). The effect of fertilisers depends on the climate zones (Garrido-Lestache *et al.*, 2004). Much of the research on efficient fertiliser use has been carried out in the temperate climate regions.

The aim of the present study was to determine the effects of increased N-fertiliser rates on grain yield and grain quality of winter wheat varieties in Ziemeļkurzeme (Northkurland) conditions.

Materials and Methods

Winter wheat was cultivated in the field at the State Stende Plant Breeding station in 2002–2004. The winter wheat varieties 'Donskaja polukarlikovaja', 'Zentos', 'Hereward', 'Tarso', 'Moda', 'Gumbo', 'Stava' and 'Kosack' were grown on a sod podzolic and sodgleysolic soil (Table 1). The winter wheat seeding rate was 500 germination seeds m^{-2}. The field experiment was carried out using a randomised block design, a plot size of 17.5 m^{-2} (1.75 m × 10 m) and 4 replicates. The previous crop in trials was mustard fallow. Pre-plant fertiliser was $N_{15}P_{26}K_{75}$ kg ha^{-1} and ammonium nitrate (NH_4NO_3 – 34%) was applied in spring at growing stages (GS, by Zadoks): renewing of plants vegetation (GS 22–24), stem elongation (31–33) and heading (51–53). N-fertiliser variants: N_{90}, $N_{120(90+30)}$, $N_{150(90+60)}$, $N_{180(90+90)}$, and $N_{180(90+60+30)}$.

Table 1. Soil characteristics (using Latvian Standard – LVST ZM 80–97, 82–97, 82–97, LVS ISO 10390:2002)

Indices	2001–2002	2002–2003	2003–2004
Soil type	sod podzolic loamy sand and sand soil	sod podzolic loamy sand soil	sod podzolic and sod-gleysolic sandloam soil
pH_{KCl}	6.2–6.5	6.1–6.3	6.0–6.5
Humus content, g kg^{-1}	12–15	17–18	19–24
P, mg kg^{-1}	115–146	125–152	55–125
K, mg kg^{-1}	147–154	122–130	106–276

The herbicide Tribenuron-methyl (Granstar, 750 g a.i. kg^{-1}, Du Pont de Nemour) and Florasulam (Primus, 50 g a.i. l^{-1}, Dow AgroSciences) was used at GS 26-29 at the rate of 12 g ha^{-1} + 75 ml ha^{-1}. The fungicide Methil-krezoksim, Epoxiconozol and Fenpropimorph (Allegro Plus, 125 + 125 + 150 g a.i. L^{-1}, BASF) was used at GS 31-33 and GS 47-51 at the rate of 0.5 l ha^{-1} + 0.5 l ha^{-1}. The retardant Clormecvat chloride (Cikocel, 750 g a.i. L^{-1}, BASF) was used at GS 26-29 at the rate of 0.75 l ha^{-1} and Mepikvat chloride + Etephon (Terpal, 305 + 155 g a.i. L^{-1}, BASF) was used at GS 37-49 at the rate of 0.5 l ha^{-1}.

The crop was harvested from 29 July to 3 August in 2002, 8–18 August in 2003, and 11–27 August in 2004. The plots were combine-harvested at grain ripeness. The grain samples were cleaned by removing impurities with a 2.1 × 20 mm slotted sieve. The cleaned grain was milled and following qualitative indices were determined: protein content, g kg^{-1} (by Kjeldahl, by Latvian Standard – LVS 277 – 2000), falling number, s (by Latvian Standard – LVS ISO 3093 – 2003), Zeleny index (by Latvian Standard – LVS ISO 5529 – 2003), starch content, g kg^{-1} (by Everss), and volume weights, g l^{-1} (by Latvian Standard – LVS ISO 7971 – 2 – 2003).

The meteorological conditions in 2002–2004 were different compared to average long-term observations and this difference influenced plant development and yield. The year 2002 was characterised by wet and warm beginning of July, but in 2003 drought was observed and July was warm, and the middle of August was wet and warm. The weather of the growing period of cereals in 2004 was wet and cold, however at the time of harvesting the weather became drier and warmer.

MS Excel program was used for data statistical processing by the methods of two-factor analysis with replication (A – increased N fertiliser rates, B – winter wheat varieties, n – years) and of correlation analysis, the coefficient of variations (S, %). The test of statistically significant differences ($\gamma_{0.05}$) at Fischer criterion (F) and density of factors' influence (η^2, probability < 0.05%) were used for the analyses of means differences.

Results and Discussion

The influence of factors shows that the greatest difference in yield capacity was provided by differences in soil and meteorological conditions during the trial years, the choice of increased norm of N fertiliser and interaction of factors (AB). The choice of variety – factor B – had the least influence on the yield capacity. Non-investigated factors also had great influence (Table 2).

Comparing the influences of different factors, the biggest differences in protein content, starch content Zeleny index, falling number and volume mass results were marked by the choice of the variety and changes in agro-meteorological conditions during the vegetation periods (Table 2).

Table 2. The influence of factors on winter wheat grain yield and grain quality indices, η %, 2002–2004

Factors	Grain yield	Protein content	Zeleny index	Falling number	Starch content	Volume weight
Increased N fertiliser rates – factor A	16.15*	12.05*	6.48*	0.82	5.91*	1.48
Winter wheat varieties – factor B	3.49	33.29*	38.12*	9.50	41.69*	39.47*
Interaction between factors AB	29.37*	1.90	1.49	3.06	3.07	5.56
Agro-meteorological conditions	23.19*	39.28*	34.65*	28.02*	27.17*	28.90*
Effect of unexplored factors	27.79	13.48	19.26	58.61	22.17	24.58

* $F > F_{0.05}$.

The winter wheat crop, when using increased norms of N fertiliser (above N_{120}) did not provide increase of yield capacity in the years 2002 and 2003. It might have been influenced by the small amount of precipitation during the stalking phase of winter wheat, and the low cold-resistance of several varieties during the wintering period in 2003. In 2004, increased norms of N fertiliser above 120 kg ha^{-1} also did not provide increase of significant yield capacity, however, a gradual yield capacity increase has been noted. As the fertiliser norm was increased, the variation of yield capacity data decreased and the lowest was observed in 2003 (Table 3).

Table 3. The effect of increased N fertiliser rates on grain yields of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	t ha^{-1}	±	S %	t ha^{-1}	±	S %	t ha^{-1}	±	S %	t ha^{-1}
N90	7.01	0.00	19.1	7.81	0.00	7.7	7.30	0.00	16.3	7.37
N120(90+30)	8.16	1.15	5.7	8.07	0.26	8.2	8.88	1.58	11.9	8.37
N150(90+60)	7.78	0.77	5.4	7.66	–0.15	3.8	8.96	1.66	5.4	8.13
N180(90+90)	8.07	1.06	6.0	7.70	–0.11	2.6	9.03	1.73	5.2	8.27
N180(90+60+30)	8.16	1.15	5.2	7.44	–0.37	4.2	9.50	2.20	5.3	8.37
$LSD_{0.05}$ A										0.350

The studies have shown that the protein content of winter wheat cultivars does not increase with the increase in N-fertiliser application until the N rate exceeds that required for maximum yield. Hence, methods for increasing the grain protein content must rely on a more efficient use of the N applied for maximum grain yield as well as grain protein (Cochran *et al.*, 1978). Nitrogen supply is still a much-debated question of nutrition, which is one of the factors determining the protein content of wheat to the greatest extent. Spring top-dressing usually is the most efficient method of nitrogen application to obtain higher grain yields and protein content. Grain protein is an important quality factor to be considered in the N-fertiliser management model. Split application of N-fertiliser to cereals is a common practice in Nordic and Baltic countries, especially for spring and winter wheat, for which high grain protein contents are desired in order to improve baking quality (Hoel, 2002). This practice gives the possibility of adapting the total application rate to the actual growing conditions. When N-fertiliser was applied to a growing crop near heading the grain protein content was increased but yields were decreased or not affected (Cochran *et al.*, 1978; Ruza *et al.*, 2003). Results, however, are often contradictory. There are studies, however, which do not confirm these findings (Berecz *et al.*, 1998).

The highest protein content in wheat grains (140.0–152.0 g kg^{-1}) was in 2003. In the same year, when the weather during grain formation period was dry and sunny, the modifying of data was the lowest. On the whole, use of increased norms of N fertiliser provided for a significant increase of protein content. In 2004, when the weather during grain formation and ripening period was cool and humid, a considerably lower increase of protein content was ascertained when using increased norms of N fertiliser (Table 4).

Table 4. The effect of increased N fertiliser rates on grain protein content of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	g kg^{-1}	±	S %	g kg^{-1}	±	S %	g kg^{-1}	±	S %	g l^{-1}
N90	118.4	0.0	11.4	140.0	0.0	3.8	117.6	0.0	13.0	125.3
N120(90+30)	124.0	5.6	10.5	146.2	6.2	4.9	116.3	-1.3	5.2	128.8
N150(90+60)	129.3	10.9	13.9	151.1	11.1	3.0	125.9	8.3	10.9	135.4
N180(90+90)	135.2	16.8	10.9	152.0	12.0	4.5	129.6	12.0	10.3	138.9
N180(90+60+30)	136.5	18.1	12.4	150.6	10.6	4.1	132.3	14.7	11.6	139.8
$LSD_{0.05}$ A										4.33

The positive relationship between grain protein and N-fertiliser is well-documented (Jackson and Sims, 1977). Although grain protein percentage has frequently been reported to be negatively correlated with grain yield (Loffer and Busch, 1982; McNeal *et al.*, 1972; Hülsbergen *et al.*, 2002). High temperatures and water shortage during the filling stage increase the rate of senescence, thus limiting photosynthesis and grain growth and reducing grain accumulation of carbohydrates rather than of N (Garrido-Lestache *et al.*, 2004). Simultaneous increases of both grain protein percentage and grain yield have been obtained by genetic improvement (Davis *et al.*, 1961; Stuber *et al.*, 1962) and from late applications of N-fertiliser (Hucklesbly *et al.*, 1971; Miezan *et al*, 1977).

During trials in Stende statistically significant negative correlation between the yield capacity and protein content in grains has also been ascertained (r = /–0.202/ > $r_{0.05}$ = 0.196, R^2 = 0.040). An essential positive correlation has been ascertained between the protein content and Zeleny index (r = 0.795 > $r_{0.05}$ = 0.196, R^2 = 0.632), starch content and volume mass (r = 0.435 > $r_{0.05}$ = 0.196, R^2 = 0.189), but essential negative correlation – between protein content and starch content (r = /–0.760/ > $r_{0.05}$ = 0.196, R^2 = 0.578), as well as between Zeleny index and starch content (r = /–0.633/ > $r_{0.05}$ = 0.196, R^2 = 0.401).

As there exists a positive correlation between protein content and Zeleny index and negative correlation between protein content and starch content in grains, increasing the norm of N fertiliser Zeleny index increases, but the starch content decreases correspondingly. Very small variation inf starch content, but high – in Zeleny index has been stated in varieties included in the trial (Tables 5, 6).

Table 5. The effect of increased N fertiliser rates on grain starch content of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	g kg^{-1}	±	S %	g kg^{-1}	±	S %	g kg^{-1}	±	S %	g l^{-1}
N90	616.6	0.0	1.9	589.6	0.0	1.8	597.4	0.0	4.0	601.2
N120(90+30)	608.8	–7.8	2.3	582.9	–6.7	1.6	591.9	–5.5	3.7	594.5
N150(90+60)	601.3	–15.3	2.9	578.8	–10.8	1.0	590.5	–6.9	3.8	590.2
N180(90+90)	599.3	–17.3	2.5	580.1	–9.5	1.9	588.9	–8.5	2.9	589.4
N180(90+60+30)	602.1	–14.5	3.1	580.8	–8.8	1.6	587.3	–10.1	3.1	590.1
$LSD_{0.05}$ A										6.15

Table 6. The effect of increased N fertiliser rates on Zeleny index (ml) of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	ml	±	S %	ml	±	S %	ml	±	S %	ml
N90	34	0.0	17.2	47	0.0	15.7	34	0.0	22.6	38
N120(90+30)	37	3.0	15.4	48	1.0	12.9	36	2.0	19.7	40
N150(90+60)	39	5.0	18	49	2.0	12.8	37	3.0	20.9	42
N180(90+90)	42	8.0	15.5	50	3.0	13.3	39	5.0	20.1	44
N180(90+60+30)	42	8.0	14	49	2.0	13.5	41	7.0	24.7	44
$LSD_{0.05}$ A										2.7

The biochemical changes that occur in the pre-harvest sprouted wheat have been the focus of several reviews. The effects of pre-harvest sprouting on baking quality are well known. It is known that a low falling number corresponds to a high alpha-amylase activity (Chanberlain *et al.*, 1981). It is declared that in glasshouse experiments applied N-fertiliser led to a reduction in alpha-amylase activity (Kettlewell, 1999), and that application of N-fertiliser to wheat crops in the field can increase the falling number of harvested grain in the absence of visible sprouting (Svenson, 1990). So, the high falling number is presumably a result of reduced alpha-amylase activity, it can also be influenced by starch properties. The relationship between N-fertiliser, alpha-amylase activity and falling number is investigated (Kettlewell, 1999). Kettlewell's conclusion: 'Effect of nitrogen fertiliser in increasing falling number in the absence of sprouting resulted from reduced alpha-amylase activity rather than an effect on starch properties.'

Usage of increased norms of N fertiliser in our experiment does not influence the falling number. It has been significantly influenced by meteorological conditions during the grain ripening period (Table 2). The highest variation of data has been ascertained in 2004, but the lowest – in 2003, which shows that the influence of a particular variety increases in unfavourable meteorological conditions (Table 7). Increased norms of N fertiliser do not essentially influence the volume weight, either (Table 8).

Table 7. The effect of increased N fertiliser rates on the falling number of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	s	±	S %	s	±	S %	s	±	S %	s
N90	341	0.0	21	401	0.0	11	303	0.0	33.5	348
N120(90+30)	411	70.0	9.1	399	–2.0	8	302	–1.0	36.2	371
N150(90+60)	371	30.0	24.2	407	6.0	10.1	298	–5.0	37.7	359
N180(90+90)	382	41.0	9.9	414	13.0	5.1	300	–3.0	35.8	365
N180(90+60+30)	378	37.0	12.6	412	11.0	7.2	302	–1.0	38.6	364
$LSD_{0.05}$ A										45.9

Table 8. The efect of increased N fertiliser rates on volume weight of winter wheat

N fertiliser rates, kg ha^{-1}	2002			2003			2004			Average
	g l^{-1}	±	S %	g l^{-1}	±	S %	g l^{-1}	±	S %	g l^{-1}
N90	821.0	0.0	1.5	792.9	0.0	5.2	807.0	0.0	2.2	807.0
N120(90+30)	826.1	5.1	1.9	792.5	–0.4	4.3	810.2	3.2	2.3	809.6
N150(90+60)	831.8	10.8	2.0	799.5	6.6	3.0	810.4	3.4	2.7	813.9
N180(90+90)	833.1	12.1	1.9	798.5	5.6	2.2	809.4	2.4	2.7	813.7
N180(90+60+30)	835.1	14.1	1.9	800.1	7.2	2.4	809.8	2.8	2.7	815.0
$LSD_{0.05}$ A										8.85

Conclusions

Usage of increased norms of N fertiliser essentially influences the yield capacity, protein content and variation of Zeleny index and starch content data, but the influence of interaction between the increased norms of N fertiliser and choice of varieties on grain yield was much higher. The influence of agro-meteorological conditions in per cent was higher, too, therefore the influence essentially differs by years.

The choice of variety essentially influence changes in volume weight, starch content, Zeleny index and protein content more than increased norms of N fertiliser, but all qualitative indices were more significantly influenced by agro-meteorological conditions than increased norms of N fertiliser.

References

1. Berecz K., Debreczni K., Presing M. (1998) Studies on the utilisation of late-season applied fertilizer nitrogen in field and model experiments with winter wheat. Commun Soil SCI Plant Anal, 29 (11–14), 1863–1874.
2. Chamberlain N., Collins T. H., McDermott E. E. (1981) Alpha-amylase and bread properties. Journal of Food Technology, 16, 127–152.
3. Cochran V. L., Warner R. L., Papendick R. I. (1978) Effect of N depth and application rate on yield, protein content, and quality of winter wheat. Agronomy Journal, 70, 964 –968.
4. Davis W. H., Middleton G. K., Hebert T. T. (1961) Inheritance of protein, texture and yield in wheat. Crop Science, 1, 235–238.
5. Garrido-Lestache E, Lopez-Bellido R. J., Lopez-Bellido L. (2004) Effect of N rate, timing and splitting and N type on bread-making quality in hard red spring wheat under rainfed Mediterranean conditions. Field Crops Research, 85, 213 – 236.
6. Gooding M. J., Smith G., Davies W. P., Kettlewell P. S. (1997) The use of residual maximum likelihood to model grain quality characters of wheat with variety, climatic and nitrogen fertilizer effects. Journal of Agricultural Science, Cambridge, 128, 135–142.
7. Hoel B. O. (2002) Chlorophyll meter readings in winter wheat: cultivar differences and prediction of grain protein content. Acta Agric. Scand., Sect. B, Soil and Plant Sci., 52, 147–157.
8. Hucklesbly D., Brown C. M., Howell J. E., Hageman R. H. (1971) Late spring application of nitrogen for efficient utilisation and enhanced production of grain and grain protein of wheat. Agronomy Journal, 63, 274–276.
9. Hülsbergen K. J., Feil B., Diepenbrock W. (2002) Rates of nitrogen application required to achieve maximum energy efficiency for various crops: results of a long-term experiment. Field Crops Research, 77, 61–76.
10. Jackson G. D., Sims J. R. (1977) Comprehensive nitrogen fertilizer management model for winter wheat. Agronomy Journal, 69, 373–376.
11. Kettlewell P. S. (1999) The response of alpha-amylase activity during wheat grain development to nitrogen fertiliser. Annals of applied biology, 134 (2), 241–249.
12. Livmanis J., Vucans R., Lipenite I. (2003) Effect of fertilisation on grain quality indices of spring wheat. In: Proceedings in Agronomy, Jelgava, Latvia, 5, 196 – 202.

13. Loffer C. M., Busch R. H. (1982) Selection for grain protein, grain yield, and nitrogen partitioning efficiency in hard red spring wheat. Crop Science, 22, 591–595.
14. McNeal R. H., Berg M. A., McGuire C. F., Stewart V. R., Baldridge D. E. (1972) Grain and plant nitrogen relationships in eight spring wheat crosses, *Triticum aestivum* L. Crop Science, 12, 599–601.
15. Miezan K., Heyne E. G., Finney K. F. (1977) Genetic and environmental effects on the grain protein content in wheat. Crop Science, 17, 591–593.
16. Nielsen D. C., Halvorson A. D. (1991) Nitrogen fertility influence on water stress and yield of winter wheat. Agronomy Journal, 83, 1065–1070.
17. Ruza A., Kreita Dz., Krotovs M, Malecka S., Stramkale V. (2003) Nitrogen fertilizer use efficiency in winter wheat trials. In: Environment. Technology. Resources. Proceedings of the 4th International Scientific and Practical Conference, Rezekne, Latvia, 232–237.
18. Stuber C. W., Johnson V. A., Schmidt J. W. (1962) Grain protein content and its relationships to other plant and seed characters in the parents and progeny of a cross of *Triticum aestium* L. Crop Science, 2, 506–508.
19. Svenson G. (1990) Linkages between sprouting resistance and some agronomic traits in wheat. In: K. Ringlund, E. Mosleth and D. J. Mares (eds) Fifth International symposium on pre-harvest sprouting in cereals, Boulder, Colorado, Westview Press, 227–232.
20. Teesalu T., Leedu E. (2001) Effect of weather conditions and use of fertilizers on crop and soil mineral nitrogen content in years 1999–2000 during field experiment IOSDV/ Tartu. In: Science for country development. LAU International scientific conference, Jelgava, Latvia, 53–56.
21. Лазарев В. И. (1997) Зависимость урожайности озимой пшеницы от основных природных и антропогенных факторов. Зерновые культуры, 3, 16–17.

DIFFERENT METHODS OF POTASSIUM ANALYSIS AND THEIR SUITABILITY FOR LITHUANIAN SOILS

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Abstract

The most suitable analysis method for measuring potassium content in the soil of moraine, fluvic and glacial lacustrine origin was selected from the following group: A-L method, 0.238M $NaHCO_3$ + 0.045M $(NH_4)_2SO_4$; 0.1M $CaCl_2$; 0.0025M $MgSO_4$; 2M HCl; 0.5M CH_3COONH_4+0.05M CH_3COOH + 0,02M Na_2EDTA (pH 4.65) is 0.5M CH_3COONH_4 + 0.05M CH_3COOH + 0.02M Na_2EDTA (pH 7.0) solutions.

The amounts of available potassium in the soil, measured in different extracts, correlated significantly and strongly (η = 0.75–0.92) with the amount of potassium measured using A-L methods, when soils were of moraine and fluvic origin. The correlation was weaker for soils of glacial lacustrine origin, where the dependence on extraction was irregular. However, the efficacy of potassium in silty loam soils was more dependent on the content of potassium in the soil measured in 0.01M $CaCl_2$ and 0.3 g $kg^{-1}$$MgSO_4$ solvents. As a result, the latter solvents can also be used for potassium content measuring in these soils. Assessment scales of these solvents are presented in this article.

Taking into account the versatility of the method, accuracy of the data obtained, and based on our specified assessment scale, preference in potassium content measurement in the soil should be given to the A-L extraction.

Key words: potassium analysis methods, soil

Introduction

Potassium is one of the major plant nutrients, which largely determines soil fertility. According to plant availability it is divided into potassium present in soil solution, in exchangeable form, as well as non-replaceable and present in soil crystal lattice (Barber, 1984; Mengel, Kirkby, 1987).

Very diverse methods of available potassium determination are used in various countries differing in soil types. In most of the methods, except for ionic resins and water solution, potassium in the soil is measured in solution extracts. In the non-chernozem zone of West Russia, Kaliningrad region, and Belarus potassium content in soil is determined by Kirsanov, in Latvia and Estonia by Egner-Riehm, in Hungary and Slovakia by Egner-Riehm-Domingo, in Germany by Egner-Riehm and Egner-Riehm-Domingo methods, in Belgium in the solution of ammonium oxalate and oxalate acid (Počvy, metody analiza, 1984; Jaundzen, 1989; Hofman, 1995).

The application of Egner-Riehm method for available potassium content determination by extraction in calcium lactate was started in 1961 in Lithuania. Although this method was used for soil analyses until 1970 in our country, its suitability was not substantiated by either field or pot trials. Later Egner-Riehm-Domingo (A-L) method was started to use for determination of available potassium content in the soil. The advantages of this method over the previously used Egner-Riehm were substantiated by the data of field and pot trials, and laboratory analyses obtained by E. Pliupelytė (1974).

The latest research evidence generated in Lithuania suggests, that in the soil of different origin the yield of agricultural crops and efficacy of potassium fertilisers do not identically depend on the soil potassium content extracted in A-L extract (Arbačiauskas, 2001).

As a result, the objective of the present study was to assess the suitability of soil potassium analysis methods used in the neighbouring countries, and to compare them with the A-L method currently employed in Lithuania.

Materials and Methods

To identify the most suitable method for determination of plant available potassium content in the soil, field expeditions were arranged during which 598 soil samples were collected from the humus-rich horizon of various soils of Lithuania differing in genesis, texture, acidity, organic matter content, and available P_2O_5 and K_2O contents. Samples were also taken from fertilisation trials conducted by the LIA's Agrochemical

Research Centre (ARC) in Radviliškis distr. (Skėmiai), Šakiai distr. (Kriūkai), and Vilkaviškis distr. (Rumokai), at the Lithuanian Institute of Agriculture in Dotnuva and other branches of this institute.

Potassium (K_2O) contents in the soil samples were determined at the LIA ARC laboratory using the following methods: 0.1M $CH_3CH(OH)COOH$+0.29M CH_3COOH+0.1M CH_3COONH_4 (Egner-Riehm-Domingo or A-L method) (Počvy, metody analiza, 1984); in 0.238M $NaHCO_3$ + 0.056M $(NH_4)_2SO_4$ extract (Perez, 1995); in 0.01M $CaCl_2$ extract (Saloman, 1998); 0.0025M $MgSO_4$ by Dashevski method (Počvy, metody analiza, 1984); in 2M HCl solvent (Počvy, metody analiza, 1984); 0.5M CH_3COONH_4+0.05M CH_3COOH+0.02M Na_2EDTA, pH 4.65 (ammonium acetate +acetic acid +trilone B) extract (buffer solution, pH 4.65) (Methods…, 1986); 0.5M CH_3COONH_4+0.05M CH_3COOH+0.02M Na_2EDTA, in pH 7.0 (ammonium acetate + acetic acid + trilone B) extract (buffer solution, pH 7.0) (Simonis, 1996).

Statistical reliability of the experimental data was evaluated using correlation ratio (η) and the criteria of correlation ratio (t) (Dospechov, 1985).

Results and Discussion

Potassium concentrations were determined using different soil analysis methods. The intensity of potassium transformation processes occurring in the soil depends on soil texture and mineralogical composition, moisture regime, acidity, presence of other cations in the soil solution. As a result, soils with different properties can contain different amounts of potassium present in various forms (Barber, 1984).

The contents of available potassium determined in 0.238M $NaHCO_3$+0.045M $(NH_4)_2SO_4$ solvent differed only insignificantly from those extracted by the acetate-lactate solution (A-L method) (Table 1). They did not regularly depend on soil genesis, acidity and potassium content. The ratios of potassium contents measured by these methods were 0.80–1.03:1.

Table 1. The amount of potassium (K_2O) in 0–20 cm soil layer determined by different solutions and relative coefficients of correction according to A-L method

Number of soil samples	The amount of K_2O measured using A-L method, mg kg^{-1}	Relative coefficients according to A-L method					
		0.238M $NaHCO_3$ +0.045M $(NH_4)_2SO_4$	0.01 M $CaCl_2$	0.0025M $MgSO_4$	2M HCl	Buffer solution pH 4.65	Buffer solution pH 7.0
Moraine and fluvic sandy loam and light loam soils							
pH≤5.0							
4	83.6±15.1	0.97±0.27	0.40±0.27	1.07±0.49	2.27±0.53	0.92±0.20	0.80±0.14
33	144.1±25.3	0.99±0.22	0.34±0.12	1.13±0.34	3.21±0.65	0.87±0.22	0.83±0.19
11	222.3±17.2	0.99±0.19	0.37±0.09	1.02±0.24	2.86±0.91	0.89±0.13	0.84±0.30
pH>6.0							
137	84.7±10.5	0.96±0.21	0.19±0.07	0.61±0.07	5.46±1.71	0.84±0.18	0.77±0.14
406	138.4±25.6	0.92±0.24	0.23±0.11	0.68±0.33	4.50±1.21	0.82±0.25	0.82±0.22
70	252.3±60.5	0.91±0.39	0.31±0.11	0.84±0.39	3.24±1.00	0.91±0.41	0.87±0.35
Glacial lacustrine sandy loam and light loam soils							
pH 5.1–6.0							
8	94.9±5.2	1.01±0.16	0.26±0.06	0.55±0.14	5.42±2.22	1.04±0.20	1.01±0.14
98	137.1±22.9	0.89±0.17	0.21±0.07	0.59±0.37	4.52±1.62	0.86±0.14	0.80±0.11
2	217.0±12.7	0.80±0.18	0.18±0.03	0.73±0.09	3.69±0.64	0.79±0.12	0.89±0.18
pH > 6.0							
3	89.3±9.3	1.03±0.08	0.24±0.08	0.55±0.13	4.87±0.97	1.08±0.30	1.06±0.06
159	159.2±24.9	0.96±0.54	0.17±0.05	0.41±0.10	5.43±3.21	0.93±0.50	0.81±0.14
23	217.8±19.8	0.85±0.17	0.14±0.03	0.39±0.10	4.92±1.13	0.80±0.16	0.81±0.22

* x±S/comparable coefficient to amount of potassium, measured using A-L method

The most readily plant available potassium, determined in weak 0.01M $CaCl_2$ solvent, whose ratio compared with the contents extracted by the other solvents, is the lowest and accounts for 0.19–0.44 of potassium content determined by the A-L method. Relatively less available potassium in 0.01M $CaCl_2$ extract was determined in slightly neutral acidity and containing higher potassium content in moraine and fluvic origin soils.

Having determined available potassium in 0.0025M $MgSO_4$ extraction in moraine and fluvic soils it was found that the ratio of this element with the content determined by A-L method was 0.61–1.13:1; and for glacial lacustrine soils this ratio was found to be 0.39–0.73:1.

In buffer solutions pH 4.65 and pH 7.0, similar but slightly lower (10–20%) contents of available potassium were identified for A-L method, they did not depend on soil physical and agrochemical properties.

Soil genesis had the greatest effect on the ratio of exchangeable and non-exchangeable potassium content determined in 2M HCl solution and the content of this element determined by A-L method. In moraine and fluvic soils this ratio was found to be 2.27–5.46:1, and in glacial lacustrine soils this ratio was 3.69–5.42:1.

In moraine and fluvic origin soils the contents of available potassium determined in different extracts, except for 2M HCl, significantly (η = 0.81–0.92) correlated with the contents of this element determined by A-L method.

Exchangeable and non-exchangeable potassium contents extracted in a strong 2M HCl solution, correlated with available potassium contents determined by A-L methods more weakly (η = 0.57). Whereas in glacial lacustrine origin soils the correlation was weaker, and while extracting in 2M HCl the correlation was insignificant η = 0.19 (Table 2).

Table 2. The amount of available potassium determined in different solvents (y) in relation to amount of this element by A-L method (x) in sandy loam soils

Extraction	Coefficients of eguation $y = a + bx + cx^2$			η	t
	a	b	c		
Moraine and fluvic soils					
pH >6.0					
0.238M $NaHCO_3$+0.045M $(NH_4)_2SO_4$	0.0014	0.44	36.90	0.89*	48.51
0.01M $CaCl_2$	–0.0003	0.48	–24.97	0.81*	34.64
0.0025M $MgSO_4$	0.0012	0.55	–4.14	0.83*	35.59
2M HCl	–0.0023	2.96	239.56	0.57*	17.07
Buffer solution. pH 4.65	0.0005	0.79	–3.14	0.85*	39.63
Buffer solution. pH 7.0	0.0007	0.70	1.12	0.92*	56.26
Glacial lacustrine soils					
pH > 6.0					
0.238M $NaHCO_3$+0.045M $(NH_4)_2SO_4$	0.0011	0.19	90.30	0.22	3.04
0.01M $CaCl_2$	–0.0004	0.22	0.89	0.37*	5.39
0.0025M $MgSO_4$	–0.00026	0.49	–6.16	0.69*	12.64
2M HCl	0.034	–9.35	1442.89	0.19	2.59
Buffer solution. pH 4.65	0.0060	–1.71	259.20	0.20	2.59
Buffer solution. pH 7.0	–0.0014	0.19	143.30	0.30*	4.08

* Correlation significant at 95% probability level

Assessing the methods for determination of available potassium content in the soil. This was done taking into account the strength of the relationship between potassium contents extracted in different solutions and the contents determined by A-L method, as well as simplicity and accuracy of analyses.

Considering the versatility of the method and accuracy of analyses, preference should be given to acetate-lactate extract (A-L method). However, numerous experiments conducted in Lithuania on potassium fertilisation of various crops on glacial lacustrine origin silty soils and moraine origin sandy loam soils suggest that in the soils low in potassium (51–100 mg kg^{-1} – A-L method), potassium fertiliser efficacy differed for some crops (winter wheat, sugar beet); significantly increased the yield on sandy loam soil, but practically did not have any effect on silty loam (Mažvila *et al.*, 2004), whereas the efficacy of potassium fertilisers on silty glacial lacustrine origin soils was much more dependent on the content of available potassium, determined in 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ extracts.

Since potassium fertiliser efficacy and soil potassium contents determined by A-L method correlated better with the contents of this element extracted in 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ extracts for moraine origin sandy soil, slightly less correlated on glacial lacustrine silty loam soils, consequently, for determination of potassium contents in glacial lacustrine origin silty loam soils one can also use 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ solutions.

Soil potassium levels according to K_2O contents determined in 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ extracts are presented in Table 3.

Table 3. Estimation of amount of available potassium (K_2O) in mineral soil in 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ solutions

Potassium availability in the soil	Moraine and fluvic soils		Glacial lacustrine soils
	pH<6.0	pH>6.0	
	Amount of K_2O, mg kg^{-1}		
0.01M $CaCl_2$ solution			
Very low	0–20	0–15	0–15
Low	21–40	16–30	16–30
Medium	41–60	31–45	31–45
Sufficient	61–90	46–60	46–60
High	91–120	61–90	61–90
Very high	>120	>90	>90
0.0025M $MgSO_4$ solution			
Very low	0–50	0–35	0–25
Low	51–100	36–70	26–50
Medium	101–150	71–105	51–75
Sufficient	151–200	106–140	76–100
High	201–300	141–200	101–150
Very high	>300	>200	>150

However, agrochemical tests conducted on farms are primarily focused on determination of pH and available P_2O_5 and K_2O contents. As a result, testing of available P_2O_5 and K_2O using different methods would be uneconomical. A common method most suitable for the determination of both elements should be used.

Our experimental evidence suggests that on silty loams low in potassium (A-L method) potassium fertilisers exhibit a low efficacy due to markedly higher non-exchangeable potassium contents (800–1400 mg kg^{-1}) than in moraine origin soils (500–600 mg kg^{-1}). Having determined non-exchangeable potassium content in 2M HCl extract on larger areas of glacial lacustrine soils, we could use the A-L method for analysing available K_2O, as well as available P_2O_5, but after some specification of the assessment scale.

Conclusions

Research with a view to identifying the most suitable analyses methods for determination of potassium contents in moraine, fluvic and glacial lacustrine origin soils using acetate-lactate (A-L method); 0.238M $NaHCO_3$ + 0.045M $(NH_4)_2SO_4$; 0.01M $CaCl_2$; 0.0025M $MgSO_4$; 2N HCl; 0.5M CH_3COONH_4 + 0.05M CH_3COOH + 0.02M Na_2EDTA (pH 4.65) and 0.5M CH_3COONH_4 + 0.05M CH_3COOH + 0.02M Na_2EDTA (pH 7.0) extracts enabled us to draw the following conclusions

The contents of available potassium determined in 0.238M $NaHCO_3$+0.045M $(NH_4)_2SO_4$ solution differed little from the contents of potassium extracted using acetate-lactate solution (A-L method). The ratios of potassium contents determined by these methods were found to be 0.80–1.03:1.

In weak 0.01M $CaCl_2$ solution available potassium accounts for only 0.19–0.40 relative numbers of the content of this element determined by A-L method. Relatively less available potassium was identified in 0.01M $CaCl_2$ extract in the soils of higher in potassium level moraine and fluvic origin soils.

While analysing available potassium in 0.0025M $MgSO_4$ extract in moraine and fluvic soils, the ratio of this element with the content determined by the A-L method was 0.61–1.13:1; and for neutral acidity soils this ratio was 0.39–0.73:1.

Similar contents (10–20% lower) of available potassium were determined in 0.5M CH_3COONH_4+0.05M CH_3COOH+0.02M Na_2EDTA (pH 4.65) and 0.5M CH_3COONH_4+0.05M CH_3COOH+0.02M Na_2EDTA (pH 7.0) solutions. These contents did not depend on soil texture, potassium level and acidity like for the A-L method.

Soil genesis had the greatest effect on the ratio of exchangeable and non-exchangeable potassium content extracted in 2M HCl solution and the content of this element extracted in acetate-lactate extract. For moraine and fluvic soils this ratio was found to be 2.27–5.46:1, and for glacial lacustrine soils this ratio was 3.69–5.42:1.

The contents of available potassium in the soil measured in the tested extracts strongly and significantly (η = 0.81–0.92) correlated with the content of this element, determined by the A-L method in moraine and fluvic origin soils, and in glacial lacustrine origin the correlation was weaker, and their dependence on extraction was irregular.

Apart from A-L extract, potassium contents can also be determined in 0.01M $CaCl_2$ and 0.0025M $MgSO_4$ solutions.

References

1. Arbačiauskas J. (2001) Žemės ūkio augalų derliaus ir trąšų veiksmingumo priklausomumas nuo agrocheminių savybių moreniniuose ir limnoglacialiniuose dirvožemiuose . Daktaro disertacija. Akademija, 134.
2. Barber S.A. (1984) Soil nutrient bioavailability. A mechanistic approach. Willey & Sons, Inc. New York. 188–238.
3. Hofman G.(1995) Proposal of animal manure management in Flanderes /Belgium/. Soil Fertility and Fertilizer Management. Bridge between Science, Industry and Practice. 9th International symposium of CJEC, Turkey, 27–33.
4. Mažvila J., Antanaitis A., Arbačiauskas J.,Lubytė J., Adomaitis T., Mašauskas V., Vaišvila Z.(2004) Kalio tyrimai skirtingais metodais ir jų tinkamumas Lietuvos dirvožemiams. Žemdirbystė: mokslo darbai, LŽI, LŽŪU, Akademija, t. 87, 12–29.
5. Methods of soil and plant analysis.(1986) MTTV-Jokionen, ISBN 951-729-785-6, Finland, 45.
6. Perez M.J. (1995) Comparicion de cuatro metodes extractante, de fosforo de differrentes grades de solubilidad. Agron. trop. /Venez./, № 4, 507–526.
7. Mengel K., Kirkby E.A. (1987) Principles of plant nutrition. International potash institute. – Bern, Switzerland, 427–452.
8. Saloman E. (1998) Extraction of soil potassium with 0,01M calcium chloride composed of official Swedish methods. Communications of soil science and plant analysis, Vol. 29, Iss 19–20, 2841–2854.
9. Simonis A.D. (1996) Int. Symp. Soil Test. and Plant Anal. Quality Soil and Plant Anal. View Sustainable Agr. and Environ. Waginengen, Commun. Soil Sci. and Plant Anal., 27, № 3–4, Pt. 2, 665–684.
10. Доспехов Б.А. (1985) Методика полевого опыта. Москва, 335.
11. Плюпелите Э.А. (1974) Выбор и оценка наиболее приемлемого метода определения усвояемого растениями фосфора и калия в различных почвах Литовской ССР // Расширенный автореферат кандидата селькохозяйственных наук. Каунас, 47.
12. Почвы, методы анализа (1984) Москва, 55.
13. Яудзен Я.А. (1989) Сравнительная оценка методов определения обменного калия. Особенности культурного почвообразовательного процесса и моделирования почв нечерноземной зоны РСФСР. Сборник научных трудов, 88–89.

EXPEREMENTAL STUDIES ON SOIL ENZYMES CHANGES UNDER THE CRITICAL HEAVY METALS ACCUMULATION IN *LUVISOLS* AND *ALBELUVISOLS*

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Abstract

Studies on soil biological activity is one of the most representative indicators of soil pollution because of its sensitivity to chemical status change in the soil environment. The aim of the present investigation – to determine enzymes activity change in Lithuanian *Luvisols* and *Albeluvisols* under the influence of heavy metals sorption via simulated soil pollution conditions. Therefore investigations were carried out using such a model system: soil – physical chemical parameters of heavy metals migration and accumulation in the soil – impact of heavy metals on soil enzymes activity. The results obtained demonstrated a great potential of the 'modelling' *Luvisol* and *Albeluvisol* to accumulate different fractions of heavy metals. At the maximum soil saturation with heavy metals up to sorption capacity the influence on the activity of soil enzymes and intensity of soil respiration was evident. However, it was found to be different. Results showed a very significant activity decrease of dehydrogenases (95–98%), urease (65–97%), saccharase (57–77%) and soil respiration intensity (38–65%) compare to unpolluted soils.

Key words: soil, heavy metals, soil enzymes

Introduction

Nowadays concern regarding the long-term productivity and sustainability of ecosystems is leading to the development and protection of soil resources (Kanchikerimath *et al.*, 2001; Svirskienė, 2003). Pollution of soils is among the most important ecological problems nowadays. Ecological consequences are numerous: disturbances in soil functionality, effect on the incidence and composition of the microbial population and activity of enzymes in soil (Mikanova *et al*., 2002; Grigaliuniene *et al*., 2003). The toxicity of heavy metals to animals, plants and other living organisms are known, but these heavy metals cannot be removed from soils, as they become irreversibly immobilized within different soil components (humidified organic matter, Fe and Al oxides and hydroxides, clay particles etc.). There is concern about the long-term effect of these elements at high concentration in the environment as they can persist in the soil for tens of thousands years (Ghorbani *et al.*, 2002).

The main sources of pollution of soil and environment are motor transport, industry and agriculture. It becomes evident the great increase of soil pollution near by roadsides with heavy metals due to more and more intensive motor transport on the highways (Motuzas *et al.*, 2002). Particularly high amount of Pb discharged into the environment from the passing motor transport is found. The highest amount of heavy metals was accumulated in 0–10 cm layer of soil closer to a highway (at the distance of 5 m, rarely 25 m from a highway). The heavy metals enter the human organism through fruits and vegetables grown near the highways and make them diseased (Eitmanavicius *et al.*, 2001).

The investigations on soil biological activity is one of the most representative indicators of soil pollution because of its sensitivity to chemical status changes in soil environment (Sastre Conde *et al.*, 2003; Krushelnickaja, 2001). Investigations of E. Kandeler (1996) show that in the soil polluted with heavy metals significantly decreases enzyme activity, compared to unpolluted soil. G. Renella (2002) has presented data indicating that combination of heavy metals Cd, Cu and Zn much more inhibits respiration intensity in soil than single heavy metals. A lot of investigations on heavy metals accumulation in soil have been carried out in Lithuania, but they are unsatisfactory regarding soil biological activity changes. The aim of this work was to evaluate soil biological activity changes of the *Luvisols* and *Albeluvisols* maximum saturated with heavy metals up to sorption capacity.

Materials and Methods

Four experimental sites, located close to a highway Vilnius–Kaunas–Klaipeda in two places with different soils cover and different distance were chosen: 20 m from a highway with heavily influenced emissions of motor transport (I and III objects); 350 m from a highway with background pollution (II and IV objects). Two soils were chosen: moraine sandy loam on clay loam *Calcari – Endohypogleyic Luvisol (LVg-n-w-cc)* and moraine light loam on medium loam *Eutri-Hypostagnic Albeluvisol (ABj-w-eu).* Samples for soil biological activity analyses were taken at depths 0–10, 20–25, 39–43, 56–61, 78–83 and 95–100 cm, according genetic soil horizons.

The special four modelling columns system was designed and filled up with natural soil monoliths. Out of them three modelling soil columns were saturated with solutions of heavy metals salts until full soil capacity with these elements: Pb up to 838 mg kg^{-1}, Cu – 773 mg kg^{-1} and Zn – 844 mg kg^{-1}. The fourth modelling soil column was saturated with distilled water as a control. Having finished soil saturation process, samples for the analysis were taken at the same depth as in natural profiles.

For the analyses of enzymes activity and soil respiration intensity air-dried soil samples were used. Saccharase (EC 3.2.1.26) and urease (EC 3.5.1.5) were determined by Hofmann method, modified by Chunderova A. И. (1970). Determination of dehydrogenase activity (EC 1.1.1.) was based on 2,3,5 – triphenyltetrasol chloride (TTCH) colourless oxidized form reaction to red formasane (Methodical recommendations for dehydrogenase activity determination, 1978). Soil respiration intensity was established by Öhlinger method (Schinner *et al.*, 1995).

Results and Discussion

Soil enzyme activity and soil respiration in natural *Luvisols* and *Albeluvisols*. Average data of our investigations show that soil biological activity, irrespective of the distance from a highway, in both soil profiles was decreasing in proportion to soil genetic horizon depth (Fig. 1).

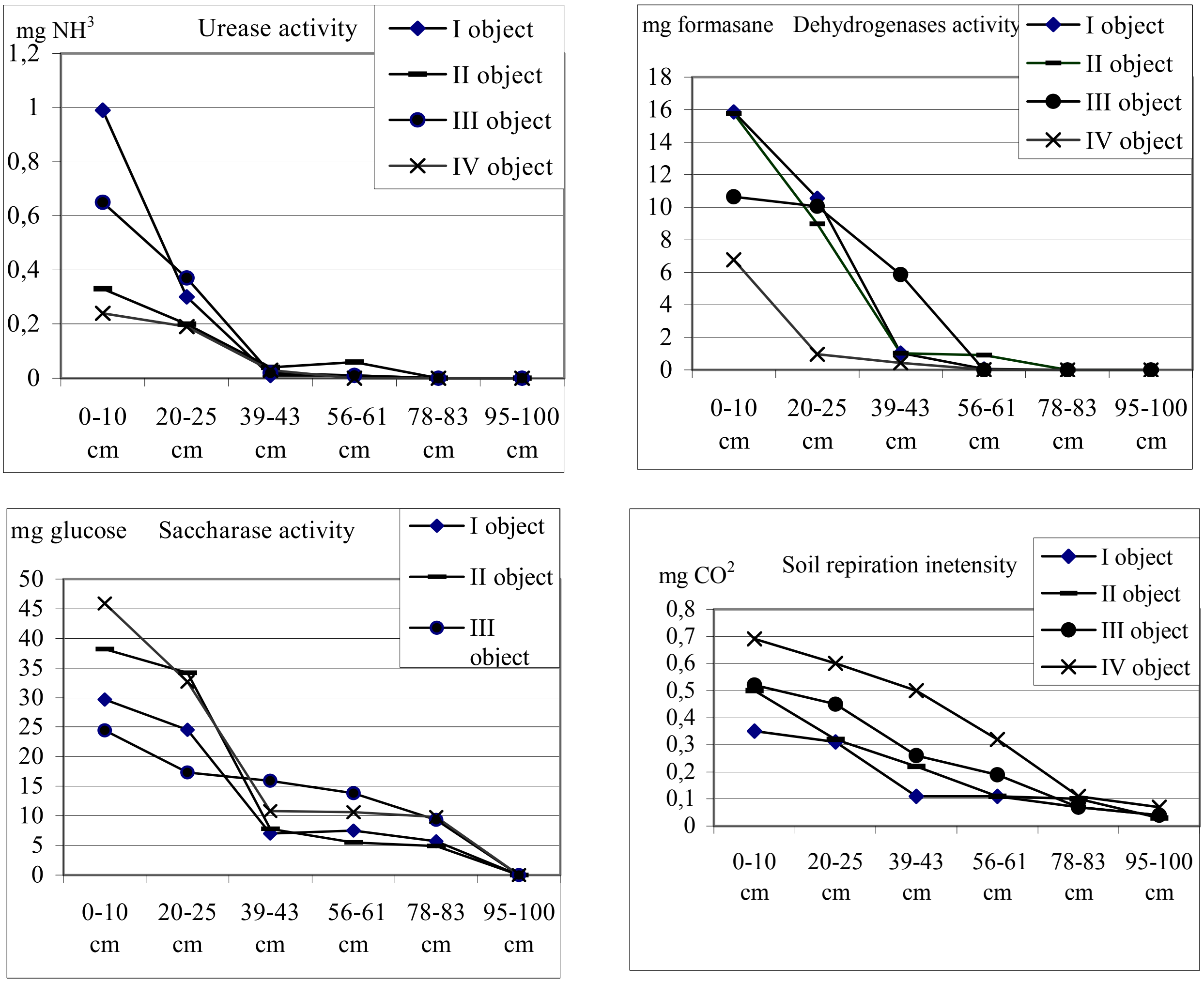

Figure 1. Enzyme activity and soil respiration intensity in *Luvisols* (I–II objects, 20 m and 350 m from a highway) and *Albeluvisols* (III–IV objects, 20 m and 350 m from a highway)

Soil enzyme activity and respiration intensity were highest in humic Ap horizon at 0–10 cm depth and somewhat lower at 20–25 cm depth in both soils. Soil enzyme activity and respiration intensity significantly decreased in ElBt (39–43 cm) horizon in both soils. The comparison of biological activity of both soils shows, that oxidation-reduction processes were higher in *Luvisols* (Giraite, Kaunas distr.), whereas hydrolysis processes, reflecting more intensive mineralization processes of organic matter, were higher in *Albeluvisols* (Kryzkalnis, Raseiniai distr.).

The effect of distance from a highway on biological activity of *Luvisols* and *Albeluvisols* in Ap horizon at 0–10 cm depth showed that in soils located 20 m from a highway and heavily influenced by emissions of motor transport, urease activity was significantly lower (2–3 times), compared with soils located 350 m from a highway. S. Ivleva and others (2001) have provided the similar results showing the inhibitory effects induced by toxic material in soil.

Table 1. Enzyme activity and soil respiration in 'modelling' *Luvisols* saturated with Pb, Cu and Zn salts until full soil sorption capacity

	Object of investigations	Soil horizon and sampling depth, cm	Enzyme activity, mg g^{-1} in air-dried soil			Soil respiration, CO_2 mg g^{-1} in air-dried soil
			urease	saccharase	dehydrogenases	
I object	Modelling *Luvisol*, saturated with heavy metals	Ap 0–10	0.061±0.012	10.24±0.650	0.29±0.03	0.14±0.015
		Ap 20–25	0.040±0.010	5.28±0.520	0.12±0.01	0.10±0.012
		ElBt 39–43	0.035±0.020	4.81±03.611	0.04±0.17	0.07±0.016
		Btkg 56–61	0.00	2.45±0.781	0.07±0.02	0.12±0.008
		Bkg 78–83	0.00	0.00	0.00	0.09±0.015
		BCkg 95–100	0.00	0.00	0.00	0.04±0.019
	Modelling *Luvisol*, saturated with distilled water (*control*)	Ap 0–10	0.35±0.020	18.82±0.636	9.71±0.225	0.20±0.019
		Ap 20–25	0.15±0.012	10.47±0.217	4.50±0.05	0.13±0.024
		ElBt 39–43	0.03±0.04	7.15±0.721	4.51±0.017	0.12±0.009
		Btkg 56–61	0.01±0.065	3.45±0.345	0.82±0.052	0.01±0.00
		Bkg 78–83	0.00	0.00	0.00	0.01±0.004
		BCkg 95–100	0.00	0.00	0.00	0.1±0.004
II object	Modelling *Luvisol*, saturated with heavy metals	Ap 0–10	0.07±0.003	10.40±0.677	0.54±0.052	0.31±0.030
		Ap 20–25	0.08±0.018	14.58±0.297	1.88±0.660	0.25±0.026
		ElBt 39–43	0.04±0.009	9.39±0.410	0.34±0.138	0.13±0.021
		Btkg 56–61	0.02±0.004	6.15±0.231	0.21±0.063	0.07±0.020
		Bkg 78–83	0.00	3.95±261	0.00	0.05±0.018
		BCkg 95–100	0.00	0.00	0.00	0.07±0.021
	Modelling *Luvisol*, saturated with distilled water (*control*)	Ap 0–10	0.21±0.004	25.18±0.338	6.27±0.145	0.33±0.018
		Ap 20–25	0.08±0.004	26.18±0.327	1.37±0.213	0.22±0.01
		ElBt 39–43	0.01±0.002	11.91±0.171	0.83±0.004	0.12±0.013
		Btkg 56–61	0.00	7.45±0.455	0.54±0.158	0.05±0.01
		Bkg 78–83	0..0	3,26±0.345	0.00	0.02±0.004
		BCkg 95–100	0.00	0.00	0.00	0.00

Saccharase activity was found less influenced by heavy metal pollution of motor vehicle. Literature sources affirm, that enzymes involved in the C-cycling are least affected by pollution of heavy metals, whereas enzyme activity related to the cycling of N, P and S show a considerable decrease in activity (Kandeler *et al.*, 1996). Dehydrogenases activity is thought to reflect the total range of activity of soil microflora and consequently may be associated to be a good indicator of microbiological activity (Nannipieri *et al.*, 1990). Dehydrogenases activity in both soils in humic horizon (0–10 cm) was similar, despite the distance from a highway.

From this point of view soil respiration intensity was increased when the distance to a highway decreased. Obtained data might be connected with higher amount of some bacteria and actinomicetes, which exuded higher amount of CO_2 in soil closer to a highway. Literature sources have reported the noticeable changes of soil respiration when soil ecological balance is disturbed due to intensive growth of microorganisms and rapid mineralization (Kandeler *et al.*, 1993). N. Ghorbani and others (2002) have observed positive relationships between the concentration of heavy metals and soil respiration: only at very high concentration – > 1 000 mg kg^{-1} Cu and Zn – soil respiration decreased.

Soil enzyme activity and soil respiration in modelling *Luvisols* and *Albeluvisols.* Having saturated with heavy metals modelling soils in special columns, the influence of pollutants (Pb, Zn and Cu) on soil biological activity was determined. The results showed more significant decrease of the biological activity in profiles of the polluted 'modelling' *Luvisols* and *Albeluvisols* (Tables 1, 2).

Table 2. Enzyme activity and soil respiration in 'modelling' *Albeluvisols*, saturated with heavy metals Pb, Cu and Zn salts until full soil sorption capacity

	Object of investigations	Soil horizon and sampling depth, cm	Enzyme activity, mg g^{-1} air dried soil			Soil respiration, CO_2 mg g^{-1} air dried soil
			urease	saccharase	dehydrogenases	
III object	Modelling *Albeluvisol*, saturated with heavy metals	Ap 0–10	0.02±0.002	8.96±0.735	0.15±0.036	0.18±0.034
		Ap 20–25	0.03±0.028	7.98±0.59	0.10±0.025	0.16±0.017
		AElj 39–43	0.01±0,003	5.94±0.96	0.04±0.173	0.11±0.041
		ElBtj 56–61	0.00	5.53±0.311	0.06±0.021	0.09±0.03
		Btj 78–83	0.00	0.00	0.00	0.05±0.033
		BC(g) 95–100	0.00	0.00	0.00	000
	Modelling *Albeluvisol*, saturated with distilled water (*control*)	Ap 0–10	0.42±0.023	20.92±0.821	4.62±0.257	0.24±0.003
		Ap 20–25	0.34±0.12	14.11±0.607	2.92±0.156	0.21±0.004
		AElj 39–43	0.06±0.041	5.26±0.518	0.05±0.026	0.14±0.006
		ElBtj 56–61	0.01±0.009	4.8±0.30	0.00	0.04±0.006
		Btj 78–83	0.00	0.00	0.00	0.09±0.003
		BC(g) 95–100	0.00	0.00	0.00	0.07±0.029
IV object	Modelling *Albeluvisol*, saturated with heavy metals	Ap 0–10	0.12±0.019	19.55±0.977	0.52±0.52	0.27±0.023
		Ap 20–25	0.1±0.007	11.96±0.65	0.68±0.06	0.14±0.023
		AElj 39–43	0.08±0.001	7.27±0.209	0.32±0.181	0.19±0.035
		ElBtj 56–61	0.06±0.003	5.36±0.325	0.11±0.06	0.04±0.009
		Btj 78–83	0.00	3.78±0.118	0.00	0.02±0.003
		BC(g) 95–100	0.00	0.00	0.00	0.00
	Modelling *Albeluvisol*, saturated with distilled water (*control*)	Ap 0–10	0.17±0,03	29.25±0.822	8.65±0.372	0.30±0.04
		Ap 20–25	0.10±0.021	13.56±0.607	0.09±0.006	0.29±0.065
		AElj 39–43	0.05±0.001	10.56±0.518	0.55±0.076	0.11±0.035
		ElBtj 56–61	0.00	5.51±0.99	0.04±0.08	0.06±0.006
		Btj 78–83	0.00	0.00	0.00	0.03±0.001
		BC(g) 95–100	0.00	0.00	0.00	0.00

There was observed obvious decrease of soil enzyme activity in *Luvisols* saturated with solutions of heavy metals salts in comparison with natural soils: saccharase activity up to 57–77%, dehydrogenases – 95–98% and urease – 65–97%. Similar results have been obtained by E. Kandeler (1996) suggesting that aside from the loss of rare biochemical capabilities such as the growth of organisms at the expense of aromatics – heavy metal contaminated soils loose very common biochemical properties necessary for the functioning of the ecosystem. The pollution with heavy metals severely decreases the functionality diversity of soil microbial community and impairs specific pathways of nutrient cycling.

Soil respiration intensity is a measure of the background microbial respiration and it is commonly regarded as the overall decomposition of the organic material (Stenberg B., 1999). The critical accumulation of heavy metals decreased soil respiration intensity in *Luvisols* up to 38–60% and in *Albeluvisols* – 61–65%, as compared with natural soils.

Comparison of the results of both 'modelling' *Luvisols* and *Albeluvisols*, saturated with solutions of heavy metals salts with those treated with distilled water showed significant enzyme activity decrease under the influence of high load pollution: dehydrogenases up to 91–97%, urease – 67–95%, saccharase – 33–59%. The same tendency of soil respiration intensity in 'modelling' soil was evident – 6–25%.

It should be noted that soil biological activity of 'modelling' *Luvisols* and *Albeluvisols,* saturated with distilled water, was rather low compared with natural soil due to an anaerobic conditions.

According sensitivity of soil biological activity to pollution with heavy metals the following decreasing order was derived: dehydrogenase → urease → saccharase → soil respiration.

Conclusions

Soil biological activity in profiles of *Luvisols* and *Albeluvisols* was highest at 0–10 cm depth in the humic Ap horizon. It decreased in proportion to depth of soil genetic horizon.

Influence of the soil site distance to a highway showed enzyme activity 2–3 times lower in soils located 20 m from a highway compared with those located 350 m from the pollution source. In contrary, soil respiration intensity increased when the distance to a highway decreased.

Investigated 'modelling' soils biological activity under the influence of high pollution with heavy metals decreased in the following order: dehydrogenase (95–98%) → urease (65–97%) → saccharase (57–77%) → soil respiration (38–65%).

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References

1. Ghorbani N. R., Salehrastin N., Moeini A. (2002) Heavy metals affect the microbial populations and their activities. 17th WCSS, Thailand, 2234.
2. Grigaliunienė K., Zakarauskaite D., Vaisvila Z. J. (2003) Dirvozemio biologinio aktyvumo ir zemes ukio augalu produktyvumo pokyciai nuo mineraliniu trasu nevienodos kilmes dirvozemiuose. Zemes ukio mokslai, 1, 3–10.
3. Kanchikerimath, M., D. Singh (2001) Soil organic matter and biological properties after 26 years of maize-wheat-cowpea cropping as affected by manure and fertilization in a Cambisol in semiarid region of India. Agri. Ecosyst. Environ, 86, 155–162.
4. Kandeler E., Kampichler C., Horak O. (1996) Influence of heavy metals on the functional diversity of soil microbial communities. Biology and fertility of soils, Vol. 23, Issue 3, 299–306.
5. Kandeler E., Margensin R., Öhlinger R., Schinner F. (1993) Bodenmikrobiologisches Monitoring – Vorschlaege fuer eine Bodenzustandsinventur. Die Bodenkultur, B. 44, Heft 4, 357–377.
6. Krushelnickaja, T. P. (2001) The changes of enzyme activities in sod-gleyic soil under anthropogenic influence. Soils and their fertility on border of centuries. IIth Congress of Belorussian Soil Science Society, Minsk, Book 2, 148–150 (in Russian).
7. Eitmanavicius K., Matusevicius K., Antanaitis A. (2001) Pakeliu dirvozemiu ir augalų uzterstumas sunkiaisiais metalais. In.: Mazvila J. (ed.) Heavy metals in Lithuanian soils and plants, Kaunas, 327.
8. Methodical recommendations of dehydrogenase activity determination (1978). Moscow. (In Russian).
9. Mikanova O., Kubat J., Novakova J. (2002) Some microbiological characteristics and enzymatic activities in soils polluted with heavy metals. 17th WCSS, Thailand, 792–7.
10. Motuzas A., Vaisvalavicius R., Procycevas I. (2002) Application of new physical chemical methods in soil ecological investigation. Environmental science and pollution research, 1, 55–62
11. Nannipieri P., Greco S. and Ceccanti B. (1990) Ecological significance of the biological activity in soil. Soil Biochemistry, vol. 6, 293–355.

12. Renella G., Chaudri, Brookes P.C. (2002) Fresh additions of heavy metals do not model long-term effects on microbial biomass and activity. Soil Biology and Biochemistry, Vol. 34. Issue 1. 121–124.
13. Sastre Conde I., Vicente M. A., Lobo M. C. (2003) Contamination and environmental impact on soil biological activity. In: Lobo M. C., Ibanez J. J. (eds) Preseving soil quality and soil biodiversity, IMIA-CSIC, Madrid, Italy, 99–118.
14. Schinner, F., Öhlinger R., Kandeler E. and Margesin R. (1995) Methods in Soil Biology, Springer – Verlag, Berlin, Heidelberg, 93–97.
15. Stenberg B. (1999) Monitoring of soil quality of arable land: Microbiological indicators. Soil and plant science, Vol. 49, Nr. 1, 1–21.
16. Svirskiene, A. (2003) Microbiological and biochemical indicators of anthropogenic impacts of soils. Eurasian Soil Science, 36, 192–200.
17. Ивлева С. Н., Шимко Н. А. (2001) Ферментативная активность как показатль степени загрязнения почвы. Почвы и их плодородие на рубеже столетий. Материалы съезда белорусского общества почвоведов, Минск, Белорусия, 51–52.
18. Чундерова А. И. (1970) Активность инвертазы в дерново – подзолистых почвах. Почвоведение. No. 12, 104–109.

SOIL STRUCTURE VARIATIONS UNDER DIFFERENT ANTHROPOGENIC ACTIVITY

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Abstract

The paper presents the results of investigations, which were performed in the Vezaiciai branch of the Lithuanian Agriculture institute in 1996–2002. The effect of different anthropogenic activities: long term liming (at a rate 0.5 every 7 years, 1.0 and 2.0 rates every 3–4 years), fertilizing with different organic materials (manure, straw and green manure) and different tillage implements (moldboard and non-moldboard with rototiller and stubble cultivator using herbicide Roundup) on topsoil structure was investigated. The soil at the site is Dystric Albeluvisol, textural class – morain loam (clay content 12–15%). It was found that intensive periodical liming for 50 years by dust limestone at a rate 2.0 every 3–4 years on the background of primary and repeated liming by slaked lime and conventional tillage did not give any significant positive effect on the soil structure. The largest amount (54–59%) of meso-aggregates (5–0.25 mm) and water stable aggregates (> 0.25 mm) – 66% was obtained in the soil after introduction of manure and grain straw. Soil tillage, especially moldboard had a negative effect on morain loam soil structure. From the viewpoint of morain loam soil structure preservation or improvement this management system: incorporation of manure or straw +optimal liming + non-moldboard tillage could be in use.

Key words: soil structure, liming, manure, non-moldboard tillage

Introduction

Soil structure varies in time and space as a function of soil properties, climatic conditions and land management practices (Angers *et al.*, 1993; Arlauskienė *et al.*, 2002; Arlauskas *et al.,* 1996; Lenksaite, 1977; Chaney *et al.*, 1984; Douglass *et al.,* 1999). The resistance of soil to structural degradation is largely controlled by the presence and abundance of water stable aggregates. Factors affecting water stability of soil aggregates have been determined as follows: amount of clay, humus, calcium carbonate and organic matter, clay/silt ratio and clay mineralogy (Canarache *et al.*, 1998; Berglund, 1986).

The relationship between water content and aggregatation can vary with different management systems. Soil structure water stability deterioration is the first step in the physical degradation of the soil. This deterioration is observed even under a very extensive cropping system, while other soil physical properties have become obvious only with a more intensive agriculture land use (Canarache *et al.*, 1998). Soils under no-till, alfalfa or perennial grasses show a greater resistance to slaking at low water content than their annually tilled counterparts (Angers *et al.*, 1993; Angers, 1992; Chantigny *et al.*, 1997). Short – range temporal variations in macroaggregations can be induced by the direct mechanical impact of tillage as revealed by the decrease in water stable aggregations observed after tillage operations (Anger *et al.*, 1993). Research done in Lithuania indicated the superiority of non-moldboard tillage from moldboard and the non-moldboard tillage efficiency depends on soil texture and climate conditions (Arlauskienė *et al.*, 2002; Arlauskas *et al.,* 1996).

Long – term trends in stable soil aggregation were often a function of organic matter management. The direct effect of C inputs in soil is determined when the animal manure is annually used (Anger, 1993). Addition of humified materials such as humic peat or marine silty clay has had a slow but long – lasting effect on soil aggregates stability (Dinel *et al.*, 1991).

A close relationship (r = 0.8–0.9) between the proportion of stable aggregates and soil clay content as well as a relationship between aggregatation and clay-associated organic matter is found in different soil types (Elustondo *et al.,* 1990). This has confirmed the dominant role of the clay particles in determining soil structure.

The findings of scientific research of Berglund A., Kindval T., Lenksaite E. have already showed a positive liming effect on soil structure stability. The soil texture and the type of lime fertilizers are very important for the liming efficiency on soil structure. According to the majority of authors chemically active fertilizers (slaked and burned lime) have the greatest effect on the soil structure and these lime fertilizers are especially effective in clay soils and ineffective in the soils with low clay content 11–13% (Berglund, 1986; Wikklander, 1986; Kindval, 1999). There exists an opinion that liming efficiency depends on geochemical environment that lime fertilizers get into (Eidukevičienė, 1993).

The aim of this investigation was to evaluate the changes in topsoil structure of morain loam soils under different anthropogenic load: long term liming, organic fertilizing, moldboard and non-moldboard tillage implements.

Materials and Methods

The investigations were carried out in Western Lithuania, on the eastern part of the seacoast lowland with moderately warm, humid agro-climate. Object of investigations – naturally acid soil and the same soil exposed to different anthropogenic activity: liming, organic fertilizing and tillage. The soil was low and moderately cultivated Dystric Albeluvisol on light textured morain loam with low content of clay (<0.002mm 12–14%), humus (1.57–2.12%), acid and neutral reaction (pH_{KCl} 4.2–6.4), amount of water stable aggregates (>0.25mm) accounting for 55–70%. Methods of investigations were field trial and laboratory analyses.

Studies included investigations on the effect of periodical liming, different organic fertilizers and different tillage implements on the morain loam topsoil aggregate composition and content of water stable aggregates in three-field trials with the following design:

- 1st trial – un-limed and limed at the rates: 0.5 every 7th year; 1.0 – every 3rd–4th year, 2.0 – every 3rd–4th year according to the soil hydrolytic acidity. Periodical liming was done by pulverized limestone (92.5% $CaCO_3$) on the background of primary and repeated liming by slaked lime. Minimal organic fertilizing (40 t ha^{-1} manure during 7-field rotation), conventional tillage and the following crop rotation: sugar beets, barley with under-sowing grasses, perennial grass (two years), winter wheat, vetch-barley mix for grain and vetch-oat mix for green forage were used. The soil samples for humus and structural analyses were taken from topsoil when the harvest of winter wheat, barley-peas and vetch-oats mixtures was taken off.

- 2nd trial – eight different flax crop rotations were involved (Table 1).

Table 1. Plant change in crop rotation

Crop rotation	Rotating crop		
	I (1997, 1998, 1999)	II (1998, 1999, 2000)	III (1999, 2000, 2001)
1. B+Bu+Pg	Barley	Barley + under-sowing crop	Perennial grasses, 1st year of use
2. B+Pg.+Ww	Barley + under-sowing crop	Perennial grasses, 1st year of use, (2 grasses for forage)	Winter wheat
3. B+Pg.+Ww	Barley + under-sowing crop	Perennial grasses, 1st year of use (for green manure)	Winter wheat
4. B+F (manure)+W	Barley	Fallow + manure	Winter wheat
5. B+F+W.	Barley	Fallow	Winter wheat
6. B+W (green m.)+B	Barley	Winter wheat + green manure	Barley
7. B+W+R	Barley	Winter wheat	Winter rye
8. B+W+R (straw)	Barley (plowdown of straw)	Winter wheat (plowdown of straw)	Winter rye (plowdown of straw)

B – barley; Bu – Barley + undersowing crop; Pg – Perennial grasses; W – Winter wheat; R – Winter rye; F – fallow.

Trials were made in flax field every year (1996, 1997, 1998) as well as the flax was the last (4th) number of crop rotation (1999, 2000, 2001). Soil samples for structure analysis in flax field and after incorporation of different organic materials were taken from topsoil (0–20 cm) after flax harvest every year mentioned above. Soil enrichment with organic materials in individual treatment (crop rotation) was different. The lowest in humus and most intensive was the 7th crop rotation – only remains of plants there were ploughed in the topsoil. More extensive crop rotations fixed were the 3rd, 4th and the 8th. In these treatments besides plant remains the additional fair amount of green manure (biomass of perennial grasses 32.3±4.8 t ha^{-1}), and manure (60 t ha^{-1}) and the cereal straw (14.9±0.3 t ha^{-1}) were ploughed down in topsoil.

- 3 rd trial – mouldboard tillage: disc-harrowed and ploughed, ploughed and non-mouldboard tillage: loosening using a stubble cultivator + Roundup, loosening with rototiller + Roundup.

Preparation of the second year clover field for winter wheat sowing was started after the first cut. The first treatment was tilled with a disc harrow BDT at 10–12 cm depth. The soil in the first and second treatments was ploughed with a mouldboard plough PLN-3-35 one month before the optimal time for winter wheat sowing, and on a sowing day the field was cultivated at 8–10 cm depth. The third and fourth treatments were sprayed with Roundup 4 l ha^{-1} and on a sowing day the soil was tilled with a stubble cultivator KEN-1.8 at 15–8 cm depth and with a rototiller F-N-100 at 8–10 cm depth. The soil samples for humus and structural analyses were taken from topsoil when the harvest of winter wheat was performed.

Laboratory analyses were done using the following methods: humus was analysed by Tyurin′s method and soil structure and its water stability by Savinov. Experimental findings were processed using dispersion analysis.

Results and Discussion

Results of our investigations show that 50-year systematic and intensive liming on the background of minimal organic fertilizing (40 t ha^{-1} manure in 7-field rotation) and conventional tillage had not exerted significant positive effect on humus content and structure of morain loam soil (Table 2). From agronomic point of view, valuable structural aggregates (0.25–5.0 mm) prevailed (55–62%) in both soils acid and limed with different intensity. The tendency of the increase of less valuable (>5 and 0.25 mm) structural aggregates was already observed in most intensively limed soils. Its negative effect on soil structure was shown by the decreasing coefficient of structurality. When the quality estimation of these soils structure was done, it could be affirmed that the amount of water stable aggregates (>0.25 mm) was optimal as it formed 51–57% of general soil amount. The fact that 0.25–0.5 mm micro-aggregates (30–33%) prevailed in un-limed and intensively limed soil and agronomically more important macro-aggregates (>1 mm) forming only 10–12% did not give any promises that physical soil conditions could be improved. According to 3-year data the greatest amount of water stable aggregates (>0.25 mm) occurred in the most intensively limed soil. Although liming helped to increase amount of these aggregates by 2% units compare to naturally acid soil, nevertheless this amount was still low compare to highly cultivated soil with 75–80% of these aggregates.

Table 2. Effect of periodical liming on topsoil aggregates composition and structure stability

Treatment	Year	Mesoaggre-gates, % 5–0.25 mm	Coefficient structurality	Water stable aggregates, % > 1.0 mm	Water stable aggregates, % > 0.25mm	Humus, %
Un-limed	1996	54.6	1.20	11.7	57.4	
	1997	68.1	2. 14	11.2	50.5	
	1998	64.1	1.78	13.5	56.5	
	average	62.3	1.71	12.1	54.8	2.21±0.1
Limed at 0.5	1996	58.2	1.42	9.3	51.6	
Rates applied	1997	63.9	1.80	9.4	49.0	
Every 7 years	1998	50.5	0.96	11.3	53.4	
	average	57.6	1.39	10.0	51.3	2.33±0.1
Limed at 1.0	1996	51.4	1.06	9.9	51.9	
rate every	1997	63.4	1.74	10.4	50.8	
3–4 years	1998	50.9	1.04	10.9	54.5	
	average	55.3	1.28	10.4	52.4	2.38±0.1
Limed at 2.0	1996	50.3	1.01	11.8	56.1	
rates every	1997	64.1	1.92	11.7	55.9	
3–4 years	1998	54.3	1.19	13.4	58.4	
	average	56.2	1.37	12.3	56.8	2.32±0.1
LSD_{05}	average	6.7	–	1.7	3.0	0.21

Note: soil field moisture and plant variety at the time of soil sampling: 1996 – 11% (winter wheat);
1997 – 17% (barley – vetch mixture); 1998 — 11% (oat – vetch mixture).

To sum up, data of systematically limed soil structural changes allow conclusion that intensive periodical liming with minimal organic fertilizing was not an efficient means to improve this soil structure. It was necessary to enrich the soil with organic colloids.

Results of a trial with different organic fertilizers showed that the highest amount of soil humus (1.97%) was obtained in the soil after introduction of manure (60 t ha^{-1}) (Table 3). Compare to this soil, significantly lower (3–9%) amount of humus was found in the soil after introduction of green manure (perennial grasses or over-ground biomass of oats and vetch mixture). During crop rotation period there were observed any changes of organic matter and humus in the soil after incorporation of green manure (over-ground biomass of white mustard) or straw (barley, winter wheat and rye).

Table 3. Effect of crop rotation plants and organic fertilizers on topsoil aggregates composition and structure stability

Treatment	Year	Meso-aggre-gates, % 5–0.25 mm	Coefficient structurality	Water stable aggregates, % > 0.25 mm	Water stable aggregates, % > 1.0 mm	Humus, %
Background (flax)	2000	–	–	77.0	28.1	1.87
	2001	53.8	1.20	68.9	25.2	1.76
	2002	54.3	1.17	65.0	14.4	1.58
	average	54.1±1.6	1.19±0.45	70.3±1.3	19.9±	1.73±0.06
1. B+Bu+Pg	2000	–	–	69.7	21.0	2.02
	2001	57.5	1.38	69.0	13.8	1.75
	2002	49.8	1.00	51.2	10.7	1.68
	average	53.6	1.1	63.3	15.2	1.82
2. B+Pg+Ww	2000	–	–	73.6	21.8	2.01
	2001	55.3	1.24	58.7	12.7	1.80
	2002	51.8	1.08	52.0	8.6	1.81
	average	53.6	1.16	61.4	14.4	1.88
3. B+Pg+Ww	2000	–	–	68.9	20.2	2.08
	2001	54.1	1.19	59.5	12.6	1.73
	2002	55.7	1.27	53.8	10.3	1.77
	average	54.9	1.23	60.7	14.4	1.86
4. B+F(manure) + W	2000	–	–	71.2	21.0	2.08
	2001	56.0	1.29	61.8	11.9	1.97
	2002	52.6	1.12	57.0	10.6	1.87
	average	54.3	1.21	63.3	14.5	1.97
5. B+F+W	2000	–	–	70.5	19.0	2.04
	2001	54.5	1.21	62.7	11.6	1.80
	2002	52.7	1.12	54.6	9.7	1.70
	average	53.6	1.17	64.8	13.4±	1.85
6. B + (green manure) + B	2000	–	–	71.0	21.2	1.92
	2001	56.6	1.31	63.8	12.3	1.66
	2002	52.2	1.09	45.6	6.1	1.60
	average	54.4	1.20	60.2	13.2	1.73
7. B+W+R	2000	–	–	72.3	20.1	1.97
	2001	58.2	1.39	67.1	13.9	1.73
	2002	51.5	1.07	50.5	7.8	1.61
	average	54.8	1.23	63.3	13.8	1.77
8. B (straw)+ W (straw)+ R (straw)	2000	–	–	70.9	19.6	1.93
	2001	55.2	1.23	64.3	12.3	1.64
	2002	52.6	1.12	53.1	9.9	1.62
	average	53.9	1.18	62.8	13.9	1.73
LSD_{05}	average	5.1	–	6.7	4.1	0.23

The largest amount (54–59%) of meso-aggregates 5–0.25 mm in size and water stable aggregates >0.25mm (65–66%) was obtained in the soil after introduction of manure and grain straw. Compare to this soil, significantly higher (4–5 percentage units) content of these aggregates were found in the soil after introduction of underground mass of grain crops or over-ground biomass of white mustard. The summarised data of investigations allows conclusion that the amount of introduced organic fertilizers was so small that could ensure significant increase of humus and soil structure stability. From the viewpoint of soil structure improvement, manure and straw gained an advantage over the green manure.

The data obtained regarding the use of different soil tillage implements allow conclusion that soil structure and its aggregate stability in arable layer deteriorated under the effect of mouldboard and non-mouldboard soil tillage as compared to these indicators before tillage in the second year clover field (Table 4). Different soil tillage methods did not have any significant effect on the soil structure, structurality coefficient and on the amount of water stable aggregates and humus content. During vegetation period a trend of an increase in the content of water stable aggregates (>0.25 mm) was determined in the soil loosened with non-mouldboard implements, particularly with a rototiller. The content of these aggregates was by 1.6–5.6 percentage units higher as compared with the disc-harrowed and ploughed soil.

Table 4. Effect of soil tillage implements on topsoil aggregates composition and structure stability

Treatment	Year	Mesoaggre-gates, % 5–0.25 mm	Coefficient structurality	Water stable aggregates, % > 0.25 mm	Water stable aggregates, % > 1.0 mm	Humus, %
Background (peren. grasses, 2nd year of use	1996	65.9	1.95	56.7	10.7	
	1997	66.7	2.02	59.7	10.7	
	1998	43.6	0.78	61.9	21.8	
	average	58.7	1.55	59.4	14.4	2.62±0.80
Disc-harrowed	1996	62.5	1.69	46.8	9.8	
Ploughed	1997	48.3	0.98	50.9	8.9	
	1998	48.7	0.97	55.7	11.2	
	average	53.2	1.21	51.1	9.97	2.91±0.62
Ploughed	1996	61.8	1.57	46.8	10.9	
	1997	49.8	1.05	51.9	9.8	
	1998	47.9	0.96	56.0	11.7	
	average	53.2	1.20	51.6	10.8	2.90±0.59
Loosened with stubble-culti-vator +Roundup	1996	62.2	1.68	43.2	9.14	
	1997	50.3	1.06	53.1	12.9	
	1998	47.3	0.93	55.4	12.0	
	average	53.3	1.23	50.6	11.3	2.74±0.45
Loosened with	1996	63.6	1.82	47.8	9.6	
rototiller +	1997	49.4	1.05	53.3	9.8	
Roundup	1998	48.3	0.96	55.4	12.1	
	average	53.8	1.28	52.2	10.5	2.89±0.32
LSD_{05}	average	5.8	–	7.0	2.7	0.44

B – barley, Bu – barley + undersowing crop, Pg – perennial grasses, W – winter wheat, R – winter rye, F – fallow.

In all field trials variation of morain loam soil structure at different investigations years was determined. It could affirm that morain loam structure was not stabile in time and space. It was under the influence of many factors such as soil moisture, humus content, level of cultivation and plant species.

Conslusions

Great variation of morain loam soil meso-aggregates (from 42 to 66%) and water stable aggregates >0.25 mm (from 43 to 77%) were the result of both natural and anthropogenic factors.

From the viewpoint of morain loam soil structure preservation or improvement of this management system could be achieved through manure or straw incorporation + optimal liming + use of non-moldboard tillage.

References

1. Angers D. A. (1992) Changes in soil aggregatation and organic carbon under corn and alfalfa. Soil Science, 56, 1244–1249.
2. Angers D. A., Samson N., Legere A. (1993) Early changes in water-stable aggregatation induced by rotation and tillage in a soil under barley production. Soil Science, 73, 51–59.
3. Arlauskiene A., Maikštėnienė S. (2002) Molingų dirvožemio savybių gerinimas ankstiniais augalais ju biomase panaudojant zaliajai trasai, Zemdirbyste. Mokslo darbai. Akademija, 79, 229–243.
4. Arlauskas M., Slepetiene A., Maikstienene S. (1996) Skirtingu zemes dirbimo sistemu poveikis augalu derliui ir dirvu savybems, Zemdirbyste. Mokslo darbai. Akademija,73, 39–56.
5. Berglund G. (1986) Crushed limestone or burnt lime. Yournal of Royal Swedish Academy of Agriculture and forestry, 113, 9–24.
6. 6. Canarache A., Dumitru E., Enache R. (1998) Estimation of soil sensitivity to structure degradation. Proceedings of the 16th World Congress of Soil Science. Montpellier, Symposium 24, 8 (CD-ROM).

7. Chaney K., Swift S. (1984) The influence of organic matter on aggregate stability in some British soils. Soil Science, 35, 223–230.
8. Chantigny M., Angers D., Prevost D., Vezina L., Chalifour F. (1997) Soil aggregation and fungal and bacterial biomas under annual and perennial cropping systems. Soil Science, 61, 262–267.
9. Dinel H., Mehuys G., Levesque M. (1991) Influence of humic and fibric materials on the aggregation and aggregate stability of a lacustrine silty clay. Soil Science, 151, 228–239.
10. Douglass J., Goss M. (1999) Stability and organic matter of surface soil aggregates under diffrerent methods of cultivation in grassland. Soil Tillage research, 182, 155–175.
11. Eidukeviciene M. (1993) Geochemical and geographical validation of optimalization of liming acid soils in Lithuania. The work of doctor habilitatis. Vilnius, 6–90.
12. Elustondo J., Angers D., Laverdiere M., N'dayegamiye A. (1990) Influence de la culture de mais et de la prairie sur l'agregation et la matier organique de sept sols de Quebes. Soil Science, 70, 395–403.
13. Kindval T. (1999) Strukturkalking pa lerjordar. Uppsala, 52.
14. Lenksaite E. (1977) Influence of liming on soil physical properties and spreading of microorganisms in sod-podzolic soil in Lithuania. Summary of doctoral thesis. Kaunas, 2–8.
15. Wikklander L. (1986) The effect of lime on soil. Yournal of Royal Swedish Academy of Agriculture and forestry, 113, 68–78.

EFFECT OF MANURE RATES ON SOIL PROPERTIES AND PRODUCTIVITY OF AGROCENOSIS

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Abstract

Acid soil contains little calcium and a great amount of mobile aluminium. Liming and organic fertilisers are the main means to improve such soils properties and fertility of such soils. Two long – term stationary field trials are being carried out since 1949. The aim of the present experiments was to investigate the influence of systematic fertilisation with increasing rates of manure on chemical soil properties, weed infestation and productivity of sixth crop rotation in acid and limed soils. The soil of one field trial was acid and that of another one was limed. The increasing rates of manure (0, 20, 40, 80, 120 t ha^{-1}) were applied in both field experiments. At the increasing rate of manure from 20 to 120 t ha^{-1} soil acidity over sixth crop rotation (1996–2002) decreased from pH_{KCl} 4.1 to 4.4 in acid soil and from pH_{KCl} 5.8 to 6.1 in limed soil. There were changes of others soil properties in both soils too. The efficiency of fertilisation by manure 80 and 120 t ha^{-1} in acid soil was like that of liming by 1 rate according hydrolytic soil acidity. The productivity of crops in crop rotation increased, and there was observed change in weed infestation and weed flora under manure application in both soils.

Key words: acid, limed soil, manure, crop yield, weeds

Introduction

Acid soils make a part of cultivable plots in Lithuania and in other countries of the Baltic Region. Acid soil contains little calcium, and a big amount of mobile aluminium, which is harmful to plants (Mazvila, 1998). Due to leaching and removal with yield the arable soil layer looses up to 200 kg ha^{-1} of calcium carbonate every year (Ciuberkiene and Ezerinskas, 2000). Recently the process of soil acidification has become more active. Results of the experiments, carried out in the Lithuanian Institute of Agriculture, show that the acidity in excessively humid soils increases by 0.1–0.2 pH_{KCl} unit annually (Ciuberkiene and Ezerinskas, 2000). Liming and application of mineral and organic fertilisers are the main means to improve such soils (Jankowska-Huflejt *et al.*, 2002; Burgt and Baars, 2001; Pleseviciene, 1993). Under the effect of lime fertilisers the following changes occur in the main soil chemical properties: decline of soil acidity and amount of aluminium in soil, and soil base saturation increases (Criznikova, 1998; Шильников *et al.*, 1997). Liming and application of organic fertilisers, which increase microbiological soil activity, play an important role in soil fertility maintenance (Pleseviciene *et al.*, 1997; Perucci *et al.*, 1997). The calcium, contained in manure, partially neutralises the mobile aluminium that is harmful to plants, and decreases soil acidity (Ciuberkiene and Ezerinskas, 2000). Application of organic fertilisers can prevent the harmful effects of soil acidity on cultivated crops. Farmyard manure is not only the main and most valuable organic fertiliser but it has also a soil neutralising effect. Experimental evidence obtained by various countries' researchers suggests that manure application results in a reduction in mobile aluminium content in the soil, an increase in pH_{KCl} value as well as an increase in organic matter content (Jankowska-Huflejt *et al.*, 2002; Baars, 2001; Pleseviciene *et al.*, 1997). In order to obtain a stable yield of agricultural crops it is necessary to combine organic and mineral fertilisation (Vasileva and Kostov, 2002; Baars, 2001).

However, some amount of weed seed is incorporated into the soil with manure. 1 kg of cattle manure contains approximately 460 weed seeds (Ciuberkis, 1996). Therefore, manure application increases weed seed stock in soil and may change number and composition of weed species (Forcella *et al.*, 1996; Monstvilaite, 1996). Thus, under the influence of antropogenic activity the stock of weed seeds in the soil as well as weed infestation of crop stands may change. It is important to consider it in planning weed control measures, particularly in organic agriculture. There is a lack of information regarding changes of soil properties, weed flora and productivity obtained from long-term experiments.

The aim of the present experiments was to investigate the influence of systematic fertilisation with increasing rates of manure on chemical soil properties, weed infestation and productivity of sixth crop rotation in acid and limed soils.

Materials and Methods

Two stationary long-term field trials are being carried out since 1949 at the Vezaiciai Branch of the Lithuanian Institute of Agriculture. The experiments were conducted on *Dystric Albeluvisol* (***Ab***, FAO-

Unesco, 1998) sandy loam acid (pH_{KCl} 4.0–4.2) soil. They are located in the same field very close to each other. Soil of one field trial was acid, and soil of another one was limed by one rate according hydrolytic soil acidity with pulverised limestone before the establishment of the experiment and later periodically after every 7 years, i.e. at the end of each crop rotation. The size of the initial plot was 8.5 m by 6 m (51 m^{-2}). Five replications were used in each experiment. The following crop rotation was applied: 1) winter wheat (*Triticum aestivum* L.), 2) spring barley (*Hordeum vulgare* L.), 3) oat (*Avena sativa* L.), 4) fodder beet (*Beta vulgaris* L.), 5) spring barley, 6) first year (1^{st}) perennial grasses: red clover (*Trifolium pratense* L.) + timothy (*Phleum pratense* L.), 7) second year (2^{nd}) perennial grasses. The increasing rates of farmyard manure (0, 20, 40, 80 and 120 t ha^{-1}) were applied in both field experiments. Half a rate of manure was incorporated to winter wheat and other half a rate to fodder beet. Soil agrochemical properties in topsoil were established using the following methods: pH_{KCl} – electrometric determination, mobile aluminium – by Sokolov, mobile phosphorus and potassium – by A-L method, humus – by Tyurin.

Weed flora was assessed in 4 quadrates (0.5 m × 0.5 m) per plot at the end of May – first decade of June, i. e. before weeding of fodder beet and at tillering phase of cereals.

Statistical analyses package was used for data calculations. Experimental data was evaluated by computer programme ANOVA for EXCEL version 343. Correlation analysis was estimated by Fisher's protected LSD test in dependence of soil properties, weed density on rates of manure.

Results and Discussion

Systematic fertilisation with manure had significant influence on the ecological conditions of plant growth. At the increasing rate of manure from 20 to 120 t ha^{-1} soil acidity over the sixth crop rotation decreased from pH_{KCl} 4.1 to 4.4 in acid soil and from pH_{KCl} 5.8 to 6.1 in limed soil. The decrease of aluminium was correspondingly from 117.8 to 26.8 and from 1.5 to 1.0 mg kg^{-1}, while that of humus increased from 1.79 to 2.26 in acid soil and from 1.87 to 2.33% in limed soil (Table 1). The amounts of mobile phosphorus and potassium, which were available to plants, increased in both types of soils. Data of some investigation conducted in Lithuania showed that application of manure increased the amount of nutrients and humus content in the soil and at the same time slowed down soil acidification and accumulation of mobile aluminium (Ciuberkiene, 2000; Pleseviciene *et al.* 1997; Lukosiuniene *et al.* 1997; Salonen J. 1993) indicate that evident relationship takes place between the soil properties and weed composition in the field. Some of these properties, e.g. soil pH_{KCl} can be manipulated.

Table 1. Effect of manure on agrochemical parametres of topsoil (1996–2002)

Agrochemical parameters		Rates of manure, t ha^{-1} per rotation					$LSD_{0.05}$
		0	20	40	80	120	
pH_{KCl}	Acid soil	4.1	4.2	4.2	4.3	4.4	0.09
	Limed soil	5.8	5.9	5.9	6.0	6.1	0.13
Mobile Al mg kg^{-1}	Acid soil	117.8	91.2	69.2	48.3	26.8	16.58
	Limed soil	1.5	1.7	1.8	1.3	1.0	0.98
Mobile P_2O_5 mg kg^{-1}	Acid soil	163	169	166	188	211	10.4
	Limed soil	150	160	193	227	239	11.3
Mobile K_2O mg kg^{-1}	Acid soil	245	249	252	276	299	18.2
	Limed soil	196	216	251	294	319	17.4
Humus, %	Acid soil	1.79	1.86	1.96	2.12	2.26	0.289
	Limed soil	1.87	1.87	2.10	2.28	2.33	0.14

$LSD_{0.05}$ – Least significant difference at $p \le 0.05$.

Winter wheat is very sensitive to soil acidity, especially to mobile Al. In acid soil fertilisation with increasing rates of manure resulted in the reduction in mobile Al content and an increase in wheat grain yield. Lime fertilisers had a more considerable effect on wheat yield compared with manure only. In acid soil incorporation of the highest rate of manure 120 t ha^{-1} per rotation resulted in the grain yield of 4.21 t ha^{-1}, i. e. yield increased by 297%. After incorporating manure rates 80 and 120 t ha^{-1} in limed soil the winter wheat grain yield increase was by 22 and 23%, respectively as compared to plots without manure application (Table 2). However, the highest grain yield was produced in limed soil, compared with the acid soil. Like wheat, spring barley is sensitive to mobile Al. Variation trend of spring barley grain yield remains similar to that of wheat. Experimental findings suggest that for spring barley (1997) the best combination was liming and fertilisation by manure at 80 and 120 t ha^{-1}, which resulted in the highest yield 3.10 and 3.69 t ha^{-1}, respectively. Similar spring barley grain yield variations were identified in 2000. Due to unfavourable weather conditions, spring barley grain yields were lower, compared with yields obtained in 1997. Insignificant drought (hydrothermal coefficient – 0.9) was prevailing during the vegetative period of spring barley in 2000. For oats the effect of manure was similar in both acid, and limed soil, the grain yield increased by 11–40% and 8–45%, respectively. Although oats are not sensitive to soil acidity, in limed soil application of 40–120 t ha^{-1} of manure resulted in the highest (4.52–5.0 t ha^{-1}) oat grain yield increase (Table 2). Fodder beets are sensitive to soil acidity, consequently, they responded positively to the neutralisation of soil acidity indicators by manure.

Table 2. Effect of manure on yield of rotation crops in acid and limed soils

Manure rate, t ha^{-1} per rotation	Crop of rotation and year						
	winter wheat, 1996	spring barley, 1997	oats, 1998	fodder beet, 1999	spring barley, 2000	perennial grasses DM yield t ha^{-1}	
	grain, t ha^{-1}			roots, t ha^{-1}	grain, t ha^{-1}	1st year, 2001	2nd year, 2002
Acid soil							
1. 0	1.06	0.82	2.63	3.30	0.71	2.49	1.58
2. 20	1.44	0.84	2.93	3.30	0.88	3.68	2.09
3. 40	2.13	1.10	3.30	12.19	1.18	4.49	2.32
4. 80	3.89	2.44	3.52	25.71	1.60	5.08	2.32
5. 120	4.21	2.74	3.69	34.91	1.62	5.13	2.30
$LSD_{0.05}$	1.18	0.49	0.87	7.43	0.57	1.15	0.59
Limed soil							
1. 0	4.53	2.35	3.44	35.45	1.21	4.30	2.08
2. 20	5.53	2.67	3.72	44.11	1.79	4.84	2.45
3. 40	5.34	2.88	4.52	53.79	2.35	5.05	2.35
4. 80	5.54	3.10	4.72	56.74	2.29	5.33	2.62
5. 120	5.57	3.69	5.00	64.07	2.66	5.89	2.63
$LSD_{0.05}$	0.89	0.45	1.09	5.40	0.67	0.99	0.39

The highest effect of fertilisation by manure was identified in acid soil – the root yield of fodder beets increased as much as 10 times. Soil liming had the same effect on fodder beet yield as incorporation of the maximal (120 t ha^{-1}) manure rate in acid soil. Application of the highest manure rate in acid soil resulted in a fodder beet root yield of 34.91 t ha^{-1}, and in limed soil without manure application the yield was 35.45 t ha^{-1}. Although the greatest fertilisation by manure effect was achieved in acid soil, in limed soil fertilised with manure the highest (44.11 and 64.07 t ha^{-1}) and most stable yields of fodder beet roots were obtained. When perennial grasses were grown on an acid soil all manure rates had a significant effect on dry matter (DM) yield increase, except for the effect of the lowest (20 t ha^{-1}) rate on DM yield of perennial grasses of the 2nd year of use (Table 2). Only the highest (80 and 120 t ha^{-1}) manure rates had a statistically significant effect on DM yield of perennial grasses of the 1st and 2nd year of use grown on limed soil. In terms of perennial grass yield, manure was more effective on acid soil compared with limed soil. Nevertheless, the highest DM yield of perennial grasses was produced on limed soil, compared with acid soil. In terms of perennial grass DM yield, long-term systematic manure fertilisation at moderate (40 t ha^{-1}) and higher rates was superior to liming. When growing perennial grasses on acid soil and fertilising with 40 t ha^{-1} of manure per rotation the dry matter yield of perennial grasses of the 1st year of use was 4.4 9 t ha^{-1}, and on acid soil without manure application the dry matter yield was 4.30 t ha^{-1}. On acid soil fertilised with the highest (80 and 120 t ha^{-1}) manure rates the dry matter yield of grasses was similar to that obtained on limed soil applied with 40 t ha^{-1} of manure per rotation.

In acid and unfertilized by manure soil the most weed-infested crops were spring barley (1997), oat and fodder beet (Table 3). There were identified 16 weed species. At the increasing rate of manure from 20 to 120 t ha^{-1} in acid soil constant decrease of weed infestation was observed in all crops. Acidophilic weed species *Spergula arvensis* L. and *Scleranthus annuus* L. predominated in spring barley (1997), oats and fodder beet. They made 87, 39 and 358% of all weeds, respectively. Growth of cultural plants in acid soil was poor and they were not able to compete with weeds. No *Spergula arvensis* L. and *Scleranthus annuus* L. plants were found in the crops of perennial grasses but there dominated *Rumex acetosella* L. (42% of all weeds). The number of *Spergula arvensis* L., *Scleranthus annuus* L. and *Rumex acetosella* L. significantly decreased in the crops because soil properties have been changed and cultural plants shaded these weeds which were sensitive to competition for light. Medium strong and strong correlation was established between rates of manure and weed infestation in crop stands in acid soil (r = –0.66–0.94). *Chenopodium album* L., which positively responded to fertilisation, application of the increasing rate of manure resulted in increased number of this weed in the crops of spring barley, oat and fodder beet. Results of investigation obtained in Finland show that there are no significant differences in infestation by the most abundant weed species between farm types, except that the density and biomass of *Spergula arvenses* L. are twice as high on crop husbandry as on animal husbandry farms (Salonen, 2001).

In limed soil, weed infestation of crop in the plots untreated by manure was 2.5–3.4 times lower as the number of *Spergula arvensis* L. and *Scleranthus annuus* L. significantly decreased and *Rumex acetosella* L. disappeared. However, nitrophilous weed *Chenopodium album* L. predominated in limed and nutrient rich soils. In the crops of spring barley (1997), oat, fodder beet and spring barley (2000) *Chenopodium album* L. made correspondingly 28, 55, 57 and 41% of all weeds in the crops mentioned above. The total number of weeds did not change in the crops of winter wheat, oat, spring barley (2000) and perennial grasses (2002). However, the number of weeds increased in plots after application of 80 t ha^{-1} manure to spring barley (1997) and fodder beet, and decreased in 1st year perennial grasses in plots treated by manure 120 t ha^{-1} (Table3). This could be more important for sustainable and organic farming systems.

Table 3. The effect of manure on weed infestation of crops on acid and limed soils before weed control, number of weeds per m^{-2} (* $p \le 0.05$, ** $p \le 0.01$)

Rates of manure, t ha^{-1}	Crop of rotation and year						
	winter wheat, 1996	spring barley, 1997	oats, 1998	fodder beet, 1999	spring barley, 2000	perennial grasses	
						1st year, 2001	2nd year, 2002
Acid soil							
0	88.3	190.0	340.3	205.0	59.0	79.5	88.8
20	89.3	189.7	285.3	297.3*	82.9	68.6	62.0*
40	77.0	109.5*	246.9*	309.0*	87.8	89.3	56.3*
80	49.8*	80.8**	239.1*	227.5	89.5	68.1	38.7**
120	48.9*	89.0**	244.4*	191.0	74.4	56.2*	35.4**
Limed soil							
0	46.0	57.6	122.1	70.9	56.3	25.7	36.3
20	43.3	63.4	114.4	71.1	45.1	21.6	33.3
40	43.6	64.8	112.4	83.4	51.0	28.0	37.1
80	46.1	75.2*	124.0	100.2*	42.2	25.3	38.3
120	47.6	61.9	119.4	92.0	46.8	14.3*	32.8

Conclusions

At increasing rates of manure from 20–120 t ha^{-1} in acid and limed soils pH_{KCl} levels decreased from 4.1 to 4.4 and from 5.8 to 6.1, respectively, and amount of mobile aluminium decreased from 117.8 to 26.8 in acid soil.

The yields of all crops in crop rotation were highest produced on limed soil, i. e. when liming was adjusted to manure. The efficiency of fertilisation by manure 80 and 120 t ha^{-1} in acid soil was similar to that of liming by 1 rate according hydrolytic acidity of soil.

Weed infestation of crops at the increasing rates of manure from 20 to 120 t ha^{-1} decreased by 26% in acid soil and did not change in limed soil compare to plots untreated by manure.

References

1. Baars T. (2001) Effect of animal manure on the growth dynamics of grass/clover on sandy soils. Organic Grassland Farming, Grassland Science in Europe, Witzenhausen, Germany, 6, 291–294.
2. Burgt G. J. and Baars T. (2001) Manure effects on soil fertility and earthworm populations in organic grass/clover swards on sandy soils. Organic Grassland Farming, Grassland Science in Europe, Witzenhausen, Germany, 6, 281–283.
3. Chriznikova N. P. (1998) Clay minerals in sody-podzolic soils of Russia and the problem of acidification. 16th World congress of soil science: summaries Symposium No 24. – Le Corum, 1, 457.
4. Ciuberkis S. (1996) Changes of Weed Flora Depending on Soil Reaction and Fertilization. Proceedings of the Second International Weed Control Congress, Flakkebjerk, 1, 221–226.
5. Ciuberkiene D. and Ezerinskas V. (2000) The changes of agrochemical properties and nutrient migration in differently limed and fertilized soil. Agriculture. Scientific Articles. Academy, 71, 32–48 (in Lithuanian).

6. Ciuberkiene D. (2000) Variation of agrochemical properties of soils with different reaction in the conditions without and with organic fertilizers. Soil acidificatiun and liming. Proceedings, Vezaiciai, 41–48 (in Lithuanian).
7. Forcella, F. Durgan, B. R. and Buhler D. D. (1996) Management of Weed Seedbanks. Proceedings of the Second International Weed Control Congress, Flakkebjerk, 1, 21–26.
8. Jankowska-Huflejt, H., Niczyporuk A. and Zastawny J. (2002) Comparing the long term effect of mineral and manure fertilization on the botanical composition of sward and some parameters of the meadow soil. Multi-Function Grasslands. Quality Forages, Animal Products and Landscapes, Grassland Science in Europe, La Rochelle, France, 7, 694–695.
9. Lukosiuniene E., Buciene A. and Slepetiene A. (1997) Diverse manure duration activity and it consequence to accumulation of humus in soil. Agriculture. Scientific articles. Academy, 57, 80–89 (in Lithuanian).
10. Mazvila, J (ed.) (1998) Agrochemical properties of Lithuanian soils and their changes, Kaunas, 11–36 (in Lithuanian).
11. Monstvilaite J. (1996) The problems weed infestation of fields, Dotnuva-Akademija, 4–88. (In Lithuanian)
12. Perucci P., Bonciarelli U., Santilocchi R., and Bionchi A. A. (1997) Effects of rotation, nitrogen fertilization and management of crop residues on some chemical, microbiological and biochemical properties of soils. Biology and Fertility of Soils, 24 (3), 311–316.
13. Pleseviciene A. (1993) Influence of manuring on agrochemical properties in acid and limed soils. Batic Region. Agriculture in Acid Soils, Vilnius, 163–167.
14. Pleseviciene A., Veitiene R., Lenksaite E., Arlauskiene E. P., Ciuberkis S. and Janusiene V. (1997) The changes of agrochemical, physical, biological properties under impact of different rates of manure in moderately podzolized derno-podzolic acid and limed soils. Agriculture. Scientific article, Academy, 60, 38–59 (in Lithuanian)
15. Salonen J. (1993) Weed infestation and factors affecting weed incidence in spring cereals in Finland a multivariate approaching. Agriculture Science Finland, 1. 2, 525–536.
16. Salonen J., Hyvonen T. and Jalli H. (2001) Weed flora in organically grown spring cereals in Finland. Agricultural and food science in Finland, 10, 231–242.
17. Vasileva V. and Kostov O. (2002) Effect of different fertilization on the lucerne productivity under water deficiency stress. Multi-Function Grasslands. Quality Forages, Animal Products and Landscapes, Grassland Science in Europe, La Rochelle, France, 7, 484–485.
18. Минеев В. Г. и Ремпе Е. Х. 1990 Агрохимия, биология и экология почвы. Москва, 6–67.
19. Шильников И. А., Удалова Л. П., Аканова Н. И. и др. (1997) Эффективность сочетания известкованых и минеральных удобрений под зерновые культуры в длительном стационарном опыте, Агрохимия, 4, 34–39.

INTEGRATING SOIL ORGANIC CARBON NODEL IN ESTIMATES OF SUSTAINBLE AGRICULTURAL MANAGEMENTS PRACTICES

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Abstract

Data on soil response to changes in agricultural management from controlled experiments in representative climatic regions and on representative soils make it possible to minimise the time and cost of the evaluation of a particular practice. The development of sustainable land management technologies in agriculture implies a wide application of field experimental data and models designed to describe changes which occur very slowly, such as changes in soil organic C (SOC) levels. The combined impact of different management practices (inorganic fertilisers, manure and different rotations), climate and soil properties on SOC changes was analysed using a static model. The information for the model was integrated from 60 long-term experiments on arable soddy-podzolic soils in the Russian Federation, Belarus, Ukraine, Latvia and Lithuania. The model was applied for the elaboration of optimal crop rotations and fertilisation practices that lead to SOC sequestration. Quantitative estimates of management options for enhancing the SOC pool thus improving soil quality and biomass productivity were presented for different districts of the Moscow Region and regions of the European Russia under current climate. Different possibilities of applying the SOC model in combination with GIS databases were demonstrated. The proposed approach links assessments of crop yields, soil fertility and incomes in the management practices tested.

Key words: sustainable agriculture, agricultural management, model, long-term experiments, soil organic carbon, carbon sequestration

Introduction

Soil organic carbon (SOC) represents the largest pool in the total terrestrial C and the rate of its change is quite slow, particularly in relation to the size of the SOC pool (Paul *et al*., 2003). In fact, the SOC pool integrates changes in production and decomposition in an ecosystem over long-term period and reflects land use history, as well as the former land management practices. Changes in the agricultural management may increase or decrease the SOC pool. The SOC pool increases most rapidly soon after a C-enhancing land management change is implemented, but the rate of SOC accumulation in the soil decreases with time as the SOC pool approaches the new equilibrium (Smith, 2004). As a result, large sample size and long periods of time are necessary for obtaining detectable differences in SOC levels; accurate prediction of soil C change with time as based on empirical approaches is a challenge.

The most important source of data on the SOC change upon soil cultivation are field experiments under controlled conditions with a duration of more than 20 years on representative soils containing well-documented yield data, management history and relevant climate information (Powlson, 1996), because crop yields and efficiency of fertilisation and, hence, C inputs into the soil are highly weather-dependent. The lack of sufficient data from such long-term controlled experiments is a bottleneck for the application of local-scale SOC dynamic information on a regional scale. As a result, in the 1980s–1990s, static modelling approaches were widely used for estimating requirements in the farmyard manure (FYM) application to sustain a deficit-free SOC balance. Shevtsova (1988) used a minimum set of driving variables that characterise the management practice, initial levels of soil C and soil texture for the quantitative assessment of SOC change under croplands. This approach made it possible to calculate steady state SOC levels for the given rotation systems and rates of mineral and organic fertilisers without using crop yield data. Thus, a large body of data from long-term experiments on the C dynamics in arable ecosystems could be used for model estimates. A regression model for assessing the effect of changes in agricultural practices on the SOC balance in arable soddy-podzolic soils was developed (Shevtsova *et al*., 1992). The database for the model was developed from 60 long-term experiments in the Russian Federation, Belarus, Ukraine, Latvia and Lithuania (838 records with the time span varying from 7 to 60 years).

To answer the question if the SOC response to cultivation is climatically controlled, the meteorological indices were introduced in the database as independent variables. These indices represent output data from the Climate-Soil-Yield dynamic model, calculated locally for the experimentation period at each of the sites

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(Sirotenko *et al*., 1995). The new version of the Soil–Weather static C model that was constructed separately for sandy and clay loam classes, revealed a substantial role of precipitation during the growing season, potential evapotranspiration and bioclimatic potential on the SOC dynamics. The influence of each climatic factor was interrelated with the soil and management conditions and discussed elsewhere (Shevtsova *et al*., 2003).

In this paper, we present the latest version of the model which unifies all soil texture classes. Our goal was to apply this model at different scales: local, district and regional. The first two levels were used to study the sensitivity of the SOC pool to changes in specific management practices within a given climatic zone; the regional scale was used to simulate the effect of climatic gradients on soil organic matter over large areas.

Materials and Methods

A non-linear regression analysis was used to identify the parameters of the model variables. The following native and agricultural factors were most significant in the SOC dynamics and were chosen as a set of eight driving variables: *Cini,* initial C content (%); *L,* content of soil particles <0.01 mm (%); *M,* annual FYM (farmyard manure) rate for the modelling period (Mg ha^{-1} y^{-1}); *N,* annual mineral N rate (kg ha^{-1} $year^{-1}$); *Rp,* percent of row crops and fallow in the rotation (%); *Gp,* percent of perennial grasses in the rotation (%); *H,* humidity coefficient (precipitation/evaporation ratio per growing season (T>5 °C); *BCP,* bioclimatic potential corresponding to a permanent grassland yield under multi-cutting regime during the growing season (kg 10^3 ha^{-1}).

$\Delta C = f\ (Cinit,\ L,\ M,.\ N,\ Rp,\ Gp,\ H,\ BCP)$ (1)

To provide for an even geographical distribution of the sites, some treatments were excluded from the database. The best-fit structure was identified on the basis of double and triple non-linear interactions between parameters and posterior information on their interdependence. Estimates of the values of parameters are shown in Table 1. Probability estimates of all the values were less than 0.02 and significant within 98% of the confidence interval. Standard deviation of the model was 0.01605, multiple correlation coefficient was 0.78. The model can be applied within an *L* value range from 20 to 45%. The most significant variable was *Cinit* that mainly controls the intensity of biochemical processes in the soil. The significance of *L* as the driving variable is explained by the role of surface area in the activity of biogeochemical soil processes. The relationship between *Cinit* and *L* is mediated by the rotation system and humidity coefficient (Table 1).

Table 1. Estimates of linear parameter values for all independent variables and their significance for calculating annual C changes in soddy-podzolic soils (%, $year^{-1}$) for the soil-weather static model

Independent variables	Parameter values	Standard deviation	t-criteria
Constant	–7.2368e-4	2.54996e-3	–0.2838
$Rp \cdot Cinit^{4.4} \cdot L^{0.9}$	–1.02595e-5	7.50023e-7	–13.679
$Gp \cdot Cinit^{4} \cdot L^{3}$	1.83512e-9	1.47516e-10	12.4402
$(M+4)^{0.6}\ Cinit^{2.7} \cdot (BCP\text{-}40)$	6.66184e-5	9.12897e-6	7.29747
$H^{5.5} \cdot Cinit^{3.1}$	–1.3692e-2	5.63296e-3	–2.4231
$(PP+25)^{2} \cdot BCP^{1.5}$	7.45441e-9	1.35285e-9	5.51016
$L^{3} \cdot (M+2)^{0.6}$	4.36274e-8	7.57494e-9	5.75945
$(N+35)^{0.5} \cdot Cinit^{4} \cdot BCP^{3.3}$	1.85033e-10	6.8096e-11	2.71724
$L \cdot BCP^{3}$	–2.05859e-9	2.96247e-10	–6.94891

The specificity of rotation systems can be defined as the ratio between *Rp, Gp* and cereals. The percent of cereals is calculated as *100 – (Rp + Gp).* The *BCP* controls phytomass production and, hence, C inputs from the above- and below-ground parts of plants. The decomposition rate is controlled by *H* and increases with an increase in the soil moisture content (up to a certain limit). Interrelation was found between the potential productivity (*BCP*), fertilisation efficiency (*FYM* and *N* rates) and soil fertility (initial SOC level). The influence of the percent of row crops in rotation on the SOM dynamics is expected to be dependent on the soil texture.

The model allows determining steady state conditions for different combinations of the driving variables, so that the SOC pools remains the same or increases. In fact, the model provides a sort of a compromise between empirical approaches and dynamic C models, which take into account soil–plant–atmosphere relationships.

Moscow Region was used for GIS ILWIS 2.2 linking with the model; in this region, soddy-podzolic soils occupy about 2,623,000 ha and correspond to 30.5% of the arable fund. Variables for SOC (%) and fraction <0.01 mm in the upper horizon of arable soddy-podzolic soils were obtained using a regular 5×5 km grid. Land management data were taken from the Moscow Regional Department of Agriculture as averaged for 1986–1990 by separate districts; the following ranges were considered: 5–60 t ha^{-1} FYM rates, 70–120 kg ha^{-1} rates of mineral N, 6–41% of cereals, 11–32% of row crops and 38–69% of annual and perennial grasses in the rotation. Details can be found in (Savin *et al*.. 2002; Shevtsova *et al*.. 2003).

Results and Discussion

The sensitivity analysis of SOC dynamics displays the effects of changes in soil texture and management practices. The case study region was Moscow Region. All the ranges of SOC analysed are based on a GIS database of the Dokuchaev Soil Science Institute; ranges of management practices, on agricultural statistics. Climate indices in the model are as follows: *H* – 0.62, *BCP* – 51.9 kg 10^3 ha^{-1}. Average rates of mineral N in 2000 were 22.5 kg ha^{-1}; percent of row crops in the rotation, 23% and percent of perennial grass, 56%. Two figures illustrate how a successive change in one of the parameters of a particular management regime, with the other parameters fixed, influences the SOC level.

The effect of FYM fertilisation on the SOC pool at steady state was estimated for clay loam soil (*L* = 45%). For the initial SOC level of less than 2.0%, the current management practice resulted in the increase in the SOC storage even without FYM application (Fig. 1). At the initial SOC level of 2.5%, it is necessary to apply no less than 3.2 Mg ha^{-1} FYM annually to sustain this level, everything else being constant. This approach allows one to calculate local farm requirements in FYM application to sustain current SOC levels and to estimate possible effect of increasing rates of organic fertilisers on enhancing C sequestration. The magnitude of the latter was relatively low for the SOC level of 1.0% but increased with an increase in the initial C storage (Fig. 1).

The other factor controlling the SOC pool is the percentage of grasses in crop rotation. Figure 2 illustrates the effect of changes in crop rotation upon current fertilisation levels in Moscow Region and at a constant percent of cereals (21%), with an assumption that a change in the percentage of perennials is only possible at the expense of row crops. The model simulations showed that the response of SOC is dependent on the initial SOC level.

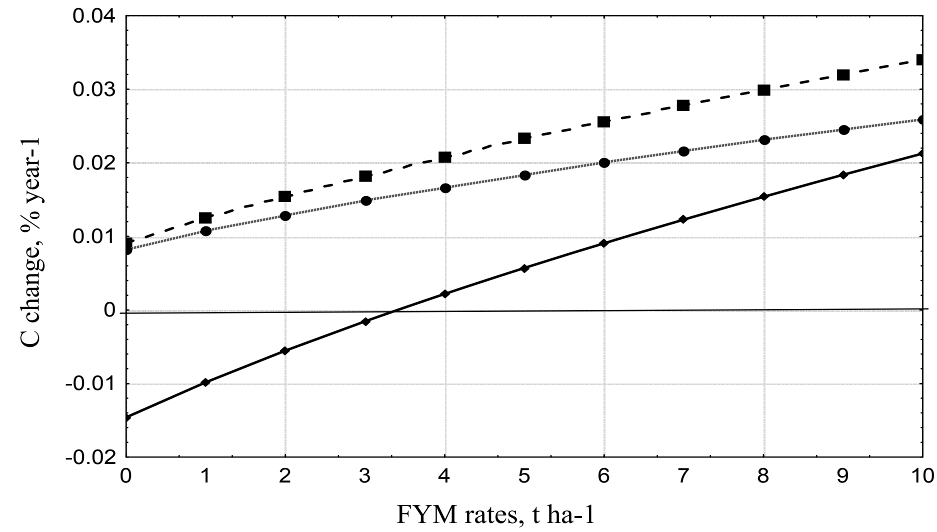

Figure 1. Simulated values of annual change in the SOC content (%) for clay loam arable soddy-podzolic soil as affected by FYM rates. Initial C content for upper dashed line 2%, lower dashed line – 1.5%, solid line – 2.5%

The change in C balance is slightly noticeable after reducing the portion of row crops in the rotation by one-third (from 65% to 47%) at the initial SOC level of about 1.5%. However, with an increase in the initial SOM level, the effect of this factor of C sequestration will be higher. To sustain the initial SOC pool in soils containing 1.5% C, a crop rotation with about one-half of perennial grasses is necessary, while for soils with 2.5% C, the percent of perennial grasses must be no less than 58% (4 years with grasses in a 7-year rotation). If the crop rotation changes, this percent may either increase or decrease. Note that the predicted response in a crop rotation with 57% of perennial grasses is independent from the initial SOC level (node on Fig. 2).

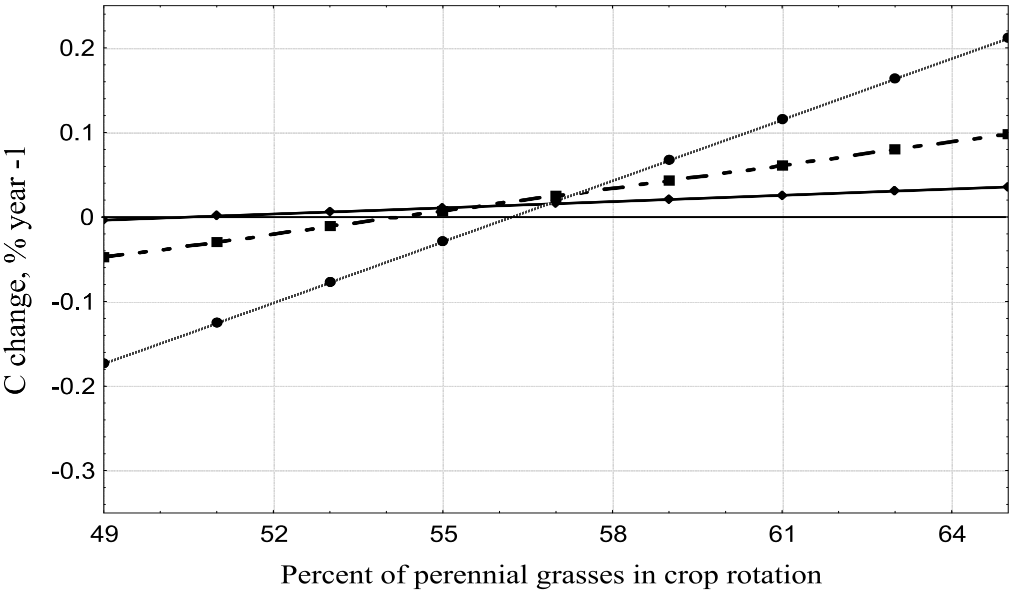

Figure 2. Simulated values of annual change in the SOC content (%) for clay loam arable soddy-podzolic soil as affected by crop rotation. Initial C content for dashed line 2.5%, dash and dot line – 2%, solid line – 1.5%

If we consider spatial variability in the soil management, the simulation procedure would require aggregation of information with different spatial resolution. The performance of the model was tested by using the statistical data on intensive farming in 39 districts of Moscow Region for 1986–1990 (Savin *et al.*, 2001). The response of SOC dynamics to changes in the agricultural management factors was the highest for increasing the percentage of grass in the crop rotation, followed in importance by the rates of FYM and mineral N application (Romanenkov *et al.*, 2001). The results suggest that a crop rotation with less than 38% perennials in all the districts should lead to the C loss from the soil. The effect of changes in the management factors is most pronounced for coarse-textured soils of glacio-fluvial and alluvial plains in the north of Moscow Region and in the Meshchera Lowland.

Linking meteorological information of regional level with the model demonstrates the possibility of simulating SOC regional trends. The model was used to determine crop rotations and FYM rates providing for the stability of the SOC content in soils of a given texture and initial C level. This approach was used by Parton *et al.* (1987) for the CENTURY model validation. It allows predicting the SOC level as a function of climatic factors. Estimates of SOC indicate that under the same initial C levels, soil texture and rotation systems, the magnitude of changes depends on the climatic region; it is different for the north-western and south-eastern regions. That is, the vector of potential C sequestration in arable soils has a distinct north-western direction across the Russian Plain. This coincides with a decrease in the aridity of the climate manifested by the lowering of potential evapotranspiration and summer temperatures with a simultaneous increase in precipitation. For example, for soils with 1.5% C, the zero change in the C pool is expected upon crop rotation with 20% of row crops and 30% of perennial grasses on the average. However, under the climatic conditions of Kaliningrad Region, the percent of perennials can be as 18%, while for the northern part of Perm Region it should be at least 36% (Table 2). Everything else being constant, corresponding values for the soils with 2% initial C are 50% of perennials and 10% of row crops on the average; in the north-western regions, the necessary percentage of perennials is 28%, while in the south-eastern regions it should be increased to 77%. The simulation also demonstrates that a change in the crop rotation system is a more substantial factor of additional C sequestration as compared with FYM application. Thus, for some regions, low SOC levels can be maintained constant even without manure application, though a 20% increase in the SOC content (from 1.5 to 1.8%) would require a ten-fold increase in the rate of FYM application (for Moscow Region, from 2 to 20 t ha $^{-1}$). The same effect can be achieved as a result of a two-fold increase in the percentage of perennial grasses in the crop rotation.

Table 2. Estimates of agricultural management factors for the selected regions in the Russian Plain providing zero annual C change for clay loam arable soddy-podzolic soils (40% of soil particles <0.01 mm)

Region	Perennial grass, % *Rp* 20%, *H* 2 t ha^{-1}		FYM annual rates, t ha^{-1} *Rp* 25%, *Gp* 40%	
	Cinit 1.5%	*Cinit* 2.0%	Cinit 1.5%	*Cinit* 2.0%
Kaliningrad	18	28	4	36
St'Petersburg	30	66	1	17
Novgorod	26	56	6	47
Moscow	26	54	2	20
Kaluga	23	44	1	16
Mordovia	26	54	1	18
Udmurtia	29	64	12	73
Average	27.6	58.3	3.3	28.6

The first regional database, which links crop yield, soil and land management data with regional economic model indices for the current and sustainable farming scenarios for the European Russia, is being developed by the joint efforts of the All-Russia Research Institute of Agrochemistry, All-Russia Research Institute of Agricultural Meteorology, the Dokuchaev Soil Science Institute and the All-Russia Research Institute of Agricultural Problems and Informatics. The outputs of the economic model for the sustainable scenario include the results of the solution of the problem of maximum profit with a proviso that the SOC level must remain constant or increase according to the Soil–Weather static C model. It is suggested that the database will be used for developing optimal regional fertilisation practices and crop rotation systems ensuring additional C sequestration.

Conclusions

The Soil–Weather static C model, which unifies all soil texture classes, was proposed for soddy-podzolic soils. The model interrelates data on the climate, soil and land management practices to simulate the conditions necessary for sustaining the SOC level and estimate possible effects of changes in the land management on C sequestration.

On a local scale, the model helps to choose optimal fertilisation practices and crop rotation systems providing for the stability or increase in the initial SOC level. Linking the model with GIS technology, it is possible to outline the areas where the effect of changes in management practices will be most pronounced and to suggest optimal land management strategies for particular regions on the basis of available data.

The impact of climatic factors on SOC dynamics was simulated on the basis of the regional model application. It was demonstrated that a change in the crop rotation system is a more substantial resource for additional C sequestration as compared with the FYM application. The integration of the Soil–Weather static C model with regional economic models can be used for developing the most efficient agricultural management strategies ensuring the stability of the initial SOC level or additional C sequestration in the particular regions.

Acknowledgements

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References

1. Parton W. J., Schimel D. S., Coke C. V. and Ojima D.S. (1987) Analysis of factors controlling soil organic matter levels in Great Plains grasslands. Soil Sci. Soc. Am. J., 51, 1173–1179.
2. Paul K. I., Polglase P.J. and Richards G. P. (2003) Sensitivity analysis of predicted change in soil carbon following afforestation. Ecological Modelling, 164, 137–162.
3. Savin I. Y., Sirotenko O. D., Romanenkov V. A. and Shevtsova L. K. (2002) Assessment the role of agricultural management strategies in balance of organic carbon in arable soils of Moscow Region. In: Shishov L. L. and Voitovitch N. V. (eds.) Soils of the Moscow Region and their use. Dokuchaev Soil Institute, Moscow, Vol. I, 324–335 (in Russian).
4. Shevtsova L. (1988) Humus status and nitrogen stock in the main types of soil under long-term fertilisation. Doctoral thesis. Moscow, 24 (in Russian).
5. Shevtsova L.K., Mikhailov B. G., Turovetts V.M., Nikitin V.S. and Volodarskaya I.V. (1992) Regulation of soil humus balance based on statistical analysis of long-term experimental database. Russian Academy of Agricultural Sciences, Moscow, 38 (in Russian).
6. Shevtsova L., Romanenkov V., Sirotenko O., Smith P., Smith Jo U., Leech P., Kanzyvaa S. and Rodionova V. (2003) Effect of natural and agricultural factors on long-term organic matter dynamics in arable soddy-podzolic soils – modeling and observation. Geoderma, 116, 165–189.
7. Sirotenko O. D., Abashina A. and Pavlova V. (1995) Sensitivity of the Russian Agriculture to Changes in Climate, atmospheric chemical composition and soil fertility. Meteorology and Hydrogeology, 4, 107–114 (in Russian).
8. Powlson D. S. (1996) Why evaluate soil organic matter models? In: D.S. Powlson, P. Smith and Jo. U. Smith (Eds.) Evaluation of soil organic matter models using existing, long-term datasets. NATO ASI series, Global Environmental change, Vol.38, Springer-Verlag, Berlin, 3–11.
9. Romanenkov V. A, Sirotenko O. D. and Shevtsova L. K. (2001) Modeling carbon balance of the agroecosystems based on the database of long-term experiments. In: Proc. of International Symposium Functions of Soils in the Geosphere-Biosphere Systems. Moscow State University Press, Moscow, 170–171.

EFFICIENCY OF OIL RADISH GROWING IN CROP ROTATION

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Abstract

The purpose of our experiment with oil radish were to clarify the effect of applied nitrogen (N) and phosphorus (P) fertilizer norms on dry matter (DM) yield and chemical composition of oil radish green mass, as well as green manure effect on the changes of plant nutrients in soil.

The field experiments (2000–2004) were carried out on heavy loam pseudo-gley soil (GLx) on the crop rotation long-term field experimental plots of the Department of Soil Science and Agrochemistry in the Study and Research farm ″Peterlauki″. The 5-year average results showed fluctuations in DM yields being 4.3–5.2 t ha^{-1} depending on N-fertilizer and P-fertilizer norms. Nitrogen content in oil radish DM yields was mainly influenced by the N-fertilizer, but the fertilizer P effect was observed only in particular years. The tendency of calcium and magnesium medium high increase was observed with the increase of the fertilizer norms, but potassium (K) content increased at the lowest N-fertilizer norm N_{30} when the P-fertilizer norms were increased.

Climatic conditions were one of the most significant factors when growing oil radish as green manure crop. Highest yields of green cut material and DM yields were provided with the fertilizer norm $N_{90}P_{26}K_{50}$. Increased P-fertilizer rates had no significant effect on the oil radish yield, however insignificant yield increase was observed. Incorporation of great oil radish mass in soil resulted in the increase of N, K and Ca mass in soil. Green manure both contributed to organic mass in soil and eliminated the risk of leaching out plant nutrients from soil.

Key words: oil radish, fertilizer, dry matter, chemical composition, off-take

Introduction

The increase of soil humus content is topical for almost all the mineral soils of Latvia including heavy textured soils more widely occurring in Zemgale region. With the decreasing use of the traditional organic fertilizers, ever increasing interest has been observed in growing green manure crops. Italian ryegrass, sweetclover, fodder lupine as well as cruciferous plants, such as winter rape, oil radish, etc. are most widely used as a plowdown or green manure.

The conclusions reached by many researchers suggest that green manure not only increases the level of organic matter of soil, contributes to soil structure, increases soil biological activity, reduce the weed pressure but also build up soil nutrients and gradually release them (Meelu, 1994; Ковлягин, 2001; Romanovskaja, 2003; Vucans, 2004). Cruciferous plants used as green manure crops due to their deep root system both aerate the heavy soil and can take up nutrients from the deepest soil layers (Ковлягин, 2001, Meelu, 1994).

Research findings reported in other studies suggest that oil radish is one of the most suitable green manure crops due to its fast growth habit providing great mass of herbage and roots and its tolerance to wider differences in soil conditions. In autumn, oil radish without chopping is easily incorporated into soil particularly when using modern plows.

Till now, we have conducted experiments with winter rape. However, in particular years we experienced serious problems connected with germination in spring and damage caused by insects during germination. For that reason we decided to study the suitability of oil radish to Zemgale soils.

The objectives of our experiment with oil radish were to clarify the effect of applied nitrogen (N) and phosphorus (P) fertilizer norms on dry matter (DM) yield and chemical composition of oil radish green mass, plant nutrient input into the soil as well as green manure effect on the changes of plant nutrients in soil, but also in prospective in rotation cycle.

Materials and Methods

The field experiments were carried out on sandy clay loam pseudo-gley soil (Stagni-Gleyic Luvisol according to WRB, 1998) at the Study and Research farm ″Peterlauki″ of LUA. The oil radish was grown in crop rotation (winter wheat – green manure crop – spring wheat – barley – barley + clover – clover) from 2000. Agrochemical parameters before the experiment were as follows: pH_{KCl} 7.1–7.3, organic matter content 29–31g kg^{-1} (C_{org} – 17–18 g kg^{-1}) (Tyurin's method), medium high plant available level of P and high potassium (K) sufficiency level (Egner-Riehm DL method).

The experiment scheme included no fertilizer treatment and nine fertilizer treatments with constant potassium (K_{50}), four phosphorus (P_0, P_{13} P_{20} P_{26}) and three nitrogen (N_{30}, N_{60} N_{90}) rates. The experiment was established in four replications according to standard replication method in double rows. Ammonium nitrate, single superphosphate and potassium chloride were pre-plant applied. Oil radish at the end of flowering was cut, chopped and incorporated into the soil as green manure.

Samples of plants for yield chemical analysis were taken from all experimental plots. The nitrogen content in oil radish dry mass was determined by the Kjeldahl method, phosphorus – photocolorimetrically and potassium by a flame photometer, calcium and magnesium – complexometrically in plant ash extraction.

Soil samples were collected at the beginning of each rotation prior to sowing of winter cereals, in the middle of rotation prior to sowing of barley, and starting a new rotation cycle prior to sowing of winter cereals. Soil samples were taken from 0 to 20 cm depth.

Obtained results were mathematically processed using analysis of variance, statistically significant difference analysis was calculated (*LSD* test) and Tukey criteria (*Tukey HSD* test) performed. Interconnection between the oil radish yield composition and meteorological conditions were determined using correlation analysis. Changes in soil agrochemical parameters under experimental treatments are estimated by comparing means of Paired-Samples T Test.

Meteorological conditions were quite variable during experimental years. In the beginning of summer 2000, the winter rape failed to germinate due to prevailing drought, but after repeated ploughing the field was oil radish seeded in 13 July. In the second half of summer comparatively cool weather rich in rainfall (120–160% of norm) was setting in. That year low mean day/night temperatures delayed the growth of oil radish, which was suitable for plowdown only 61 day after sowing. During experiment, the highest sum of rainfall was recorded in 2001. In the first half of the oil radish growth period rainfall was considerably above the long-term averages nearly by four times exceeding the precipitation norm in the middle of the growth period. The average air temperature during the oil radish growth period, as well as in the years 2002 and 2003, gradually increased exceeding in July long-term averages by 4.0–4.8 °C. Meteorological conditions in the second half of the summer 2002 were most favourable for the oil radish growth: moist (180–280% of norm) and warm beginning of the period (2nd and 3rd decades of June), comparatively dry and moderately warm (1.4–3.8 °C above norm) end of the growth period. The second half of the summer 2003 was characterized with lowest rainfall during experiment. The oil radish germinated comparatively well due to sufficient productive moisture reserves in soil. During growth period the mean day/night temperature rapidly increased exceeding long-term averages by 3.4–5.6°C in the second half of July. That year the oil radish was in bloom already in the middle of June and was suitable for plowdown 43 days after sowing. In 2004, the second half of June and the beginning of July were characterized with excessive moisture resulting in delayed sowing of the oil radish. However, in the 2nd and 3rd decades of July as well as in August values of the recorded meteorological indices were very close to long-term averages.

Results and Discussion

In oil radish, amount and composition of the produced biomass like in many other fast-growing plants are greatly dependent on the conditions of growth in their short vegetation period. The 5-year results showed significant differences in yield and composition of the oil radish under the influence of both fertilizer and climatic conditions. Research results indicate fluctuations in dry matter (DM) mass incorporated in soil ranging from 3.95 to 5.16 t ha^{-1} on the average, but in particular years being in the range of 1.20 to 8.88 t ha^{-1}. Moreover, significant differences in DM yield were caused by both applied fertilizer ($F = 5.356$; $P = 0.000$) and the factor "year" ($F = 442.921$; $P = 0.000$) as well as by interaction of both these factors ($F = 1.572$; $P = 0.032$). Results of data mathematical processing show insignificant differences in DM yield only between data of 2001 and 2003. Both these production years gave in no way highest DM yields due to rather different reasons: either excessive rainfall (2001) or non-typically high mean day/night temperature (2003).

The 5-year average results showed fluctuations in DM yield being 4.3–4.4 t ha^{-1} with the lowest applied nitrogen fertilizer norm N_{30} depending on P-fertilizer norm ranging from 4.4 to 4.8 t ha^{-1} with the N-fertilizer norm 60 kg ha^{-1}, and reaching 5.2 t ha^{-1} with the N-fertilizer treatment 90 kg ha^{-1}. The average highest DM yield was provided with the fertilizer treatment $N_{90}P_{26}K_{50}$. Even results obtained with more strict Tukey HSD test lead to the conclusion that on average in 5 experimental years significantly higher DM yield was obtained in this fertilizer treatment compare to unfertilised one, in all treatments with the nitrogen fertilizer N_{30} as well as in treatments $N_{60}P_0K_{50}$ and $N_{60}P_{13}K_{50}$. The fertilizer treatments $N_{60}P_{20}K_{50}$ and $N_{60}P_{26}K_{50}$ as indicated by the 5-year averages significantly surpassed in productivity only the treatment $N_0P_0K_0$. Results of the less strict LSD test indicate that the fertilizer treatment $N_{60}P_{20}K_{50}$, which, on the average, did not significantly drop behind the most productive treatment but significantly surpassed all other treatments with the nitrogen fertilizer N_0 and N_{30} as well as treatments $N_{60}P_0K_{50}$ and $N_{60}P_{13}K_{50}$, must be admitted equal to fertilizer treatment $N_{90}P_{26}K_{50}$. The average 5-year results presented by LSD test indicate that only the fertilizer treatments $N_{30}P_0K_{50}$, $N_{60}P_0K_{50}$ and $N_{30}P_{20}K_{50}$ were significantly lower in productivity compare to the control treatment.

In particular years, the chemical composition of oil radish and namely N and K content showed rather significant change. In fertilizer treatments the highest N content was noted in the years 2000 (3.74–4.55%) and 2004 (3.7–4.00%), but the lowest in the year 2001 (1.74–2.45%). The N content in DM was most closely affected by those external environment conditions, which favoured leaching out nitrogen compounds from the soil (sum of rainfall in the vegetation period (r = –0.516), mean day/night precipitation in this period (r = –0.659), as well as those factors, which contributed to the increase of DM yield and content in oil radish – mean day/night temperature in oil radish vegetation period (r = –0.862). Mathematical processing of data obtained in our experiment shows negative correlative relationships between DM yield (r = –0.344), DM content (r = –0.364) and N content in oil radish dry matter. The 5-year averages of the nitrogen content in DM yield accounted for the following: 2.85% (fluctuations from 1.84% to 4.35% in particular years) with the application of N_{30}, 3.33% (fluctuations from 2.12% to 4.49%) with N_{60}, and 3.41% (fluctuations from 2.45% to 4.35%) with N_{90} treatment. Increasing of N-fertilizer norm from N_{30} to N_{60} in particular years resulted in N content increase from 0.00 to 0.44%, and by 0.13% in 5 years on average. The nitrogen uptake by plants due to increased P-fertilizer norms was not observed on average, however in particular years N content had a tendency to grow with the increase of P-fertilizer norm on fertilizer background $N_{30}K_{50}$. The N content in DM is in close correlation with the content of phosphorus (r = 0.759), potassium (r = 0.686) and magnesium (r = 0.715) but does not show close correlation with calcium (r = 0.144) content in oil radish DM.

Changes in P content between years were not so sharp as in N content and were in the ranges from 0.42% to 0.75%. Due to specific P compounds uptake from soil, P content was positively affected by the length of vegetation period (r = 0.698), but negatively by mean day/night temperature in oil radish vegetation period (r = –0.789). Phosphorus, to a greater extent closely correlates both with DM yield (r = –0.632) and DM content (r = –0.745) compare to other plant nutrients included in the experiment. The increase of P-fertilizer norm with the fertilizer background $N_{30}K_{50}$ and $N_{60}K_{50}$ resulted in the increase of P content, it was practically constant (0.55%), but further increase in N-fertilizer norm led to the increase of P content up to 0.58%. Phosphorus content in oil radish DM is in close correlation with the content of nitrogen, potassium (r = 0.488) and that of magnesium (r = 0.662).

Comparatively great fluctuations of potassium content in DM (3.00–7.03%) were observed during experiments. Potassium content in oil radish DM, like nitrogen content, was affected by moisture and heat regimes in soil. Lowest values of K content were observed in experimental years with highest temperatures. Effect of mean day/night temperature on K content is characterised by correlation coefficient r = –0.572. The K content, compare to P and N content, was not dependent on oil radish DM yield produced in a particular year. The DM content as well influenced K content to a less extent (r = –0.300; P = 0.034) than it was observed with P and N content. The increase of K content in DM was most favourably affected by N content increase (r = 0.686) followed by P content increase (r = 0.488), and lastly by the increase of Mg content (r = 0.368). Close correlation is not observed between Ca and K content in oil radish DM.

Our experiment was conducted on soils developed on calcium carbonate-rich parent material. There are not established any correlative relationships between Ca content in oil radish DM and meteorological parameters during the experimental years as well as between other plan nutrient content in oil radish DM. Applying increased fertilizer norms resulted in the increase of Ca content being in the range of 2.18–2.82% on average.

Change of magnesium content in oil radish DM was similar to that of potassium content. However, content of this element practically was not affected by precipitation but it was affected more by mean day/night temperature (r = –0.745) in the vegetation period. Magnesium content was not affected by the increase of other nutrients in DM as it was observed in case with potassium. Magnesium content increased with the increase of nitrogen, phosphorus and potassium content. Mg content ranged from 0.41% to 0.52% on average, but on fertilizer background $N_{60}K_{60}$ with increasing P norms it tended to increase.

Table1. Effect of fertilizer on oil radish DM yield and plant nutrient off-take, on average in 2000–2004

Treatment	DM yield,	Off-take, kg ha^{-1}				
	t ha^{-1}	N	P	K	Ca	Mg
$N_0P_0K_0$	3.95	114.1	21.5	207.7	80.5	13.2
$N_{30}P_0K_{50}$	4.30	145.4	25.4	229.3	115.6	16.4
$N_{30}P_{13}K_{50}$	4.36	147.9	27.3	248.3	119.5	17.1
$N_{30}P_{20}K_{50}$	4.34	149.1	28.4	257.1	154.0	18.3
$N_{30}P_{26}K_{50}$	4.40	152.0	28.5	258.9	147.5	17.6
$N_{60}P_0K_{50}$	4.35	153.3	25.9	255.5	141.6	16.0
$N_{60}P_{13}K_{50}$	4.39	164.5	28.2	247.8	150.5	16.0
$N_{60}P_{20}K_{50}$	4.84	189.5	31.9	273.0	168.3	17.4
$N_{60}P_{26}K_{50}$	4.73	176.9	30.2	252.1	160.2	20.2
$N_{90}P_{26}K_{50}$	5.16	210.9	35.3	296.1	197.5	25.1

Depending on a particular year and fertilizer treatment, plant nutrient off-take from soil with DM mass widely ranged: nitrogen 45.2–311.6, phosphorus 8.4–41.8, potassium 57.0–413.5, calcium – 24.0–407.3, magnesium 6.6–42.5 kg ha^{-1}. DM yield was the decisive factor, which determined values of plant nutrient off-take for all five analysed elements. This dependence was most expressed for phosphorus ($r = 0.957$), followed by potassium ($r = 0.925$), nitrogen ($r = 0.884$), magnesium ($r = 0.885$), and finally calcium ($r = 0.850$). In its turn, the effect of plant nutrient content on its off-take value was rather different for various fertilizer elements. Close positive correlation is established only for calcium ($r = 0.874$). For nitrogen, potassium and magnesium, weak correlation is established between contents of these elements in oil radish DM and off-take with herbage yield, but in case with phosphorus negative coefficient of correlation ($r = -0.424$) is stated. It could be explained by highest concentration values of these four elements in DM recorded in low-yielding years. Total N amount (off-take) accumulated in DM of herbage yield was negatively affected by both exceedingly high precipitation in vegetation period ($r = -0.464$) (increased nitrogen leaching out of soil) and exceedingly high average day/night temperature sum in this period ($r = -0.490$) (decreased length of oil radish vegetation period). Effect of meteorological conditions on accumulation of less dynamic potassium, magnesium and phosphorus in DM was considerably smaller. Thus, e.g., correlation coefficients between sum of rainfall in the vegetation period and plant nutrient off-take with oil radish herbage are as follows: $r = -0.355$ for potassium, $r = -0.428$ for magnesium, but only $r = -0.236$ for phosphorus. Correlation between mean day/night temperature sum in the vegetation period and plant nutrient off-take is characterised by correlation coefficient: $r = -0.393$ for potassium, $r = -0.408$ for magnesium, and $r = -0.274$ for phosphorus. Mathematical data processing indicates, that values of calcium off-take are not dependent on meteorological conditions of a particular year. Obtained average data indicate that total nutrient off-take was affected both by nitrogen and phosphorus fertilizer. The greatest immobilised plant nutrient amount (764 kg) was ensured by fertilizer treatment $N_{90}P_{26}K_{50}$, where N accounted for 211, P – 35, K – 296, Ca – 197, and Mg – 25 kg ha^{-1}.

Plant nutrient off-take with 1 tonne of basic products was mainly dependent on DM content in oil radish yield: $r = 0.826$ for phosphorus, $r = 0.817$ for potassium, $r = 0.700$ for calcium, $r = 0.578$ for nitrogen, and $r = 0.310$ for magnesium. Close correlation between plant nutrient content in DM and amount of this element in 1 tonne of herbage is established only for nitrogen ($r = 0.532$), calcium ($r = 0.927$), and magnesium ($r = 0.728$). Direction of meteorological conditions effect on plant nutrient amount in 1 tonne of oil radish herbage was exactly the same as on off-take of these elements with the whole yield of oil radish. Difference is found only in the level of closeness of this expression, which is significantly higher. Thus, e.g., correlation between mean day/night temperature sums recorded in oil radish vegetation period and nitrogen amount in 1 tonne of herbage is characterised by correlation coefficient $r = -0.904$. Obtained data showed, that each tonne of oil radish herbage contained 2.9–3.1 kg N, 0.5–0.7 kg P, 4.2–5.1 kg K, 2.6–3.1 kg Ca, and 0.3–0.4 kg Mg on the average. So, when growing oil radish for green manure, each tonne of herbage contained 8.2 kg NPK and 3.2 kg (Ca + Mg) on average. As a result, soil is amended both with organic matter and plant food elements.

Large amount of plant nutrients added with green manure more rapidly changed nutrient content in soil at the end of the first crop rotation link (winter wheat – green manure – spring wheat). Results of soil agrochemical analysis indicate that green manure exhibited greatest effect on potassium content in soil. In oil radish fields with large amount of potassium immobilised in herbage, there was observed increased content of available potassium forms after the first crop rotation link. For example, in the first crop rotation field under oil radish in 2000, due to unfavourable meteorological conditions potassium off-take was

1.6–2.9 times smaller, compare to the second oil radish field in 2001. As a result, significant changes in potassium content were not observed in the first field but were significant in the second field in all treatments ($t = 3.375–10.442$; $P = 0.043–0.002$). It should be emphasized that in fertilized variants all cultivated crops grown in crop rotation received constant potassium norm according to requirements. Significant green manure after-effect on change of available phosphorus content in soil was not observed.

Conclusions

The results of this investigation indicate that fluctuations in meteorological conditions of a particular year caused significant differences in DM yield and chemical composition of oil radish. Fertilizer effect on DM yield was most expressed in the years with meteorological conditions in the second half of summer being very close to recorded long-term averages.

Nitrogen fixation in oil radish herbage was favoured by availability of P, K and Mg compounds to plants but was reduced by high rainfall in the vegetation period.

Largest amount of immobilized plant nutrients – N – 211, P – 35, K – 296, Ca – 197 and Mg – 25 kg ha^{-1} was provided by the fertilizer treatment $N_{90}P_{26}K_{50}$.

Herbage of oil radish grown as a green manure crop on heavy loam soils contained 8.2 kg NPK and 3.2 kg (Ca + Mg) per tonne on average.

References

1. Green manuring for soil productivity improvement / by O. P. Meelu. – Rome, 1994, 119.
2. Vucans R., Livmanis J. (2004) Humusa satura izmaiņas augsekā. Agronomijas Vēstis / LLMZA, LLU LF, Nr. 6., 116.–119.
3. Romanovskaja D., Tripolskaja L. (2003) Effect of different organic fertilizers on soil organic matter content and strukture / The importance of green manure for soil fertility and plant nutrition. Conference abstract. Lithunian University of Agriculture, 9–10 October 2003, 37.
4. Почва и компост / под. ред. М. Ковлягина. – М.: Изд. – во ЭКСМО – Пресс, 2001. – 144.

THE INFLUENCE OF EMISSIONS OF METALLURGICAL WORKS 'SEVERONIKEL' (MONCHEGORSK) ON SOIL MICROMYCETES

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Abstract

The influence of industrial emissions of Monchegorsk metallurgical works on soil fungal community has been investigated. It was shown that the structural and functional alterations in microbe community could be the indicator of environmental condition and evaluates the level of technogenical (pollution) effect.

Key words: micromycetes, heavy metals, pollution, soil, biogeocenose, industrial emission

Introduction

The nature of Far North easily collapses in the process of its development. Extreme destruction of Arctic ecosystems is explained by low circulation of substances and energy basically owing to low temperatures, weak self-cleaning ability of water and soils, low biological productivity (Evdokimova *et al*., 1984).

The problem of soil protection from chemical pollution is one of the most important in the North region of Russia due to the accumulation of industrial enterprises in this area. Emission of different pollutants in the atmosphere results in the alteration of physical, chemical and biological characteristics of soil. Soil quality and particularly its fertility is dependent on the metabolic activity of soil microbiota. The data of our investigations have repeatedly proved that micromycetes could be successfully used as indicators in the bioassessment of soil pollution (Lebedeva *et al.*, 1999).

Materials and Methods

The investigation had been carried out in the area of 'Severonikel', Monchegorsk, in 1998 and 2001. Soil samples were taken from the plots located at a distance of 3 km from the plants. Soil samples were taken on the depth of 0–10 cm where the highest quantity of pollutants accumulates and where the maximum of micromycetes have been observed (Lebedeva *et al.*, 1991). The frequency of micromycetes species occurrence was estimated by plating each soil sample in 5 replications. Chapek agar was used as universal medium. To characterize the structure of micromycetes complexes and reveal dominant and occasional species the frequency index was used (Mirchink, 1988).

The gross maintenance of heavy metals in soils was determined after decomposition of soil sample by the hydrofluoric acid. The active forms of heavy metals were determined in the extract of 1N hydrochloric acid. The analyses of samples were conducted by method of atomic-emission spectrophotometry on the recorder '5700 PC ZEEVAV' ('Perkin-Elmer', U.S.A.). The error of quantitative definitions does not exceed 10 per cent.

Results and Discussion

The explorations which have been carried out in vicinities of Monchegorsk (Kola peninsula) on podzol Al – Fe – humus soils showed, that the industrial emissions of works 'Severonikel', in which prevailed chemical ecotoxicants (such as SO_2, Ni, Cu, Co *etc.*), were accumulated in greater degree in a superficial layer of soil, at the distance of 3 km from the works (zone of complete degradation of forest ecosystem). Among the heavy metals – the pollutants of upper soil horizons in the Monchegorsk industrial region take place the increasing of gross concentrations of Cr, Pb, Fe, Sr, Cd, Cu and Ni as well (Table 1).

Table 1. Heavy metals' concentrations in soils, mg kg $^{-1}$,Monchegorsk-city, the territory of works "Severonikel" (n = 30)

Metals	Co	Cr	Cu	Ni	Mn	Zn	Cd	Pb	Sr	Fe
1	2	3	4	5	6	7	8	9	10	11
Gross mainte-nance	615 ± 115	193 ± 20	12700 ± 2438	23100 ± 4101	315 ± 57	112 ± 20	57 ± 9	138 ± 25	227 ± 38	10600 ± 2650
Active forms	398 ± 67	8,8 ± 1.7	7903 ± 1317	5230 ± 945	83 ± 14	8,5 ± 1.7	54 ± 9	7.8 ± 1.3	104 ± 17	182 ± 32

From the investigated soils in 2001, 49 species of micromycetes, in 1988 – 31 species were allocated. In soils the representatives from genus *Penicillium* (13) and *Aspergillus* (5) prevailed. From the general list of species the complexes of micromycetes, specific to the given ecological conditions, consisting from dominant, often, rare and casual species were allocated. The dominant and often species playing the main functional role in soil ecosystem are presented in the Table 2. From the table it is clear, that for ten years the structure of complexes of typical species of micromycetes in polluted by emissions of works soils appreciably has changed.

Dominant in 1988 *Aspergillus fumigatus* and *Penicillium funiculosum* were sent in 2001 to group of frequent species, and *Aspergillus terreus* was not marked at all in community. These species are strong toxic-formed fungi. Germination of barley seeds is suppressed as a result of the influence of metabolites of these cultures (Lebedeva, 1993). Among dominant species in 1999 there have appeared *Penicillium frequentans* and *Aspergillus araneaarum.* The first one was noted in 1988 as a dominant species in control (75 km) soils, and in 1999 with identical distribution in non-contaminated and polluted soils. The second one was noted only in 2001 both in the above mentioned and others soils. The community of frequent species considerably has increased and completely has changed. The experiment on identifying phytotoxic species showed, that almost all these micromycetes, excluding *Penicillium funiculisum, P. cyclopium* and *Aspergillus fumigatus*, did not suppress the germination of barley seeds, i.e. their metabolites were not phytotoxic. The quantity of rare and casual species also increased in comparison with 1988.

Table 2. The structure of complexes of typical species of micromycetes allocated from polluted soils (3 km) from the works 'Severonikel'

1988	2001
Dominant species	
Aspergillus fumigatus Fresenius (89%)	*Penicillium frequentans Westling* (60%)
Penicillium funiculosum Thom (80%)	*Aphanocladium aranearum(Petch) W. Gams* (60%)
Aspergillus terreus Thom (72%)	
Frequent species	
Penicillium purpurogenum Stoll (55%)	*Trichoderma viride Pers: Fr.* (50%)
Paecilomyces farinosus(Holm) Brown et G. Smith (55%)	*Penicillium raistrikii Smith* (50%)
Penicillium lilacinum Thom (43%)	*Acremonium roseum (Oud.) W. Gams* (50%)
P. pulvilorum Turfitt (30%)	*Acremonium kiliense Grutz* (50%)
	Penicillium funiculosum (40%)
	P. cyclopium Westling (40%)
	P. restrictum Gilm. et Ab. (30%)
	P. luteum Zukal (30%)
	Aspergillus fumigatus Fres. (30%)
	A. ustus (Bain). Thom (30%)
	Cladosporium cladosporioides(Fres.) de Vries (30%)

Note. The frequency of distribution of species is specified in brackets.

In non-contaminated control zone (75 km) the complex of typical species of micromycetes practically had not changed for 10 years both in quantitative, and qualitative respect. Among dominant and frequent species typical for the northern soils were: *Penicillium frecuentans, P. nigricans, P. decumbens, P. pulvillorum, P. brevi-compactum, P. lanoso-coeruleum, P. commune, Mortierella isabellina, Trichoderma koningii, T. viride, Mucor racemosus, Cladosporium cladosporioides.*

In addition to a cup method used for study of microbial system of soils the method of initiated microbial community (Guzev *et al.*, 1980) was used. This method both in 1988 and in 2001 has confirmed the data obtained by us, though the amilolytic community of micromycetes differed a little from the community obtained by a cup method, but in it the same regrouping and replacement of species of fungi was observed. According to criteria used in estimation of the soil pollution degree, with the help of this method for the past 10 years the transition of microbial system of soils from a zone is noted: resistance – repression to a zone of stable resistance.

The above mentioned data testify that in view of decrease of volumes of manufacture, the technogenical loading on soil biota considerably decreased and the micromycetes just quickly enough reacted by the regrouping of species, by increase of a species variety and by reduction of phytotoxic species in an industrial zone of the works (3 km).

The industrial emissions had a negative influence not only on chemical, but also on biological parameters of soil. So, using a parameter of frequency distribution of fungal species, it was noted, that the structure of a complex of typical species of micromycetes has undergone practically complete 'regeneration' of this complex near to works. It was shown, that micromycetes, both tolerant and sensitive to anthropogenic pollution are expedient to use as the bioindicators (Zachinyaeva, 2003).

The purpose of the present work was the comparative analysis of data of species composition and structure of complexes of micromycetes in 1988 and in 2001, after 13 years (during which the works functioned on partial capacity). Thus, the opportunity has appeared to analyze, as far as the condition of soil mycobiota under the influence of emissions of the works has changed. As a comparison July of 1988 and 2001 was taken only, when the weather conditions were completely identical (dry, unusually hot for Kola peninsula summer with average temperature +22 ^{0}C).

Conclusions

In soils the process of self-cleaning has begun, and fungi in this process play an important role. The obtained results confirm that the complexes of micromycetes and separate species – indicators could be successfully used at biomonitoring.

References

1. Evdokimova G. A., Kislykh E. E. and Mozgova N. P. (1984) The biological activity of soils in conditions of aerotechnogenic pollution in Far North, Nauka, Leningrad, Russia, 120 (in Russian).
2. Lebedeva E. V., Nazarenko A. V., Kozlova I. S. and Tomilin B.A. (1999) Influence of increasing concentration of Cu^{2+} ions on the species diversity of soil micromycetes. Mikologija i Fitopatologija, **33**, 4, 18–25 (in Russian).
3. Lebedeva E. V. and Kanivets T. A. (1991) Micromycetes of soil affected by the wastes from a mine – metallurgic plant. Mikologija i Fitopatologija, **25**, 2, 111–116 (in Russian).
4. Mirchink T. G. (1988) Soil mycology, Ed. Moscow State University, Moscow, Russia, 220 (in Russian).
5. Zachinyaeva A.V. and Lebedeva E.V. (2003) Micromycetes of polluted soils of North West region of Russia and their role in the pathogenesis of allergic forms of mycoses. Mikologija i Fitopatologija, **37**, 5, 69–74 (in Russian).

Crop production

COMPARATIVE EVALUATION OF THE YIELD AND QUALITATIVE TRAITS OF HULLESS AND HULLED BARLEY

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Abstract

Barley grain is used mainly as a source of energy and concentrated nutrients for all classes of livestock. The aim of the investigation was to evaluate seven hulless barley varieties and lines – 'MC Gwire', 'Gainer' (Canada), "KM-2084", "KM-2045", "KM-2001/2" (the Czech Republic), "L-302" (Latvia), "SW-1291" (Sweden) to grain yield and its quality in comparison with two feed hulled varieties – 'Linga' (check variety) and 'Klinta'. Field experiments were carried out at the Research and Study Farm "Vecauce" of the Latvia University of Agriculture (2003) and at the State Stende Plant Breeding station (2003 and 2004). Average yield of hulless barley was from 4.47 t ha^{-1} ("L-302") to 5.86 t ha^{-1} ('Gainer') that was from 78.1 to 102.4% from the yield of hulled variety 'Linga' (5.72 t ha^{-1}). Lines "L-302" and "KM 2084" had the highest crude protein content (respectively 163 and 144 g kg^{-1}), nevertheless the crude protein yield of these hulless varieties didn't exceed the check variety 'Linga'. Hulless varieties, compared with hulled barley varieties, had a reduced fibre content (22.9–29.2 g kg^{-1}, 'Linga' – 54.3 g kg^{-1}) and increased starch content (626–662 g kg^{-1}, 'Linga' – 603 g kg^{-1}). The portion of essential amino acids in protein were higher in hulless genotypes with medium protein content.

Key words: hulless and hulled barley, yield, grain chemical composition, amino acids

Introduction

Both the food and feed industries are interested in specific cereal products suited to different purposes. Over the years, barley have been used extensively as feedstuff for domestic animals (Campbell, 1996a).

From a nutritive standpoint, starch provides the largest portion of bioavailable energy to the animal, followed by proteins and to a lesser extent – fat and soluble sugars (Black, 2001). A great deal of research emphasis has been placed on protein and protein quality. Ideal protein is the concept of providing essential amino acids in optimal amount in animal feed. Higher levels of limiting essential amino acids could displace synthetic amino acids added to the diet (Campbell, 1996 b). Barley protein contains high levels of non-essential amino acids, such as proline and glutamic acids in the hordein fractions of barley and their proportions generally increase with increasing grain protein level (Molina-Cano *et al.*, 2000; Newman, 1991).

Today there are different cereals available with a wide range of different chemical composition. In the world, hulless barley production has increased rapidly over the last years. The advantage of hulless barley is that without the hull, the level of crude fibre decrease and the level of starch and protein increase (Hickling, 1999). The energy value of hulless barley is approximately 10% higher than for covered barley, and is similar to wheat and corn, and protein content is similar to wheat. It has a better amino acid profile than wheat and hulled barley. This makes hulless barley suited for use in high-energy feeds for all groups of domestic animals (Dupchak, 2004). The relatively higher fibre content of barley has been a limiting factor with regard to their utilization in the diet of rapidly growing animals (Campbell, 1996 b).

The aim of our study was to evaluate the yield and qualitative traits of hulless barley varieties in comparison with hulled barley varieties.

Materials and methods

The trials were carried out at the Research and Study Farm "Vecauce" of the Latvia University of Agriculture (2003) and at the Stende Plant Breeding Station (2003 and 2004). Seven hulless barley varieties and lines ('MC Gwire', 'Gainer' (Canada), "KM-2084", "KM-2045", "KM-2001/2" (Czech Republic), "L-302" (Latvia), "SW-1291" (Sweden)) and two feed hulled varieties ('Linga' (check variety) and 'Klinta' (Latvia)) were included in the study. The soil characteristics and growing conditions are shown in Table 1. Crude protein content (g kg^{-1}) was determined by Kjeldahl method (LVS 277), amino acids – with an automatic analyzer T-339 (Sparkman D.H., Stein W.H. and Moores S. (1958) Anal.Chem., vol. 30, 1181). Starch content (ISO 10520), fiber content (ISO 5498) and fat content (ISO 6492) were determined.

During the vegetation period, lodging resistance was evaluated (point 1 – very susceptible, point 9 – very resistant). Plant height, cm, 1000 grain weight, g (ISTA method), and volume weight, g l^{-1} (ISO 7971-2) were determined.

Table 1. Characteristics of soil and growing conditions

Indices	2003		2004
	Vecauce	Stende	Stende
Soil type	Sod-calcareous leached	Sod-podzolic loamy sand	Sod-podzolic sandy loam
Organic matter, mg kg^{-1}	21	14	15
pH_{KCl}	6.8	6.1	5.1
P, mg kg^{-1}	85	105	93
K, mg kg^{-1}	77	105	173
Fertilisers	N90 P20 K94	N60 P10 K22	N60 P15 K40
Previous crop	Potatoes	Potatoes	Potatoes
Sowing time	28.04	5.05	17.04
Plot size	10	10	10
Number of replications	4	4	6

In Stende in 2003, the air temperature in the third decade of April and in the first decade of May was above the long-term average (accordingly 0.3 and 1.1 °C), but rainfall respectively 90.7 and 81.4% from the norm. Such meteorological conditions provided uniform germination of barley. As the air temperature was under the long-term average by 2.1 °C and 0.9 °C in the second and third decades of June, the period length of cereal tillering was rather long. At the beginning of June, barley plants had moisture insufficiency (rainfall was 1.6% from long-term average). The second and third decades of July were warm (air temperature accordingly 4.8 and 2.1 °C above long-term average) and dry (rainfall was 66.0 and 13.2% from long-term average). Barley rapidly reached the maturity. In Vecauce, meteorological conditions were similar to those in Stende. Springtime was dry and during the first developing stages plants suffered from deficiency of moistu-re. The end of July and beginning of August was very hot and dry and promoted fast ripening of barley.

April in 2004 was warm and dry in Stende. The soil conditions were suitable for germination. The temperature in the first decade of May was 6.4 °C above long-term average, but precipitation – only 50.7% from long-term average. The second and third decades of May were cool; temperature was lower by 3.3–3.4 °C compared with the norm. The rainfall was 150% from the norm in the third decade of May. The weather was cool and rich in rainfall (199% from long-term average) in June. In the first and second decades of July the amount of precipitation was accordingly 127.5% and 110.0%, which promoted lodging of barley. The harvest period of barley prolonged due to rainy August.

ANOVA procedures were used for data analysis.

Results and Discussions

In the competitive trials, hulless varieties and lines were compared with hulled feed barley varieties 'Linga' and 'Klinta'. In Vecauce, only hulless barley variety 'Gainer' exceeded the standard variety 'Linga' (6.49 t ha^{-1}; Table 2) by 0.72 t ha^{-1} ($\gamma_{0.05}$ = 0.356 t ha^{-1}). The yield of the three lines – "KM 2045", "KM 2001/2", and "SW 1291" – was on the level of the check variety, but "KM 2084", 'Mc Gwire' and "L-302" gave a yield lower by 0.68–1.65 t ha^{-1} ($\gamma_{0.05}$ = 0.356 t ha^{-1}).

Table 2. The grain yield, 1000 grain weight and volume weight of barley genotypes (2003–2004)

Variety	Grain yield, t ha^{-1}					1000 grain weight, g	Volume weight, g l^{-1}
	Vecauce 2003	Stende 2003	Stende 2004	Average	%		
Linga	6.49	5.44	5.23	5.72	100.0	42.9	684.5
Klinta	7.42*	6.64*	5.72*	6.59*	115.2	52.2*	731.0*
Mc Gwire	4.89	4.88	4.78	4.85*	84.8	39.7*	777.5*
Gainer	7.21*	5.21	5.17	5.86	102.4	39.2*	731.5*
KM 2084	5.81*	4.54*	5.53	5.29	92.5	43.0	724.0*
KM 2045	5.78*	4.42*	5.46	5.22	91.3	43.9	777.8*
KM 2001/2	6.14*	4.34*	4.51*	5.00*	87.4	38.8*	748.2*
SW 1291	6.32	5.20	5.49	5.67	99.1	41.6*	752.7*
L-302	4.84*	4.15*	4.42*	4.47*	78.1	48.1*	776.7*
$LSD_{0.05}$	0.356	0.637	0.460	0.463	–	1.201	15.134

* Difference +/– standard is significant at the level of 95%.

In Stende, the grain yield of three hulless barley genotypes (‘McGwire’, ‘Gainer’, “SW 1291”) was lower but this difference was not significant. Other four genotypes (“KM 2084”, “KM 2045”, “KM 2001/2”, “L-302”) had a significantly lower grain yield (by 0.90 to 1.29 t ha^{-1}; $\gamma_{0.05}$ = 0.637 t ha^{-1}) in comparison with the check ‘Linga’ (5.44 t ha^{-1}). In both places, the hulled variety ‘Klinta’ out-yielded significantly the variety ‘Linga’.

In 2004, the trials were established only in Stende. In this year, which was characterized by a cool and wet summer, the yield of hulless barley was higher than in the dry and hot 2003. For genotypes “KM 2084”, “KM 2045” and “SW 1291”, a heightened yield was observed but the difference was not significant compared with the standard (+0.23 to +0.30 t ha^{-1}; $\gamma_{0.05}$ = 0.460 t ha^{-1}). These lines had short straw (76.1–85.0 cm) and good lodging resistance (8.8–9.0 points). By comparison, Canadian varieties were taller (103.4–104.6 cm) and had medium lodging resistance (5.8–6.1 points). As a result of lodging the yield of Canadian varieties was by 0.06–0.45 t ha^{-1} lower compared to hulled variety ‘Linga’ (5.23 t ha^{-1}).

On average, the yield of hulless barley was 4.47 t ha^{-1} (“L-302”) to 5.86 t ha^{-1} (‘Gainer’) (Table 2). It was 78.1 to 102.4% from the yield of hulled variety ‘Linga’ (5.72 t ha^{-1}) and 67.8 to 88.9% to better yielding hulled variety ‘Klinta’ (6.59 t ha^{-1}). In both years and places the yield of most of the varieties and lines from Canada, the Chech Republic, and Sweden exceeded significantly the lowest yielding line “L-302”(Latvia).

The average 1000 grain weight of hulless genotypes was 38.8–48.1 g. A significantly higher 1000 grain weight in comparison with variety ‘Linga’ was noted for line “L-302” (+5.2 g; $\gamma_{0.05}$ = 1.201 g). Four genotypes were characterized by a significantly lower 1000 grain weight. All hulless lines had a significantly higher volume weight by 39.5–93.3 g l^{-1} (γ0.05 = 15.134) or 105.7–113.6% in comparison with hulled check variety ‘Linga’ (684.5 g l^{-1}).

Table 3. Characteristics of the grain chemical composition of barley genotypes (2003–2004)

Variety	Crude protein, g kg^{-1}	Crude protein yield, kg ha^{-1}	Starch, g kg^{-1}	Starch yield, t ha^{-1}	Fat, g kg^{-1}*	Fibre content, g kg^{-1}*
Linga	132.7	759	603	3.45	24.4	54.3
Klinta	128.9	850	619	4.08	24.3	45.9
Mc Gwire	134.0	650	651	3.16	27.3	25.8
Gainer	122.8	720	657	3.85	22.4	27.1
KM 2084	144.3	764	630	3.33	25.5	27.7
KM 2045	132.8	693	652	3.40	22.2	22.9
KM 2001/2	128.9	644	662	3.31	21.7	27.0
SW 1291	133.1	754	648	3.67	28.6	29.7
L-302	153.0	684	626	2.80	21.2	23.2

* Data of 2004.

The starch is the primary nutrient in cereals and is the principal source of available energy. Hulless barley had higher starch content (626–662 g kg^{-1}), compared to hulled variety ‘Linga’ (603 g kg^{-1}) and ‘Klinta’ (619 g kg^{-1}).

Protein is one of the most important nutrients in barley. The breeders strive for high grain protein if the barley is to be used for livestock feed or human food. Protein in barley is nutritive unbalanced due to a deficiency in essential amino acids lysine, threonine, methionine plus cystine, isoleucine and tryptophan (Newman, 1991).

Canadian hulless barley varieties had crude protein on average 122.8–134.0 g kg^{-1}, the Czech lines – 128.9–144.3 g kg^{-1}, and line from Sweden “SW 1291” – 133.1 g kg^{-1}. The highest crude protein content had line “L-302”(Latvia) – 153.0 g kg^{-1} (Table 3). Protein yield of hulless barley varieties, except “KM 2084”, did not exceed the check hulled variety ‘Linga’ (759 kg ha^{-1}) and ‘Klinta’ (850 kg ha^{-1}), the protein content of which was similar to hulless barley.

The advantage of hulless barley is that hull, which is indigestible fibre, is removed. Compared with hulled barley cultivars hulless ones had a reduced fibre content (22.–-29.7 g kg^{-1}), ‘Linga’ – 54.3 g kg^{-1}, and ‘Klinta’ – 45.9 g kg^{-1}. Due to reduced fibre content and increased starch content, hulless barley have better feed quality for beef cattle compared to hulled cultivars (Newman, 1991). There were no large differences between hulless varieties in the fat content if compared with hulled ones. “SW 1291” (28.9 g kg^{-1}) and ‘McGwire’ (27.3 g kg^{-1}) had the highest fat content (Table 3).

In 2004, for characterisation of hulless and hulled barley quality, the amino acids were determined in the grain and protein. The content of essential amino acids was dependent on the variety.

Table 4. The content and sum of essential amino acids in the grain, g kg^{-1} DM (2004)

Variety	Lysine	Threonine	Methionine	Isoleicine	Cystine	Sum
Linga	6.16	4.38	2.60	7.05	2.29	22.48
Klinta	5.93	4.23	2.43	6.82	2.23	21.64
Mc Gwire	6.26	4.60	2.67	7.33	2.20	23.06
Gainer	5.85	4.25	2.38	7.12	2.33	21.94
KM 2084	6.30	4.56	2.73	7.25	2.27	23.14
KM 2045	5.97	4.33	2.45	7.19	2.26	22.20
KM 2001/2	6.16	4.45	2.59	7.08	2.36	22.64
SW 1291	6.02	4.33	2.52	6.91	2.37	22.15
L-302	6.71	5.17	2.80	7.63	2.42	24.73

The highest total amount of essential amino acids (lysine, threonine, methionine, isoleicine, and cystine) in the grain (Table 4) was found for hulless lines "L-302" (24.73 g kg^{-1}) and "KM 2084" (23.14 g kg^{-1}) with the highest protein content (153.0 g kg^{-1} and 144.3 g kg^{-1}; Table 3). The variety 'McGwire' with a comparatively lower protein content (134 g kg^{-1}) had equally valuable protein (23.06 g kg^{-1}).

Table 5. Portion of essential amino acids in the crude protein, % (2004)

Variety	Lysine	Threonine	Methionine	Isoleicine	Cystine	Sum
Linga	4.64	3.30	1.96	5.31	1.72	16.93
Klinta	4.60	3.28	1.88	5.29	1.73	16.78
Mc Gwire	4.67	3.42	1.99	5.47	1.64	17.19
Gainer	4.76	3.46	1.94	5.79	1.89	17.84
KM 2084	4.36	3.16	1.89	5.02	1.57	16.00
KM 2045	4.49	3.26	1.84	5.41	1.70	16.70
KM 2001/2	4.77	3.45	2.00	5.49	1.83	17.54
SW 1291	4.52	3.25	1.89	5.19	1.78	16.63
L-302	4.38	3.37	1.83	4.98	1.58	16.14

The analyses showed that proportion of essential amino acids in crude protein (Table 5) was higher in hulless genotypes (17.19–17.84%) with protein content 122.8 g kg^{-1} ('Gainer'), 128.9 g kg^{-1} ("KM 2001/2"), and 134.0 g kg^{-1} ('Mc Gwire'), whereas the lines "L-302" and "KM 2084" with the highest protein content, from this point of view, were of lower quality – percentage of essential amino acids in the crude protein made only 16.14 and 16.00%. The quality of hulled feed barley varieties 'Linga' and especially 'Klinta' was also high – the portion of essential amino acids in the crude protein was accordingly 16.93 and 16.78%. During barley breeding for feed, attention should be paid not only to protein content but also to its quality.

Conclusions

The average yield of investigated hulless barley genotypes was 78.1–102.4% to check feed barley variety 'Linga'. In comparison with hulled barley, hulless barley is characterized by a significantly higher starch content. A portion of essential amino acids in protein was higher in hulless genotypes with a medium protein content, which was equal to feed hulled barley 'Linga' and 'Klinta'. Compared with hulled barley varieties, hulless ones had a reduced fibre content due to an increased feed quality of hulless barley.

References

1. Black J. L. (2001) Quality Feed Grains–research highlights and opportunities: http:www.regional.org.au/au/abts/2001/m3/black.htm.
2. Campbell L. D. (1996 a) Barley and oat improvement for non-ruminants. In: Proceedings V International Oat Conference & VII International Barley Genetic Symposium, Saskatoon, Vol 6, 91–96.
3. Campbell L. D. (1996 b) Oat and barley as livestock feed – the future. In: Proceedings V International Oat Conference & VII International Barley Genetic Symposium, Saskatoon, Vol. 6, 77–81.
4. Dupchak K. Hulless barley in dairy diet (2004) http:/www.engormix.com/e_articles_dairy_cattle.asp?ID=25.htm
5. Hickling D. R. (1999) Does the feed industry have barley quality needs? In: Proceedings of Canadian Barley symposium 1999, 55–57.
6. Molina-Cano J. L. *et al.* (2000) Genetic and environmental effect on malting and feed quality of barley: a dynamic field of study. In: Barley genetics VIII. The 8th International Barley Genetic Symposium, Adelaide, 127–134.
7. Newman C. W. and Newman R. K. (1991) Characteristic of the ideal barley for feed. In: Barley Genetic VI. Proceedings of the Sixth International Barley Genetic Symposium, Helsingborg, Vol. II, 925–939.

THE INFLUENCE OF DIFFERENT LENGTH WEEDY PERIODS ON POTATO YIELD

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Abstract

Field experiments were conducted during the period of 1998–2000 at the Vezaiciai Branch of the Lithuanian Institute of Agriculture. The objective of our investigation was to estimate the effect of different length weedy crop intervals on potato yield after emergence of natural weed populations having applied regular soil tillage operations. Potato was grown at respective growth stages in weed-free plots and together with the weeds that had survived after inter-row cultivations. Weeds germinated unevenly during the whole growing season of potato. Weed density was less in the plots where weeds were allowed to grow only from planting to potato emergence, or from planting to 20 cm high tops as compared with weedy control plots. Biomass of weeds was significantly lower in the plots where weedy periods lasted from planting to flowering as compared with those where weeds were growing the entire potato vegetation period. Weeds had most detrimental effects on potato yield when they grew together with potatoes from planting to flowering, from planting to 25 days after flowering, and during the whole growing season. Potato yield reduced by 8.1, 8.4, and 6.4%, respectively, compared to that of weed-free potato crop.

Key words: potato, growth stages, weedy intervals, weed, yield

Introduction

Weeds are better adapted to the local environmental conditions and often win battle for resources and cause yield reduction. Crop weediness during the vegetative season is in direct relationship with the environmental conditions and weed seedbank in topsoil (Kroff and Laar, 1993; Forcella *et al.*, 2000). Strategic weed control planning requires accurate prediction of seedling emergence and their impact on crops under certain farming conditions. Weeds, which are better adapted to the local environmental conditions, they often win the battle for resources and cause yield reduction. The competitiveness of weeds depends on species composition, time of emergence, and abundance. Yield losses are high, when weeds emerge before or together with the crop (Aldrich, 1987; Blackshaw *et al.*, 1981; Jakstaite, 1988 ...see the References). Yield losses are minimized if the weeds emerge after the crop.

Potatoes like other row crops may not be competitive with weeds due to ecological factors (Cuturilo and Mijatovic, 1983; Lazauskas and Razukas, 2001) Timely control of weeds can increase potato productivity from 15% to 50% (Eberlein *et al.*, 1997; Jaiswal and Lal, 1996). Some experimental evidence suggests that the critical period of weed harmfulness is from 3 to 5 weeks after the potato emergence (Lazauskas and Razukas, 2001). Other investigators assert that the critical period for weed removal from potato crop is about 4 to 6 weeks after planting (Tharkal *et al.*, 1989). Some authors indicate that weeds are less harmful to potato during the period from planting to potato emergence and most harmful – from potato emergence to harvest (Everaarts and Satsyati, 1978; Hoffman-Kakol, 1990).

Harmful effect of weeds on potato depends on weed species and their abundance. When during the whole growing season there were 5 plants of common lambsquarters (*Chenopodium album*) per square meter, potato productivity declined by 43%, and in the case of 40 plants m^{-2} of scentless mayweed (*Matricaria discoidea*) the decline in productivity was 73% (Everaarts and Satsyati, 1978). Under the conditions of Ukraine, 10 annual weeds m^{-2} reduced potato productivity by 36% (Мартинюк, 1986). Quackgrass (*Elytrigia repens*) at density of 25 stems per m^{-2} caused potato tuber yield reduction by 10% (Baziramakenga and Leroux, 1998). Even 2–5 weeds m^{-2} can significantly decline potato productivity and lower the quality because of weak potato competition with weeds and because they can be a source of infection with diseases and pests (Kartoffelbestande…, 1995).

Determination of the critical period of weed competition in potato crop would enable better planning of reliable strategies for integrated weed management.

The objectives of our research was to:

- estimate the effect of different length weedy periods with regular soil tillage operation on weed density and biomass, and
- determine the effect of different duration of weedy intervals with natural species composition on potato yield and critical weed-potato competition period.

Materials and Methods

Field trials were conducted in 1998–2000 at the Vezaiciai Branch of the Lithuanian Institute of Agriculture. The experiments were conducted on an Albi-Endohypogleyic Luvisols (LVg-n-w-ab) light loamy soil, which had pH_{KCl} 5.3, 5.7 and 5.7 and humus content – 2.5, 2.1 and 2.7% in 1998, 1999 and 2000, respectively. The size of the initial plot was 2.8 by 2.5 m with 4 rows spaced 0.7 m apart. Data were collected from 2 center rows of each plot. A sampling area was 1.4 m by 2.0 m. Six replications of the treatments were used. The experimental area was cultivated, mineral fertilizers $N_{90}(P_2O_5)_{60}(K_2O)_{120}$ were applied and second cultivation to incorporate fertilizers was done. After cultivation, each plot was furrowed at the depth of approximately 10 cm below the soil surface. Having prepared and furrowed the experimental site, 4 potato variety 'Mirta' tubers per one longitudinal meter were planted in the beginning of May and hilled-up forming raised beds 15 cm high and 0.7 m wide. A hilling-up + harrowing operation was performed twice before potato emergence and the crop was hilled-up twice after potato emergence but before potato row closure (Table 1).

Table 1. The time of potato growth stages and inter-row cultivation operations

Event	1998	1999	2000
Planting	May 8	May 7	May 1
First inter-row cultivation	May 21	May 21	May 9
Second inter-row cultivation	Jun 2	Jun 2	May 20
Emergence	Jun 12	Jun 14	May 30
First hilling-up	Jun 19	Jun 21	Jun 9
20 cm tops height	Jun 26	Jun 24	Jun 21
Second hilling-up	Jun 28	Jun 29	Jun 22
Flowering	July 10	July 7	July 14
25 d past flowering	Aug 4	July 31	Aug 11
Harvesting	Sep 9	Sep 7	Sep 11

Experiment treatments of the experiment consisted of the appropriate weedy and weed-free periods (Table 2). The weeds, germinating and growing in the potato crop, were counted by species, manually removed and air-dried to obtain biomass weights at the end of each weedy period of appropriate treatment. After removal of weeds for the rest of the growing season, those corresponding plots were kept weed-free for the duration of the season until potato harvest. Weeds in these plots were removed manually at the end of each respective growth stage. In the entire weed-free season, plots' (sixth treatment) weeds were counted, removed manually approximately in 2 weeks periods throughout the growing season.

Table 2. Detailed treatments of the experiment

Weedy periods	Length of periods, weeks	Planting to potato emergen-ce	Emergen ce to 20 cm tops height	20 cm tops height to flowering	Flowerin g to 25 days past flowering	25 days past flo-wering to harvest
Entire growing season	18	*****	*****	*****	*****	*****
Planting to 25 days past flowering	13	*****	*****	*****	*****	
Planting to potato flowering	9	*****	*****	*****		
Planting to 20 cm tops height	7	*****	*****			
Planting to potato emergence	4.5	*****				
Weed-free entire growing season	18					

□ weed-free period, * weedy period.

Potato tubers were harvested from two center rows of each record plot by a manual digger and were weighed for yield.

Assumptions for analyses of variance for weed infestation data were checked and after that they were transformed by $\sqrt{x+1}$ before applying "ANOVA" analyses. Potato yield data were statistically evaluated by Fisher's protected LSD test. Correlation and regression analyses were done to estimate the dependence of potato crop yield on weed abundance.

Results and Discussion

The weed infestation consisted of fifteen natural different weed species in the potato trial area. Dominant weed species were *Chenopodium album, Polygonum convolvulus, Viola arvensis, Capsella bursa-pastoris, Galeopsis tetrahit* and *Stellaria media.* There was a significant interaction between different weed infestations and growing seasons, so average data of weed density and biomass are not presented. In weed-free treatment, where weeds were calculated and removed at the end of the appropriate growth stages of potato, weeds germinated unevenly in different growing seasons too (Table 3). Uneven weed germination had influence on density of weeds in other treatments with different length weedy periods. Weed emergence is influenced by many variables and environmental factors and cannot be characterized easily by a simple index (Forcella *et al.*, 2000). Lithuanian climatic conditions enable most intensive weed germination in spring barley in May (Stancevicius and Spokiene, 1974 ... see the References; Spokiene, 1995). Prediction and investigation of weed germination in potato crop is more complicated than in cereal crops because this process is influenced not only by uncontrollable environmental factors but also by human activity such as row hilling-cultivation.

Table 3. The number of weed seedlings emerged at different weed-free potato growth periods, number m^{-2}

Potato growth periods	Length in weeks	1998	1999	2000
Planting to emergence	4.5	4.0	4.4	6.8
Emergence to 20 cm tops height	2.5	1.5	3.7	5.4
20 cm tops height to flowering	2	5.1	6.3	12.2
Flowering to 25 days past flowering	4	4.7	8.0	7.1
25 days past flowering to harvest	5	1.8	1.4	10.2
Total emerged weeds over entire growing season	18	17.1	23.8	41.7

During the entire weedy growing season (18 weeks), the number of weeds in plots, where weeds had not been removed, did not exceed 12 plants m^{-2} (Table 4). There were weeds that survived after a periodical mechanical weed control. Some germinating weeds were killed by hilling/cultivation operations. The majority of different length weedy periods had a significant influence on weed number and biomass as compared with that where weeds grew together with potato during the entire season. In 1998, less density of weeds was found in the plots, where weeds were allowed to grow from planting to potato emergence, from planting to 20 cm tops height, from planting to flowering or from planting to 25 days past flowering, i.e. where weedy periods lasted 4.5, 7, 9 and 13 weeks, respectively. In 1999, however, weed density was greater in the periods from planting to 20 cm tops height and from planting to flowering than the density in the plots where weeds were allowed to grow the entire season. In 2000, weed density was less in the plots where weeds were allowed to grow only from planting to potato emergence or from planting to 20 cm height of potato tops as compared with weed density in the control plots. Weather conditions in 1999 during the period from potato emergence to 20 cm tops height were of optimal humidity, but air temperature was 2.4 °C higher than long term average, which positively influenced weed emergence. Some investigators indicate that weed germination can be strongly influenced by environmental conditions and is dependent on previous values of soil temperature (Forcella, 1993). Excessive humidity was observed in 1998 (precipitation was 41% over the long term average) and slight drought – in 2000, which determined the character of weed emergence. No significant correlation between the number of germinated weeds and precipitation or hydrothermal coefficient was established.

Table 4. Total weed density and biomass at different length weedy periods

Weedy periods, length in weeks	Number, m^{-2}			Biomass, g m^{-2}		
	1998	1999	2000	1998	1999	2000
Entire growing season, 18	9.6	5.3	12.2	13.7	18.8	27.0
Planting to 25 d past flowering, 13	6.2**	7.4	10.5	10.5	17.5	19.2
Planting to flowering, 9	5.2**	11.1**	12.7	2.1**	7.7*	13.8**
Planting to 20 cm tops height, 7	2.5**	9.0*	7.3*	0.2**	8.6*	9.3**
Planting to emergence, 4.5	6.2**	5.1	6.8**	0.6**	3.0**	1.7**
Weed-free entire season, 18	0.0	0.0	0.0	0.0	0.0	0.0

* Significant differences ($P< 0.05$) compared with the entire season's weedy crop;

** Significant differences ($P< 0.01$) compared with the entire season's weedy crop.

The biomass of weed plants before potato harvesting was comparatively low (13.7–27.0 g m^{-2}) in the plots where the crop had been weedy the entire season. Mechanical weed control, which was used in plots of all treatments, decreased weed density and weed biomass. Biomass of weeds was significantly lower (in 1998 and 2000, $P < 0.01$; in 1999, $P < 0.01$ or $P < 0.05$) in the plots where weedy periods lasted from planting to potato emergence, from planting to 20 cm tops height and from planting to flowering, i.e. 4.5, 7, and 9 weeks, respectively (Table 4). Some investigators state that weed emergence, their biomass production and effects on crop depend on the specific weather conditions of the year, soil tillage and other factors (Galandt *et al.*, 1998).

Interaction between the influence of different length weedy periods on potato tuber yield and growing seasons was not significant so those data were pooled over the years (Table 5). Potato yields were significantly reduced when weeds were allowed to grow from planting to flowering or from planting to 25 days after flowering, as well as during the entire growing season compared with weed-free potato.

Table 5. The effect of different length weedy and weed-free periods on potato yield

Weedy periods, length in weeks	Average of 1998–2000
Entire growing season, 18	3.31*
Planting to 25 d past flowering, 13	3.28*
Planting to flowering, 9	3.29*
Planting to 20 cm tops height, 7	3.44
Planting to emergence, 4.5	3.46
Weed-free entire season, 18	3.60
LSD 05 0.200	

* significant differences (P< 0.05) compared with the entire season's weedy crop.

When potato was infested with weeds for the periods of 9, 13 and 18 weeks after planting, the yield reduced by 8.1, 8.4, and 6.4%, respectively as compared with weed-free crop. A significant inverse linear dependence of potato yield on the number and biomass of weeds was established (Fig. 1). However, yields were not reduced when weeds were allowed to grow only from planting to potato emergence and from planting to 20 cm tops height. The most critical weed-crop competition period, when the presence of weeds is most detrimental to potato yield, is from 20 cm potato tops height to 25 days after flowering.

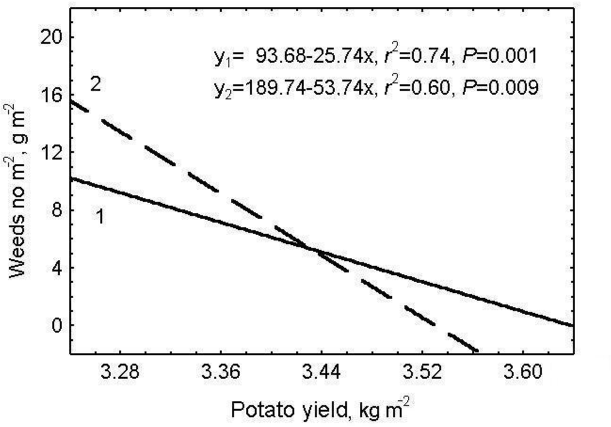

Figure 1. Dependence of the potato yield on the number (1) and biomass (2) of weeds. Average data of 1998–2000

Therefore, in the case of conventional soil tillage operations being performed before and after potato emergence, the most important period for additional weed control is that from potato planting to 20 cm tops height. In such a case, when potato crops have not been weedy until tops reach a height of 20 cm and in later periods, weeds do not have the detrimental effect on potato yield.

References

1. Aldrich, R. J. (1987) Predicting Crop Yield Reduction from Weeds. Weed Technology,1, 199–206.
2. Baziramakenga R. and G. D. Leroux. (1998) Economic and interference threshold densities of couchgrass (*Elytrigia repens*) in potato (*Solanum tuberosum*). Weed Science, 46, 176–180

3. Blackshaw, R.E., E. H. Stoble, and A.R.W. Sturko. (1981) Effects of seedling dates and densities of green foxtail *(Setaria viridis*) on the growth and productivity of spring wheat (*Triticum aestivum*). Weed Science, 29, 212–217.
4. Cuturilo, S. and N. Mijatovic.(1983) Kvalitativna i kvantitativna zakorovljenost krompira u ekolopkim uslovima razlinitih stanipta. Zaptita Bilja, 34, 151–161.
5. Eberlein, C. V., P. E. Patterson, M. J. Guttieri, and J. C. Stark. (1997) Efficacy and economics of cultivation for weed control in potato (Solanum tuberosum). Weed Technology, 11, 257–264.
6. Everaarts, A. and Satsyati. (+ the initial) (1978) Critical period for weed composition for potatoes in Java. Proceedings of the sixth Asian-Pacific weed science society conference, Jakarta, 1, 173–177.
7. Forcella, F. (1993) Seedling Emergence Model for Velvetleaf. Agronomy Journal, 85, 929–33.
8. Forcella, F., Arnold Roberto L. Benech, Sanchez Rudolfo, and Ghersa Claudio M. (2000) Modeling seedling emergence. Field Crops Research, 67, 2, 123–139.
9. Gallandt, E. R., M. Liebman. and S. Coron et al. (1998) Effects of pest and soil management systems on weed dynamics in potato. Weed Science, 46, 238–248.
10. Hoffman – Kakol, I. (1990) Plonovanie ziemniaka w zaležnošci od dlugošci pozostawania chwastow lanie. Zesz. Nauk. Rol. A.R. Szczenie, 141, 49–63.
11. Jaiswal, V. P., and S. S. Lal. (1996) Efficacy of cultural and chemical weed-control methods in potato (*Solanum tuberosum*). Indian Journal of Agronomy, 41, 454–456
12. Jakstaite, A. (1998) Weed harmfulness critical period on spring barley. Scientific works of Lithuania Institute of Agriculture, 36, 108–124 (in Lithuanian).
13. Kartoffelbestande unkrautfrei halten. (1995) DLZ, 46, 52–58.
14. Kroff, M. J. and H. H. van Laar. (1993) Modeling crop-weeds interactions. CAB International, Sweden, 12–115.
15. Lazauskas, J. and A.Razukas. (2001) Potato growing in Lithuania 1900–2000 years, Vilnius, 92–100 (In Lithuanian).
16. Spokiene, N. (1995) Germination of the Predominated Annual Weed in the Field Condition. Weed control in the changing situation of farming in the Baltic Region. Proceedings. Kaunas, 267–275.
17. Stancevicius, A. and N. Spokienė. (1972) The dynamic of emergence of weed seeds during the period of vegetation. LAA Scientific works. Kaunas, 47, 15–24 (in Lithuanian).
18. Tharkal, K. K., M. L. Pandita, S. C. Khurana, and G. Kalloo. (1989) Effect of time of weed removal on growth and yield of potato. Weed Research, 29, 33–38.
19. Мартинюк И. В. (1986) Эффективност в гербицидов и их комплексов на посевах картофеля в зоне Украины. Автореферат kaнд. дисс. Киев, 20.

A FIELD STUDY OF EARLY POTATO WITH DIFFERENT PHYSIOLOGICAL AGE

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Abstract

Early potatoes proved to be profitable crops in Estonia. Varieties from the Estonian variety list are suitable for growing in Estonia's agro-climatic conditions despite the relatively short vegetation season. Pre-planting seed tuber treatment has allowed to make early potatoes more profitable. The vegetation period is relatively common for potato growth and development in most years but one of the yield limiting factors can be potato late blight caused by *Phytopthora infestans* (Mont.) de Bary. In most years the potato growing season can be divided into two periods: 1) there is no risk of late blight infection, 2) there is risk of late blight infection. When the growing season does not reach the second period, it is possible to harvest a profitable yield without spraying fungicides. This avoids the use of toxic chemicals and decreases environmental pollution. Early varieties can provide a good yield, whereas quicker yield formation is characteristic of physiologically older plants. Pre-sprouting and thermal treatment of seed tubers increase the physiological age of potato plants. The production of an early crop requires rapid plant emergence and foliage development, and tuber initiation at a low leaf area index (LAI). Physiologically older earlies are capable of developing sufficient leaf area for rapid assimilation. They also start accumulating nutrients into forming tubers.

Key words: earlies, tuber, pre-sprouting, thermal treatment, late blight, leaf area index

Introduction

According to the data of the ESA (Statistical Office of Estonia), 2004, and FAO (Food and Agricultural Organization) (http://apps.fao.org/page/collections?subset=agriculture), potatoes were grown in Estonia on 22,000 hectares in 2001, on 16,000 hectares in 2002, on 16,976 hectares in 2003 and on 22,900 hectares in 2004. The area slightly increased last year but it is not enough to provide the entire Estonian population (1.4 million) with potatoes. The deficit is covered by export. Our natural and climatic conditions currently enable us to grow early potatoes in larger amounts than previously. If we grow too little, early potatoes will be brought in from Western Europe. However, Estonian people prefer early potatoes grown in Estonia for their specific delicate and fresh taste (Tartlan, 2000). The market demand for fresh early potatoes is huge. In late July 2004, the price of early potatoes in the market in Tartu was 16 kroons (approx. 1 euro) per kilogram while old potatoes harvested in 2003 cost as little as 5 kroons.

To supply the population with potatoes, it is important to cultivate varieties that provide a high quality yield as early as possible. To get an early potato harvest, growers cultivate special early-maturing varieties having a relatively short dormancy and developing sprouts already in February or March, while still being kept at a storage temperature of 5–10 ºC. By early May, the physiological maturity of seed tubers advances to a level where, after being planted into a soil that has a temperature of 7–10 ºC, existing sprouts will start growing very fast and if the weather conditions are normal potatoes can be harvested 75–90 days after planting, i.e. in late July or early August. This is too late for the local consumers of earlies. Pre-sprouting and thermal treatment add physiological age to potato tubers and therefore shorten the chronological period required to get a ripe yield of tubers (Allen *et al.*, 1992).

Materials and Methods

An experiment was carried out by the Department of Field Crop Husbandry of the Estonian Agricultural University using methods developed by the same Department (Lauk, 1995; 1996; Lauk *et al.*, 1996) to investigate the possibilities of different pre-planting tuber treatment methods. The early varieties 'Maret' (bred at Jõgeva Plant Breeding Institute) and 'Vineta' (bred at Europlant (Kartoffelzucht Böhm)) were used in the experiment. All cultivars were treated in the following ways:

A – pre-sprouting (PS): the tubers were kept for 35–38 days before planting in a lit, sufficiently humid room at 12–15 ^{o}C;

B – thermal treatment (TT): a week before planting the seed tubers were kept for 48 hours at 30 ^{o}C, then in a warm (12–15 ^{o}C) and lit room (Lõhmus *et al.*, 1999);

C – the tubers were not treated (0): the tubers were taken to the field directly from the cellar. No thermal treatment was conducted (Fig. 1).

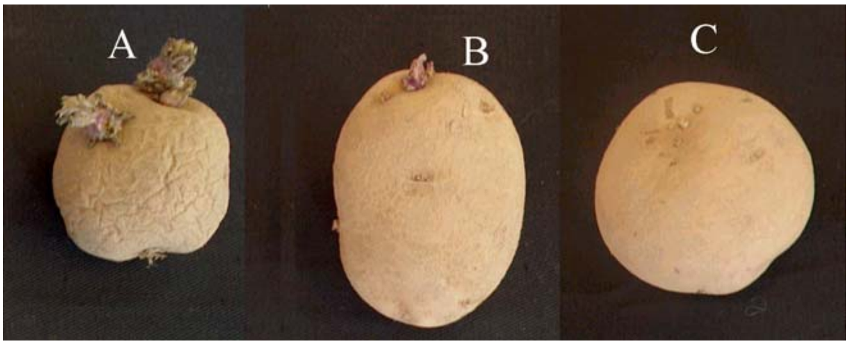

Figure 1. Seed tubers after treatment

The soil of the experimental field was LP pallescent (Kõlli & Lemetti, 1995). Agrotechnics were typical of potato experiments. The yield formation dynamics was determined every 2 to 6 days.

As different tuber treatment methods were used, the first samples were taken at different times (Table 1). The sampling time and number of samples were different for different options. The number of samplings also depended on the duration of the vegetation period.

Table 1. The number of samples during the vegetation period

	To determine LAI	To determine yield, t ha^{-1}
Number of samples	21–22	18–20
First sampling	Days after planting 37	Days after planting 43–54
Last sampling	Days after planting 118–120	Days after planting 124

The results were statistically improved using the regression analysis method with the following quadratic equation:

$$y = a + bx + cx^2,$$

where: y – argument function, yield calculated on the basis of the equation, t ha^{-1},
a – constant term of the equation,
b and c – regression coefficients,
x – argument, number of days after planting.

All numerical values shown in the tables are calculated on the basis of regression equations obtained in the regression analysis. To assess the reliability of differences (d) between the experimental variants, limit differences (LSD) were calculated based on the appropriate methods (Lauk et al., 2004) with 95% reliability degree.

Results and Discussion

Pre-planting treatment of seed tubers (addition of physiological age) ensures earlier emergence of plants (Table 2). In the event of later emergence (in physiologically younger plants), the leaf area index was not as big as in plants that emerged earlier. If we look at the leaf area index by variety (Table 3), we can see that in 'Maret' the leaf area index was biggest 75 days after planting and in 'Vineta' –5 days later. The differences in the leaf area index were greatest when both varieties and variants had reached the largest leaf assimilation area within their growth period.

Table 2. The emergence of potato plants

Variant	Number of days from planting	
	to beginning of emergence	to total emergence
Untreated (0)	32	34
Thermal treatment (TT)	30	32
Pre-sprouting (PS)	25	27

Table 3. The effect of the seed tuber pre-planting treatment method on the leaf area index in different varieties

Day	'Maret'			'Vineta'		
	0	Difference		0	Difference	
		TT-0	PS-0		TT-0	PS-0
40	0.34	0.18	1.00*	0.34	–0.29	0.24
45	1.40	0.32	1.07*	1.10	–0.11	0.60*
55	3.09	0.54	1.18*	2.32	0.18	1.14*
65	4.17	0.69	1.22*	3.17	0.38	1.45*
75	4.65	0.75	1.21*	3.63	0.47	1.51*
85	4.53	0.73	1.13*	3.72	0.47	1.33*
95	3.81	0.64	0.99*	3.42	0.36	0.92*
105	2.50	0.46	0.80*	2.74	0.15	0.26
115	0.58	0.20	0.54	1.69	–0.15	–0.63*
$LSD_{0.05}$		0.84	0.78		0.59	0.50

* Reliability.

Reliable differences in the leaf area index appeared in the pre-sprouted variety 'Maret' as early as on day 40 after planting. Fig. 1 and 2 shows how fast the leaf area index changes. The results of measuring the leaf area index showed that pre-sprouted 'Vineta' was fastest in terms of leaf area formation from day 40.

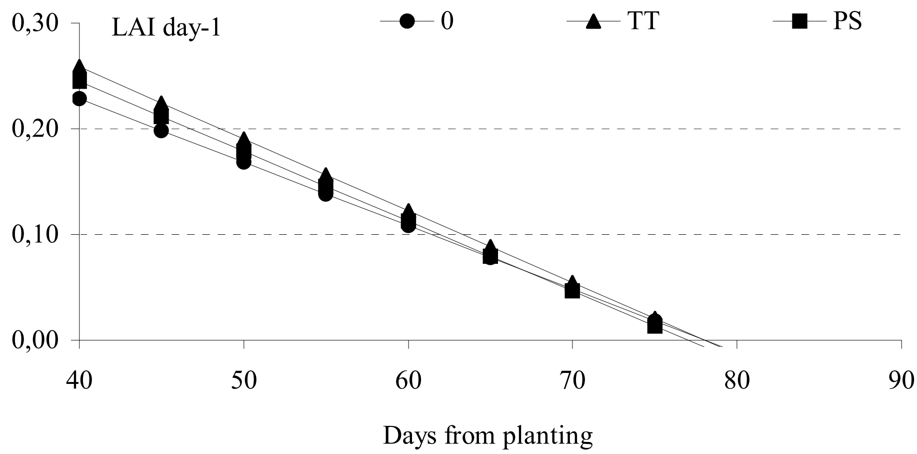

Figure. 2. The growth speed of the leaf area index per hectare, variety 'Maret'

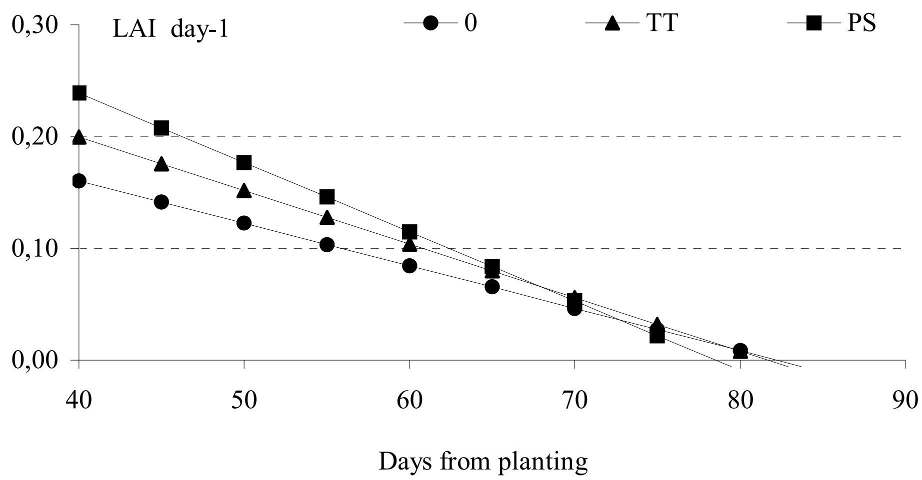

Figure 3. The growth speed of the leaf area index per hectare, variety 'Vineta'

The leaf area index was growing by 0.24 units a day. In the thermally treated variant, the leaf area index was increasing slightly slower, by 0.20 units a day, and in the untreated variant by 0.16 units a day. After that the growth speed decreased on each subsequent day until the maximum leaf area was formed, i.e. 75–85 days after planting. Then the leaf area of the plants began to decrease. The figure indicates that the strategy to achieve higher yields was to develop a leaf area index (of 3–4) as rapidly as possible, to maintain the canopy assimilating efficiently for as long as possible (Pashiardis, 1987).

Tuber formation began already before the growth day 60 (Table 4), i.e. when the leaf area index was increasing by 0.08–0.12 units a day. At the same time, the speed of tuber increment per hectare was more than 1.3 tons a day. The tuber yield increment was fastest in the untreated variant of 'Maret' in the period 60–100 days after planting as at this time physiologically younger plants try to make maximum use of the favourable growth conditions provided by the local climate and soil (Fig. 4). However, the fall in the tuber yield growth was steepest and the yield of the untreated variant of 'Maret' was not the highest. In the variants with treated seed tubers, the leaf area is formed earlier and tubers begin to form earlier, therefore the commercial tuber yield can be marketed at an earlier stage. The formation of a bigger tuber yield of 'Vineta' throughout the vegetation period was boosted by both pre-sprouting and thermal treatment (Fig. 4), whereas in the latter case the speed of tuber yield increment exceeded the respective figures in the other variants throughout the growth period.

Table 4. The effect of the seed tuber pre-planting treatment method on the yields of different varieties, t ha^{-1}

Day	'Maret'			'Vineta'		
	0	Difference		0	Difference	
		TT-0	PS-0		TT-0	PS-0
60	8.21	3.45*	9.01*	5.62	4.87*	12.51*
65	15.86	2.13	7.63*	12.35	5.39*	12.75*
75	29.36	–0.01	5.22*	23.88	6.65*	13.14*
85	40.46	–1.48	3.29*	32.86	8.19*	13.44*
95	49.16	–2.30	1.84	39.27	10.01*	13.63*
105	55.46	–2.46	0.87	43.13	12.12*	13.72*
115	59.36	–1.95	0.38	44.42	14.50*	13.72*
125	60.86	–0.79	0.38	43.16	17.16*	13.61*
$LSD_{0.05}$		3.12	2.53		4.62	4.54

* Reliability.

Late blight control started on 9 July 2004. Ridomil Gold 2.5 kg ha^{-1} was used. Subsequent sprayings took place with 14-day intervals. Spraying ensured the preservation of potato leaves and enabled us to study the physiological aging of the tops until the end of the vegetation period. The early potato that is grown and marketed commercially is sprayed little. Our experimental data showed that by the time the need for spraying had arisen the yield level was sufficient for harvesting: for plants with thermally treated seeds it was 18.0 t ha^{-1} in 'Maret' and 17.7 t ha^{-1} in 'Vineta'; for plants with pre-sprouted seeds 23.5 t ha^{-1} in 'Maret' and 25.1 t ha^{-1} in 'Vineta'.

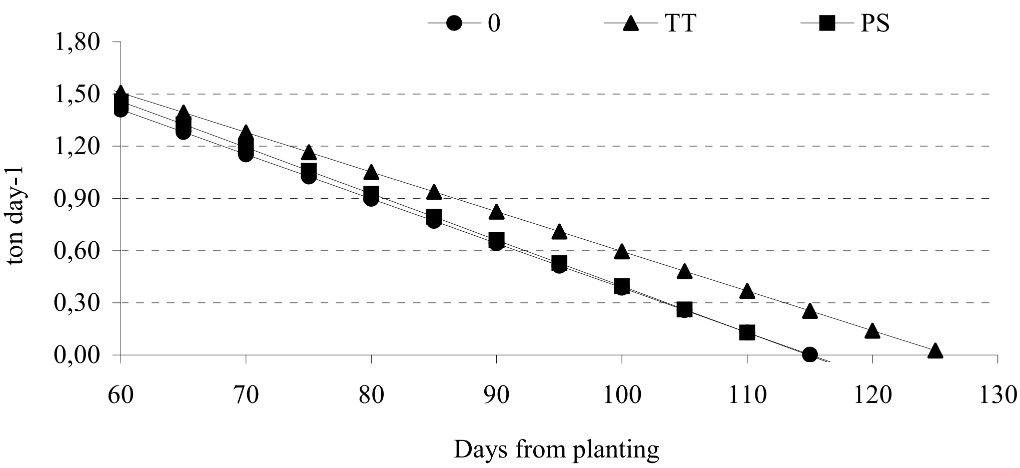

Figure 4. Tuber increment speed per hectare, variety 'Maret'

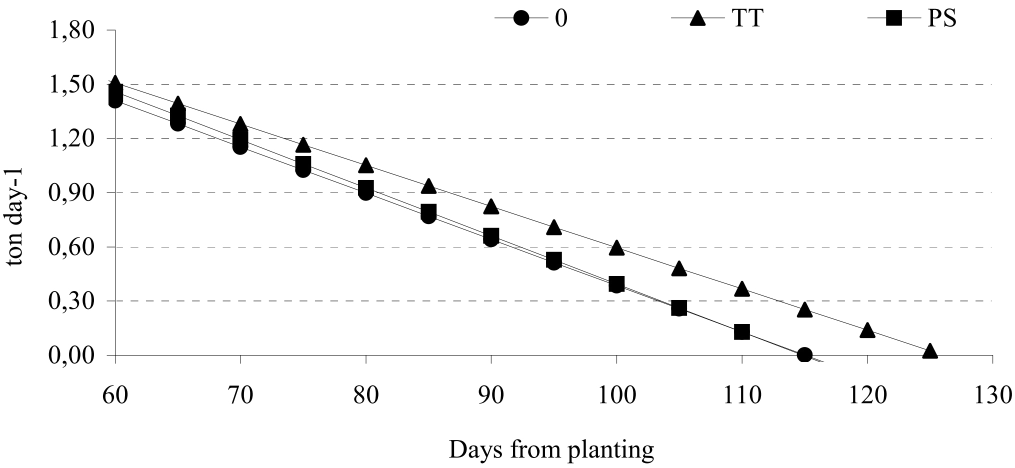

Figure 5. Tuber increment speed per hectare, variety 'Vineta'

In fact, the unsprayed potato leaves in the untreated variant of 'Vineta' were unaffected by the late blight for another 20 days, i.e. until late July. During this period the tuber increment still averaged 0.5 tons a day and the yield of tubers that were not affected by the late blight was 32.86 t ha^{-1}.

Conclusions

One of the main components to obtain a stable economically viable potato yield is the healthy biologically active seed with a high yield potential which is prepared for planting as needed. The field germination of the potato, the formation of tops and the speed of field surface covering depend on the quality of the seed. Efficient late blight control ensured actively working leaf area until harvesting. The results of measuring the leaf area index showed that pre-sprouted 'Vineta' was fastest in terms of leaf area formation from day 40. The leaf area index was growing by 0.24 units a day. In the thermally treated variant, the leaf area index was increasing slightly slower, by 0.20 units a day, and in the untreated variant – by 0.16 units a day. As a result of pre-sprouting, a statistically reliable extra yield was obtained in 'Maret' until day 105, and in 'Vineta' until the end of the vegetation period. A reliable positive effect of thermal treatment on the yield could be seen in 'Maret' until day 60 and the tendency towards increasing the yield – in 'Vineta' until the end of the vegetation period.

References

1. Allen E. J. *et al.* (1992) Seed tuber production and management. The Potato Crop. Edited by Harris. P. M. Chapman & Hall. London, New York, Tokyo, Melbourne, Madras, 247–29.
2. ESA (Statistical Office of Estonia) (2004) Statistical Yearbook of Estonia. (in Estonian), 463.
3. FAO (Food and Agricultural Organization) (http://apps.fao.org/page/collections?subset=agriculture).
4. Kõlli R., Lemetti I. (1995) Soils of Eerika Experimental Station. Mitteilungen der internationalen Arbeitsgemenschaft für Bodenfruchtbarkeit der internationalen Bodenkundlichen Gesellschaft, 132–146.
5. Lauk E. (1995) Regressioon Analysis: A Good Method for Analysing the Field Experiments Data. Proceedings of the Fourth Regional Conference on Mechanisation of Field Experiments (IAMFE/BALTIC '95), Kaunas/Dotnuva, Lithuania, 35–41.
6. Lauk E. (1996) Regression analysis in the variety field tests. Transactions of the Estonian Academic Agricultural Society. (in Estonian), 1, 45–48.
7. Lauk E. *et al.* (1996) Methodological additions to research on mixed seeds of agricultural cultures. Proceedings of the Tenth International Conference on Mechanization of Field Experiments (IAMFE/FRANCE '96), Paris/Versailles, France, 156–160.
8. Lauk E. *et al.* (2004) Experimental planning and methods in regression analyses. Proceedings of the 12th International Conference and Eschibition on Mechanization of Field Experiments. JAMFE/RUSSIA 2004. St. Petersburg, Pushkin, Russia, CD-ROM, 51–56.
9. Lõhmus A. *et al.* (1999) Potato quality improvement with pre-planting treatment of seed tubers. Agroecological optimization of husbandry technologies, 66–74.
10. Pashiardis S. M. (1987) Improvements of potato yields. Potato Agro meteorology, 27–44.
11. Tartlan L. (2000) Varajast kartulit tasub kasvatada. Eesti Maaviljeluse Instituut. (in Estonian), 34.

CALLI CULTURE OF OIL FLAX: ESTABLISHING AND REGENERATION

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Abstract

By using somaclonal variation it is possible to obtain plant breeding source material with modified agronomical traits. In flax is known somaclonal variation in resistance to biotic and abiotic stress, plant height, number of seeds in a vessel and number of seeds. The best for obtaining somaclonal variation is calli culture. This study was carried out to determine the best method of obtaining oil flax calli culture. Different parts of plants were used as explants (stem segments, leaves, root segments). For calli culture establishment, MS basal medium with 2 mg l^{-1} 2,4-D was used. For inducing shoot formation, MS medium supplemented with 0.2 mg l^{-1} IAA or 1 mg L^{-1} BAP and MS medium without phytohormones were used. As a carbohydrates source, 30 g l^{-1} of sucrose was used in all mediums. For shoots rooting, MS medium with 0,1 mg l^{-1} IAA and 1 g l^{-1} $AgNO_3$ and 10 g l^{-1} sucrose were used. Development of root-like structures and regeneration zones was dependent on both the used medium and explants type, which calli were derived from, but did not relate with calli size. Shoots were only observed on calli derived from leaves and grown on media with phytohormones: shoots given 5% of calli grown on MS basal medium with IAA and 72% of calli grown on MS basal medium with BAP. In total, 3–22 shots were obtained from a single callus.

Key words: calli culture, oil flax, somaclonal variation

Introduction

The possibility to apply a plant tissue culture to many plant physiology, genetics and practical breeding research studies has encouraged rapid development of cultivation methods. After cultivation *in vitro*, especially in calli culture, regenerated plants have higher variation, so-called somaclonal variation. Somaclonal variation has been described for many plant species (Larkin and Scowcroft, 1981; Leike, 1985), including flax. Due to somaclonal variation, new flax genotypes have been derived with resistance to biotic and abiotic stress, plant height, number of seeds in a vessel and number of seeds (Поляков, 2000). Therefore this method is useful for obtaining source material for flax breeding.

In Latvia, mainly fibre flax is cultivated. At the moment there are no local oil flax varieties suitable for changeable Latvian weather conditions (Stramkale *et al.*, 2004). Cultivation and breeding of oil flax has started in Latvia only less than ten years ago. This study was carried out to determine the best method for obtaining oil flax calli culture and plants-regenerants. We choose this method to improve the Lithuanian oil flax 'Lirina' variety that has a very good seed yield and oil quality, but has not good resistance to biotic and abiotic stresses.

Materials and Methods

Flax seeds were sterilized using pre-treatment by 0.15% KMO_4 solution for 10 min and treatment by 50% solution of the commercial bleach Belizna for 20 min with continuous stirring (Ornicāne and Rashal, 1997). After both pretreatment and treatment, the seeds were rinsed three times with sterile water. Sterilized seeds were germinated on basal Murashige and Skoog's (MS) medium, 3% sucrose and 0.7% agar, pH 5.8. Cultures were incubated at 20 °C in darkness till seeds germination and then moved in light conditions (26 °C, 16h/8h of day/night, light intensity 3000 lx), and cultivated till plantlets reached four leaf stage.

In order to determine the best explants for calli culture establishment, three different parts of plants were used:

1) leaves (before putting on medium each leaf blade was cut in four places till the central nerve);
2) stem segments (0.5–2 cm);
3) root segments (0.5–2 cm).

All explants were placed on the MS basal medium with 2 mg l^{-1} 2,4-dichlorphenoxyacetic acid (2,4-D) (added after autoclaving), adjured to pH 5.8. Cultures were grown in light conditions (26 °C, 16h/8h of day/night, light intensity 3000 lx).

After four weeks, cultures established calli were placed on regeneration medium. For inducing shoot formation, MS medium was supplemented by 0.2 mg l^{-1} IAA (indole-3-acetic acid) (Bergmann and Friedt, 1997) or 1 mg l^{-1} BAP (6-benzylaminopurine) (Rutkowska-Krause *et al.*, 2003). As control, MS medium without phytohormones was used. Cultures were grown in light conditions.

After eight weeks of cultivation, the diameter of calli (mm), number of calli with root-like structures, and calli with regeneration zones were measured.

Shoots formed from calli were cut and planted on rooting medium (MS basal medium with 0,1 mg l^{-1} IAA and 1 g l^{-1} $AgNO_3$) (Nichterlein, 2003). Cultures were grown in light conditions.

Results and Discussion

Calli were obtained from all explants of the variety 'Lirina'. Calli formation started two weeks after establishment of the culture. Root segments and stem segments longer than 0.5 cm formed calli only along the cutting lines. Stem segments with length about 0.5 cm and leaves developed homogeneous calli structures.

Several authors (Поляков, 2000; Rutkowska-Krause *et al.*, 2003; Yildiz and Özgen, 2004) reported that establishing of flax calli culture is possible from various explants (roots, hypocotyls, cotyledons, stem, leaves). Depending on the genotype and explants type, the rate of successful cultures ranged from 50 to 90% and more. Our results showed that the variety 'Lirina' is excellent for obtaining calli cultures.

Table 1. The diameter of calli eight weeks after establishment of the culture on media with different phytohormones

Explants	Number of calli	Diameter of calli (mm)		
		MS	MS + IAA	MS + BAP
Stem segments	71	7.1 ± 0.2	8.8 ± 0.1	9.1 ± 0.2
Leaves	67	5.5 ± 0.3	7.6 ± 0.2	8.9 ± 0.1
Root segments	56	6.7 ± 0.3	10.1 ± 0.1	10.2 ± 0.2

After eight weeks growing on media with phytohormones (IAA or BAP), calli generally were larger than calli planted on MS basal medium (Table 1), especially calli that were formed from root segments.

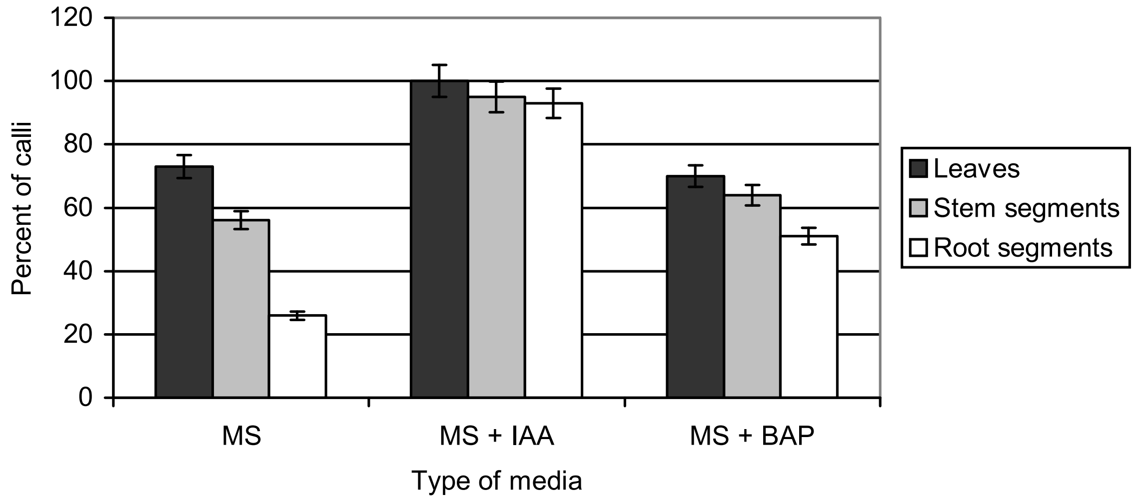

Figure 1. Per cent of calli with root-like structures depending on explants type and media

After four weeks of calli cultivation, root-like structures were formed (Fig. 1). The highest percentage of root-like structures occurred from calli on MS basal medium with IAA.

Formation of regeneration zones started (Fig. 2) after five weeks of cultivation. If calli on MS basal medium without phytohormones formed roots they did not form regeneration zones. On MS basal medium with phytohormones, roots and regeneration zones were formed on the same calli. Development of root-like structures and regeneration zones depended on both the used medium and explants, which calli were derived from, but did not relate with calli size.

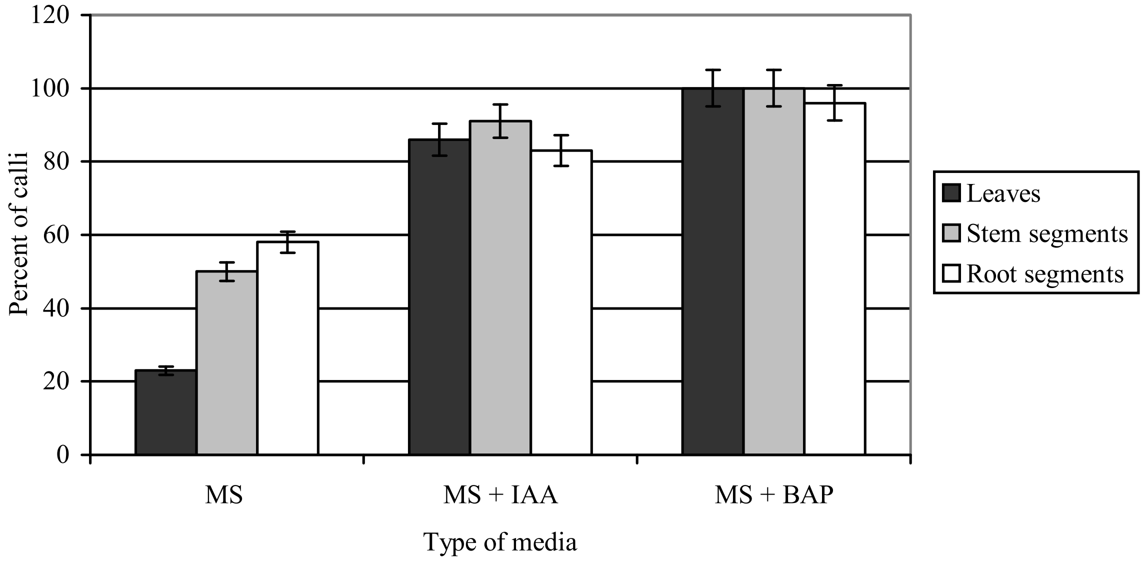

Figure 2. Per cent of calli with regeneration zones depending on explants type and media

Shoots, in their turn, were observed only on calli derived from leaves and cultivated on media with phytohormones. Shoot formation started after 10 weeks of calli cultivation on medium with IAA and after 11 weeks of cultivation on medium with BAP. Shoots formation continued for 5–6 weeks.

After 17 weeks of cultivation, 5% of calli derived from leaves and grown on MS basal medium with IAA and 72% of calli grown on MS basal medium with BAP had formed shoots.

Some authors (Rutkowska-Krause *et al.*, 2003) reported that by using a medium with BAP 1 mg L^{-1} plants-regenerates were obtained from 25% of stems and leave 28% calli of three genotypes. Our results showed that leaves are better explants than stem segments. Even if calli derived from leaves were the smallest it turned out that they were the best explants for obtaining both calli and plants-regenerates.

On average calli from leaves had 3–4 shoots, but some calli formed up to 22 shoots. When shoots were 3–4 cm long, they were cut and planted on rooting medium. During the next 2 weeks all shoots were rooted.

Conclusion

Development of root-like structures and regeneration zones depended on both the used medium and explants type, which calli were derived from, but did not relate to calli size. Shoots were only observed on calli derived from leaves and grown on media with phytohormones (5% of calli derived from leaves and grown on MS basal medium with IAA and 72% of calli grown on MS basal medium with BAP). In total, 3 to 22 shoots were obtained from a single callus.

References

1. Bergmann R., Friedt W. (1996) Haploidy and related biotechnological methods in linseed (*Linum usitatissimum* L.). In: Jain M. S., Sopory, S. K., Veilleux R. E (eds) *In vitro* Haploid Production in Higher Plants, Kluwer Academic Publishers, Dordrecht, Netherlands, 1–9.
2. Larkin, P. J., Scowcroft, W. R. (1981) Somaclonal variation – a novel source of variability from cell culture for plant improvement. Theoretical Applied Genetics, 60, 197–214.
3. Leike, H. (1985) Methoden der Gewebekultur zur Beschleunigung des Zuchtfortschrittes. Tagungoberichts Akademie Landwirtschaft – Wissenschaft., 237, 19–33.
4. Nitchterlein, K., (2003) Anther culture of linseed (*Linum usitatissimum* L.). In: Maluszynski, M., Kasha, K. J., Foster, B. P., Szarejko, I. (eds) Doubled Haploid Production in Crop Plants, Kluwer Academic Publishers, Dordrecht, Netherlands, 249–254.
5. Ornicāne, D., Rashal, I. (1997) Callus initiation from mature barley embryos and growth: influence of silver nitrate and the method of sterilisation. Proceedings of the Latvian Academy of Sciences. Section B, 51, No 1/2, 72–74.
6. Stramkale V., Grauda D., Rašals Ī. (2004) Latvijā izveidoto linu šķirņu un hibrīdu izvērtēšana. Agronomijas Vēsts, 6, 15–22.
7. Rutkovska-Krauze, I. et al. (2003) Regeneration of flax (*Linum usitatissimum* L.) plants from anther culture and somatic tissue with increased resistance to *Fusarium oxysporum*. Plant Cell Reports, 22, 110–116.
8. Yildiz, M., Özgen, M. (2004) The effect of a submersion pretreatment on *in vitro* explant grow and shoot regeneration from hypocotyls of flax (*Linum usitatissimum* L.). Plant cell, tissue and Organ Culture, 77, 111–115.
9. Поляков А. В. (2000). Биотехнология в селекции льна., Формат, Тверь, Россия, 15–19.

OAT GRAIN YIELD RESPONSES TO CLIMATIC CONDITIONS IN THE VEGETATION PERIOD

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Abstract

The aim of the present study was to show a substantial impact of climatic conditions on the productivity of oat (*Avena sativa* L.) lines and varieties. The yield of oat lines was studied for five years (1999–2003) in field trials. All lines gave the lowest yield in 1999. The highest yield was produced in 2001. It was tried to ascertain why the yield in 1999 was the lowest and in 2001 the highest. The environmental factors of the two years were investigated, namely, precipitation and the air temperature during the growing season of oats. The correlation between the yield of oats lines, the air temperature and precipitation during separate decades of a month was assessed. No correlation between the yield of five investigated lines and the mean air temperature in the vegetation period was found. The comparison of correlation between the yield and air temperature in separate decades of a month revealed a positive linear correlation in the first decade of May (r = 0.906). Inverse correlations between the yield and the air temperature were revealed in the first, second and third decades of June. Positive correlations between the yield and precipitation were found in the first decade of July (r = 0.848 – variety 'Jaugila') and in the second decade of May (r = 0.564 – line 1407-30). A significant negative correlation between the yield and precipitation was recorded in the third decade of June (r = –0.854 – variety 'Jaugila').

Key words: oats, precipitation, air temperature, correlation, decade, yield

Introduction

The effects of climate on the yield of oats intended for food and forage production have been examined by different authors. Considerable annual variations in the yield of agricultural crops have been observed. Most of these variations directly correlated with rainfall, either positively or negatively, depending on the time of the season when rainfall occurred (Svenningsson, 1984).

The sharp rise in the air temperature, i.e. drought, is a new phenomenon in Lithuania as well as all over the world (Frey, 1998). This phenomenon has encouraged us to study the effects of environmental factors on crop productivity.

There have been numerous studies made on the relationship between climate and crop yield. S. Zute indicates that meteorological conditions during the crop's growing period have a significant effect on the yield of oat varieties. She has come to the conclusion that 65% of oat yield is determined by the meteorological conditions of a year and 32.1% – by the choice of a variety (Zute, 2002).

Besides the variations in temperature and precipitation, changes in the climate may also have an impact on agriculture through greater competition of weeds, increased occurrence of plant diseases, changes in soil nutrients and pests, and increased conflicts for available water (Kane *et al.*, 1998).

S. Zute suggests that the air temperature at the seedling growth stage has a marked effect on the productivity of crops. She reports that the grain yield was higher in the years when daily mean temperature was lower at stem elongation-flowering stage, and confirms the linear correlation between the daily mean air temperature during the period before anthesis and the grain yield (Zute, 2001).

During the critical period, which is in the stage of shooting and flowering, the optimum level of precipitation rises to 20–23 mm per 10 days. Prolonged periods of dry weather around the time of heading result in considerable decline in the yield and cause decrease in grain plumpness. In the milk ripe stage, during which the content of dry matter in grain rises intensively (in July), oats need 26–28 mm of precipitation per 10 days (Budzynski, 2001).

In Poland, the researchers indicate that the goal of breeding for resistance is to obtain cultivars with genetic control mechanisms against different negative effects of environment (Packa et al.).

In this study, the correlation between oat yield, precipitation and air temperature during specific growth stages of plants has been assessed.

The aim of the present study was to show the substantial impact of climatic conditions on the productivity of oat (*Avena sativa* L.) lines and varieties.

Materials and Methods

The study was carried out at the Lithuanian Institute of Agriculture in Dotnuva on a light loam sodgleyic soil with the humus content – 20–30 g kg^{-1}, and pH – 6.4–7.2. The previous crop was legumes. Over the period 1999–2003, phosphorus and potassium fertilizers were applied in autumn at the rate of $P_{60}K_{60}$, and nitrogen fertilizer N_{60} was applied early in spring.

The data of the grain yield of oat lines was taken out from competitive variety trial nurseries. The trials were made in four replications each years. The plot size was 20 m^2. The data of grain yield of five separate lines was studied for five years during 1999–2003.

The sowing and harvesting dates of oats and plant development stages were as follows (d. – decade):

	1999	2000	2001	2002	2003
Sowing date	April 24	April 12	April 27	April 12	April 18
Germination	May I d.	April III d.	May I d.	April III d.	April III d.
Emergence	May I d.	April III d.	May II d.	May I d.	May I d.
Tillering	May III d.	May III d.	June I d.	May II d.	May III d.
Booting	June I d.	June I d.	June II d.	June I d.	June I d.
Heading	June II d.	June II d.	June III d.	June II d.	June III d.
Flowering	June III d.	June II d.	July I d.	June II d.	June III d.
Ripening	August I d.	August II d.	August II d.	July III d.	August I d.
Harvesting date	August 10	August 18	August 16	July 31	August 07

The Lithuanian climate varies between maritime and continental. The warm period (mean daily air temperature above 0 °C) lasts for 230–270 days. The duration of plant growing season is 135–150 days when the mean daily temperature is above +10 °C. According to the long-term data (1924–2003), the annual precipitation in Dotnuva amounts to 567 mm, and the mean air temperature is 6.2 °C. About 50% of the annual precipitation rate falls during the growing season of oats.

To describe the relationship between temperature, rainfall and plant development, the data from the Dotnuva Meteorological Station was used (Tables 1 and 2).

During the experimental period (1999–2003), the weather conditions in different years were diverse. During this period the mean annual air temperature in Dotnuva was 8.6 °C. The average rainfall during the crop growing season was approximately 203 mm. In 1999 and 2001, the mean air temperature during the growing season of oats was similar, i.e., +16.5 °C. In 1999 and 2001, the air temperature tended to go down from sowing to emergence, whereas from tillering to flowering, the air temperature was characterized by a steady increase, and from flowering to ripening it decreased again. In 1999, during the tillering-flowering stage, the air temperature was 6 °C higher than in 2001, which determined the formation of droughty conditions.

The aim of the study was to ascertain why the yield in 1999 was the lowest and in 2001 – the highest. The environmental factors of these two years were studied, i.e. precipitation and air temperature during the growing season of oats. From all the studied lines and varieties, the line 1407-30 and variety 'Jaugila' most markedly demonstrated the results of multiple observations, i.e., the yield in 1999 was the lowest and in 2001 the highest. This is the reason why they were chosen for observations.

The correlation between the yields of oat line 1407-30 and variety 'Jaugila', the air temperature and precipitation during separate decades of a month were assessed. The experimental data were processed by statistical methods, using software package 'Selekcija' (programme STAT and ANOVA) (Tarakanovas, 2003).

Results and Discussions

In the field trials, five oat lines were observed for five years. Figure 1 demonstrates the yield of the five lines during 1999–2003. The data suggests that the yield potential is dependent not only on environmental factors. S. Zute indicates that 32.1% of the yield depends on varietal characteristics (Zute, 2002). The diagrams in Fig. 1 show that the lowest yield was produced in 1999. All lines and varieties studied in all breeding nurseries in 1999 revealed a similar tendency. The highest yield was obtained in different years, for example, three lines gave the highest yield in 2000 and two lines – in 2001. In 2001, most of the tested lines and varieties produced the highest yield, therefore this year was chosen as the most favourable year for oat development.

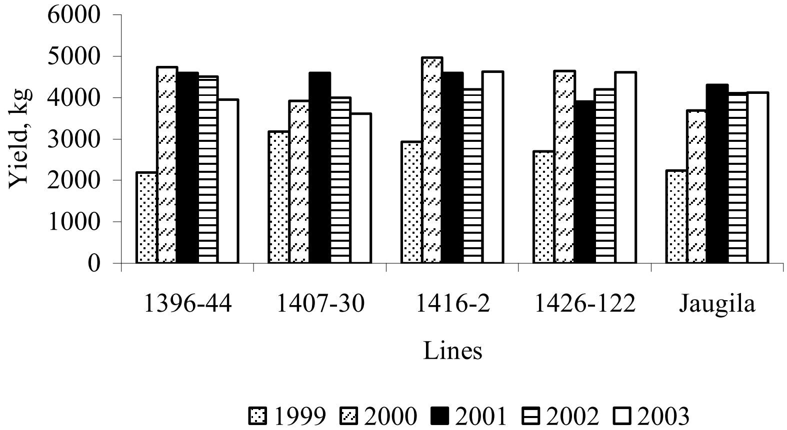

Figure 1. The grain yield of oat lines and varieties in 1999–2003 (LSD_{05} 0.258)

In 1999, the trial fields were sown on the 24th of April. Cool and damp weather prevailed during sowing. After sowing, during emergence and tillering stages, the weather was cold (6.7–11.1 °C). Later, till the flowering stage, the air temperature increased steadily. During the ripening stage, the air temperature was on average +20 °C (Table 1). In 1999, in the third decade of June after emergence of oats, precipitation was insufficient and only during the anthesis stage (45.6 mm). During the ripening stage, precipitation was insufficient again, but during harvesting, in the first decade of August, the weather was rainy, which delayed harvesting (Table 2).

Table 1. The air temperature during the vegetation period of oats in 1999–2003

Month	Decade	1999		2000		2001		2002		2003	
		°C	± to the norm	°C	± to the norm	°C	± to the norm	°C	± to the norm	°C	± to the norm
April	III	11.1	–1.7	18.1	+5.7	12.2	–1.6	10.8	–1.4	9.0	–2.7
May	I	6.7	–4.8	11.5	–0.3	15.2	+4.1	16.3	+3.9	12.1	–0.7
“	II	9.3	–2.8	13.8	+1.4	12.8	+0.8	13.2	+1.0	11.9	+0.2
“	III	15.5	+1.6	14.8	+1.3	10.5	–3.1	16.4	+1.7	16.5	+2.7
June	I	17.5	+2.7	13.5	–1.4	12.4	–2.1	16.8	+1.4	16.6	+1.4
“	II	22.1	+5.7	14.7	–2.1	14.1	–2.9	18.0	+1.4	14.2	–1.9
“	III	18.0	+0.9	16.4	–1.1	16.8	–0.3	15.8	–0.7	15.7	–0.6
July	I	20.9	+2.9	15.4	–2.9	20.4	+1.5	18.4	–0.3	18.3	+0.2
“	II	20.5	+1.1	16.0	–3.3	21.0	+1.8	22.5	+2.5	20.2	+0.8
“	III	19.1	+0.1	17.2	–2.3	21.4	+2.2	20.1	–0.1	23.0	+3.1
August	I	19.5	+2.1	16.3	–1.3	17.4	–0.3	20.4	+1.7	19.8	+0.8
“	II	16.1	–0.1	16.7	–0.6	19.3	+1.9	21.2	+3.0	17.7	+2.5
“	III	14.9	–0.3	14.5	–0.9	16.2	+1.0	19.4	+3.5	14.7	–1.2

In 2001, the trial fields were sown on the 27th of April. The weather was warm during sowing. After sowing, during emergence and tillering stages of oats, the air temperature dropped. The air temperature began to rise steadily in the first decade of June. The weather was the warmest in the third decade of July when oats were in the ripening stage (Table 1). The flowering stage of oats lasted from 26 June till 5July. The sufficient precipitation during the tillering stage of oats and the insufficient precipitation from tillering till the end of flowering had a positive impact on the yield. Very heavy precipitation at the end of the second decade of July (64.9 mm), when the flowering stage was over, had a positive influence on grain formation (Table 2). Of all the studied lines and varieties, the line 1407-30 and variety ‘Jaugila’ gave the lowest yield in 1999 and the highest yield – in 2001.

Table 2. The pPrecipitation during the vegetation period of oats in 1999–2003

Month	Decade	1999		2000		2001		2002		2003	
		mm	± to the norm	mm	± to the norm	mm	± to the norm	mm	± to the norm	mm	± to the norm
April	III	10.2	–2.7	0.0	–12.8	6.9	–5.9	8.9	–3.8	8.1	–4.5
May	I	14.0	–4.4	0.0	–16.4	1.0	–16.7	1.3	–15.4	11.2	–6.3
“	II	0.0	–16.4	37.4	+19.6	25.3	+8.9	13.5	–4.0	24.2	+6.7
“	III	6.3	–12.3	9.3	–9.8	8.3	–10.7	4.7	–13.7	0.9	–16.6
June	I	4.8	–16.0	25.6	+5.5	14.3	–6.0	1.3	–19.6	0.8	–17.8
“	II	9.0	–12.4	3.2	–16.3	13.1	–6.4	18.8	–1.3	28.6	+9.2
“	III	45.6	+25.3	41.1	+18.1	25.4	+2.7	33.1	+11.7	25.5	+1.2
July	I	10.4	–13.4	24.0	+0.4	22.5	–0.9	27.7	+3.9	20.0	–4.4
“	II	9.9	–14.5	87.9	+63.3	64.9	+40.1	5.8	–18.3	19.6	–7.2
“	III	5.8	–19.2	24.7	–1.1	15.1	–11.1	2.2	–23.8	15.0	–7.5
August	I	23.3	–0.5	10.5	–13.1	35.1	+10.0	29.1	+5.7	2.8	–22.8
“	II	46.4	+22.1	34.9	+10.6	9.4	–15.2	0.0	–23.2	20.1	–3.5
“	III	21.8	–4.0	35.7	+9.6	14.6	–9.5	0.0	–26.7	43.6	+19.6

The correlation between the yield of oat lines, the air temperature and precipitation during separate decades of a month was assessed. The data for correlation analysis was taken from five-year observations (1999–2003). A positive linear correlation was established between oat yield and temperature in the first decade of May (r = 0.906) for the variety ‘Jaugila’ (Table 3).

Table 3. Correlation between the yield and air temperature and between the yield and precipitation in separate decades of a month, 1999–2003

Air temperature	Line 1407-30		Variety ‘Jaugila’	
	r	$Sr.t_{05}$	r	$Sr.t_{05}$
May I decade	0.829 n	±0.323	0.906*l	±0.245
May II decade	0.739 n	±0.389	0.816 n	±0.334
May III decade	–0.746 n	±0.384	–0.270 n	±0.556
June I decade	–0.817 n	±0.333	–0.495 n	±0.502
June II decade	–0.678 n	±0.424	–0.855 n	±0.299
June III decade	–0.360 n	±0.539	–0.838 n	±0.315
July I decade	–0.083 n	±0.575	–0.332 n	±0.545
July II decade	0.091 n	±0.575	0.126 n	±0.573
July III decade	0.161 n	±0.570	0.474 n	±0.508
Precipitation				
May I decade	–0.832 n	±0.320	–0.645 n	±0.441
May II decade	0.564 n	±0.477	0.661 n	±0.433
May III decade	0.402 n	±0.529	–0.162 n	±0.570
June I decade	0.395 n	±0.530	0.070 n	±0.576
June II decade	–0.044 n	±0.577	0.462 n	±0.512
June III decade	–0.620 n	±0.453	–0.854 n	±0.300
July I decade	0.711 n	±0.406	0.848 n	±0.306
July II decade	0.548 n	±0.483	0.288 n	±0.553
July III decade	0.278 n	±0.555	0.271 n	±0.556

Number of observations – 5; l – linear correlation; n – nonlinear correlation.
* Correlation substantial at $p<0.05$.

The line 1407-30 demonstrated a high coefficient of correlation (r = 0.829) during the 1st decade of May. The positive correlation between the yield and air temperature was lower in the second decade of May (r = 0.816 for variety ‘Jaugila’ and r = 0.739 for line 1407-30).

The obvious negative correlation between the yielding ability and air temperature was noticeable in the first, second and third decades of June.

The warm weather (12.8–15.2 °C) had a positive effect on the development of oats in the first and second decades of May and in the third decade of July, which coincided with the germination, tillering, and ripening stages of oats.

A more significant correlation between the grain yield and precipitation was identified in the second decade of May (r = 0.661 for 'Jaugila' and r = 0.564 for line 1407-30) and in the first decade of July (r = 0.848 for 'Jaugila' and r = 0.711 for line 1407-30) (Table 3). A significant negative correlation between the grain yield and precipitation was recorded in the first decade of May (r = –0.832 for line 1407-30 and r = –0.645 for 'Jaugila') and in the third decade of June (r = –0.854 for 'Jaugila' and r = –0.620 for line 1407-30). Similar correlations were identified by Stig Larsson (Larsson, 1986).

It can be concluded that more abundant precipitation during tillering and at the end of the flowering stages (May – second and third decades, June – first decade) had a positive effect on oat yield. The precipitation had a negative effect on the development of oats during emergence and at the beginning of flowering (April – third decade, May – first and second decades, June – second decade).

Conclusions

Comparison of the productivity of variety 'Jaugila' and line 1407-30 in relation to the air temperature during separate decades revealed a positive correlation during the first decade of May (germination) (r = 0.906 and r = 0.829). In the second decade of May (emergence), the correlation coefficient was lower (r = 0.816 and r = 0.739). A strong negative correlation between oat productivity and air temperature was identified in the first, second and third decades of June (booting and heading).

A positive correlation between oat productivity and amount of precipitation was identified in the first decade of July (flowering) (r = 0.848 and r = 0.711) and in the second decade of May (emergence) (r = 0.661 and r = 0.564). A negative correlation between oat productivity and amount of precipitation was found in the first decade of May (germination) (r = –0.645 and r = –0.832) and in the third decade of June (heading and flowering) (r = –0.620 and r = –0.854).

References

1. Budzynski W. (2001) Principles of selecting cultivation technology. www.eurequa.pl/eng/1.3.htm.
2. Frey K. (1998) Genetic responses of oat to environmental factors. Field crops research, 56, 183–185.
3. Kane S., Reilly J., Tobey J. (1998) An empirical study of the economic effects of climate change on world agriculture. Climatic Change, 21, 135.
4. Larsson S. (1986) New screening methods for drought resistance and cold hardiness in cereals. In: Research and results in plant breeding, Stockholm, 241–251.
5. Packa D., Kuraczyk A., Tworkowski J. (2001) Principles of barley breeding. www.eurequa.pl/eng/1.3.htm.
6. Svenningsson M., Larsson S. (1984) Oats grain and weather. Sveriges Utsadesforen Tidskr., 94, 211–216.
7. Tarakanovas P., Raudonius S. (2003) Agronominų tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT, SPLIT-PLOT iš paketo SELEKCIJA ir IRRISTAT,Akademija, 30–40.
8. Zute S. (2001) Selection criteria in oat hybrid populations and their significance in the development of promising lines. Doctoral thesis, State Stende PBS, Jelgava, 54.
9. Zute S. (2002) Grain yield of oats and different factors influencing it under growing conditions of Latvia. In: Žemdirbystė, 78, 71–77.
10. The results of correlation (variety 'Jaugila').

IMPACT OF THE ADDITIONAL LEAF SPRAY FERTILIZATION OF RAPE ON THE YIELD AND ITS STRUCTURAL ELEMENTS

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Abstract

Over the years 2003–2004, at the experimental station of the Lithuanian University of Agriculture, trials directed toward determining the impact of leaf spray fertilization of winter rape on seed yield and its structural elements were carried out. Leaf spray fertilisation of winter rape at the beginning of the flowering with 25 kg ha^{-1} of ammonium sulphate improved self-pollination and substantially increased pod number in the plant by 9–19 units. Additional leaf spray fertilization at the end of the flowering (30 kg ha^{-1} carbamide) or after pods had been formed (50 kg ha^{-1} carbamide) resulted in the increase of 1000 seed mass in the pods on the lateral stalks. Additional leaf spray fertilization of winter rape at the beginning of flowering had better effect on yield increase than fertilization after pod formation. Three-time fertilization (at the beginning of flowering, at the end of flowering, and after pod formation) resulted in seed yield additions of 1.05–1.09 t per ha^{-1}.

Key words: winter rape, leaf spray fertilization, seed yield

Introduction

Leaf spray of cultured plants has a long history. The very first written sources on this method of fertilization date back to Paris, 1844. The author of the study E. Grisso suggested applying of leaf spray fertilisation on fruit trees and garden plants. Later additional leaf spray fertilization was applied on field plants. This way of fertilization is positively evaluated by plant scientists from various countries as it allows to economise on fertilizers and to more effectively provide plants with macro- and micro-elements (Созинов, 1977).

A number of investigations on the impact of additional leaf spray fertilization of corn on their yield and grain quality were carried out in Lithuania. The investigations were performed with winter wheat, summer wheat, potatoes, and sugar beet (Šiuliauskas, Kviklienė, 1995; Vaizgirdaitė, Šiuliauskas, 1999). Having applied additional leaf spray fertilization of winter wheat with kg ha^{-1} N concentration of carbamide solution reliably increased wheat yield, gluten amount in grain, and hyaloidness, which resulted in the production of highest quality grain (Šiuliauskas, Vaizgirdaitė, 1998; Šiuliauskas, Vagusevičienė *et al.*, 2001). The investigations were carried out in the neighbouring countries as well. Russian scientists performed trials with winter wheat by applying leaf spray fertilization after ear formation (Воллейдт, Мяделец, 1997). V. Kriščenko presented a very exhaustive investigation. He proved that additional leaf spray fertilization of winter wheat with higher than kg ha^{-1} nitrogen ratios in the milky stage not only prolongs flag leaf vegetation and makes the process of photosynthesis more active but also stimulates the recovery of root system (Крищенко, 1992). In the meantime, there were no thorough investigations on leaf spray fertilization of winter rape. Winter rape produces 10–12 t ha^{-1} of biomass yield, where seeds make 3–5 t ha^{-1}. To produce such a yield, rape needs many various nutritious combinations, the greatest part of which they absorb from fertilizers (Никоноренков, Носов, 2001). Winter rape is mainly fertilized with nitrogen, phosphorus, potassium, sulphur and magnesium macrofertilizers; and from microelement fertilizers, boron, manganese, and zinc fertilizers are most often applied (Bernotas, Mineikienė, 2000; Jackson, 2000). The investigations indicated that to produce 1,0 t ha^{-1} yields, seeds need 54–62 kg of nitrogen, 24–34 kg of phosphorus, 56–116 kg of potassium, and 15–20 kg of sulphur. The average need of rape for sulphur makes 50–70 kg ha^{-1}. However, recently, new selection hybrids grown under a new intensive technology need 80–100 kg ha^{-1} of sulphur to produce 4,5 t ha^{-1} seed yield (Fismes *et al.*, 1999; Jackson, 2000; Kučinskas, Velička *et al.*, 2003; Velička, Marcinkevičienė *et al.*, 2003).

Developing the trial scheme, we followed the scheme of root and leaf nutrition of Russian scientists O. Fomina and P. Fomin as well as the theory of plant mineral nutrition of plant physiologist prof. N. Tretjakov (Фомина, Фомин, 1977; Третьяков, 1998). It was supposed that additional leaf spray fertilization process reduces the degree of pod languishing in the course of growth and increases the seed mass. This opinion is supported by the fact that after winter rape leaves languish and pod formation photosynthesis process is taken over by the green pods, assimilative surface of which is close to the assimilative surface of former leaf surface. After pods are formed and leaves languish the absorbing power highly weakens, and the supply of pods with mineral elements decreases (Jakienė, Malinauskaitė, 2001).

Little is known about time and frequency of additional leaf fertilization of winter rape.

Reasearch aim – to identify the impact of frequency and time of leaf spray fertilization of winter rape on seed yields and their structural elements.

Material and Methods

Trials on additional leaf spray fertilization were carried out over 2003–2004 at the experimental station of the Lithuanian University of Agriculture (LUA).

Soil was IDg8-k (LVg-p-w-cc) – (*Calc(ar)i-Epihypogleyic Luvisols*). Granulometric composition – loam of mean heaviness. Acidity of soil exchange – 7.0–7.2 pH_{KCl}, humus – 2.2–2.8. Amount of phosphorus – 174–188 mg kg^{-1}, potassium – 98–139 kg ha^{-1}.

Meteorological conditions. Climate in Lithuania – sea continental. The warm period lasts on average for 205–215 days. Sum of active temperatures is 2000–2400 °C. Average amount of precipitation – 650–700 mm. The year 2003 conformed to the mean parameters of many years, while 2004 was colder, and the level of precipitation was higher.

Trial scheme. Seven fertilization variants were compared in the trials:

- control – without additional leaf spray fertilization (background fertilization $N_{240}P_{100}K_{150}$);
- fertilized at the beginning of flowering (5 N + 6 S);
- fertilized at the end of flowering (14 N);
- fertilized after pod formation (23 N);
- fertilized at the beginning (5 N + 6 S) and at the end of flowering (14 N);
- fertilized at the beginning of flowering (5 N + 6 S) and after pod formation (23 N);
- fertilized at the beginning of flowering (5 N + 6 S), at the end of flowering (14 N) and after pod formation (23 N).

Fertilizer modes: at the beginning of flowering – 25 kg ha^{-1} of ammonium sulphate; at the end of flowering – 30 kg ha^{-1} of carbamide; after pod formation – 50 kg ha^{-1} of carbamide. The rates for the main and additional fertilization where calculated to obtain 5 t ha^{-1} seed yield.

Research details. Hybrid variety of winter rape 'Kasimir' was investigated. Undecrop – winter wheat. In 2003, winter rape was sown on the 5th of August, whereas in 2004 – on the 12th of August. Seed ratio – 0.6 mln ha^{-1}, sowing depth – 2 cm. Size of the control plot – 24 m^{-2}. There were four replications. Variants in replications were distributed in random order.

Research methods. Rape yield was harvested from each of the plots separately with combine harvester "Sampo". Yield was calculated for 7% seed moisture. Biometric assessment of rape crop and yield was completed from little trial sheaves from 0.25 m^{-2} plots located in each of the observation plots. Sheaves were pulled before harvesting. Measurements were completed according to the methodics developed at LUA (Velička *et al.*, 2003).

Results and Discussion

The experience of Lithuanian farmers shows that it is a quite frequent phenomenon in industrial practice that winter rape fertilized with rather high fertilization ratios produces only 3–4 t ha^{-1} seed yields. The main reason for this is both the low number of pods on the plant and the low number of seeds in the pod. That is why we chose the variant where rape were additionally leaf spray fertilized with 25 kg ha^{-1} of ammonium sulphate. The aim of this fertilization was to improve the self polination process that might result in the increase of pod number on the plant and seed number in the pod. Before flowering, winter rape crops were leaf spray fertilized with ammonium sulphate in variants 2, 5, 6, and 7. It follows from the data presented in the table that our hypothesis proved correct.

The number of pods on the plant and seed number in pods essentially increased in all the above mentioned variants. In variant where winter rape was additionally leaf spray fertilized once with ammonium sulphate before flowering, the number of pods on the plant increased by 9 units in 2003, whereas in 2004 – by 19 units. Due to this fertilization, the number of seeds in the pod essentially increased only in the 2003 variant. Leaf spray fertilization of rape had no impact on 1000 seed mass in both years of investigation. In the 5th trial variant, winter rape in addition to leaf spray fertilization with ammonium sulphate was once more leaf spray fertilized at the end of flowering with carbamide – 30 kg ha^{-1}. Comparing the means of biometric measurements of this variant with the means of the second variant, a trend of further increase in pod number on the plant and seed number in the pod might be detected.

Table 1. The impact of additional leaf spray fertilization on winter rape seed yields and their structural elements, Experimental station at LUA (2003–2004)

Fertilization variant*	Pod number on the plant, units		Seed number in the pod, units		1000 seed mass, g		Seed yield, t ha^{-1}	
	total	of which, the lateral stalks	total	of which, the lateral stalks	total	of which, the lateral stalks	total	of which, the lateral stalks
Year 2003								
1.	156	107	14,1	12,1	4,39	3,95	3,67	1,95
2.	165	114	15,2	13,5	4,31	3,87	4,09	2,25
3.	160	109	14,9	13,0	4,40	3,99	3,98	2,13
4.	158	108	15,1	13,5	4,57	4,30	4,14	2,37
5.	168	115	15,6	13,8	4,43	4,06	4,42	2,52
6.	167	116	15,4	13,8	4,61	4,35	4,51	2,61
7.	168	116	16,0	14,5	4,65	4,36	4,76	2,79
$LSD_{0,05}$	4,52	–	1,23	–	0,34	–	0,23	–
Sx%	1,14	–	2,62	–	3,57	–	2,01	–
Year 2004								
1.	144	98	15,7	13,4	4,21	3,74	4,19	2,19
2.	163	111	15,5	13,4	4,03	3,70	4,50	2,27
3.	153	103	16,0	13,9	4,16	3,66	4,48	2,29
4.	145	99	15,6	13,3	4,50	4,10	4,48	2,55
5.	163	111	16,1	14,1	4,18	3,71	4,81	2,85
6.	162	110	15,6	13,5	4,46	4,06	4,96	2,62
7.	163	112	16,2	14,2	4,50	4,09	5,24	2,85
$LSD_{0,05}$	6,93	–	0,87	–	0,28	–	0,26	–
Sx%	1,81	–	2,25	–	2,42	–	2,56	–

* Investigation variants are presented in materials and methods.

In the sixth variant, winter rape was additionally leaf spray fertilized two times; the second time – after pod formation, when plant badly needs nutritious elements and when root system weakens.

The presented data indicate that under the impact of ammonium sulphate the number of pods on the plant increased, while under the impact of carbamide essentially increased the 1000 seed mass, which resulted in additional seed yield increase by 0.42–0.46 t ha^{-1} if compared with the second variant.

Three-time leaf spray fertilization of winter rape resulted in essential increase in pod number on the plant, seed number in the pod, and 1000 seed mass, which is why the seed yields in this variant were higher (4.76–5.24 t ha^{-1}) than those obtained in the sixth variant (by 0.25–0.30 t ha^{-1}).

In the third and fourth trial variants, winter rape were additionally fertilized with carbamide. In the first case, 30 kg ha^{-1} at the end of flowering, in the second – 50 kg ha^{-1}. Fertilization of rape at the end of flowering resulted in a higher number of pods on the plant and seed number in the pods than fertilization after pod formation, however, in the latter case it resulted in 1000 seed mass increase from the pods on lateral stalks.

After generalizing investigation data it should be noted that additional leaf spray fertilization of winter rape contributes more to the productivity of lateral stalks than of the main stalks. The obtained data indicate that lateral stalks produce a higher rape seed yield than the main. The pods on the main stalks are more productive and their seeds are larger. Additional leaf spray fertilization of winter rape increases the productivity of lateral stalks (Fig. 1, 2).

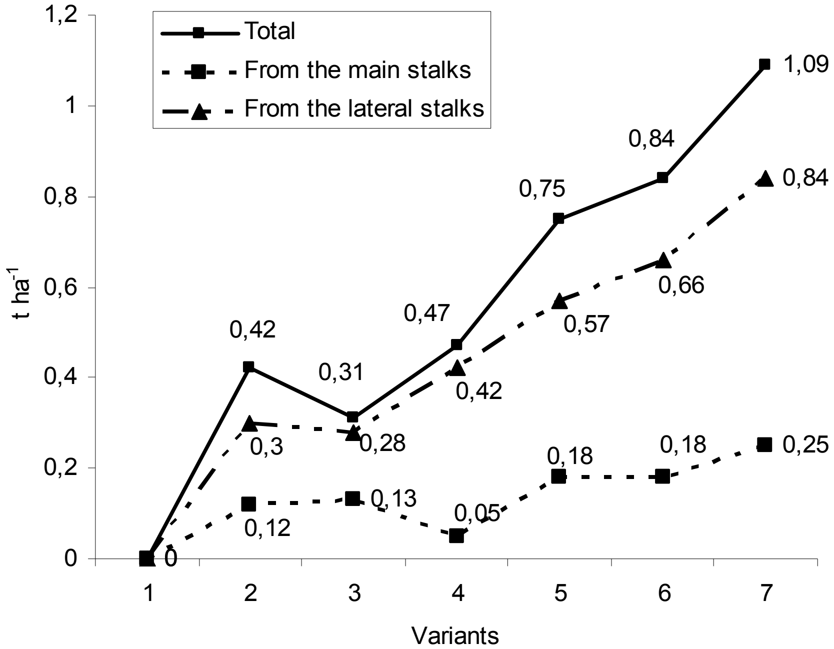
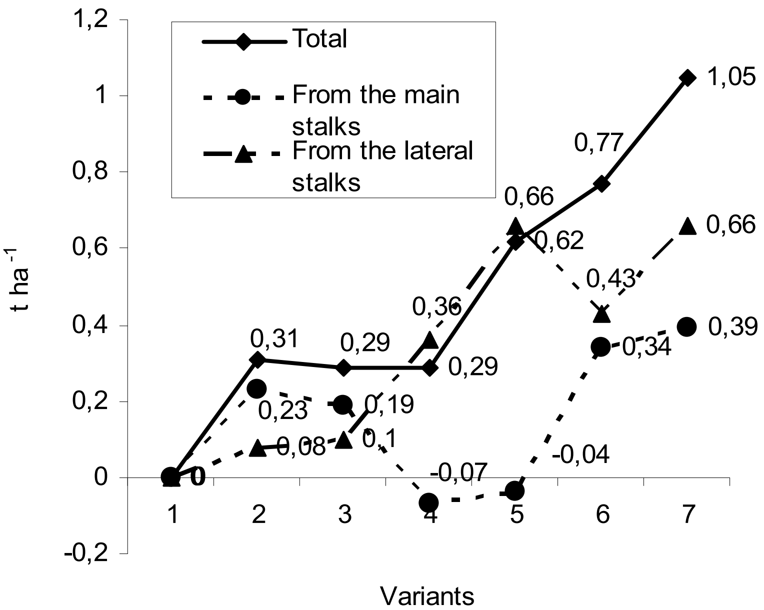


Figure 1. The impact of additional leaf spray fertilization of winter rape on yield additions, Experimental Station at LUA (2003)



* investigation variants are presented in materials and methods.

Figure 2. The impact of additional leaf spray fertilization of winter rape on yield additions, Experimental Station at LUA (2004)

Conclusions

Leaf spray fertilization of winter rape with ammonium sulphate 25 kg ha^{-1} at the beginning of flowering improved the process of rape fecundation, which resulted in a higher number of pods (9–19 units) on the plant and seed number in the pods on lateral stalks. This method of fertilization contributed to the increase of rape at an average by 0.31–0.42 t ha^{-1}.

Fertilization of winter rape with corbamide solution 30 kg ha^{-1} at the end of flowering reduced the process of pod languishing, which resulted in the increase of pod number on the plant (by 9 pods more) than in the control.

Fertilization of winter rape with corbamide solution 50 kg ha^{-1} after pod formation essentially increased seed number and 1000 seed mass in the pods on lateral stalks and due to this rape seed yield was by 0.29–0.47 t ha^{-1} higher than in the control.

Fertilization with ammonium sulphate 25 kg ha^{-1} at the beginning of flowering and at the end of flowering with carbamide solution 30 kg ha^{-1} resulted in essential increase of pod number on the plant and seed number in the pod, which contributed to seed yield increase by 0.62–0.75 t ha^{-1}.

Leaf spray fertilization of winter rape at the beginning of flowering with ammonium sulphate 25 kg ha^{-1} and after pod formation with carbamide solution 50 kg ha^{-1} resulted in an essential increse of pod number on the plant and seed mass, which contributed to seed yield increase by 0.77–0.84 t ha^{-1}.

Fertilization of rape three times: at the beginning of flowering, at the end of flowering, and after pod formation resulted in an essential increase of pods on the plant, seed number in the pod, 1000 seed mass, and the highest yield addition was obtained (1.05–1.09 t ha^{-1}).

References

1. Bernotas S., Mineikienė E.V. (2000) Boro įtaka žieminiams rapsams kalkintoje dirvoje. Žemdirbystė. Mokslo darbai. Akademija, 71, 120–134.
2. Fismes J., Vong P. C. *et al.* (1999) Use of labeled sulphur-35 for tracing sulphur transfers in developing pods of field-grown oilseed rape. Communal Soil Science and Plant Anglysis, 30, N1-2, 221–234.
3. Jackson G. D. (2000) Effects of nitrogen and sulfur on canola yield nutrient uptake. Agronomic Journal, 92, N 4, 644–649.
4. Jakienė E., Malinauskaitė R. (2001) Pavasarinio purškimo įtaka žieminių rapsų biologijai. Vagos: mokslo darbai. LŽŪU, 52 (5), 5–8.
5. Kučinskas J., Velička R. *et al.* (2003) Mineralinių trąšų, turinčių skirtingą sieros kiekį, poveikis rapsų žiemojimui, augimui, sėklų derliui ir jo kokybei . Vagos: mokslo darbai. LŽŪU, 59 (12), 49–54.
6. Šiuliauskas A., Kviklienė N. (1995) Leaf spray fertilization of potato crop and its influence on productivity and quality of potato production. Problems of Field Crop Husbandry and Soil Management in Baltic States. Tartu, 109–112.
7. Šiuliauskas A., Vagusevičienė I. *et al.* (2001) Additional fertilization of winter wheat through leaves. Conference on Sustainable Agriculture in Baltic States. Proccedings of the International Conference. Tartu, 183–188.
8. Šiuliauskas A., Vaizgirdaitė I. (1998) Papildomas žieminių kviečių tręšimas per lapus. Žemės ūkio mokslai, 3, 28–33.
9. Vaizgirdaitė I., Šiuliauskas A. (1999) Papildomo tręšimo per lapus įtaka žieminių ir vasarinių kviečių derliui bei grūdų kokybei. Žemdirbystė. LŽI mokslo darbai. Dotnuva-Akademija, 68, 35–49.
10. Velička R., Marcinkevičienė A. *et al.* (2003) Žieminių rapsų įprastinių ir hibridinių veislių derliaus formavimosi ypatumai skirtingo tankumo pasėliuose. Vagos: mokslo darbai. LŽŪU, 58 (11), 47–54.
11. Воллейдт Л. П., Мяделец П. С. (1997) Поступление и использование азота поздней подкормки на синтез белков в зерне озимой пшеницы. Агрохимия, 9, 7–12.
12. Крищенко В. П. (1992) Биохимические основы получения зерна высокого качества при интенсивных технологиях возделывания и современные методы его контроля. Дисс. д-ра биол. наук в форме научного доклада. Белорусский НИИПА. Минск, 95.
13. Никоноренков В. А., Носов В. В. (2001) Международный семинар “Актуальные проблемы сбалансированного применение удобрений под рапс и другие масличные культуры”, Познань, 16–17 мая, Агрохимия, 2, 92–94.
14. Созинов А. А., Хохлов А.Н., *at al* (1977) Проблемы увеличения белковости зерна пшеницы. В кн.: Проблема повышения качества зерна. М.: “Колос”, 8–20.
15. Третьяков Н. Н. (1998) Физиология и биохимия сельскохозяйственных растений. Москва, 134–162, 590–597.
16. Фомина О. Г., Фомин П. И. (1977) По соотношении корневого и листового питания растений серщий. Агрохимия, 1, 107–112.

WHEAT POWDERY MILDEW POPULATION IN LITHUANIA

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Abstract

The presence and relative frequency of virulence genes in wheat (*Triticum aestivum* L.) powdery mildew, caused by *Blumeria graminis* DC. f. sp. *tritici* Marchal, population in Lithuania was studied during 2000–2002. Virulence frequencies, complexity and racial composition of the pathogen population were determined. Data were analyzed for associations among pairs of virulence genes and for distribution of virulence genes among pathotypes and isolates. A total of 175 isolates were characterized in three years. Genes *Pm1, Pm2, Pm3a, Pm3b, Pm3c, Pm4a, Pm4a+, Pm4b*, *Pm4b+, Pm5, Pm6, Pm7, Pm8, Pm17, Pm 1+4b, Pm1+2+9, Pm2+6,* and *Pm2+Mld* were evaluated. Relative disease severity was the highest for genotypes carrying genes *Pm2*, *Pm3a, Pm3c, Pm7,* and *Pm2+6*. The most effective resistance genes were *Pm4a, Pm4a+,* and *Pm17*. Virulence to other genes was high but a little different among years. Distribution of virulence genes among pathotypes indicates that sexual reproduction contributes to the variability of the pathogen. The investigated population of *B. graminis* f. sp. *tritici* was composed of complex and highly variable pathotypes. The majority of pathotypes had virulences to most resistance genes used in European wheat.

Key words: powdery mildew, wheat, virulence genes, Lithuania

Introduction

Wheat powdery mildew (*Blumeria graminis* DC. f. sp. *tritici* Marshal) is found wherever wheat is grown. In the case of severe epidemics, losses may be as great as 30%, while in years with average infection damage are 5–8%. This disease is harmful mostly in wet climate countries (Niewoehner and Leath, 1999; Villareal and Lannou, 2000).

There are several ways to control this disease. The biological control is based on cultivating wheat varieties carrying specific or non-specific resistance or on growing mixtures of varieties (Bennett, 1984; Pearce *et al.*, 1996; Yu *et al.*, 2001). Development and cultivation of resistant varieties is of great importance in maintaining satisfactory yield, reducing the extent of damage and in protecting the environment (Wiik, 1991; Everts and Leath, 2001). As powdery mildew conidia are spread by wind, populations in different countries can influence each other because there are no obstacles to this pathogen across different countries (Limpert *et al.*, 1999). This reason causes increased virulence shifts in *B. graminis* f. sp. *tritici* populations and makes the resistance ephemeral (Sperling and Wächter, 1991).

Disease management programs employing host resistance require information on both the nature of the resistance genes deploying and virulence spectrum of the pathogen population. This information permits the replacement of ineffective host resistance genes with those that are currently effective. Distribution and efficiency of resistance genes in current cultivars is necessary to introduce new genes or substitute no longer effective genes (Hsam and Zeller, 2002).

The objective of this study was to determine and characterize the virulence spectra of *B. graminis* f. sp. *tritici* populations and effectiveness of wheat powdery mildew resistance genes that are involved in the winter wheat breeding program of the Lithuanian Institute of Agriculture (LIA).

Materials and Methods

Collection of isolates. Isolates of the wheat powdery mildew pathogen, *B. graminis* f. sp. *tritici,* were obtained from infected leaves collected in wheat breeding fields of LIA during 2000–2002. Sections of diseased leaves, 5 cm in length, were collected, placed in a Petri dish filled with benzimidazole agar (1.0 g kg^{-1} agar with 100 mg of benzimidazole per litre) and transferred to a cold growth chamber (5±2 t °C with 8 h light per 24 h period) in the laboratory.

Virulence analysis. The tested wheat lines were grown in 5 × 5 cm plastic pots in coarse sand in a 18±2 t °C chamber with 16 h daylight per 24 h period. Virulence genes of each single-pustule isolate were assessed on a host differential set using 2 cm-long segments cut from the middle part of the primary leaf of 10-day-old seedlings laid on filter paper moistened with benzimidazole solution (30 mg of benzimidazole per liter of water). The differential host series consisted of wheat containing 18 resistance genes or those combinations and susceptible check, Carsten V (Table 1). Leaves infected with each isolate were used to inoculate wheat leaves in each Petri plate. The plates were placed in a 18±2 t °C growth chamber with 16 h of light and rated after 10 days using an evaluation scale, in which 0 = immune, no visible signs or symptoms; 1 = highly resistant, chlorotic flecks; 2 = resistant, small lesions; 3 = moderately susceptible, moderate lesions; 4 = susceptible, large lesions. For each single-pustule isolate screened in this study, three leaf segments of each wheat genotype were assessed and two independent tests were performed.

Data analysis. Virulence genes of Lithuanian population of *B. graminis* f. sp. *tritici* were determined based on the reaction of host differential lines to the different isolates (Table 1). Susceptibility of a differential line carrying a known resistance gene to a specific isolate indicated the presence of the corresponding virulence gene in the isolate. For each virulence gene and each year, virulence frequencies were determined based on the proportion of isolates inducing moderate to susceptible reactions (evaluation scale 3 and 4). Virulence genes were categorized into two classes based on observed frequencies. The first class contains genes observed at low and intermediate frequencies (<40%). The second class contains genes observed at frequencies (>40%). For each year, pathotypes (Table 2) were defined on the basis of the virulence-avirulence formula, and isolates having the same formula were grouped together. The distribution and frequency of the number of virulence genes per isolate were analyzed for each year. A X^2 (Chi-square) statistical test was used to compare the observed and expected values of pairs of virulence genes based on independent assortment. The data for 2000–2002 are presented in Table 3. All pairs of genes were analyzed for the 18 resistance loci/loci combination listed in Table 1.

Results and Discussion

A total of 175 isolates collected from breeding nurseries were characterized for virulence on the 18 host differentials in 2000–2002. (Reaction of infection type ranged from 0 to 4.) Virulence was detected for all genes in various degrees. The highest and stable virulence for genotype carrying genes *Pm2, Pm3a, Pm3c, Pm7,* and *Pm2+6* occurred over three years (Table 1).

Table 1. Virulence frequencies of *Blumeria graminis* f. sp. *tritici* isolates in 2000–2002 at LIA

Differential cultivars	Resistance gene (*Pm*)	2000, %	2001, %	2002, %	Average, %
Carsten V – check	none	100.0	100.0	100.0	100.0
Axminster	*1*	68.0	54.0	67.0	63.0
Red Fern	*2*	92.0	78.0	76.0	82.0
Asosan	*3a*	94.0	100.0	85.0	93.0
Chul	*3b*	90.0	42.0	56.0	62.7
Sonora	*3c*	98.0	72.0	85.0	85.0
Khapli	*4a*	40.0	14.0	8.0	20.7
Tp 309/A	*4a+*	42.0	40.0	11.0	31.0
Weihenstephan M1	*4b*	66.0	50.0	89.0	68.3
TP 315/2	*4b+*	86.0	58.0	83.0	75.7
Hope	*5*	90.0	60.0	47.0	65.7
TP 114* Starke B2	*6*	92.0	56.0	77.0	75.0
Transec	*7*	84.0	80.0	93.0	85.7
Salzmünde 14/44	*8*	50.0	74.0	87.0	70.3
Amigo	*17*	40.0	50.0	21.0	37.0
Rang	*1+4b*	66.0	44.0	77.0	62.3
Normandie	*1+2+9*	70.0	64.0	83.0	72.3
TP 114/65 A	*2+6*	88.0	80.0	75.0	81.0
Halle st. 13471	*2+Mld*	86.0	92.0	31.0	69.7

Virulence for genes *Pm4a, Pm4a+* and *Pm17* occurred at the relatively lower and stable frequency. Very high virulence for genes *Pm2* and *Pm2+6* can be explained by high frequency of these genes in grown wheat cultivars, which is admitted in the studies of other authors too (Sperling and Wächter, 1991; Szunics, 1998; Huszar *et al.*, 2001).

The growing conditions during the period 2000–2002 were different. They affected the frequency of isolates but to a different degree.

There was an increase in frequency of isolates with virulence to *Pm8.* Virulence to *Pm3b, Pm4a, Pm4a+,* and *Pm5* decreased. *Pm5* showed increased effectiveness from 10.0 to 53.0%. It is somewhat unexpected because wheat varieties containing this gene are widely grown. Isolates virulent to *Pm1, Pm1+2+9, Pm4b and 4b+, Pm1+4b* were medium frequent. Some varieties with *Pm4b* especially in combination with other *Pm* genes had good field resistance (Yu *et al.*, 2001; Skinnes, 2002).

Virulence frequencies were highly influenced by the resistance genes carried by cultivars grown in a specific area. Genes *Pm2, Pm4b, Pm5, Pm6,* and *Pm8* and their combinations are very frequent in cultivars grown in Lithuania and in neighboring countries. It appears that this pathogen is able to carry a large number of virulence genes without serious impact on general fitness (Imani *et al.*, 2002). Virulence to *Pm2+Mld* was very different between the years – it was very high in 1999 and 2000, but very low in 2002. The summer of this year was exceptionally dry and hot in Lithuania and mildew infection was very low in many places. Some virulences were not so low that year, but isolates virulent to *Pm4a+* and *Pm17* were less abundant. The response of virulence genes was different among the years. Some changes of virulences were inconsistent (*p3b, p6*). Increase in the number of isolates with virulence corresponding to *Pm8*, could posses a certain advantage, such as superior fitness that may have contributed to this increase in frequency.

Some resistance genes have not been used in cultivars in Lithuania or surrounding countries, but there may be a selective advantage to the fungus in carrying virulence to these genes, or it may be present in uncharacterized cultivars (Svec and Miklovičova, 1998). Host driven selection may account for the presence of high levels of virulence to some of these genes, but this does not explain the high levels of virulence to genes of *Pm3* locus (Bousset and Vallavieille-Pope, 2003).

Association of virulence genes among pathotypes. There have been several reports of associations between virulence genes in the wheat powdery mildew fungus (Niewoehner and Leath, 1999; Imani *et al.*, 2002). It was reported that associations occur between virulence factors in relation to their occurrence segregation, and maintenance in pathogen population. The frequencies of 153 associations of gene pairs were analyzed for all years of the study (Table 2). Among 153 pairs of genes, 32 had a frequency significantly different than the product of frequency of individual genes, which indicates that these pairs of virulence genes occurred together in the pathogen population to a greater or lesser extent than expected with normal recombination.

Table 2. Result of chi-square test for independence of virulence genes using aggregate data from 2000–2002

Virulence genes		Virulence pairs				Chi-square statistics	
A	B	A+B	A, not B	B, not A	Neither	Value	Probability
p1	*p2*	82	29	60	4	10.5	0.001
p2	*p3b*	92	50	15	18	4.2	0.040
p1	*p3c*	98	12	50	14	3.8	0.050
p2	*p2+6*	118	24	22	11	4.5	0.030
p3a	*p2+Mld*	108	53	4	10	8.3	0.004
p3b	*p5*	87	20	23	45	40.2	0.000
p3b	*p6*	89	18	43	25	8.9	0.003
p3b	*p8*	71	36	56	12	5.4	0.020
p3b	*p1+2+9*	71	36	57	11	6.5	0.010
p3c	*p4a+*	37	111	12	14	4.9	0.030
p4a	*p4a+*	14	19	35	107	4.2	0.040
p4a	*p7*	24	9	128	14	7.1	0.008
p4a	*p8*	18	15	109	33	6.6	0.010
p4a	*p1+4b*	25	5	82	60	8.4	0.004
p4a	*p2+Mld*	27	6	85	57	5.6	0.020
p4b	*p4b+*	108	16	26	25	26.3	0.000
p4b	*p5*	67	57	43	8	14.2	0.000
p4b	*p7*	112	12	40	11	4.5	0.030
p4b	*p17*	34	90	26	25	8.9	0.003
p4b	*p1+4b*	88	34	22	29	12.0	0.001
p4b	*p2+Mld*	70	54	42	9	10.5	0.001
p4b+	*p7*	121	13	31	10	5.9	0.020
p4b+	*p1+4b*	92	42	18	23	8.2	0.004
p4b+	*p2+Mld*	80	54	32	9	4.6	0.030
p5	*p8*	73	37	54	11	5.7	0.020
p5	*p1+4b*	62	48	48	17	5.3	0.020
p5	*p2+Mld*	81	29	31	34	11.9	0.001
p6	*p17*	39	93	21	22	5.4	0.020
p7	*p1+4b*	91	61	19	4	4.4	0.040
p7	*p2+Mld*	93	59	19	4	4.0	0.045
p8	*p2+Mld*	73	54	39	9	8.5	0.003
p1+4b	*p2+Mld*	64	46	48	17	4.4	0.040

Significant positive associations between pairs of virulence genes may indicate selection pressure in favour of genotypes carrying these combinations of virulence genes. The most frequent pairs of genes significantly associated in this study were between *Pm4b+* and *Pm17* (69%), *Pm3a* and *Pm2+Mld*, *Pm4* and *Pm4b+* (62%).

Characterization of pathotypes. For each year, isolates of *B. graminis* f.sp. *tritici* were classified on the basis of their virulence-avirulence formulae. In the year 2000, 16 different pathotypes were identified among 50 isolates. These pathotypes possessed 3 to 6 virulence genes corresponding to the 6 most widespread genes in European varieties. The most abundant pathotype (15.6%) possessed virulence to all genes in grown cultivars and the mean number of virulence genes per isolate was 5.0. In 2001, 50 isolates were characterized and 24 pathotypes possessing 2 to 6 virulence genes were identified. In all, 75 isolates were tested in 2002 and 25 pathotypes were found. The total ratio of identified pathotypes to the total number of isolates evaluated (0.32 for 2000, 0.48 for 2001, and 0.33 for 2002) indicates that the *B. graminis* f. sp. *tritici* population in Lithuania is not very variable genetically. All major pathotypes were found each study year, only pathotypes avirulent to *Pm5* were less frequent in 2002. The most prevalent pathotypes had (vir/avr *Pm2, 4b, 5, 6, 8, 2+6/* and *2, 4b, 6, 8, 2+6 / 5) 6* or *5* virulence genes and other pathotypes with 3 to 4 virulence genes were much less frequent. Many of them were found only once or twice. Considering that virulence was found for the 18 resistance gene/genes combination tested in this study and pathotypes possessing combined virulence to as many as 16 of these genes were identified, it is unlikely that combinations of these race-specific genes will provide long-term durable resistance.

The rather high degree of variability of the pathogen population and lack of the only main predominant pathotype provide some evidences that sexual reproduction and genetic recombination play significant role in the life cycle of the pathogen, as reported by Bousset and de Vallavieille-Pope (2003).

Table 3. Frequency of pathotypes of *Blumeria graminis* f. sp. *tritici* collected during 2000–2002

Pathotype	Years			Total	Frequency,
Virulence/Avirulence	2000	2001	2002		%
2, 4b, 5, 6, 8, 2+6 /-	12	4	10	26	15.6
2, 4b, 6, 8, 2+6 / 5	1	4	16	21	12.6
2, 4b, 5, 6, 2+6 / 8	9	–	5	14	8.4
2, 5, 6, 8, 2+6 / 4b	4	4	3	11	6.6
2, 5, 6, 2+6 / 4b, 8	9	2	–	11	6.6
2, 4b, 8, 2+6 / 5, 6	2	3	5	10	6.0
2, 4b, 5, 6, 8 / 2+6	2	1	5	8	4.8
2, 4b, 6, 2+6 / 5, 8	2	4	–	6	3.0
2, 5, 8, 2+6 / 4b, 6	1	3	1	5	3.0
2, 4b, 5, 8, 2+6 / 6	1	2	2	5	2.4
2, 5, 6 / 4b, 8, 2+6	3	1	–	4	2.4
4b, 5, 6, 8, 2+6 / 2	2	–	2	4	2.4
4b, 6, 8, 2+6 / 2, 5	–	2	4	6	2.4
2, 4b, 6, 8, / 5, 2+6	–	1	2	3	1.8
2, 6, 8 / 4b, 5, 2+6	–	2	1	3	1.8
2, 6, 8, 2+6 / 4b, 5	2	–	1	3	1.8
4b, 5, 6, 8 / 2, 2+6	1	–	2	3	1.8
4b, 6, 8 / 2, 5, 2+6	–	–	3	3	1.8

Complex pathotypes are predominant, and strategies for deployment of resistance genes should take into account this complexity. Control of powdery mildew via pyramiding resistance genes would likely not be effective in the long term (Bennett, 1984; Skinnes, 2002).

In our study, presence of pathotypes carrying up to 16 virulence genes in the pathogen population and dominance of pathotypes virulent to all resistance genes used could induce rapid breakdown of resistance in cultivars carrying one or many resistance genes. Race nonspecific resistance to powdery mildew has been identified and shown to be durable. This type of resistance, known as slow mildewing or adult plant resistance, offers an alternative to the ephemeral hypersensitive major gene resistance (Paillard, Goldringer *et al.*, 2000 a, b).

Conclusions

Virulence frequencies of wheat powdery mildew pathogen were the highest for differential wheat cultivars carrying genes *Pm2*, *Pm3a, Pm3c, Pm7,* and *Pm2+6*. The most effective resistance genes were *Pm4a, Pm4a+,* and *Pm17*. Virulence to other genes was high but a little different among years. Distribution of virulence genes among pathotypes indicates that sexual reproduction contributes to the variability of the pathogen. Investigated population of *B. graminis* f. sp. *tritici* was composed of complex and highly variable pathotypes. The majority of pathotypes had virulences to most resistance genes used in European wheat.

References

1. Bennett F. G. A. (1984) Resistance to powdery mildew in wheat: a review of its use in agriculture and breeding programmes. Plant Pathology 33, 279–300.
2. Bousset L., de Vallavieille-Pope C. (2003) Effect of sexual recombination on pathotype frequencies in barley powdery mildew populations of artificially inoculated field plots. European Journal of Plant Pathology 109, 13–24.
3. Everts K. L., Leath S. (2001) Effect of early season powdery mildew on development, survival and yield contribution of tillers of winter wheat. Phytopathology 82, 1273–1278.
4. Hsam S. L. K., Zeller F. J. (2002) Breeding for powdery mildew resistance in common wheat (*Triticum aestivum* L.). // In: The powdery mildews: A comprehensive treatise. APS Press, St. Paul, Minnesota, USA, 219–238
5. Huszar J. *et al.* (2001) Importance of wheat disease resistance for sustainable agriculture. Acta fytotechnica et zootechnica 4, 292–294.
6. Imani Y. *et al.* (2002) Virulence of Blumeria graminis f. sp. tritici populations in Morocco. Plant Disease 86, 383–388.
7. Limpert E. *et al.* (1999) Dispersal of cereal mildews across Europe. Agricultural and Forest Meteorology 97, 293–308.
8. Niewoehner A. S., Leath S. (1999) Virulence of Blumeria graminis f. sp. tritici on winter wheat in the Eastern United States. Plant Disease 82, 64–68.
9. Paillard S. *et al.* (2000a) Evolution of resistance against powdery mildew in winter wheat populations conducted under dynamic management. I – Is specific seedling resistance selected? Theor Appl Genet. 101, 449–456.
10. Paillard S. *et al.* (2000 b) Evolution of resistance against powdery mildew in winter wheat populations conducted under dynamic management. II – Adult plant resistance. Theor Appl Genet. 101, 457–462.
11. Pearce W. L. *et al.* (1996) Partial resistance to powdery mildew in soft red winter wheat. Plant Dis. 80, 1359–1362.
12. Skinnes H. (2002) Breakdown of race specific resistance to powdery mildew in Norwegian wheat. Cereal Rusts and Powdery Mildews Bulletin 30 [www.crpmb.org/] 2002/1201skinnes.
13. Sperling U., Wächter V. (1991) Race and virulence surveys of wheat powdery mildew in the German Democratic republic. Integrated Control of Cereals Mildews: Virulence Patterns and Their Change, 9–13.
14. Svec M., Miklovičova M. (1998) Structure of populations of wheat powdery mildew (Erysiphe graminis DC f. sp. tritici Marchal) in Central Europe in 1993–1996: I. Dynamics of virulence. European Journal of Plant Pathology 104, 537–544.
15. Szunics L. (1998) Wheat powdery mildew resistance genes. Növenytermeles. vol.47, 697–708.
16. Villareal L. M. M. A., Lannou C. (2000) Selection for increased spore efficacy by host genetic background in a wheat powdery mildew population. Phytopathology 90, 1300–1306.
17. Wiik L. (1991) Mildew populations of barley and wheat in Sweden. Integrated Control of Cereals Mildews: Virulence Patterns and Their Change, 33–37.
18. Yu D. Z. *et al.* (2001) Assessment of partial resistance to powdery mildew in Chinese wheat varieties. Plant Breeding 120, 279–284.

VARIETY – BY – ENVIRONMENT INTERACTIONS FOR WINTER WHEAT QUALITY TRAITS

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Abstract

Improvement of end-use in winter wheat (*Triticum aestivum.* L) depends on thorough understanding of influences of environment, variety, and their interaction. The objectives were to determine relative contribution of variety (V), environment (E) and V x E interaction to variation in quality characteristic of winter wheat. Field experiments with 10 winter wheat varieties of different origin were conducted on brown lessive soils of the Study and Research farm "Peterlauki" of the Latvia University of Agriculture from 2002 to 2004. Wet gluten content (WG), gluten index (GI), dry gluten (DG), water binding capacity in wet gluten (WBC), sedimentation value (SED), grain protein content (GPC), test weight (TW), thousand kernel weight (TKW), Hagberg falling number (HFN) and starch (S) were measured. Highly significant differences were detected among the environments and varieties for each of the quality variables. Both variety (V) and environment (E) had a significant effect on quality traits. Significant V x E interactions indicated that quality traits evaluations must be undertaken for environments. A close positive correlation was determined between the wet gluten and dry gluten, sedimentation value. Dry gluten positively correlated with sedimentation value, water binding capacity and thousand-kernel weight. A significant positive correlation was found between gluten index and starch.

Key words: winter wheat, grain quality, variety x environment interaction

Introduction

Wheat is the major field crop grown in Latvia. Understanding genetic and environmental influences responsible for variation in end-use quality of winter wheat is important for the production and marketing of a consistent and high quality products. Environmental conditions are known to have significant influence on end-use quality characteristic of wheat, but the relative magnitude of environmental, variety, and V x E effects on quality is unclear. Environmental variation has often been considered the most important factor influencing wheat quality characteristics (Finney and Bains, 1999). The quality of wheat is mainly determined by management techniques and environmental conditions, however, it can be influenced by the genetic basis (Grausgruber *et al.*, 2000).

Variety's quality depends not only on its genetic potential for particular characters but also on its ability to realize this potential in actual production and under different environmental conditions (Dotlacil and Toman 1991; Mladenov, Misics *et al.*, 2001). Wheat varieties differ significantly in their grain quality. Nonetheless, environmental factors play a major role in the expression of genotype characteristics (Ruza, 2003; Bassett *et al.*, 1989; Lukov and McVetty, 1991). Their impact, however, is rarely optimal; one or more of them will always limit the yield and quality of the product. Quality parameters of winter wheat are not stable between production years because of the inconsistency of the variables such as initiation of growing season, distribution of rainfall and heat units available for crop growth during corresponding phases of plant growth and development (Linina and Ruza 2004). Addition of nitrogen fertilizer in accordance with the plant requirement is necessary to attain high yields and quality of winter wheat (Masauskiene *et al.*, 2001; Ruza and Linina, 2001).

Our objectives were to determine relative contributions of variety, environment, and V x E interaction to variation in quality characteristic of winter wheat.

Material and Methods

Field experiments with 10 winter wheat *(Triticum aestivum* L.) varieties: 'Donskaja polukarlikovaja' (Russia), 'Stava' (Sweden), 'Gunbo' (Sweden), 'Moda' (Latvia), 'Kobra' (Poland), 'Kosack' (Sweden), 'Tarso' (Germany), 'Kontrast' (Germany), 'Zentos' (Sweden), and Hereward (Great Britain) were conducted at the Study and Research farm "Peterlauki" of the Latvia University of Agriculture (LUA) from 2002 to 2004. The soil at the site was brown lessive medium loam with medium high phosphorus and potassium sufficiency levels, pH $_{KCl}$ – 6.9 to 7.1, humus content – 19 to 21 g kg^{-1} of soil. Previous crop was full fallow – oil radish for green manure. Trial varieties of winter wheat were sown on 18 September 2001, 24 September 2002, and 19 September 2003. The seeding rate was 500 germinating seeds per m^2. Conventional measures of agrotechnics were applied in growing; NPK (6:26:30) 200 kg ha^{-1} was used. Split nitrogen top-dressing was applied in the following way: early in spring at the beginning of vegetation period for the first time, at the end of tillering the second time – 29 ZGS (Zadoks, Chang, Konzak growing stage, 1974), and third at the end of booting – 49 ZGS.

Nitrogen top-dressing rates were as fallows: N90, N120 (90+30), N150 (90+60), and N180 (90+60+30). The influence of N top-dressing rate and time on quality parameters is not analysed in the current paper.

During the study years, the meteorological conditions were significantly different. In 2001/2002, over-wintering of winter cereals was good. In April, monthly mean temperature was by 4.5–7.3 °C higher than the long-term average, but rainfall occurring was 30 mm. May was warm but dry as rainfall was 17.9 mm, which was 36% of long-term average. June was characterized by rainy weather and sharp fluctuations in temperature. July was hot with daily temperature exceeding 30 °C. Weather conditions favoured rapid formation and ripening of wheat grain. During grain harvest in the third decade of July, the weather was dry and sunny. In general, the vegetation period of winter cereals in 2002 was favourable to achieve high yields and good quality wheat.

Due to dryness of the soil in autumn 2002, tillering of wheat was delayed. The spring of 2003 was warm and dry. Rainfall occurring in sufficient quantity in mid-June resulted in optimum conditions for the growth of winter wheat. In the third decade of July hot weather prevailed with temperature 4.8 °C above long-term average, sum of rainfall was 26.8 mm, and moisture level in soil was sufficient. Favourable weather conditions in the second half of summer provided high quality of grain.

In spring 2004, vegetation renewed comparatively early and evenly. April and first decade of May were below average precipitation with monthly rainfall 8.1 mm, i.e. only one fourth of the long-term average. Rainfall occurring in the third decade of May for most of wheat varieties coincided with the 2nd node stage when new ears were initiated in stems. Abundant rainfall and available nutrients contributed to development of highly productive ears. June was comparatively rainy with excessive rainfall exceeding long-term average nearly by more than three times. July and August were rainy as well, but rainfall was well distributed. Atmospheric temperatures were not high during the vegetation period. Some particular warm and sunny days were observed in midsummer. Such weather conditions significantly influenced the yield formation process in winter wheat increasing the length of particular growth stages significantly. Though the total length of vegetation period nearly increased by two weeks, plants were enabled to realize their productivity potential.

Quality tests were performed on the harvested grain of each variety for each year. Quality traits were calculated at 100% purity and 14% moisture level, but protein and starch – on dry matter basis.

There were determined the following baking quality indices: wet gluten (WG), gluten index (GI), dry gluten (DG), water binding capacity in wet gluten content (WBC) according to Perten-ICC method 155 (ICC 1995), grain protein content by Kjeldahl procedure (N × 5,7; moisture basis) by ICC 105/2, Hagberg falling number (HFN) according to Hagberg-Perten as measure of the degree of alpha-amylase activity in grain and flour by ICC 107/1, starch (S) was determined using ICC 123, sedimentation value (SED) according to Zeleny as an approximate measure of baking quality according to ISO 5529, kernel test weight (TW) by ISO 7971-2, and thousand kernel weight (TKW) according to ISTA method.

Analysis of variance (*ANOVA*) and estimates of the component of variance to variety (σ^2_V), variety by environment ($\sigma^2_{V \times E}$) and error (σ^2_e) were calculated according to Comstock and Moll (1963). The year was used as separate environments for statistical analyses. Using mean squares for variety x year and pooled error, respectively, the significance of mean squares for varieties, years, and variety x year interaction were tested. The percentage contribution for each variance component was estimated by summing up the appropriate terms to give an estimate of total variance and then dividing the specific variance component by the total variance (Singh *et al.*, 1993).

The ratios of variance components ($\sigma^2_V/\sigma^2_{V \times E}$) were calculated according to Peterson *et al.* (1986). Coefficient of variation and correlation was calculated according to Arhipova *et al.* (1997).

Results and Discussion

Based on the pooled ANOVA (Tables 1, 2), all sources of variation for each of the 6 qualitative traits were highly significant ($P < 0.01$). In general, V x E interactions were significant ($P < 0.01$) yet relatively small. The significant V x E interaction for all quality traits resulted from the different abilities of varieties to adjust quality to the environment as a consequence of genetic differences. For all the traits, variances due to varieties were greater than V x E variances. These results are in agreement with the findings for winter wheats (Mladenov *et al.*, 2001), soft and hard red winter wheats (Baenziger *et al.*, 1985; Peterson *et al.*, 1992), semi dwarf spring wheats (Lukow and Mc Vetty, 1991), and soft white winter wheats (Basset *et al.*, 1989).

Table 1. Mean square for analysis of variance of wet gluten (WG), gluten index (GI), dry gluten (DG), water binding capacity (WBC), sedimentation value (SED), and grain protein content (GPC) across environments in 2002–2004

Source		Quality traits					
of variation	df	WG	GI	DG	WBC	SED	GPC
Environment (E)	2	163.68**	5332.47**	0.06**	14214.50**	879.05**	31.00**
Variety (V)	9	42.80**	2150.13**	0.12**	4684.60**	228.49**	5.07**
V x E	18	7.66**	146.74**	0.01**	1010.30**	105.12**	0.69**
Pooled error	30	0.01	0.25	0.01	0.20	0.22	0.01

** Significant at $P < 0.01$.

Table 2. Mean square for analysis of variance of Hagberg falling number (HFN), test weight (TW), thousand-kernel weight (TKW), and starch (S) across environments in 2002–2004

Source		Quality traits			
of variation	df	HFN	TW	TKW	S
Environment (E)	2	14233.90**	3163.55**	285.92**	55.10**
Variety (V)	9	4239.90**	594.86**	143.78**	12.09**
V x E	18	2556.60**	351.86**	8.39**	4.97**
Pooled error	30	2.30	0.33	0.02	0.02

** Significant at $P < 0.01$.

Component of variance for each qualitative trait expressed as percentage illustrates the relative contribution of each source to total variance. The variance component due to variety explained most of the total variation, ranging from 29.70 to 64.15% of the variability associated with each quality parameter. Effects of V x E interaction ranged from a low of 8.09 of total variance for GI to a high of 40.83% of total variance for HFN. The relatively high V x E interaction for HFN, TW and SED multiple years testing to accurately assess the genetic potential.

The importance of the V x E interaction in relation to genetic effects can be shown through the ratio of the variance component $\sigma^2_V / \sigma^2_{V \times E}$ (Table 3). The ratio of variety to V x E effects differed among the quality parameters measured. A ratio > 1.0 indicates greater influence and stability of genetic factors relative to the variability associated with the interactions V x E (Peterson *et al.*, 1992). The ratios for all the quantitative traits ranged from 0.83 to 8.53. The ratios for WG (2.08), GI (7.19), DG (3.33), WBC (2.32), GPC (3.66), and TKW (8.56) showed a greater influence on variability by the variety than the V x E interaction. The ratios for HFN (0.83) and TW (0.85) were <1.0, indicating the important influence of the V X E interaction on these quality traits. Variance associated with the V x E interaction was of similar magnitude as genetic components for SED (1.09).

Grain quality is a complex character that depends on the number of traits, and the individual contribution of each trait varies depending on the specific reaction to environmental conditions.

Though meteorological conditions during trial years were variable in harvest time, wheat was harvested in optimum terms. In all three years, alpha-amylase activity in grain was not high, judging by the Hagberg falling number value, which always demand minimum 220 s. All the rest of grain quality parameters were good and exceeded minimum indices established by the European Commission intervention.

Table 3. Ratios of variances estimated for the variety and environment main effects and their interaction for various traits in wheat (2002–2004)

Source of	Quality traits									
variation	WG	GI	DG	WBC	SED	GPC	HFN	TW	TKW	S
σ^2_V	45.30	59.24	56.18	47.49	35.99	67.93	33.85	29.70	64.15	35.22
$\sigma^2_{V \times E}$	16.20	8.09	16.85	20.48	33.12	10.37	40.83	35.14	7.49	28.99
σ^2_e	0.02	0.02	0.08	0.01	0.11	8.33	0.06	0.05	0.03	0.15
$\sigma^2_V / \sigma^2_{V \times E}$	2.08	7.19	3.33	2.32	1.09	3.66	0.83	0.85	8.56	1.22

Traits explanatory notes are given in Tables 1 and 2.

Total variance in % for each source of variation (σ^2_V , $\sigma^2_{V \times E}$, σ^2_e), ratios of variances estimated for the cultivars' main effect and interaction ($\sigma^2_V / \sigma^2_{V \times E}$).

The relative magnitude of the variance components indicated that the interaction of V × E was of considerable importance in determining wheat quality. The significant variety variance component indicated that the cultivars differed in their genetic potential for quality.
A wide range of all quality parameters was observed in Table 4.

Table 4. Expression of quality traits of winter wheat across 10 varieties and 3 environments, 2002–2004

Traits	Variety min – max (n = 10)	Variety CV (%)	Environment min – max (n = 3)	Environment CV (%)	Mean (n = 30)	Mean CV (%)
WG (g kg^{-1})	263–362	6.9	256–306	9.9	289	13.3
GI	25.3–85.3	42.5	32.8–63.1	36.8	44.4	53.4
DG (g)	0.86–1.18	10.5	0.83–0.97	8.8	0.92	13.2
WBC (g kg^{-1})	1620–2600	15.0	1560–2020	14.3	1870	21.0
SED (ml)	39.0–57.7	13.0	41.7–54.4	14.1	47.0	21.0
GPC (g kg^{-1})	132–165	6.5	131–155	8.8	141	10.2
HFN (s)	344.3–440.7	7.0	356.0–408.4	7.0	380.0	11.6
TW (g l^{-1})	797.2–82.39	11.5	801.2–825.0	8.7	812	13.7
TKW (g)	38.4–54.4	1.2	38.9–46.1	1.5	43.1	2.2
S (g kg^{-1})	614–662	2.2	635–664	2.5	645	3.6

Traits explanatory notes are given in Tables 1 and 2.

Ranges in WG and GPC across the environments were notably larger than those established across the variety. Range in HFN, SED, WBC, TKW and S was similar for variety and environments.

Ranges in GI, DG and TW across the variety were notably larger than those established across environments. Some varieties were stable for one trait and unstable for another, suggesting that the genetic factors involved in V × E differed between the traits.

There was a significant V × E interaction for all the quality traits studied. The relatively large contributions (>20%) (Lukow and McVetty, 1991) of variety variance and V × E interactions for some traits SED, HFN and TW (Tables 1 and 2) also suggest that these quality parameters may require multiple environment testing to accurately assess the genetic potential of wheat varieties.

Correlations between the traits depend on genetic and environmental factors (Falkoner and Mackay, 1996). When several traits are involved in evaluation of quality, it is desirable to determine correlation among them. In the present study, 45 possible pairs of traits were examined for interrelationships. The correlations among the various traits are presented in Table 5.

Table 5. Correlations among 10 quality traits in grain of different wheat varieties

	WG	GI	DG	WBC	SED	GPC	HFN	TW	TKW
WG									
GI	0.15								
DG	0.95**	0.01							
WBC	0.98**	0.07	0.94**						
SED	0.60**	0.15	0.51**	0.59**					
GPC	0.03	0.03	0.03	0.11	0.08				
HFN	–0.13	–0.16	–0.21	–0.10	0.18	–0.12			
TW	0.02	0.48**	–0.11	0.01	–0.03	–0.09	–0.07		
TKW	0.35	0.08	0.37*	0.37*	0.13	0.04	–0.38*	0.34	
S	–0.21	0.40*	–0.27	–0.17	–0.35	–0.36	–0.11	0.24	–0.14

Traits explanatory notes are given in Tables 1 and 2.
* Significant at P < 0.05 and 0.01, respectively
** Significant at P < 0.05 and 0.01, respectively.

The traits WG showed significant positive correlation with DG, WBC and SED. DG positively correlated with SED, WBC and TKW. A significant positive correlation was found between GI, TW, and S. The trait WBC correlated with SED and TKW, but HFN correlated negatively with TKW.

The significant high positive correlations between wet gluten and sedimentation value are in agreement with the findings of most other researchers (Grausgruber *et al.*, 2000; Mladenov *et al.*, 2001).

The positive correlation between sedimentation value and gluten index in our study is in close agreement with that reported by Alvarez *et al.* (2002).

Conclusions

Highly significant effects of varieties and environments were detected on all the quality traits.

A greater influence on variability ha variety if compared with V x E interaction showed in fallowing traits: wet gluten, gluten index, dry gluten, water binding capacity, grain protein content, and thousand kernel weight. V X E interaction had an important influence on the Hagberg falling number and test weight. V X E interaction and genetic components (V) had similar influence on sedimentation value.

Close positive correlation was determined between the wet gluten, dry gluten, and sedimentation value. Dry gluten positively correlated with sedimentation value, water binding capacity, and thousand-kernel weight. A significant positive correlation was found between gluten index, starch, and test weight.

References

1. Alvarez J. B. *et al.* (2002) Evaluation of gluten strength of new cultivars of durum wheat. Book of proceedings VII Congress of the European Society for Agronomy, Cordoba, Spain 15–18 July, 433–444.
2. Arhipova I. *et al.* (1997) Mathematical Statistical Task Queue by MS Excel. Part 2. Jelgava Latvia, 1–121 (in Latvian).
3. Baenziger P. S. *et al.* (1985) Effect of cultivar, environment, and their interaction and stability analyses on milling and baking quality of soft red winter wheat. Crop. Sci. 25, 5–8.
4. Bassett L. M. *et al.* (1989) Genotype x environment interactions on soft white winter wheat quality. Agron. J. 81. 955–960.
5. Comstock R. E. and Moll R. H. (1963) Genotype-environment interactions. In: W.D. Hanson and H. F. Robinson, (eds): Statistical Genetic and Plant Breeding. National Academy of Sciences-national Research Council: Washington, Dc. 164–196.
6. Dotlacil L. and Toman K. (1991) The stability of the yield of different wheat varieties. Rostl. Vyr., 37. 33–38.
7. Falkoner D. S. and Mackay T. F. C. (1996) Introduction to Quantitative Genetic. Longman Group: London. 135.
8. Finney P.L. and Bains G.S. (1999) Protein functionality differences in eastern US soft wheat cultivars and interrelation with end – use quality test. Food. Sci. Technol. – Lebensm. – Wiss. Technol. 32(7) 406–415.
9. Grausgruber H. *et al.* (2000) Stability of quality traits in Austrian – grown winter wheats. Field Crops Research, 66, 257–267.
10. Lukow O. M. and McVetty P. B. E. (1991) Effect of cultivar and environment on quality characteristics of spring wheat. Cereal Chem. 68, 597–601.
11. Masauskiene A. *et al.* (2001) Effects of plant protecting substances applied individually or in combination with the nitrogen fertilizers on the quality of winter wheat grain and the quality of dough. Maisto scemija ir technologija: LMaI ir Mokslo darbai. – Kaunas, Lithuania, t. 35, 74–81.
12. Mladenov N. *et al.* (2001) Cultivar – by – environment interactions for wheat quality traits in semiarid conditions. American Association of Cereal Chemists, Vol. 78, 3, 363–367.
13. Linina A. and Ruza A. (2004) Variety and environment effects on quality traits in Latvian – grown winter wheat. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia. 6 : www.cropscience.org.au
14. Peterson C. J. *et al.* (1992) Genotype and environment effects on quality characteristics of hard red winter wheat. Crop Sci. 32, 98–103.
15. Peterson C. J. *et al.* (1986) Influence of cultivar and environment on mineral and protein concentration of wheat flour, bran and grain. Cereal Chem. 63, 183–186.
16. Ruza A. and Linina A. (2001) Nitrogen influence on yield and baking quality of winter wheat. Proceeding 11th Nitrogen Workshop. Reims, France, 521–522.
17. Ruza A. (2003) Relevance of winter wheat yield and quality formation. Nordic Association of Agricultural Scientists, 22nd Congress, July 1–4, 2003, Turku, Finland, 302.
18. Singh, M. *et al.* (1993) Estimation of heritability from trials data. Theor. Appl.Genet. 86, 437–441.
19. Zadoks J. C. *et al.* (1974) A decimal code for the growth stages of cereals. Weed Res. Oxford 14, 415–421.

PHOTOSYNTHETIC WATER USE EFFICIENCY OF SOME CULTIVARS OF MALTING BARLEY UNDER DIFFERENT NITROGEN FERTILIZATION AND SEASON

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Abstract

Photosynthetic Water Use Efficiency (WUE) of three malting barley (*Hordeum vulgare* L.) cultivars grown under 0, 30, 60 and 90 kg N ha^{-1} was measured using portable photosynthetic system. The experiments were carried out in the Experimental Field of the Warsaw Agriculture University on black earth soil in 2000 and 2001. The studied spring malting barley was characterized with changing water economy during the vegetation period, which was manifested in photosynthetic WUE ranging from 0.5 to 7.6 μmol CO_2 mmol H_2O^{-1}. The highest WUE usually coincided with the period from the end of tillering to shooting. The rate of nitrogen used affected positively the photosynthetic WUE of this species. Except for *cv.* Rasbet, photosynthetic WUE of other studied cultivars was modified during most of developmental phases in both vegetation seasons.

Key words: malting barley, photosynthetic WUE, nitrogen fertilization

Introduction

Barley has been known in Poland as the third most widely grown cereal species after wheat and rye (FAOSTAT, 2004). Winter cultivars of this species are used for forage and consumption, while spring ones – malting – also for malt production. In physiological evaluation of barley yielding, especially important are data concerning the process of gas exchange, enabling to determine the scale of photosynthesis and transpiration of plants in the canopy, i.e. data decissive regarding the value of WUE. More often, following Viets (1962), WUE is defined as a ratio of dry matter yield per ha to the amount of water used for producing this yield. This is the basic expression of the index. There are however, in the literature other expressions and formulae of WUE, classified as physiological, agronomic, irrigation, and economic ones (Debaeke, 2002; Steduto, 2002). One of them is photosynthetic WUE (von Caemmerer and Farquhar, 1981) or instantaneous transpiration efficiency (ITE). The latter combines photosynthetic and transpiration intensity and thus describes water economy of plants at the moment of measurement. Plants of economical use of water display higher values of WUE than those of worse ability to save the water, then those that assimilate less CO_2 moles, while releasing to the atmosphere 1 mole of water. Common use of this index stems from an extension to the practise sophisticated infra-red gaz analyzers (Nalborczyk, 1996) that measure the scale of two antagonistic processes taking place in leaf stomata: transpiration of water vapor to the atmosphere and diffussion of carbon dioxide from the atmosphere through stomata to the mesophyll (Raschke, 1976). It is possible to obtain due to some breeding processes cultivars showing more efficient water use (Yoshie, 1986). Also nitrogen, applied as mineral fertilizers can affect the size and morphology of chloroplasts thus increasing activity of photosynthetic apparatus of the plants (Kutik *et al.*, 1993).

The aim of the paper was to determine a pattern of changes in photosynthetic WUE in three cultivars of spring malting barley depending on a differentiated nitrogen fertilization and to find the effect of different and differently distributed rainfall during the vegetation season on the index.

Materials and Methods

Three cultivars of spring malting barley were used: *cv.* Maresi of good technological value of grain and high chlorophyll content, *cv.* Poldek of very good technological value of grain and low chlorophyll content, and *cv.* Rasbet of very good technological grain value and intermediate chlorophyll content (Łoboda *et al.*, 2002). The experiments in randomized blocks with 4 replicates were carried out in the Warsaw Agriculture University's Experimental Field in Chylice (40 km West of Warsaw) on black earth soil in 2000 and 2001. The plots were 5 × 6 m (i.e. 30 m^2). For both years of investigation, the forecrop was potato fertilized with farmyard manure. Winter ploughing was performed on 2.11.1999 and 29.10.2000, while in springtime – on 27.03.2000 and 24.03.2001 – hard harrowing was used. Four rates of nitrogen fertilization (0, 30, 60 and 90 kg N ha^{-1}) were applied as ammonium nitrate. The rates 30 and 60 kg N ha^{-1} were applied before sowing, while the rate 90 kg N ha^{-1} was divided into two parts (60 kg N ha^{-1} before sowing and 30 kg N ha^{-1} at shooting). In autumn, plants were also fertilized with 31.4 kg P ha^{-1} (single superphosphate granulled 18,5%) and 74.7 kg K ha^{-1} (KCl 60%). Sowing was performed on 7.04.2000 and 4.04.2001, respectively. Two weeks after sowing, the plant emergence was observed. Weeds were controlled with the herbicide Aminopielik D450 SLW (active substances 2,4-D and DICAMBA), which was sprayed at the rate 3 dm^3 ha^{-1} at tillering.

Both cropping seasons had different sum of precipitation (43.5 vs 89.3 mm) and its distribution. Total rainfall during the vegetation period (April–June) in 2000 was 11.5, 22.9 and 9.1 mm, respectively, while in 2001 – 19.4, 34.1 and 35.8 mm, respectively. Average monthly temperature for the same period in 2000 was 12.2, 15.1 and 17.6 °C, and in 2001 – 18.5, 11.4, and 11.9 °C, respectively. Therefore 2000 was the season of insufficient and 2001 – of optimal rainfall distributione.

Gas exchange parameters – photosynthetic (μmol CO_2 m^{-2} s^{-1}) and transpiration (mmol H_2O m^{-2} s^{-1}) rates – were measured using portable photosynthetic system Li-6200 (Li-Cor, Lincoln, NE, USA) and afterwards the photosynthetic WUE (μmol CO_2 mmol H_2O^{-1}) was calculated. Measurements were taken for the basic growing phases (Table 1) on the central part of young leaves just after they reached maximum leaf area. There were 12 measurements of gas exchange for each variant of N fertilization at the given developmental phase (3 measurements on each experimental field). Data were elaborated using ANOVA (Statistica), and the Tukey test was used for comparison of means.

Table 1. Basic growing phases of spring malting barley after taking gas exchange measurements

Date		Growing phase	Decimal Code (Zadocks *et al.*, 1974)
2000	2001		
26.04	–	Emergence	DC11
10.05	8.05	Tillering (start)	DC21
24.05	22.05	Tillering (full)	DC25
8.06	5.06	Shooting (end)	DC39
21.06	19.06	Heading (start)	DC51
5.07	3.07	Milk maturity	DC75

Results and Discussion

Photosynthetic WUE of three cultivars of spring malting barley was characterized by large variation of its value depending on terms of measurement throughout vegetation and applied rate of nitrogen. In 2000, the values of WUE varied from 0.5 to 5.7 μmol CO_2 mmol H_2O^{-1}, and in 2001 – from about 1.4 to 7.6 μmol CO_2 mmol H_2O^{-1} (Figs. 1 and 2). At particular developmental stages the highest WUEs were obtained with different rates of nitrogen. In 2000, the highest WUE at DC21 was observed for all three studied cultivars with 60 kg N ha^{-1}. At DC25, the highest WUE was found for *cvs* Maresi and Rasbet with 0 kg N ha^{-1}, while for *cv*. Poldek it was with 90 kg N ha^{-1}. This rate resulted in the highest WUE at DC39 in *cvs*. Maresi and Poldek and at DC51 for *cv*. Poldek. At DC39 and DC51, the highest WUE for *cv*. Rasbet was denoted at 60 kg N ha^{-1}.

In 2001, the highest WUEs for studied cultivars were also obtained with different rates of nitrogen in individual developmental phases. There were indicated both developmental phases and cultivars, where WUEs were the highest, at 0 kg N ha^{-1} (DC51 *cv*. Maresi and DC21, DC51 and DC75 *cv*. Poldek), 30 kg N ha^{-1} (DC75 *cv*. Maresi, DC25 *cv*. Poldek, DC21 and DC39 *cv*. Rasbet), 60 kg N ha^{-1} (DC21, DC25, DC39 *cv*. Maresi, DC25 *cv*. Rasbet), and 90 kg N ha^{-1} (DC25 and DC39 *cv*. Poldek and DC51 *cv*. Rasbet). This year in measurements at DC25 and DC39, of the highest WUE, the greatest values were reached usually with 60 or 90 kg N ha^{-1}. It clearly results from the presented data that it is impossible to show one nitrogen rate that caused the highest WUE value for all analyzed cultivars and phases. Photosynthetic WUE varied, probably, depending on the weather conditions. The results of the undertaken research indicate the values of WUE for spring barley in dry season for each phase of vegetation were lower than in the case of the year of optimal rainfall distribution (see also Łoboda *et al.*, 2000), except for DC 21 when they were similar (Table 2). No clear effect of analyzed cultivars upon WUE was found (Tables 2 and 3).

In both vegetation seasons the mean values of WUE of spring barley plants were increasing with increase in nitrogen rate from 0 to 60 kg N ha^{-1} almost in all developmental phases (Table 3). The highest mean values of WUE (Table 2) were observed in 2000 at DC39 (4.35 μmol CO_2 mmol H_2O^{-1}, just after rainfall) and in 2001 at DC25 (5.58 μmol CO_2 mmol H_2O^{-1}) and DC39 (5.11 μmol CO_2 mmol H_2O^{-1}), which suggests that the values of WUE for spring barley are highest during full tillering to the end of shooting, i.e. during culm elongation.

The mean WUE values of studied cultivars taken for individual developmental phases in 2000 were lower than in 2001, with the exception of mean WUE at DC21 (Table 2), e.g. the average WUE in 2000 and 2001 was for *cv.* Maresi – 2.16 and 3.68, for *cv.* Poldek – 2.24 and 3.76, and for *cv.* Rasbet – 2.42 and 3.36 μmol CO_2 mmol H_2O^{-1}, respectively (Tables 2 and 3).

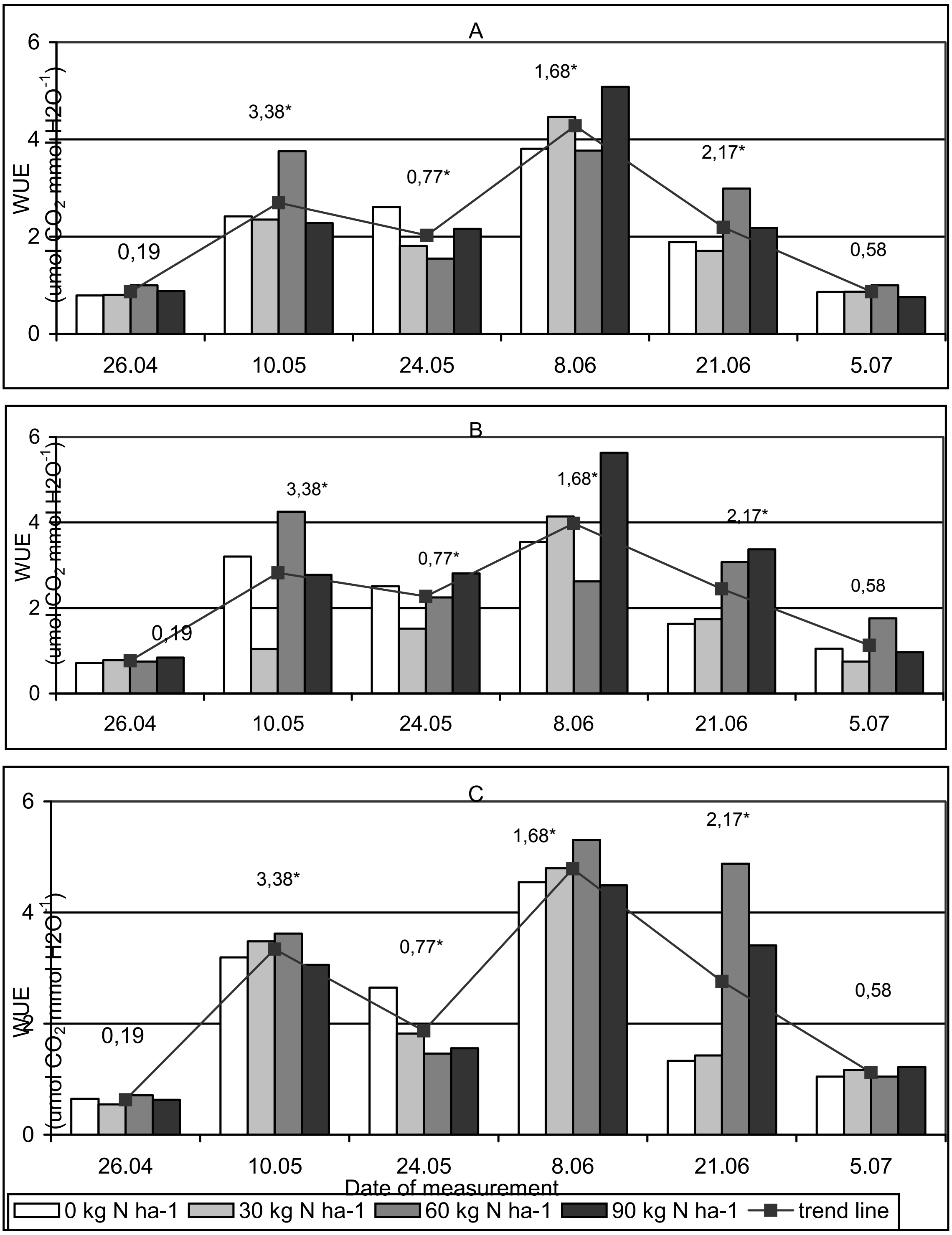

Figure 1. The influence of nitrogen dose on WUE of three malting barley cultivars (A – Maresi, B – Poldek, C – Rasbet) grown in 2000. For each date, maximal $LSD_{0,05}$ of Tukey is presented (significant differences are denoted as "*")

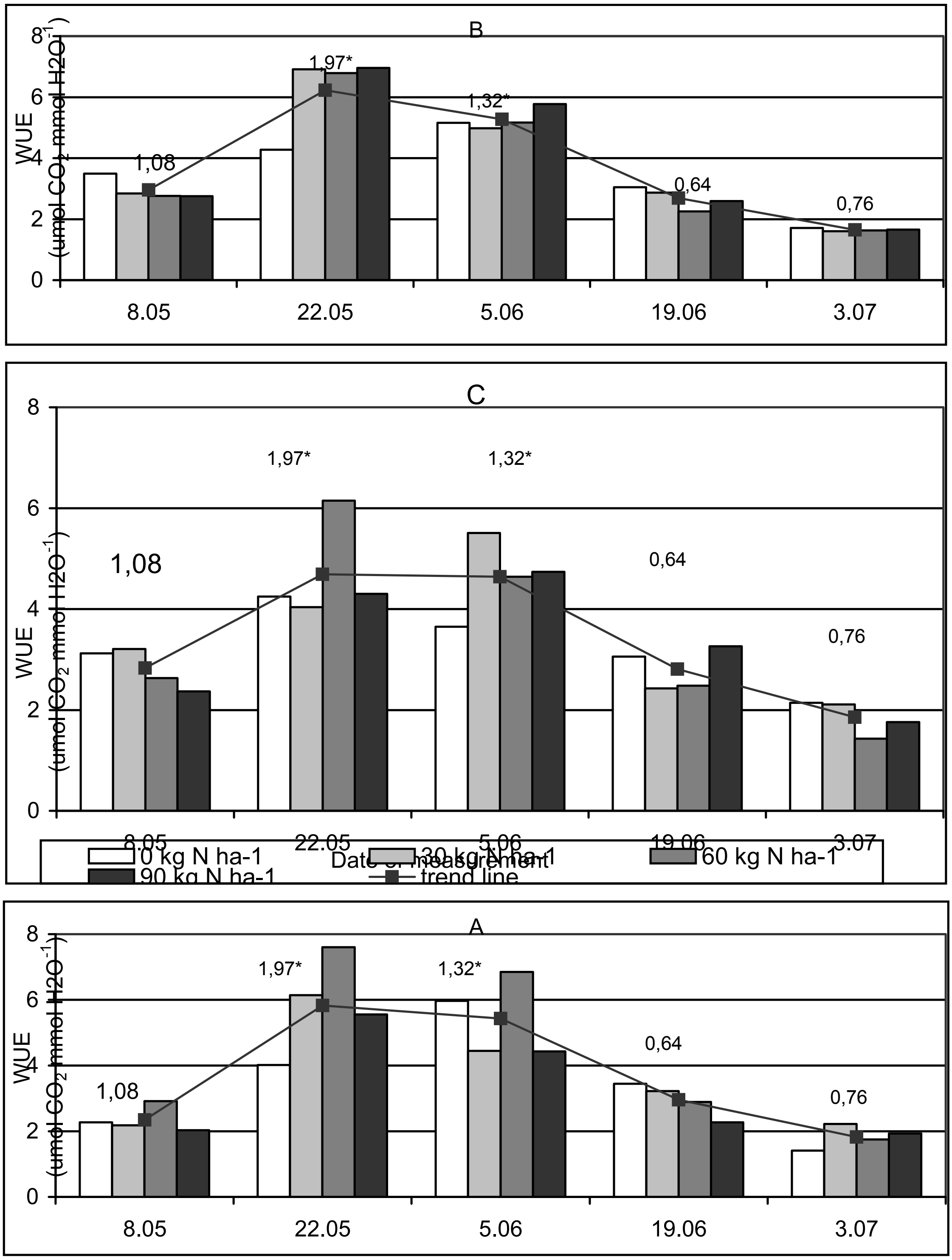

Figure 2. The influence of nitrogen dose on WUE of three malting barley cultivars (A – Maresi, B – Poldek, C – Rasbet) grown in 2001. For each date, maximal $LSD_{0,05}$ of Tukey is presented (significant differences are denoted as "*")

The obtained data did not prove the expectation that barley had saving economy of water use, based upon a suggestion of Gąsiorowski (1997) that this species is the most xeromorphic among the cereals. On the opposite, temporal rainfall as in 2000 before DC39 promoted high WUE, thus proving that water use efficiency of spring malting barley is higher when the water conditions are more optimal than under-drought conditions.

In the experiments, a slight increase in WUE was observed due to increase in the used nitrogen rate. Ripullone *et al.* (2004) showed in Douglas-fir and poplar that the response of WUE to nitrogen supply was mainly related to a possitive effect of nitrogen on photosynthetic rates. Probably that was the case in spring malting barley, where abundant water supply (see rainfall data) enabled the effective nitrogen use. The astonishing positive response of some cultivars to the 0 rate of nitrogen (biological rate) at the beginning of vegetation might be connected to the use of the amount of nitrogen stored in the soil earlier.

Table 2. Mean values of WUE (μmol CO_2 mmol H_2O^{-1}) of 3 spring barley cultivars for each time of measurement

2000							
	26.04	10.05	24.05	8.06	21.06	5.07	Mean
Maresi	0.87	2.70	2.03	4.28	2.19	0.87	2.16
Poldek	0.77	2.82	2.27	3.98	2.45	1.13	2.24
Rasbet	0.63	3.34	1.87	4.79	2.76	1.12	2.42
Mean	0.76	2.95	2.06	4.35	2.47	1.04	2.27
2001							
		8.05	22.05	5.06	19.06	3.07	Mean
Maresi	–	2.35	5.83	5.43	2.96	1.83	3.68
Poldek	–	2.96	6.23	5.27	2.69	1.65	3.76
Rasbet	–	2.83	4.69	4.64	2.81	1.86	3.36
Mean	–	2.71	5.58	5.11	2.82	1.78	3.60

Table 3. Mean values of WUE (μmol CO_2 mmol H_2O^{-1}) of 3 spring barley cultivars for each nitrogen rate

	2000				2001			
	Maresi	Poldek	Rasbet	Mean	Maresi	Poldek	Rasbet	Mean
0 kg N ha^{-1}	2.06	2.11	2.24	2.14	3.42	3.54	3.25	3.40
30 kg N ha^{-1}	2.00	1.66	2.21	1.96	3.64	3.84	3.46	3.65
60 kg N ha^{-1}	2.34	2.45	2.84	2.54	4.40	3.72	3.47	3.86
90 kg N ha^{-1}	2.22	2.73	2.39	2.45	3.24	3.95	3.29	3.49
Mean	2.16	2.24	2.42	2.27	3.68	3.76	3.36	3.60

The photosynthetic WUE can be stable for individual developmental phases for barley, although it can undergo some modification under weather and agrotechnical conditions. In our experiments, only *cv.* Rasbet showed nearly the same pattern of WUE changes for both years, the only difference was at DC25. The similar within the years values of WUE of all studied barley cultivars showed that their water economy was nearly the same. The obtained data confirmed that photosynthetic WUE is a good indicator of barley water economy during the whole vegetation period.

Conslusions

Photosynthetic WUE of spring malting barley depended on weather conditions of the vegetation season.

The highest WUE coincided with the culm elongation period.

Nitrogen fertilization at the rate from 0 to 60 kg N ha^{-1} slightly increased the WUE in both vegetation seasons, while the rate of 90 kg N ha^{-1} did not cause any increment of WUE.

Cultivar Rasbet had a similar pattern of photosynthetic WUE changes during most of developmental phases, independently of weather conditions, while the WUE of other cultivars was substantially modified by the vegetation season.

Photosynthetic WUE is very sensitive to temporal rainfall which usually increases it.

References

1. Debaeke P. (2002) Crop management adaptation to water-limited environments. VII Congress European Society for Agronomy, 15–18.07.2002, Cordoba, Spain, 33–44.
2. FAOSTAT (2004) www.fao.org
3. Gąsiorowski H. (1997) Pochodzenie, rozpowszechnienie, systematyka jęczmienia. In: Jęczmień chemia i technologia. Red. Gąsiorowski H. PWRiL. Poznań, 27–37.
4. Kutik J. *et al.* (1993) Chloroplast ultrastructural development during the ontogeny of the second leaf of wheat under nitrogen deficiency. Photosynthetica, 28, 447–453.
5. Łoboda T. *et al.* (2000) Określenie potencjału plonowania wybranych odmian jęczmienia jarego browarnego. Biuletyn IHAR, 215, 141–152.

6. Łoboda T. *et al.* (2002) Gas exchange of spring brewer's barley leaves depending on PAR instensity and nitrogen level. VII Congress European Society for Agronomy, 15–18.07.2002, Cordoba, Spain, 689–690.
7. Nalborczyk E. (1996) Dobór i wykorzystanie nowoczesnej aparatury kontrolno-pomiarowej w doświadczeniach polowych. Zeszyty Problemowe Postępów Nauk Rolniczych, 447, 81–90.
8. Raschke K. (1976) How stomata resolve the dilemma of opposing priorities? Philosophical Transactions of Royal Society London, 273, 551–560.
9. Ripullone F. *et al.* (2004) Variation in nitrogen supply changes water-use efficiency of *Pseudotsuga menziesii* and *Populus* x *euroamericana*; a comparison of three approaches to determine water-use efficiency. Tree Physiology, 24, 671–679.
10. Steduto P. (2002) Water productivity of plants and molecular biology: An Eco-Physiologist Point of View. VII Congress European Society for Agronomy, 15–18.07.2002, Cordoba, Spain, 51–56.
11. Viets, F. G. Jr. (1962) Fertilizer and the efficient use of water. Advances in Agronomy, 14, 223–264.
12. von Caemmerer S., Farquhar G. D. (1981) Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. Planta, 153, 376–387.
13. Yoshie F. (1986) Intercellular CO_2 concentration and water use efficiency of temperate plants with different life-forms and from different microhabitats. Oecologia, 68, 370–374.
14. Zadoks J. C. *et al.* (1974) A decimal code for the growth stages of cereals. Weed Research, 14, 415–421.

THE OIL CONTENT AND STEROL COMPOSITION OF SPRING OILSED RAPE SEEDS

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Abstract

Rapeseed (*Brassica napus* L. var. *oleifera* subvar. *annua*) is now the third most important source of vegetable oil in the world. While the growing area of rapeseed in Estonia has increased tremendously in the last two decades, the yields have remained relatively low. In Estonia, it is mainly grown for oil (cooking, salad dressings, etc.) and for protein-rich animal feed. Having very low content of saturated fatty acids and a relatively high content of polyunsaturated fatty acids and also being one of the richest sources of phytosterols, makes rapeseed oil very valuable from nutritional point of view. The goal of present research was to investigate the oil content of seeds according to fertilization and phytosterol content in oil of the spring rapeseed cultivar 'Mascot'. In the trials different microfertilizers were used. At harvest, the seed samples were collected. The oil content of seeds and the sterol content of the oil were analyzed. The analysis of the test results revealed that fertilizer solutions with different microelements had positive effect on the oil content of rape seeds. The total sterol content of the oil from cultivar 'Mascot' varied between 5220–6550 mg kg^{-1}. It was mainly influenced by weather (different year), while the use of different fertilizers did not have clear influence on the concentration and composition of sterols in oil.

Key words: rapeseed, microfertilizers, oil content, sterol composition

Introduction

Rapeseed (*Brassica napus* L. var. *oleifera* subvar. *annua*) is now the third most important source of vegetable oil in the world. While the growing area of rapeseed in Estonia has increased tremendously in the last two decades, yields have remained relatively low. In 2003, the average rapeseed yield in Estonia was 1494 kg ha^{-1}. Low yields are mainly due to misjudgements in agrotechnical principles.

In Estonia, the rapeseed is mainly grown for oil (cooking, salad dressings, etc.) and for protein-rich animal feed. Having very low content of saturated fatty acids and a relatively high content of polyunsaturated fatty acids and also being one of the richest sources of phytosterols, makes rapeseed oil very valuable from a nutritional point of view.

Well-balanced fertilisation is needed to reach the variety's potential oil content. Growing 1 ton of conditioned seeds requires 55 kg of nitrogen, 25 kg of phosphorus, 50 kg of potassium and 20 kg of sulphur. Besides principal mineral fertilizers, rape is very exacting to microelements as well – it needs 3–5 times more calcium, boron, magnesium and manganese than corn (Velička et al., 2001; Kaarli, 2004). Either too little or too much of available microcomponents could reduce the plant yield as much as the lack of nitrogen (Malhi et al., 2000).

Plant sterols have gained a lot of interest in recent years. It is mainly because of their cholesterol-lowering effect in human blood serum, therefore they are used as active compounds in medicaments for cardiovascular diseases. Various other important applications, for example cure for some forms of cancer (Moreau et al., 2002), are also known. Sterols are not only manufactured as medicaments but as active ingredients in various functional foods. There is an everlasting search for rich sources of natural sterols. Sterols from wood industry's tall oil and soya oil deodorisation destillate have mostly been used so far.

There are only few articles published on different factors affecting the sterol content in plants. Nevertheless, a lot of authors have mentioned that genetic backround, fertilization, weather parameters, growing medium as well as some oil refining steps could have a possible effect on sterol content and composition. Therefore, information about the phytosterol content in local rapeseed oil is needed, and due to emergence of many small-scale cold-pressing oil enterprises where the origin of the seeds could be detected, this information becomes more important.

The goal of this research was to investigate the effect of microfertilisers on the oil content of the seeds of spring rapeseed cultivar 'Mascot' and also to determine the phytosterol level in local rapeseed oil and find the possible factors affecting it.

Materials and Methods

In order to investigate the oil content of seeds and the phytosterol content in oil of the spring rapeseed cultivar 'Mascot', field trials were carried out at the Department of the Field Crop Husbandry at EAU in

2001–2003. Technical data of the variety 'Mascot': raw fat content 40–43%, mass of 1000 grains 3.5–4.5 g, growth period 90-108 days (Velička, 2003). The soil type was pallescent soil LP (Kõlli, Lemetti, 1994), a glossisol by FAO classification, and a Stagnic Luvisol by WRB classification (Deckers et al., 1998). The trial soil was neutral – pH_{KCl} 6.2, humus 2.4%, available phosphorus 77.7 mg kg^{-1} (AL), mobile potassium 169.8 mg kg^{-1} (AL), calcium 5,648.0 mg kg^{-1}, and sulphur 13.5 mg kg^{-1} of the soil.

The trial was carried out in 4 replications and the size of plots was 10 × 1 m. Seeds were sown by calculating 200 germinating seeds per m^2, sowing depth was 2–3(4) cm, pre-crop – potato. Prior to the sowing, the field was sprayed with intra-soil herbicide EK Trifluralin (0.15 l ha^{-1}) and mineral complex granular combined fertiliser OptiCropNPK 21-08-12-S-Mg-B-Ca, calculating 120 kg of the active substance agent of nitrogen per hectare (0- and 0+Fastac- variants excluded). To control pest insects, Fastac was used, calculating 0.15 l ha^{-1} (active substance agent). The trial variants were as follows: 0 (no pesticides or mineral fertilizers were used); 0+Fastac (no fertilizers were used, insect pest control with Fastac was performed); Mn (HydroPlus^{TM} Micro Manganese, active substance agent 1 l ha^{-1}); B (HydroPlus^{TM} Micro Boron, active substance agent 2 l ha^{-1}); Cu (HydroPlus^{TM} Micro Copper, active substance agent 0.5 l ha^{-1}); Mo (HydroPlus^{TM} Micro Molybdenum, active substance agent 0.25 l ha^{-1}); S (Sulphur F3000, active substance agent 7 l ha^{-1}); Mg (Hydromag 300, active substance agent 7 l ha^{-1}); MicroRape (HydroPlus^{TM} Micro Rape, active substance agent 2 kg ha^{-1}). Liquid microfertilizers (water amount of 400 l ha^{-1}) were sprayed on rapeseed field when the plants had reached growth stage 27-31 according to BBCH scale (Lancashire et al., 1991).

Rapeseed was harvested and seed samples were collected for oil and phytosterol analysis. Oil content of the seeds was determined for a 2-year period (2002–2003). Oil content was analyzed at the Jõgeva Plant Breeding Institute by using NIR-spectroscopy. For statistical data analysis ANOVA was used.

Sterol analysis. The method for phytosterol analysis was worked out by using and optimising analytical steps known from the literature. Total sterols and sterols in a free form were determined. For quantification of sterols, internal standard method was used. Sterol content and composition was detected over a 3-year period (2001-2003), and 6 different microfertilizers were used as variants. Only 3 major sterols (β-sitosterol, campesterol, brassicasterol), which take up about 90% of all the plant sterols in rapeseed oil, were determined. As sterols occur in vegetable oils in a free form or bound with fatty acids, the amount of both forms was calculated.

Sample treatment. For total sterol analysis, the dried seeds were cold-pressed and oil samples (each 500 mg) were taken in 3 replications. 200 µl of internal standard solution (500 mg of cholesterol in 100 ml of ethanol) was added. After addition of 0.5 ml KOH solution (60% in water) and 4.5 ml of ethanol, the oil samples were hydrolyzed for 45 minutes at 70 °C. Then 3 g of silica was added and the reaction mixture was evaporated to dryness. Afterwards, 1 g of Na_2SO_4, 1 g of silica and 3 g of silica with the sample were loaded onto glassfilter and eluted with 20 ml of ethyl acetate/diethyl ether mixture (1:1). The solvents were evaporated, 1 ml of dichloromethane was added. 1 µl of sample mixture was injected into the gas chromatograph.

For analysis of sterols present in free form, oil samples of 250 mg were taken. 200 µl of cholesterol in ethanol and 3 ml of dichloromethane were added. A 10 ml solid-phase extraction (SPE) cartridge, filled with 30 µm of silica, was conditioned with 10 ml of hexane/ethyl acetate mixture (80:1), and 3 ml of sample was loaded. Then, the cartridge was eluted with 20 ml of hexane/ethyl acetate mixture (80:1) and with 30 ml (20:1), and finally the sterol fraction was collected with 20 ml of hexane/ethyl acetate mixture (3:1). The solvents were evaporated, 1 ml of dichloromethane was added. 1 µl of sample mixture was injected into the gas chromatograph.

Gas chromatography. GC analysis was performed on HP5890 instrument, using 25 m × 0.25 mm, i.d. 0.22 µm, BP-5 fused silica capillary column. Nitrogen was used as carrier gas. The temperature program was used (320–340 °C, 5°C/min, total time 20 min). Injector – 350 °C, flame-ionization detector – 360 °C.

Results and Discussion

Oilseeds of good quality contain 40-44% of oil. It depends on many factors: variety, growth environment, agrotechnics, fertilization, etc. Plant scientists have found that among more than 100 known chemical elements, there are 16 that are essential for the growth of all the world's major crops. All of the essential chemical elements found in any particular plant come from soil, water and air around the plant. In estimating fertilizer requirements for oilseed rape, growers use soil tests, field cropping history, balance sheets based on estimated nutrient removal, plant testing to assess the crop nutrient status and test stripes in fields to see if adequate fertilizer has been applied (http://ssca.usask.ca, 2004). To produce seeds of good quality, special attention must be paid to the rate, placement and timing of fertilizer application. Rape should be fertilized according to the data of soil agrochemical analysis. Harvest forming depends on both the lack of fertilizers and excessive fertilization (Velička et al., 2001). Also deficiencies of micronutrients as boron, manganese, copper and molybdenum could reduce the oilseed yield (Hocking et al., 1999).

Table 1. The oil content in oilseed rape seeds, % per DM

Variant	2002		2003		Average	
	Oil content, %	d	Oil content, %	d	Oil content, %	d
0 (control)	43.1	0.0	40.8	0.0	41.9	0.0
0+Fastac	43.9	0.9	41.6	0.8	42.8	0.8
OptiCrop+Boron	44.2	1.1	40.8	0.0	42.5	0.6
OptiCrop+Hydromag	42.7	–0.3	41.6	0.8	42.2	0.2
OptiCrop+Manganese	43.6	0.5	42.9	2.1	43.2	1.3
OptiCrop+Micro Rape	43.7	0.7	41.7	0.8	42.7	0.8
OptiCrop+Molybdenum	43.4	0.3	43.4	2.5	43.4	1.4
OptiCrop+Copper	43.1	0.0	41.0	0.2	42.0	0.1
OptiCrop+Sulphur	44.5	1.5	40.7	–0.1	42.6	0.7
LSD_{05}		1.9		3.8		2.1

The oil content of spring rapeseed cultivar 'Mascot' was determined and the effect of microfertilizers was investigated. Foliar application of different micronutrients had an influence on oil content in rape seeds.

In years 2002–2003, oil content in the seeds dry matter varied between 40.7–44.5% (Table 1). Compared to the 0-variant, all the micronutrients had positive effect on oil content in the seeds. The strongest influence was exerted by elements like manganese and molybdenum. The more deficient a compound in soil, the more effective is additional fertilization with foliar application. According to this, it is advisable to spray the leaves with liquid microfertilizers when plants have the biggest leaf area (growth stage 27–31) and the ability to assimilate is higher.

Different seed samples were further characterized by their oil phytosterol content. In the present research, the effect of weather and fertilizers on the plant sterol content and composition was evaluated. The total sterol content of oil samples varied between 5220 and 6550 mg kg^{-1}, the main sterol being β-sitosterol followed by campesterol and brassicasterol. The average relative standard deviation was 4.0%.

The amount of sterols present is decided by the intensity of their biosynthesis and their role in the plant cell. Free sterols are present in cell membrane bilayer where they regulate the fluidity of the membrane and therefore also the transport of different compounds through the cell. Steryl esters are probably the deponated forms of sterols inside the cell. It is also known that plants use phytosterols for adaptation to different temperatures (Piironen et al., 2000).

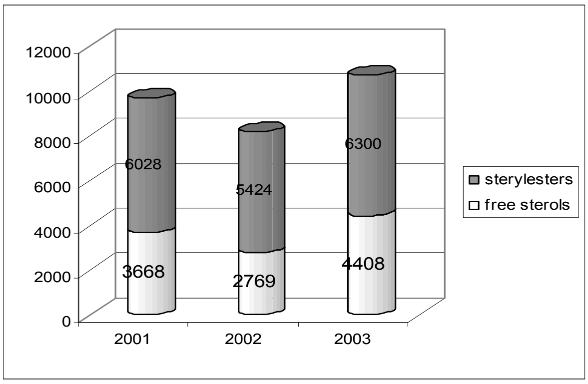

Figure 1. The sterol content (as free sterols and steryl esters) of oil from spring rapeseed variety 'Mascot' in 2001–2003, mg kg^{-1}

It was found that the weather during the growing cycle of rapeseed had a clear impact on sterols. Summer in 2002 was extremely dry and hot, totally opposite to the vegetation period in 2003, while summer in 2001 had average weather conditions. It was found that the total sterol content varied between 5220–5770 mg kg^{-1} in 2002 and 5910–6550 mg kg^{-1} in 2003 (Figure 1).

It is rather difficult to assess the influence of different weather factors on the sterol content. It is known that the sterol levels could change drastically in some plants due to long drought periods, but linear interpolations could not be made for less extreme weather conditions.

There are a couple of articles about the effect of temperature during the growing period of soya on the total sterol content. Scientists have found a positive correlation of sterol and higher temperature values (Vlahakis et al., 2000). The present research indicates rather the opposite. In 2003, the average temperatures were lower than in the two previous years, but the total sterol content in oil samples was higher. This may be due to the effect of other factors including precipitation, soil parameters, fertilization, etc.

The ratio of free sterols to steryl esters is usually 1/3 to 2/3 according to the literature (Lampi et al., 2004). The amount of different forms of sterols could change due to the plants' need to adapt to various conditions. Knowing the ratio is mainly necessary for manufacturing functional food products. Results obtained in the present research fall into the category described in the literature.

Table 2. The content of total β-sitosterol in different oil samples in 2001–2003, mg kg^{-1}

Variant	β-sitosterol, mg kg^{-1}			Average
	2001	2002	2003	
0 (control)	–	2540	2970	2760
OptiCrop+Copper	2820	2630	2670	2700
OptiCrop+Boron	2690	2500	2760	2650
OptiCrop+Manganese	2690	2370	2890	2650
OptiCrop+Sulphur	–	2440	2890	2670
OptiCrop+Micro Rape	2430	2660	2730	2610
Average	2660	2520	2820	2670

There are two important issues from the fertilization point of view. Does the fertilization, which ensures good development of the rapeseed plant and high oil yield with good quality parameters, also provide bigger amount of plant sterols? Does the fertilization with certain element(s) influence the sterol content and composition in plants? The effect of different microfertilizers on sterol levels was investigated during a 3-year period. The dynamics of the main sterol (β-sitosterol) is given below (Table 2). Significant variations were found but no certain influence could be detected over the research period. The correlations between oil yield and total sterol content were not observed too.

No influence of various micronutrients on different forms of sterols and overall distribution of individual sterols was found.

Conclusions

It was found that different micronutrients and the mixture of microfertilizers in the trial had a positive effect on the seed oil content. Foliar application of manganese and molybdenum increased the oil content in the seeds by more than one percent.

The weather during the growing period influenced the total content of sterols in rapeseed oil samples. The sterol content of oils from the investigated rape seeds, where various fertilizers were used, showed variations but the effect of different fertilizers on sterols could not be interpreted clearly.

References

1. Deckers, J. A. et al. (Eds.) (1998) World Reference Base for Soil Resources. Introduction. ACCO Leuven, 165.
2. Ferrari, R. A. et al. (1997) Alteration of Sterols and Steryl Esters in Vegetable Oils during Industrial Refining. Journal of Agricultural and Food Chemistry, 45, 4753–4757.
3. Hocking, P. et al. (1999) Crop nutrition. Proceedings of the 10th International Rapeseed Congress, Canberra, Australia,15–22.
4. Kaarli, K. (2004) Õlikultuuride kasvataja käsiraamat. Saku, OÜ Greif, 131.
5. Kõlli, R. and Lemetti, I. (1994) Eesti muldade lühiiseloomustus I. – Normaalsed mineraalmullad, EPMÜ, Tartu: Trükokoda Tartumaa, 122.
6. Lampi, A-M. et al. (2004) Analysis of Phytosterols in Foods. In: Phytosterols as Functional Food Components and Nutraceuticals (Editor P. C. Dutta). New York, Marcel Dekker, Inc., 33–70.
7. Lancashire, P. D. et al. (1991) A uniform decimal code for growth stage of crops and weeds. Ann. Appl. Biol., 119, 561−601.
8. Malhi, S. S., and Leach, D. (2000) Restore Canola Yield by Correcting Sulphur Deficiency in the Growing Season. Proceedings from the 12th Annual Meeting, Conference and Trade Show of the Saskatchewan Soil Conservtion Association, http://ssca.usask.ca/conference/2000proceedings/Malhi.html.
9. Moreau, R. A. et al. (2002) Phytosterols, phytostanols and their conjugates in foods: structural diversity, quantitative analysis and health-promoting uses. Progress in Lipid Research, 41, 457–500.
10. Piironen, V. et al. (2000) Plant sterols: biosynthesis, biological function and their importance to human nutrition. Journal of Science of Food and Agriculture, 80, 939–966.
11. Quilez, J. et al. (2003) Potential uses and benefits of phytosterols in diet: present situation and future directions. Clinical Nutrition, 22 (4), 343–351.
12. Velička, R. et al. (2001) Agrotechnics of winter rape grown for seeds. Conference on sustainable agriculture in Baltic States. Proceedings of the International Conference. Tartu, 214–221.
13. Velička, R. (2003) Rape. Summary of monograph, presented for habilitation confer. Lithuanian University of Agriculture, Kaunas. 78.
14. Vlahakis, C. and Hazebroek, J. (2000) Phytosterol Accumulation in Canola, Sunflower and Soybean Oils: Effects of Genetics, Planting Location and Temperature. Journal of the American Oil Chemists' Society, 77 (1), 49–53.
15. http://ssca.usask.ca/Fertility/FertilityIntro.htm (2004).

CONTAMINATION OF GRAIN OF VARIOUS MAIZE HYBRIDS WITH MYCOTOXINS DEOXYNIVALENOL, ZEARALENONE AND MOULD FUNGI

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Abstract

Fungi-infection of grain of various maize hybrids was tested at the Lithuanian Institute of Agriculture over the period 2003–2004. Grain of 7 maize hybrids (62 samples), harvested at hard maturity stage were analysed. The following species of fungi were identified in maize grain: *Fusarium, Alternaria, Penicillium,* and *Cladosporium.* In 2003*, Alternaria* and *Cladosporium* fungi dominated in the grain of maize hybrids, the percentage of infected grain was found to be 57.0–100.0, and 38.0–98.5%, respectively. *Penicillium spp*. prevailed in the maize grain harvested in 2004. *Fusarium* incidence in the grain of different maize hybrids was diverse. In 2003, the most heavily *Fusarium spp*. infected grain was identified for the hybrid Bixx (35.0%). The grain infection by *Fusarium spp*. on other maize hybrids was lower (3.0–26.5%). *F. sporotrichioides* and *F. avenaceum* were found in the grain of five maize hybrids: *F. culmorum* in four, *F. graminearum* and *F. poae* in 2–3 maize hybrids in 2003. *Fusarium spp*. fungi were not prevalent in the grain of various maize hybrids in 2004, however, low contents of DON and zearalenone ZEN were identified. Having harvested the crop 3 weeks later, a significant increase in *Fusarium spp*. fungi occurred, but this did not have any effect on the production of DON. The grain contamination of maize hybrid Dixxit with ZEN was moderately high (0.069 ppm).

Key words: maize hybrids, grain, mould fungi, mycotoxins

Introduction

Fungi are a major cause of spoilage in stored grain. The Food and Agriculture Association estimates that 25% of the world's food crops are affected by mycotoxins – the by-products of fungal growth during growth and storage. The damage of fungi is second only to that caused by insects in stored grain products (Miller and Trenholm, 1994). *Aspergillus, Penicillium, Fusarium, Alternaria* are examples of fungi that commonly infest crops. Contamination by these fungi can occur during growing season and as well as during storage.

Moulds, depending on type, can grow under a wide range of environments. The general conditions needed for *Fusarium spp*. field moulds to proliferate are high humidity (>70%), oxygen and temperatures that fluctuate between hot days and cool nights (Seglar, 2001). *Fusarium spp*. does not grow in maize at less than 18 to 20% of grain moisture (Munkvold and Desjardin, 1997). Interest in *Fusarium* species has started with the observed relationship of *Fusarium spp*. infected grain and animal toxicoses (Christensen and Meronuck, 1986).

Fusarium species are the most important group of mycotoxigenic moulds. They are most often encountered as contaminants of cereal grains, oilseeds and beans. The mycotoxins produced by *Fusarium spp*. include deoxynivalenol, zearalenone, nivalenol, and T-2 (Rotter and Prelusky, 1996; Miedaner and Schneider, 2001).

Mycotoxins is a chemically diverse group of compounds produced as secondary metabolites of certain fungi that may commonly infest agricultural produce. The presence of visual mould in grain does not necessarily mean that mycotoxins are present in the sample. Mould growth indicates that there are some fungi present. Many of the fungi grow under similar conditions and more than one kind of fungi can exist in or on the grain at the same time. When more than one fungus is present at the same time on the same host, they sometimes increase the toxic effects of each other by attacking different bodily functions when ingested by a human or animal. They can cancel each other out by growing and attacking each other during the growth process. The toxic by-product of moulds can remain in the kernel (USDA, 1999). Mycotoxins are predominantly a field rather than storage problem. Mycotoxin levels can vary significantly from field to field (Rankin and Grau, 2001). The production of mycotoxins in corn (*Zea mays* L.) is often influenced by moisture, temperature, and nutrient factors unfavorable to corn (Miller *et al.*, 1983).

The aim of our research work was to estimate maize grain contamination with toxic fungi, infection level of these fungi and mycotoxins content in the grain of maize hybrids under Lithuanian conditions.

Material and Methods

The field trials were conducted at the Department of Soil and Crop Management. The grain fungal infection and content of mycotoxins in various maize hybrids were investigated at the Lithuanian Institute of Agriculture's Laboratory of Microbiology, Department of Plant Pathology and Protection during 2003–2004.

Over the period 2003–2004, the grain of seven maize hybrids Dixxit, Baxxao, Trumph, Daxxar, Dixmo, Cixxom, and Bixx were tested. The grain was tested for surfaces contamination, infection level and species composition of mycofungi. The content of mycotoxins was tested in the grain of three maize hybrids: Baxxao, Dixxit, Trumph in 2003 and Baxxao, Dixxit, Daxxar in 2004. In 2004, grain samples from growing three maize hybrids were taken in two times: on 15 October and three weeks later.

The samples of the maize grain for the mycological investigations were taken from each plot. For the evaluation of grain surface contamination by fungi, dilution plating method has been used. Ten grams of each sample was suspended in 100 ml of sterile distilled water. A 1 ml sample of this feed suspension was used to prepare a dilution series from 1:1000. Dilution was uniformly dispensed under the surface of acidified potato dextrose agar (PDA) in Petri-dishes and incubated for 3–5 days at 25 ^{o}C in darkness. After incubation, the number of colonies was calculated and expressed in colony-forming unit per g of grain (cfu g^{-1}). Similarly, individual kernels from a 50 g sample of grain were surface sterilized before plating as follows: grains were immersed in 70% ethanol for 5 min, rinsed three times in sterile distilled water and dried before plating. The sterilized material (5 grains per plate, ten plates per sample) were plated on the same medium and incubated under the same conditions. The infection level of maize grain was evaluated in percent (0 – all grain healthy, 100% – all grain infected). Microscopic studies of fungi were carried out in order to determine their species composition. Fungal species were determined according to Саттон *et al.* (2002), Mathur and Kongsdal (2003), Malone and Muskett (1997), Lugauskas *et al.* (2002), and ISTA (2003). All investigations of grain fungal flora have been made according to Rabie *et al.* (1997) and Samson *et al.* (1992).

Determination of the concentration of deoxynivalenol (DON) and zearalenone (ZEN) was carried out in eighteen samples of maize grain. The level of mycotoxins DON and ZEN was determined by ELISA method. NEOGEN diagnostic tests were used for the estimation of mycotoxins. For the reading of immunoenzymic microstrips we used MULTISCAN MS. The reference contents of mycotoxins DON and ZEN are presented in Table 1 for the estimation of mycotoxins contamination level (Offenbacher, 2001).

Table 1. Identification of DON and zearalenone content by ELISA method

Evaluation	Not found or low contamination	Medium	High	Reference value (ppm)
Level	0	1	2	
		Deoxynivalenol (DON)		
ppm	<0.33	0.33–1.0	>1.0	1.0
		Zearalenone (ZEN)		
ppm	<0.05	0.05–0.15	>0.15	0.05

For the statistical processing of data we applied ANOVA (Tarakanovas, Raudonius, 2003). For the reliability of the data Fisher test was used. Averages for the other data were calculated.

Results and Discussion

The total contamination with colony forming unit (cfu) was established only in 2004. Most contaminated was maize hybrid Cixxom – 4.4 cfu $g^{-1} \times 10^{3}$. The contamination by grain of other hybrids was lower – 0.6–1.5 cfu $g^{-1} \times 10^{3}$ (Table 2). There were found 16–50% infected by *Penicillium spp*. maize grain. Infection with other mould species on maize grain was lower: 6–14% of grain was infected by *Cladosporium spp*., and only 2–4% by *Alternaria* spp. *Fusarium* fungi was not found on the grain of maize hybrids. The main species of fungi in 2003 were *Cladosporium, Alternaria,* and *Fusarium.* The grain of maize hybrid Trumph was 100% infected by *Penicillium spp*. The grain of maize hybrids Cixxom, Bixx, and Baxxao was not infected by this fungus at all. The level of *Fusarium* fungi infection on grain of maize hybrids was varied. The grain of maize hybrids Baxxao, Bixx and Daxxar had a high level of *Fusarium* fungi – 25–35% infected grain, and the grain of maize hybrids Trumph and Dixmo only 3–8.5%. There were found high levels of *Cladosporium* fungi infection on the grain of maize hybrids (38–98.5%). The level of *Alternaria* species fungi infection was the lowest on the grain of maize hybrid Dixmo (18.5%) and the highest on the grain of maize hybrid Cixxom (65.0%).

Table 2. The concentration of total fungi and species composition of fungi on the maize grain Dotnuva, 2003–2004

Maize hybrid	Colony forming unit, $g^{-1} \times 10^3$	Percentage of infected grain, %				
		Fusarium spp.	*Alternaria spp.*	*Penicillium spp.*	*Cladosporium spp.*	Other *spp.*
2003						
Daxxar	–	25.0	38.5	6.0	98.5	22.0
Dixxit	–	10.0	45.0	6.0	88.0	33.5
Dixmo	–	8.5	18.5	14.0	87.0	17.0
Cixxom	–	11.5	65.0	0	93.5	13.5
Bixx	–	35.0	46.5	0	91.5	8.5
Baxxao	–	26.5	41.5	0	56.5	17.0
Trumph	–	3.0	20.0	100.0	38.0	12.0
Experimental mean	–	17.1	39.3	18.0	79.0	17.6
2004						
Daxxar	1.4	0	0	6.7	2.0	4.0
Dixxit	0.6	0	0	31.3	6.7	0
Dixmo	0.6	0	2.0	36.0	6.0	8.0
Cixxom	4.4	0	4.0	50.0	10.0	16.0
Bixx	0.6	0	2.0	24.0	8.0	8.0
Baxxao	1.4	0	0	6.7	6.7	0.0
Experimental mean	1.5	0	1.3	25.8	6.6	6.0

The *Fusarium* species composition was estimated in 2003. *Fusarium sporotrichioides, F. avenaceum, F. culmorum, F. poae* and *F. graminearum* were found to be prevalent in maize grain. *F. culmorum* and *F. graminearum* are the main species that produce mycotoxins DON and ZEN (Gang *et al.*, 1998; Miedaner *et al.*, 2000; Muthomi *et al.*, 2000). The grain of maize hybrids Dixxit, Dixmo, Baxxao and Trumph were infected by *F. culmorum,* and the grain of hybrids Dixxit and Bixx – by *F. graminearum. F. sporotrichioides* was obtained by grain of 5 maize hybrids: Daxxar, Dixxit, Cixxom, Bixx and Baxxao (Table 3).

Table 3. Dominating *Fusarium* species in the grain of maize hybrids Dotnuva, 2003

Maize hybrid	*F. poae*	*F. sporotrichioides*	*F. culmorum*	*F. graminearum*	*F. avenaceum*	other *Fusarium spp.*
Daxar	+	+	–	–	+	+
Dixxit	–	+	+	+	+	+
Dixmo	–	–	+	–	+	–
Cixxom	–	+	–	–	+	+
Bixx	+	+	–	+	+	+
Baxxao	+	+	+	–	–	+
Trumph	–	–	+	–	–	+

The fungal concentration in the grain of maize hybrids harvested in the middle of October was low – 0.6–1.4 cfu $g^{-1} \times 10^3$. The main fungi species on the maize grain were *Penicillium* and *Cladosporium*. The most infected grain by *Penicillium* species fungi was found for the hybrid Dixxit – 31.3%. The infection by *Penicillium* fungi on grain of maize hybrids Daxxar and Baxxao was 6.7%. *Fusarium* species fungi were not identified in the grain. Most of the grains in the samples were not infected. The content of healthy grain was about 60–85% (Table 4). Maize grain contamination by mould fungi three weeks later was significantly higher. The fungal concentration was 1.7–12.3 cfu $g^{-1} \times 10^3$. *Fusarium* and *Penicillium* species were prevalent in the maize grain. The most infected by *Fusarium* fungi (28%) were the grains of maize hybrid Dixxit, while the least infected (6%) were the grains of the maize hybrid Daxxar. The main species of *Fusarium* were *F. poae*, *F. sporotrichoides* and *F. graminearum*. The ANOVA analyses as two factors trial was made. Factor A – maize hybrid, factor B – time of harvesting. Differences in the levels of infection enable us to assume that various maize hybrids have different susceptibility to mould fungi. Similar results were obtained by other authors (Mielke *et al.*, 2000).

The time of maize harvesting influenced grain infection. Higher levels of *Fusarium spp*., *Alternaria* spp. and other *spp*. of mould fungi were found on maize grain harvested later.

Table 4. The fungal concentration (cfu $g^{-1} \times 10^3$) and species composition on the grain of maize hybrids depending on harvesting time of maize Dotnuva, 2004

Maize hybrid	Colony forming unit, $g^{-1} \times 10^3$	Percent of infected grain					Healthy seed, %
		Fusarium spp.	*Alternaria spp.*	*Penicillium spp.*	*Cladosporium spp.*	other *spp.*	
Harvested in the middle of October							
Dixxit	0.6	0	0	31.3	6.7	0	60.0
Daxxar	1.3	0	0	6.7	2.0	4.0	78.0
Baxxao	1.4	0	0	6.7	6.7	0	84.7
Harvested three weeks later							
Dixxit	4.1	28.0	0	14.0	4.0	16.0	48.0
Daxxar	1.7	6.0	2.0	12.0	6.0	14.0	62.0
Baxxao	12.3	20.0	2.0	8.0	12.0	16.0	54.0
LSD 05 Factor A	1.049	2.380	0.939	4.535	4.647	4.305	8.454
LSD 05 Factor B	0.742	1.683	0.664	3.207	3.207	3.044	5.978
LSD 05 Factor AxB	1.659	3.763	1.485	7.171	7.348	6.807	13.367

Over the period 2003–2004, 18 samples of grain of four maize hybrids were tested for mycotoxins. Low contents (0.012–0.022 ppm) of mycotoxin zearalenone (ZEN) were found in all tested maize hybrids in 2003 (Table 5). Mycotoxin DON was not found at all in the grain of maize hybrids.

Table 5. The amount of mycotoxins DON and ZEN in the grain of maize hybrids Dotnuva, 2003–2004

Maize hybrid	2003		2004			
			harvesting in middle of October		harvesting three weeks later	
	DON, ppm*	ZEN, ppm	DON, ppm	ZEN, ppm	DON, ppm	ZEN, ppm
Trumph	0	0.017	–	–	–	–
Baxxao	0	0.012	0.106	0.025	0.089	0.028
Dixxit	0	0.022	0.124	0.019	0.090	0.069
Daxxar	–	–	0.165	0.030	0.095	0.049

In 2004, low contents of DON (0.106–0.165 ppm) and ZEN (0.019–0.030 ppm) were identified in all samples of the tested maize hybrids Baxxao, Dixxit and Daxxar harvested in the middle of October. Higher level of ZEN contamination (0.028–0.069 ppm) was found in the grain of maize hybrids harvested three weeks later. In the grain of maize hybrid Dixxit harvested later, the content of ZEN amounted to 0.069 ppm. According to reference content (Table 1), the level of mycotoxins in the maize grain, grown during 2003–2004, was moderately high. The time of harvesting has no influence on the mycotoxin DON amount in maize grain.

Conclusions

Fusarium sporotrichioides, F. avenaceum, F. culmorum, F. poae and *F. graminearum* were found to be prevalent in maize grain.

The time of harvesting has significant influence on the maize grain infection level. Later harvested maize grain was more infected by *Fusarium spp*. fungi.

The time of harvesting has no influence on the mycotoxin DON amount in maize grain, but later harvested maize grain was more contaminated by mycotoxin ZEN.

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References

1. Christensen, C.M., Meronuck R.A. (1986) Quality maintenance in stored grains and seeds. University of Minnesota Press. Minneapolis.
2. Gang, G. *et al.* (1998) Deoxynivalenol and nivalenol production by Fusarium culmorum isolates differing in aggressiveness toward winter rye. Phythopathology Vol. 88, 879–884.
3. Grain Fungal Diseases and Mycotoxin Reference (1999). USDA The People Department 6–8.
4. International Rules for Seed Testing (ISTA) (2003). Annexe to Chapter 7. Seed Health Testing Methods. Switzerland, Bassersdorf.
5. Lugauskas A. *et al.* (2002) Patogeniški ir toksiški mikroorganizmai žmogaus aplinkoje. Vilnius, 20–26, 44–78, 166–180, 260–294.
6. Malone J. P., Muskett A. E. (1997) Seed-Borne Fungi. Zurich, Switzerland, 19–23, 33–93, 122–125.
7. Mathur S. B., Kongsdal O. (2003) Common laboratory seed health testing methods for detecting fungi. Denmark, Copenhagen, 102–137, 176–177, 234–255.
8. Miedaner T. *et al.* (2000) Association among aggressiveness, fungal colonization and mycotoxin production of 26 izolates of *Fusarium graminearum* in winter rye head blight. Zeitschrift fur Planzenkrankheiten und Planzenschutz., 107, 124–134.
9. Miedaner T., Schneider B. (2001) Breeding strategies for reducing Fusarium head blight and mycotoxin content in cereals. 13. Wissenschftliche Fachtagung: Fusarium – Befall und Mykotoxinbelastung von Getreide. Ursachen, Auswirkungen, Vermeidungsstrategien, Vol. 92, 55–67.
10. Mielke H. *et al.* (2000) Ahrenfusariosen im Weizenanbau. Getreidemagazin, 2, 104–108.
11. Miller J. D. *et al.* (1983) Fusarium toxins in field corn. Canadian Journal of Botany, 61, 3080–3087.
12. Miller J. D., Trenholm H. L. (1994) Mycotoxins in grain: Compounds Other Than Aflatoxin. Eagan Press. Minnesota, United States,19–36.
13. Munkvold G. P., Desjardin, A. E. (1997) Fumonisins in maize: can we reduce their occurrence? Plant Diseases, Vol. 81, 556–565.
14. Muthomi J.W. *et al.* (2000) Characterization of Fusarium culmorum isolates by mycotoxin production and aggressiveness to winter wheat. Journal Plant diseases and Plant Protection, Vol. 107, 113–123.
15. Offenbacher G. (2001) Zur Analytik von Fusarium – Mykotoxinen. 13. Wissenschaftliche Fachtagung: Fusarium – Befall und Mykotoxinbelastung von Getreide. Ursachen, Auswirkungen, Vermeidungsstrategien, 92, 4–13.
16. Rabie C. J. *et al.* (1997) Enumeration of fungi in barley. International Journal of Food Microbiology, 35, 117–127.
17. Rankin, M., Grau C. (2001) Agronomic Considerations for Moulds and Mycotoxins in Corn Silage and High Moisture Corn. http://www.uwex.edu/ces/crops/MouldsMycotoxins.htm.
18. Rotter B. A., Prelusky D. B. (1996) Toxicology of deoxynivalenol (vomitoxin). Journal of Toxicology and Environmental Health, Vol. 48, 1–34.
19. Samson R. A. *et al.* (1992) Modern Methods in Food Mycology. Amsterdam: Elsevier, 275, 345–351.
20. Seglar, B. (2001) Mycotoxin effects on dairy cattle. Proceedings 25th Wisconsin Forage.
21. Tarakanovas P., Raudonius S. (2003) Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas Anova, Stat, Split – plot iš paketo Selekcija ir Irristat. Akademija, 6–26.
22. Саттон Д. *et al.* (2001) Определитель патогенных и условно патогенных грибов. Москва: Мир, 28, 32–33, 46–68, 188–205, 296–304.

EFFECTS OF CULTIVAR AND FERTILISATION PRACTICES ON BREAD-MAKING QUALITIES OF FRESH AND STORED WINTER WHEAT GRAIN

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Abstract

The trials were conducted in Central Lithuania (Dotnuva) on medium and high in phosphorus and potassium light loamy *Endocalcari-Epyhypogleyic Cambisol*. Winter wheat (*Triticum aestivum* L.) yield, grain protein content, and flour/dough stability time were studied. Over the research years 2001/02, 2002/03, and 2003/04, grain yield and bread-making qualities of the Germany-bred cv. 'Zentos' and the Lithuania-bred cv. 'Ada' were significantly affected by the weather conditions and the rate and application timing of nitrogen fertiliser. The average yield increase of up to 2.33–2.72 t ha^{-1} of grain, meeting bread-making class requirements was obtained at intensive fertilisation practice ($N_{32}P_{35}K_{100}$ before sowing and $N_{90+30+30}$ in springtime upon resumption of growth, at the stem elongation, and at the flag leaf – early booting stages) compared with the stand grown without mineral fertilisers. Differences in protein content during the 90 days' storage did not exceed 10 g kg^{-1}. Dough stability of stored grain, processed into 550 type flour, decreased compared with that of the flour processed from freshly harvested grain. Grain/flour of cv. 'Ada' exhibited better bread-making qualities compared with cv. 'Zentos'.

Key words: wheat, fertilisation, grain, storage, flour

Introduction

Variations in bread-wheat yield and technological qualities are a relevant problem to growers, grain handlers, millers and bakers. Muchova (2003) suggests that winter wheat yield is highly and significantly influenced by annual dynamics and cultivar-specific differences. The fertilisation practices (unfertilised, mineral fertilisers calculated by the balance method, mineral fertilisers in combination with incorporation of after-harvest plant residues) did not show a statistically significant effect on the yield as well as on the grain and flour properties in the experiments conducted in Slovakia on *Orthic Luvisol* with high content of soil NPK. Intensified wheat fertilisation with nitrogen resulted in better flour quality properties by farinograph through increased grain protein content (Pushman and Bingham, McNeal *et al.* in Varga *et al.*, 2003). Grain protein content significantly varied depending on the differences among cultivars. These differences were more evident under intensive production systems. Protein accumulation in bread wheat largely depends on the weather conditions of the year and distribution of nitrogen rates during the growing season (Topal *et al.*, 2003; Fowler, 2003). Panozzo (2000) reported that environment-cultivar interactions were significant for the dough rheological characteristics. The intensive cultural practices significantly improve bread-making parameters determined by farinograph. Among these parameters, dough stability is subject to the greatest variation. Thus, Varga *et al.* (2003) found that intensive production system resulted in a significant increase in dough development time and other mixing parameters by up to 138 per cent, but dough stability increase was as high as 900 per cent. In the experiments conducted in Lithuania, the coefficients of variation of protein, sedimentation and wet gluten content values for the cv. 'Zentos' grain were 12.9–24.1 per cent. However, the coefficient of variation of dough stability values was 83.2 per cent, compared to 16.0–26.3 per cent of variation of other dough mixing properties (Mašauskienė, 2002). It leads to the conclusion that dough stability index may be used as the emphatic indicator for evaluation of flour properties.

Producers with wheat stored on-farm for a few months are concerned about unexpected decreases in protein content measurements obtained from laboratories. The differences can affect the price of wheat and consumer acceptance of the finished products.

The aim of the research was to estimate the impact of zero, conventional, and intensive fertilisation on two winter wheat cultivars' grain yield, grain protein content and flour/dough stability, and to examine the changes occurring in stored grain.

Materials and Methods

The trials were conducted in Central Lithuania (Dotnuva) on medium to high in phosphorus and potassium, neutral light loamy sod gleyic soil, *Endocalcari-Epyhypogleyic Cambisol*. The Lithuanian winter wheat cv. 'Ada' and German cv. 'Zentos' were investigated in 2001/02, 2002/03, and 2003/04. The cultivars (*Triticum aestivum* L.) differed in high molecular weight (HMW) glutenin composition. Cv. 'Ada' possesses subunits 1, 7+9, 5+10 and the German cv. 'Zentos' possesses 0, 7+9, 5+10, respectively. Both cultivars are specified by the highest baking quality. The pre-crop was perennial grasses of the second year of use. According to the trial design, wheat did not receive any fertilisation (0); mineral complex fertiliser $N_{32}P_{35}K_{100}$ (P_{80} and K_{120} if indicated in oxides) was applied at sowing, and N_{90} in the spring upon resumption of vegetative growth (BBCH 22-24) (C – conventional fertilisation); $N_{32}P_{35}K_{100}$, N_{90} and additionally broadcast N_{30} at the stem elongation (BBCH 31-32), and N_{30} at the flag leaf- early booting stage (BBCH 39-41) (I – intensive nitrogen fertilisation). BBCH-identification key for growth stages was used (Growth…, 1997). Over three years, the main weather deviations from the long-term mean data were as follows: in 2002 and 2003, hot weather and shortage of rainfall during the period of grain milky ripe resulted in withering of leaves and stems and inhibited the flow of nutrients to the grain. In 2003, soil moisture content during the growing period was lower compared with that in 2002. In 2004, the cold and rainy weather delayed grain ripening for 16 days for cv. 'Ada' and for 11 days for cv. 'Zentos' compared with 2003. The number of sunny days during the grain ripening period in 2004 was exceptionally low. Therefore, climatic conditions in 2003 were unfavourable for yield formation and in 2004 adverse for protein synthesis. The grain was stored for 90 days in a storage house in which the indoor temperature depended on the outdoor temperature. Grain protein content was measured by multiplying total nitrogen content (Kjeldahl) by factor 5.7 (ICC 105/2). Grain protein measurement units g kg^{-1} were used. Grain was milled into 550 type flour by Brabender Junior mill. Flour extraction rate was approximately 700 g kg^{-1}. Flour was tested by Brabender farinograph, mixer for 50 g flour, slow blade rotation speed of 63 min^{-1} was used (ICC 115/1). The experimental data were statistically treated using the software package *STATISTICA 6.0.* Two-factor analysis of variance by Fisher's criterion (F-test) and the least significant difference (LSD_{05}) were applied to estimate the effects of fertilisation (factor A) and grain storage period (factor B).

Results

Averaged data from three experimental years suggest that in the plots where winter wheat cv. 'Ada' was treated with mineral fertilisers, the yield increase amounted to 44–63% and for cv. 'Zentos' the yield increase amounted to 39–43% compared with unfertilised plots (Table 1).

Table 1. Winter wheat grain yield as affected by the fertilisation practices, t ha^{-1}, (2002–2004)

Cultivar	Year	0*	C	I	LSD_{05}
		yield, t ha^{-1}			
'Ada'	2002	6.23 a	7.13 ab	7.61 b	1.22
	2003	3.15 a	5.28 b	5.86 b	0.68
	2004	3.60 a	6.34 b	7.68 c	0.76
	average	4.33 a	6.25 b	7.05 b	0.92
'Zentos'	2002	7.47 a	8.76 a	8.47 a	1.66
	2003	4.06 a	6.17 b	6.27 b	0.38
	2004	4.76 a	7.68 b	8.54 b	1.26
	average	5.43 a	7.54 b	7.76 b	1.22

* Fertilisation practices: 0 – $N_0P_0K_0$, C – $N_{32}P_{35}K_{100}$+N_{90}, I – $N_{32}P_{35}K_{100}$+N_{90}+N_{30}+N_{30}. Values in the rows marked by the same letter are not significantly different (P = 0.05).

The influence of weather conditions on the grain yield was evident for both cultivars. In favourable years, grain yield of wheat cv. 'Ada" in fertilised plots was 31–35% higher compared with unfavourable year. The differences in yield values between the favourable and unfavourable years for winter wheat cv. 'Zentos' tended to be 35–42%. Much more marked differences were revealed for unfertilised plots: in the year favourable for wheat growing the grain yield was 84–98% higher compared with adverse year. The impact of weather factors on the yield of both cultivars was similar. Fertilisation is a reliable way to secure not only a high grain yield but also to alleviate yield variations, resulting from the specificities of the weather conditions.

Fertilisation practices significantly affected the grain protein content. On average, under the intensive fertilisation system grain protein content for cv. 'Ada' amounted to 129–130 g kg^{-1} and in the system without fertilisation – to 108–112 g kg^{-1} (Table 2).

Table 2. Winter wheat grain protein content as affected by the fertilisation practices and grain storage period, g kg^{-1}, (2002–2004)

Cultivar	Year	Storage	0*	C	I	LSD_{05}
			protein, g kg^{-1}			
'Ada'	2002	fully ripe	117	129	141	
		after 90 days	121	134	132	
		LSD_{05}				12.7
	2003	fully ripe	112	124	128	
		after 90 days	115	126	128	
		LSD_{05}				10.3
	2004	fully ripe	96	108	121	
		after 90 days	100	109	127	
		LSD_{05}				6.2
	average	fully ripe	108	120	130	
		after 90 days	112	123	129	
		LSD_{05}				10.1
'Zentos'	2002	fully ripe	110	130	144	
		after 90 days	115	132	133	
		LSD_{05}				9.9
	2003	fully ripe	110	113	125	
		after 90 days	114	119	134	
		LSD_{05}				13.8
	2004	fully ripe	76	87	100	
		after 90 days	80	94	108	
		LSD_{05}				5.9
	average	fully ripe	98	110	123	
		after 90 days	103	115	125	
		LSD_{05}				10.4

* Fertilisation practices: 0 – $N_0P_0K_0$, C – $N_{32}P_{35}K_{100}+N_{90}$, I – $N_{32}P_{35}K_{100}+N_{90}+N_{30}+N_{30}$.

The grain protein contents for cv. 'Zentos' were 123–125 g kg^{-1} and 98–103 g kg^{-1}, respectively. In the year unfavourable for protein synthesis, grain protein of wheat grown without mineral fertiliser application met only feed grain quality requirements. However, in the years with a sufficient number of sunny days (2002 and 2003), wheat grain accumulated 110–117 g kg^{-1} of protein in unfertilised plots, which is markedly more compared with the unfavourable year 2004. The differences between the tested cultivars in terms of grain protein content averaged for 3 years were negligible. On the other hand, the results indicate that the differences between cultivars in terms of grain protein content were more distinct in the year unfavourable for protein synthesis (2004). Over the 90 days' grain storage period we did not identify any consistent decrease or increase in grain protein content. The fluctuation of this parameter in the course of the storage period could be related with sampling deflections or accuracy of measuring instruments.

Our experimental evidence suggests that freshly harvested grain and 90-day stored grain do not differ markedly in protein content, as a result, both grains often meet the requirements of the same quality class.

Among the grain/flour parameters obtained from farinograms, the dough stability is subject to the strongest variability. Dough mixing stability is an important criterion for conformity of flour to the type of fermentation and mechanical stress. Stability time of more than 10 minutes is characteristic of excellent quality flour and not less than 3 minutes – of poor quality (Flour, 2004; Wheat, 2004). In the trial, the relationship between dough stability and cultivar peculiarities was identified. Dough of cv. 'Ada' flour exhibited grater resistance to mixing compared with cv. 'Zentos' (Table 3). Despite the fact that both cultivars were attributed to the class of wheat of good bread-making properties, only in fertilised plots matured grain/flour met the requirements. During the three experimental years, grain/flour from the unfertilised plots were of poor dough mixing stability. An evident decrease in dough stability time for both cultivars was determined for stored grain. The least reduction in dough stability time during storage period occurred in grain/flour grown in unfertilised plots, while the highest reduction occurred in grain/flour from plots where late nitrogen application was used. Despite the noticeable dough stability reduction in the flour from intensively fertilised stored grain, the values of the parameter mostly met the higher flour quality class compared with the flour from conventionally fertilised or unfertilised plots. The influence of crop year's weather conditions on the grain/flour dough stability was obvious. In sunny summers of 2002 and 2003, winter wheat grain/flour dough stability was much better compared with that of grain matured under conditions of cloudy weather prevailing over the after-anthesis period in 2004. The data indicate that winter wheat cv. 'Ada" grain/flour has higher dough mixing stability compared with cv. 'Zentos'. Grain from unfertilised plots is appropriate to be milled into poor quality flour. The value of dough stability can be the main parameter for the representation of changes in dough mixing properties.

Table 3. Winter wheat 550 type flour/dough stability as affected by the fertilisation practices and grain storage period, min., (2002–2004)

Cultivar	Year	Storage	0*	C	I	LSD_{05}
			stability, min.			
'Ada'	2002	fully ripe	10.0	14.3	14.6	
		after 90 days	6.0	8.6	8.1	
		LSD_{05}				2.74
	2003	fully ripe	4.2	15.1	15.8	
		after 90 days	4.7	11.8	13.2	
		LSD_{05}				3.87
	2004	fully ripe	1.9	4.5	13.8	
		after 90 days	1.8	4.0	8.9	
		LSD_{05}				2.06
	average	fully ripe	5.4	11.3	14.7	
		after 90 days	4.2	8.2	10.1	
		LSD_{05}				2.98
'Zentos'	2002	fully ripe	3.1	9.6	12.6	
		after 90 days	2.5	10.4	7.9	
		LSD_{05}				3.15
	2003	fully ripe	5.2	3.9	6.9	
		after 90 days	3.6	4.5	6.8	
		LSD_{05}				1.88
	2004	fully ripe	1.1	1.2	2.2	
		after 90 days	1.0	1.3	2.6	
		LSD_{05}				0.29
	average	fully ripe	3.1	4.9	7.2	
		after 90 days	2.4	5.4	5.8	
		LSD_{05}				2.12

* Fertilisation practices: 0 – $N_0P_0K_0$, C – $N_{32}P_{35}K_{100}+N_{90}$, I – $N_{32}P_{35}K_{100}+N_{90}+N_{30}+N_{30}$.

Discussion

The experiments conducted in different soils with different winter wheat cultivars have clearly demonstrated that yield and grain quality are derivatives of numerous factors, including nitrogen fertilisation as being of special importance (Šíp *et al.*, 2000; Ruza, Linina, 2001; Knapowski, Ralcewicz, 2004). On medium in plant nutrients soil, grain yield of cultivars with yielding capacity over 7–8 t ha^{-1} is always related to fertilisation strategy. Protein decrease with yield increases suggests that the system was still nitrogen deficient. However, adequate rains during grain fill help the plant store carbohydrates and thus increase the yield, but these late-season rains may make achieving higher protein difficult, which was evidently demonstrated in our experiment in the 2004 crop year. In the system of conventional fertilisation, the cv. 'Ada's grain protein content was 108 g kg^{-1} and that in plots with zero fertilisation – only 96–100 g kg^{-1}, and for cv. 'Zentos' – 87–94 and 76–80 g kg^{-1}, respectively. Only in intensive N application plots the grain protein that year tended to meet the requirements of bread wheat. High nitrogen application rates in bread wheat stands increase the protein concentration but decrease the rheological value of protein. However, highlighting of only the percentage content of protein in wheat does not mean the same as the evaluation of the technological value. Furthermore, the content of total protein cannot serve as a basis to determine the quality of bread-making flour. Bread-making quality correlates with the presence or absence of specific proteins. In addition, researchers reported that quality depends on the ratio of monomeric to polymeric proteins.

The ratio is strongly influenced by environmental conditions before and after anthesis (Triboi-Blondel, 2001; Triboi *et al.*, 2003). In our experiment in the year with hot weather occurring after anthesis which was the case in 2003, dough mixing stability of cv. 'Ada' grain/flour from fertilised plots was much better compared with that of cv. 'Zentos'. This could result from the genetic differences between the tested cultivars: winter wheat cv. 'Ada', possessing subunit 1 at *Glu A1* loci formed dough of better stability compared with cv. 'Zentos' which possesses 0 at the same loci. However, the dough stability of grain/flour of unfertilised plots was poor for both cultivars. Millers and bakers improve poor flour rheological properties by different additives. In this way they meet and fulfil the requirements of consumers for tasty and voluminous bred. In our experiment there is considerable evidence that grain/flour in conventionally and intensively fertilised plots produced higher yield as well as better quality grain compared with zero fertilisation system. During grain storage period, grain/flour bread-making qualities are subject to changes. However, grain protein content over a 90-day storage period decreased/increased within the range 0–10 g kg^{-1} compared with initial values, but the differences generally ranged from 0.4 to 0.6 g kg^{-1}. Averaged findings suggest that fertilisation practices had no significant effect on the variation of grain protein content during storage. While protein content is certainly important in determining quality within market class, commercial wheat shipments blended by varieties from the different market class with the different quality attributes receive much less attention. Researchers should provide more comprehensive information on the genetic makeup of the tested cultivars in their publications. Each participant in the chain grower-grain handler-miller-baker has to understand that not all cultivars are created equal, and that protein content and market class do not necessarily reflect grain baking quality and end-use performance.

Conclusions

On medium and high in available phosphorus and potassium, light loamy *Endocalcari-Epyhypogleyic Cambisol,* intensive nitrogen fertilisation secures a high grain yield meeting bread-making requirements and alleviates yield variations, resulting from the specificities of the weather conditions. Grain from unfertilised plots is appropriate to be milled into poor quality flour.

Differences in protein content during the 90 days' storage did not exceed 10 g kg^{-1} even in the cases when intensive nitrogen fertilisation practice was applied.

Dough mixing stability of cv. 'Ada' (HMW glutenin composition 1; 7+9; 5+10) grain/flour from fertilised plots was much better compared with that of cv. 'Zentos' (HMW glutenin composition 0; 7+9; 5+10). The value of dough stability can be the main parameter for the representation of changes in dough mixing properties which occur during grain storage.

References

1. Flour – A treatise: http://www.home.earthlink.net/%7Eggda/Flours_One.htm – The resource was described on 25.05.2004.
2. Growth Stages of Mono – and Dicotyledonous Plants (1997). BBCH-Monograph. Meier, U. (ed.) Blackwell Wissenschafts-Verlag Berlin, Wien, 12–16.
3. Knapowski T., Ralcewicz M. (2004) Evaluation of Qualitative Features of Mikon Cultivar Winter Wheat Grain and Flour Depending on Selected Agronomic Factors. Electronic Journal of Polish Agricultural Universities, 7 (1), Series Agronomy, http://www.eipau.media.pl. – The source was described on 10.01.2005.
4. Mašauskienė A. (2002) Žieminių kviečių netiesioginių kepimo ir tešlos fizikinių savybių tarpusavio priklausomumas. Maisto chemija ir technologija (Food chemistry and technology. Kaunas), 36, 86–91.
5. Muchova Z. (2003) Changes in technological quality of food wheat in a flour crop. Plant Soil and Environment, 49, (4), 146–150.
6. Panozzo J. F. (2000) Cultivar and environmental effects on quality characters in wheat. II. Protein. Australian Journal of Agricultural Research, 51, 629–636.
7. Ruza A., Linina A. (2001) Nitrogen influence on yield and Baking Quality of Winter Wheat. 11th Nitrogen Workshop 9–12 September. Reims, France, 521–522.
8. Šíp V. *et al.* (2000) Effect of cultivar and cultural practices on grain yield and bread-making quality of winter wheat. Rostlinna vyroba, 46, (4), 159–167.
9. Topal A. *et al.* (2003) Efficiency of topdressed nitrogen sources and application times in fallow-wheat cropping system. Communications in Soil Science and Plant Analysis, 34, 9–10, 1211–1224.
10. Triboi E. *et al.* (2003) Environmentally-induced changes in protein composition in developing grains of wheat are related to changes in total protein content. Journal of Experimental Botany, 54 (388), 1731–1742.
11. Triboi-Blondel A. M. (2001) Environmental effects on wheat grain growth and composition. Aspects of Applied Biology, 64, 91–101.
12. Varga B. *et al.* (2003) Wheat Grain and Flour Quality as Affected by Cropping Intensity. Food Technology Biotechnology, 41 (4), 321–329.
13. Wheat: characterization by functionality: http://www.collectionscanada.ca/eppp-archive/ 100/200/301/cgc-ccg/variety_development-e/variety4-e.htm#wheat – The resource was described on 25. 05. 2004.

K-MOBILIZING BACTERIA AND THEIR EFFECT ON WHEAT YIELD

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Abstract

Testing of rhizobacteria capability of K-mobilization from soil minerals in model experiments has shown that under the same conditions bacteria more actively used potassium from hydromuscovite, muscovite and biotite (in diminishing order). Different mobility forms of K in muscovite were evaluated as K-source for bacteria, and parameters of K-releasing as affected by bacteria were presented. The effect of K-mobilizing bacteria on spring wheat yield has been studied in a field experiment on Luvisol sandy loam soil on light loess loam characterized by different degrees of water erosion. Application of K-mobilizing bacteria on severely eroded soil guarantees the possibility to obtain high wheat yields, which are comparable with yields on moderately eroded soil without bacteria introduction. Data obtained suggest that K-mobilizing bacteria may be a perspective additional technique for conservation of fertility status and productivity improvement of eroded soils.

Key words: K-mobilizing bacteria, soil erosion, wheat yield

Introduction

Plant nutrition is closely associated with the activity of rhizosphere microflora, which plays an important role in supplying plants with available nutrients as well as growth promoting substances (Аристовская u go., 1969; 1972; Глазовская, 1984; Илялетдинов, 1966; Звягинцев, 1987). The problem of K-nutrition is one of the most important for the regulation of plant productivity and soil fertility status. A significant share of soil potassium occurs in unavailable forms in soil minerals. Some species of rhizobacteria are capable of mobilizing inaccessible potassium forms in soils (Александров, 1953; Александров u go., 1950; Зак, 1963; Сурман, 1958).

There is no unified opinion about the role of K-mobilizing bacteria in the processes of soil mineral transformation. The most controversial question is the degree of soil aluminosilicates transformation as affected by K-mobilizing bacteria. Basing on the data of thermographic analysis, Zak (Зак, 1963) and Surman (Сурман, 1958) have shown that K-mobilizing bacteria do not cause deep decomposition of soil aluminosilicates. At the same time, Webley *et al.* (1960) have reported about deep decomposition of such minerals as wollastonite, apopheline and peridot under the influence of bacteria because X-ray structure analysis, gave evidence of their transformation from crystal into amorphous form. Ilyaletdinov (Илялетдинов, 1966) considered that an objective criterion of deep aluminosilicates transformation is the detection of sesquioxides and silicon in the solutions. However the degree and mechanisms of silicate transformation are still not elucidated finally, data accumulated indicate the capability of K-mobilization from aluminosilicates for different species of soil microorganisms.

The purpose of the present investigation was to study rhizobacteria capability of K-mobilization and their effect on wheat yield.

Materials and Methods

Local strains of K-mobilizing rhizobacteria were isolated from the roots of cereal crops by the use of specific potassium free medium (Александров, 1953). Active strains were tested in laboratory and field experiments.

For the estimation of strains capability of K-mobilization from soil minerals, two laboratory experiments were performed. In the first experiment, biotite, muscovite-2, glauconite and hydromuscovite were used as a single K-source for bacteria in a liquid medium containing sucrose – 0.75, $(NH_4)_2SO_4$ – 0.15, Na_2HPO_4 – 0.30, $MgSO_4$ – 0.075, $FeCl_3$, and mineral – 1 g l^{-1}. All minerals were characterized by the same degree of dispersion. The chemicals were preliminary purified from potassium by recrystallization. Bacteria were grown in flasks with 100 ml of liquid nutrient medium. After 7-day exposition at 28 °C incubation, the mixture was centrifuged during 30 min (6000 revs) and exchangeable K-content in supernatant was determined by flame photometry. As control measurements, the medium without bacteria and medium without soil mineral inoculated by bacteria were used.

In the second experiment, different mobility forms of K in muscovite were evaluated as K-source for bacteria. Muscovite was preliminary treated by following reagents (Пчелкин, 1966): water, 1N CH_3COONH_4, 0.2N HCl, 2N HCl, 20% HCl (48 h). Washed and dried mineral samples were introduced in a liquid medium with bacteria. Cultivation conditions and methods of exchangeable K estimation were the same. As control measurement the medium containing treated mineral without bacteria was used.

The effect of K-solubilizing bacteria on the yield of spring wheat Kontessa was studied in a field experiment on Luvisol sandy loam soil on light loess loam. The experiment was performed on experimental watershed plots (720–800 m^2). The soil was characterized by different degrees of water erosion: not eroded soil at the watershed, moderately eroded soil at the upper part of slope, severely eroded soil at middle part of slope, and dealluvial soil. Fertilizer treatment NPK + FYM (farm yard manure) was studied at all elements of slope. Doses of fertilizers were as follows: N70P40K50 and 30 t ha^{-1} of FYM. Agrochemical properties of the arable layer varied within the range: humus contents – 0.8–2.5%; pH – 5.2–5.9; P_2O_5 – 290–330 mg kg^{-1}, and K_2O – 180–230 mg kg^{-1} (Kirsanov method). Liquid preparation of the local strain K-81 of K-mobilizing was used by way of seed treatment before sowing.

Results and Discussion

Mobility of potassium in soil minerals and its availability for bacteria depend on different factors such as chemical structure of minerals, degree of dispersion, bacteria strain activity, and ecological conditions. One of the purposes of laboratory experiments was to test the potential local strains K-31 and K-81 capability of potassium solubilization from soil minerals. In the first experiment, micas (biotite, muscovite-2) and hydromicas (glauconite and hydromuscovite), which contain significant amount of potassium were used as a single K-source for bacteria. It was found that under the same conditions bacteria more actively used potassium from hydromuscovite, muscovite, and biotite (in diminishing order). The experiment has shown that bacteria were not capable of mobilizing K from glauconite (Fig. 1).

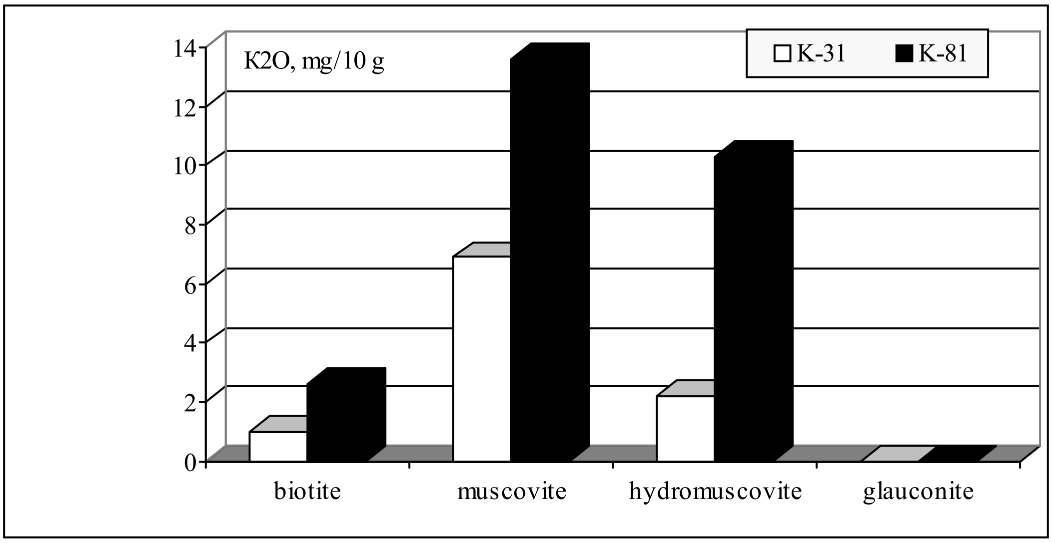

Figure 1. Activity of bacterial K-mobilization from soil minerals

Local strains of bacteria possessed different activity in respect of K-solubilization. At the same conditions, strain K-81 solubilized more significant amounts of potassium compared with strain K-31: from biotite – by 2.6 times, from muscovite – by 2.0 times, and from hydromuscovite – by 4.6 times more than strain K-31 (Fig. 1).

In the second experiment, muscovite was used as a single K-source for bacteria strain K-81. Different mobility forms of K in muscovite were evaluated as K-source for bacteria. After water treatment and elimination of water-soluble potassium, the mineral sample was exposed to bacteria strain K-81 action. For a 7-day exposition, bacteria were capable of solubilizing approximately by 2 times more potassium compared to the control with mineral sample without bacteria (Fig. 2). After treatment of muscovite by 1N CH_3COONH_4 and elimination of exchangeable potassium, the mineral sample was also exposed to bacteria during 7 days. It was found that the strain culture liquid contained by 1.5 times more potassium compared to the control. Experimental data showed bacteria capability of K-mobilization from mineral samples after their treatments by different concentration (0.2N, 2N and 20%) solutions of hydrochloric acid (7 days) as well (Fig. 2).

Potential rhizobacteria strain K-81 capability of mobilizing more available as well as less available K-forms from muscovite was shown (Fig. 2). The data of model experiment suggests that bacteria may play role in K-supply for plants.

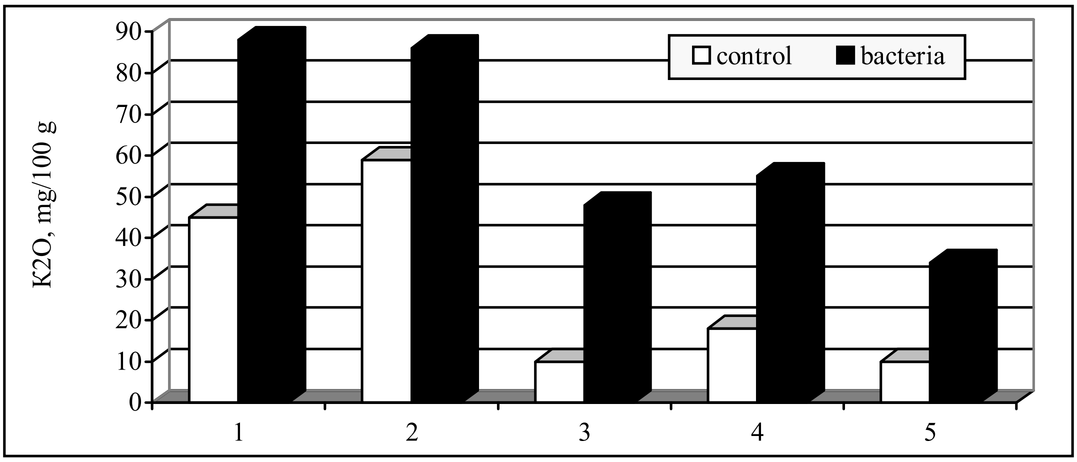

Figure 2. Mobilization of K by strain K-81 from muscovite after preliminary treatment by following reagents: 1 – water, 2 – 1N CH_3COONH_4, 3 – 0.2 N HCl, 4 – 2 N HCl, 5–20% HCl

A more active strain of rhizobacteria (K-81) was used for inoculation of field-grown wheat on Luvisol sandy loam soil characterized by different degrees of water erosion. At control treatment without bacteria, a maximal grain yield was obtained at watershed on not eroded soil. Significant reduction in grain yields was observed on severely eroded and dealluvial soils. Water erosion processes cause significant losses of soil melkozem, humus and mineral nutrition elements, which negatively affected plant nutrition and productivity. Application of K-mobilizing bacteria resulted in significant yield responses at all elements of slope. K-mobilizing bacteria application was very effective and resulted in a 1.04 t ha^{-1} yield increase at the watershed and in 0.88 and 0.90 t ha^{-1} yield responses on moderately eroded and dealluvial soils (Table 1). Bacterization provided the highest yield response (1.28 t ha^{-1}) on severely eroded soil, which indicates high efficiency of K-mobilizing bacteria under the deficit of nutrition elements. The positive effect of K-mobilizing bacteria on wheat yield was connected with plant growth promotion as well. The data obtained previously (Михайловская *et al.*, 2003) gave evidence of a significant growth promotion effect of bacteria strain K-81 that was expressed in intensive development of wheat seedlings roots. More developed roots is one of the main preconditions of mineral nutrition improvement.

Application of K-mobilizing bacteria on severely eroded soil guarantees the possibility to obtain high wheat yields, which are comparable with those on moderately eroded soil without bacteria introduction (Table 1). The data obtained suggest that K-mobilizing bacteria favors wheat nutrition and results in the formation of high grain yields on eroded soils.

Application of active natural strains of K-mobilizing bacteria is environmentally appropriate and may provide sufficient wheat nutrition and increase of wheat productivity on severely eroded soil, which are equivalent to those on moderately eroded soil.

Table 1. The effect of K-mobilizing bacteria on wheat yield in dependence on erosion degree of Luvisol sandy loam soil, t ha^{-1}, (2003–2004)

Soil	NPK+ FYM		
	Control without bacteria	Strain K-81	Response to bacteria
Not eroded	5.22	6.26	1.04
Moderately eroded	5.15	6.03	0.88
Severely eroded	4.67	5.95	1.28
Dealluvial	4.77	5.67	0.90
	$LSD_{0.05}$ for soil: F_A – 0.53 $LSD_{0.05}$ for bacterization: F_B – 0.38		

Conclusions

Local rhizobacteria strains K-31 and K-81 are capable of K-mobilization from hydromuscovite, muscovite and biotite (in diminishing order). Different mobility forms of potassium in muscovite may be a potential K-source for bacteria strain K-81. The data obtained gave evidence of benefit from K-mobilizing bacteria K-81 for wheat growth and nutrition at all elements of slope on Luvisol sandy loam soil. Highest yield response due to inoculation was observed on severely eroded soil that indicates a significant efficiency of K-mobilizing bacteria in a crisis situation under the deficit of nutrition elements. Positive effect of K-mobilizing bacteria on wheat yield was connected with mineral nutrition improvement and growth promotion. Application of K-mobilizing bacteria on severely eroded soil guarantees the possibility to obtain high wheat yields, which are comparable with yields on moderately eroded soil without bacteria introduction. Use of biological fertilizers with K-mobilizing bacteria may be a perspective additional technique for the improvement of eroded soils' productivity.

References

1. Александров В. Г., Зак Г. А. (1950) Бактерии, разрушающие алюмосиликаты (силикатные бактерии). Микробиология, 19, 2, 97–104.
2. Александров В. Г. (1953) Силикатные бактерии, Сельхозгиз, Москва, 115.
3. Аристовская Т. В. с соавт. (1972) Роль микроорганизмов в превращении минералов. В кн: География, генезис и плодородие почв, Ленинград, 222–229.
4. Аристовская Т. В. с соавт. (1969) Микробиологические факторы миграции некоторых минеральных элементов в почвах. Почвоведение, 9, 95–105.
5. Глазовская М.А. (1984) Геохимические функции микроорганизмов, МГУ, Москва, 153.
6. Зак Г. А. (1963) Освобождение калия из алюмосиликатов почвы силикатными бактериями. В: Труды межвузовской научной конференции «Микроорганизмы в сельском хозяйстве», МГУ, Москва, 298–306.
7. Звягинцев Д. Г. (1987) Почва и микроорганизмы, МГУ, Москва, 256.
8. Илялетдинов А.Н. (1966) Биологическая мобилизация минеральных соединений, Алма-Ата, 163–171.
9. Михайловская Н. А. с соавт. (2003) Влияние силикатных бактерий на развитие проростков ячменя и пшеницы. Почвенные исследования и применение удобрений, Минск, 27, 316–324.
10. Пчелкин В. У. (1966) Почвенный калий и калийные удобрения, Колос, Москва, 65–72.
11. Сурман К. И. (1958) Особенности развития силикатных бактерий при выращивании на жидких средах. Доклады ВАСХНИЛ, Москва, 4, 32–36.
12. Webley D. M. *et al.* (1960) A plate method for studying of the breakdown of synthetic and natural silicates by soil bacteria. Nature, 188, 4752, 766–767.

INCIDENCE AND SEVERITY OF ALTERNARIA BLIGHT (*ALTERNARIA* SPP.) AND DOWNY MILDEW (*PERONOSPORA PARASITICA*) AS AFFECTED BY WINTER OILSEED RAPE SOWING TIME AND NITROGEN FERTILIZER RATE

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Abstract

Incidence and severity of Alternaria blight and downy mildew in relation to sowing time (S_1 – beginning of August; S_2 – middle of August; S_3 – end of August) and nitrogen fertilizer rates (0, 60, 120, 180, 240 kg ha^{-1}) were studied in winter oilseed rape *cv.* Casino during 2000–2002. Alternaria blight severity on winter oilseed rape lower leaves at flowering (BBCH 65-69) was diverse in separate years, the highest being in the year 2000. Downy mildew in trial plots occurred only in 2000 and 2001. Some trends were identified suggesting that the severity of both diseases on lower leaves of winter oilseed rape was the highest in the treatments sown at the earliest sowing date compared with the two later sowing dates. In 2002, the severity of Alternaria blight on winter oilseed rape lower leaves at flowering stage (BBCH 65-69) was up to 3.3 times lower in the treatments sown at the latest date compared with treatments sown at the earliest sowing date. A more considerable disease incidence was recorded in the plots sown at the second and third (S_2 and S_3) sowing dates, compared with the earliest (S_1) sowing date. With increasing N fertilizer rates a trend of Alternaria blight incidence increasing on siliques was revealed in 2000 and 2001. In 2002, a significant increase in Alternaria blight severity occurred, compared with unfertilized plots. The incidence and severity of downy mildew on lower leaves was higher in N untreated, compared with N treated plots.

Key words: Alternaria blight, incidence and severity, winter oilseed rape, sowing time, N fertilizers

Introduction

Alternaria blight (*Alternaria spp.*) is one of the most important and harmful fungal diseases of winter and spring rape, turnip rape, mustard and other cruciferous plants in many countries of the world. *Alternaria spp*. species *Alternaria brassicae* and *Alternaria brassicicola* are attributed to the most dangerous and predominant group of pathogens in oilseed rape crops (Kennedy and Graham, 1995). Downy mildew is considered a less harmful oilseed rape disease (Evans and Gladders, 1981; Sadowski *et al.*, 2002), however, it is very widespread and harmful in vegetable brassicas (Jensen *et al.*, 1999; Coelho and Monteiro, 2003).

Plant nutrition has a considerable effect on the occurrence of diseases. Shortage or excess of macro- or micro-elements result in a higher susceptibility of plants to pathogenic micro-organisms (Sharma and Kolte, 1994; Sadowski *et al.*, 2002). Research on the impact of 8 combinations of NPK fertilizers on Alternaria blight severity and on the seed yield of spring turnip rape (*B. campestris*) in pot and field trials suggests that the disease severity was significantly higher (36–48%) on plants, fertilized with NP (N 90 kg ha^{-1} + P 40 kg ha^{-1}), compared with unfertilized plants. Plant fertilization also had some effect on the number and size of Alternaria blight spots. The lowest number of spots which were the smallest in size was found for the treatments where the plants had been applied with K or NK, whereas the largest spots and their highest number were spotted on siliques in the treatments fertilized with NP combinations. Fertilization with NK resulted in a decline in Alternaria blight severity, 68% seed yield increase, compared with unfertilized turnip rape, as well as in an increase in 1000 seed weight and a reduction in seed disease level (Sharma and Kolte, 1994).

There is little experimental evidence on the effects of oilseed rape sowing time on the disease incidence, however, there are some experimental data suggesting that early-sown spring rape was more severely affected by Alternaria blight. The sowing time did not have any significant effect on the incidence and severity of downy mildew (Sadowski *et al.*, 2002).

Seeking to supplement the knowledge on the effects of winter rape sowing time and intensity of nitrogen fertilization on the incidence and severity of Alternaria blight and downy mildew, assessments of these diseases were conducted in a bi-factorial trial over the period 1999–2002.

Materials and Methods

Trial design

The trials were carried out during 1999–2002 with the winter oilseed rape hybrid 'Kasimir' sown at a seed rate of 4–5 kg ha^{-1} (1.5–2.0 million seeds). Row spacing was 12.5 cm. Plots were arranged following a completely randomized design with three replications. Plot size – 18 × 3 m (54 m^2), record plot size –

15 × 2.2 m (33 m^2). Weed control in the trial was provided by Butisan 400 (2.5 l ha^{-1}), pest control – using Fastac 0.1 (l ha^{-1}). In the trial, P 90 kg ha^{-1} and K 120 kg ha^{-1} were used.

S_1 – sowing date – end of July-beginning of August;

S_2 – sowing date – middle of August;

S_3 – sowing date — end of August.

Nitrogen rates in the trial

1. N_0 – without nitrogen.
2. N_{60} – in spring, stem elongation (BBCH 30 – 39).
3. N_{120} – in spring, stem elongation (BBCH 30 – 39).
4. N_{180} – in spring, stem elongation (BBCH 30 – 39).
5. N_{240} – in spring, stem elongation (BBCH 30 – 39).

Disease assessments in the trial

Alternaria blight and downy mildew assessments on the leaves were made twice – at the flowering stage (BBCH 65-69) and at the end of siliques development (BBCH 79). Disease incidence and severity on the lower, middle and upper leaves were assessed in all plots, on 10 plants per plot. The severity of Alternaria blight was identified according to the scale described by Conn *et al.* (1990). The severity of downy mildew on leaves was identified according to Krüger (1991).

Alternaria blight assessments on siliques were made at the end of maturity stage (BBCH 87-89). Disease incidence and severity on siliques were identified in all plots, on 10 plants per plot, assessments were performed on 5 earliest-formed (lower) siliques on the main stem. In total, the disease pressure was estimated on 50 siliques per plot (200 siliques per treatment).

The experimental data were processed by analysis of variance using the computer programme STATISTICA, 5.5 version. Probability level LSD_{05} was calculated for treatment factor A, factor B and for their interaction.

Results

Since diseases tended to spread more intensively in oilseed rape crops in the second half of the growing season, their assessments were made only at the end of flowering and at even later growth stages.

At the end of flowering (BBCH 69), Alternaria blight had spread on all lower and middle leaves of winter rape, whereas upper leaves still did not exhibit any disease symptoms. In all experimental years, Alternaria blight severity on lower leaves was significantly higher than on middle leaves (Table 1).

Some trends were established suggesting that the disease severity in the earliest-sown and unfertilized or less fertilized winter rape plots, on bottom leaves was the highest compared with the two later sowing dates. In 2002, these differences were rather marked – the disease severity on the latest-sown winter rape bottom leaves was up to 3.3 times lower than that on the earliest-sown winter rape bottom leaves. Similar trends in the disease severity on middle leaves were identified.

At the end of siliques development (BBCH 79), bottom leaves had already fallen, which formed infectious background for the disease spread on other plant parts. Alternaria blight severity on upper leaves was markedly lower than on middle leaves (Table 2).

The highest disease severity on middle leaves was identified in 2000 (14.7–19.6%), the lowest in 2002 (6.52–7.72%). Neither the sowing date nor different nitrogen rates had any marked effect on Alternaria blight severity on middle leaves at siliques development stage. On upper leaves at this growth stage the highest disease severity was recorded in 2001, which was up to 15 times higher than in 2000 and up to 4 times higher than in 2002. In 2000, a significant reduction in the disease severity on middle and upper leaves was identified in the plots applied with nitrogen fertilizers, compared with the plots that had not been applied with nitrogen fertilizer, but only in early-sown winter rape plots. A positive effect of nitrogen fertilizer on the disease severity on upper leaves was identified only in 2001.

The incidence and severity of downy mildew on lower leaves at the end of flowering in 2000 were significantly lower for the plots applied with N60–240 kg ha^{-1} compared with unfertilized plots (Table 3). Winter rape sowing date did not have any significant effect on the incidence and severity of downy mildew. The spread of downy mildew was very low in all trial plots in 2001.

Table 1. The effects of the sowing time and nitrogen rate on severity of Alternaria blight on the lower and middle leaves of winter oilseed rape (BBCH 65-69), (2000–2002)

Sowing time (factor A)	N treatment (factor B) Bottom leaves					Mean A	N treatment (factor B) Middle leaves					Mean A
	0	60	120	180	240		0	60	120	180	240	
Alternaria blight severity %, 2000												
S_1	15.5	15.0	14.5	14.0	14.5	14.7	2.1	1.7	2.1	1.8	2.3	2.0
S_2	13.5	14.5	15.0	14.5	14.5	14.4	2.3	2.6	1.9	2.1	2.4	2.3
S_3	14.5	14.5	15.0	14.5	16.0	15.0	2.4	1.5	2.1	1.9	2.3	2.0
Mean B	14.5	14.7	14.8	14.3	15.0	14.7	2.3	1.9	2.0	1.9	2.3	2.1
LSD_{05}	F_A=0.37; F_B=0.53; F_{AxB}=0.99						F_A=0.23; F_B=0.33; F_{AxB}=0.62					
Alternaria blight severity %, 2001												
S_1	9.2	9.8	8.7	8.8	8.5	9.0	1.1	1.4	1.0	1.4	0.9	1.2
S_2	8.8	8.7	8.2	8.8	8.4	8.6	1.3	1.0	1.1	1.1	1.0	1.1
S_3	8.7	9.0	8.3	8.7	8.7	8.7	1.1	1.0	1.0	1.0	0.9	1.0
Mean B	8.9	9.2	8.4	8.8	8.5	8.8	1.2	1.1	1.0	1.2	0.9	1.1
LSD_{05}	F_A=0.31; F_B=0.44; F_{AxB}=0.82						F_A=0.09; F_B=0.12; F_{AxB}=0.23					
Alternaria blight severity %, 2002												
S_1	8.3	10.0	10.0	10.0	10.0	9.7	5.2	5.0	6.1	6.3	7.3	6.0
S_2	8.8	8.3	7.5	7.9	7.8	8.1	2.2	3.3	3.7	3.5	3.2	3.2
S_3	3.0	3.2	3.0	4.4	3.8	3.5	1.3	1.7	1.7	1.8	1.8	1.7
Mean B	6.7	7.2	6.8	7.4	7.2	7.1	2.9	3.3	3.8	3.9	4.1	3.6
LSD_{05}	F_A=0.81; F_B=1.14; F_{AxB}=2.14						F_A=0.49; F_B=0.69; F_{AxB}=1.30					

Nitrogen fertilizer significantly increased the incidence and severity of Alternaria blight on siliques only in 2002 (Table 4). In 2000 and 2002, in the plots sown at later dates, the disease severity on siliques was significantly higher compared with the rape plots sown at the earliest date. Contrary data were obtained in 2001.

Discussion

Having summarized our experimental data we can maintain that the differences in Alternaria blight incidence and severity between the winter rape plots sown at different dates and treated with different nitrogen rates were identified only at the beginning of the disease occurrence and at low disease severity. Later, with increasing intensity of the disease, these differences between the tested measures disappeared.

Table 2. The effects of the sowing time and nitrogen rate on severity of Alternaria blight on the middle and upper leaves of winter oilseed rape (BBCH 79), (2000–2002)

Sowing time (factor A)	N treatment (factor B) Middle leaves					Mean A	N treatment (factor B) Upper leaves					Mean A
	0	60	120	180	240		0	60	120	180	240	
Alternaria blight severity, %, 2000												
S_1	19.6	14.7	15.1	16.3	17.0	16.5	0.8	0.4	0.4	0.3	0.3	0.4
S_2	16.9	15.3	15.7	15.0	18.3	16.2	0.5	0.4	0.4	0.3	0.4	0.4
S_3	16.0	15.6	17.0	17.3	16.3	16.4	0.5	0.4	0.4	0.3	0.4	0.4
Mean B	17.5	15.2	15.9	16.2	17.2	16.4	0.6	0.4	0.4	0.3	0.4	0.4
LSD_{05}	F_A=0.93; F_B=1.32; F_{AxB}=2.47						F_A=0.06; F_B=0.08; F_{AxB}=0.16					
Alternaria blight severity, %, 2001												
S_1	10.3	9.7	10.8	8.2	9.7	9.7	6.4	5.8	5.9	5.7	6.9	6.1
S_2	10.0	10.0	10.6	9.2	10.4	10.0	5.7	5.9	6.3	5.7	5.7	5.9
S_3	10.0	10.0	10.7	9.7	9.7	10.0	5.5	6.7	7.2	6.5	7.0	6.6
Mean B	10.1	9.9	10.7	9.0	9.9	9.9	5.9	6.1	6.5	6.0	6.5	6.2
LSD_{05}	F_A=0.55; F_B=0.78; F_{AxB}=1.45						F_A=0.35; F_B=0.49; F_{AxB}=0.92					
Alternaria blight severity, %, 2002												
S_1	6.9	6.5	7.0	7.5	7.2	7.0	2.0	1.7	1.4	1.6	1.4	1.6
S_2	7.1	7.0	7.0	7.0	6.8	7.0	1.5	1.6	1.5	1.6	1.3	1.5
S_3	7.3	6.5	7.7	6.7	7.2	7.1	1.7	1.6	1.6	1.5	1.6	1.6
Mean B	7.1	6.7	7.2	7.1	7.1	7.0	1.7	1.6	1.5	1.6	1.4	1.6
LSD_{05}	F_A=0.28; F_B=0.40; F_{AxB}=0.75						F_A=0.12; F_B=0.16; F_{AxB}=0.30					

Table 3. The effects of the sowing time and nitrogen rate on the incidence and severity of downy mildew on the lower and middle leaves of winter oilseed rape (BBCH 69), (2000)

Sowing time (factor A)	N treatment (factor B) Bottom leaves					Mean A	N treatment (factor B) Middle leaves					Mean A
	0	60	120	180	240		0	60	120	180	240	
	Downy mildew incidence, %, 2000											
S_1	53.3	43.3	30.0	46.7	50.0	44.7	46.7	36.7	23.3	43.3	40.0	38.0
S_2	60.0	43.3	33.3	43.3	43.3	44.6	50.0	43.3	30.0	33.3	30.0	37.3
S_3	60.0	56.7	36.7	50.0	36.7	48.0	33.3	30.0	30.0	36.7	16.7	29.3
Mean B	57.8	47.8	33.3	46.7	43.3	45.8	43.3	36.7	27.8	37.8	28.9	34.9
LSD_{05}	F_A=4.50; F_B=6.36; F_{AxB}=11.90						F_A=4.19; F_B=5.92; F_{AxB}=11.08					
	Downy mildew severity, %, 2000											
S_1	1.5	0.7	0.6	1.0	1.0	1.0	0.6	0.6	0.4	0.7	0.4	0.5
S_2	1.4	1.1	0.5	1.1	0.6	0.9	0.8	0.7	0.3	0.6	0.3	0.5
S_3	2.0	0.7	0.9	0.9	0.4	1.0	0.3	0.3	0.3	0.4	0.2	0.3
Mean B	1.6	0.8	0.7	1.0	0.7	1.0	0.6	0.5	0.3	0.6	0.3	0.4
LSD_{05}	F_A=0.22; F_B=0.31; F_{AxB}=0.59						F_A=0.08; F_B=0.11; F_{AxB}=0.21					

Our experimental evidence suggests that high rates of nitrogen (N 180–240 kg ha^{-1}) promoted the occurrence of Alternaria blight and increased the disease severity on leaves at the end of flowering. These data confirm the earlier published data that high nitrogen rates (80 kg ha^{-1} of N and higher) and frequent irrigation promote the occurrence of Alternaria blight on mustard (Kadian and Saharan, 1988; Saharan, 1991). In our experiments, fertilization intensity had a significant effect on the disease incidence and severity on siliques only in one experimental year (2002). These data only partly agree with the data obtained in the Czech Republic that top dressing with nitrogen significantly increased Alternaria blight intensity on rape pods (Stankova, 1972). Nonetheless, it is likely that too high N rates should be avoided due to the threat of Alternaria blight spread.

Table 4. The effects of the sowing time and nitrogen rate on the incidence and severity of Alternaria blight on siliques of winter oilseed rape (BBCH 87), (2000–2002)

Sowing time (factor A)	N treatment (factor B)					Mean A	N treatment (factor B)					Mean A
	0	60	120	180	240		0	60	120	180	240	
	Alternaria blight incidence, %						Alternaria blight severity, %					
	2000											
S_1	100	100	100	100	100	100	3.5	3.2	4.0	3.4	3.5	3.5
S_2	100	100	100	100	100	100	3.8	3.7	4.0	3.9	3.6	3.8
S_3	100	100	100	100	100	100	4.2	4.6	3.9	4.3	4.1	4.2
Mean B	100	100	100	100	100	100	3.8	3.8	4.0	3.9	3.7	3.8
LSD_{05}							F_A=0.18; F_B=0.26; F_{AxB}=0.49					
	2001											
S_1	98.0	96.7	97.3	96.7	94.0	96.5	4.8	4.4	4.8	4.4	4.4	4.6
S_2	95.3	96.0	94.7	94.0	98.0	95.6	4.0	3.9	3.8	4.1	4.4	4.0
S_3	97.3	94.7	96.0	96.0	96.0	96.0	3.9	3.7	3.7	3.5	3.5	3.7
Mean B	96.9	95.8	96.0	95.5	96.0	96.0	4.2	4.0	4.1	4.0	4.1	4.1
LSD_{05}	F_A=0.64; F_B=0.91; F_{AxB}=1.70						F_A=0.20; F_B=0.28; F_{AxB}=0.52					
	2002											
S_1	45.8	45.3	53.8	49.8	48.0	48.5	0.6	0.7	1.0	0.7	0.9	0.8
S_2	52.9	60.9	70.2	63.1	74.2	64.3	0.6	0.8	1.2	1.0	1.3	1.0
S_3	60.9	65.3	60.9	58.4	64.0	61.9	0.7	0.8	0.8	0.8	1.1	0.8
Mean B	53.2	57.2	61.6	57.1	62.1	58.2	0.6	0.8	1.0	0.8	1.1	0.9
LSD_{05}	F_A=2.68; F_B=3.79; F_{AxB}=7.08						F_A=0.05; F_B=0.07; F_{AxB}=0.14					

It was found that at the end of winter rape flowering Alternaria blight in 2001 and 2002 was more abundantly spread on the bottom and middle leaves in winter rape sown at an early date. The data obtained in our experiments agree with the data obtained earlier by other researchers who have also reported that *Alternaria spp*. is likely to spread more abundantly in early-sown rape crops (Evans, Gladders, 1981). However, in our experiments the disease incidence and severity on siliques in 2000 and 2002 were significantly higher in winter rape plots sown at later dates compared with winter rape plots sown at earlier dates. The plants of the later sowing dates were more strongly infected by Alternaria blight also in Poland and India (Sadowski *et al.*, 2002; Gupta *et al.*, 2003). However, these trends were not confirmed in our experiments in 2001.

Experimental findings suggest that nitrogen fertilizers had a more marked and diverse effect on powdery mildew incidence and severity, these indicators were significantly lower for N-applied plots, compared with unfertilized plots. Other authors have concluded that the date of sowing and fertilization systems did not have any effect of statistical significance on the infection with downy mildew (Sadowski *et al.*, 2002). However, in Germany it was established that increase in the N fertilizer rate resulted in the increase in infection by downy mildew (Söchting and Verreet, 2004). As we can see, the data on the effects of sowing data and nitrogen fertilization intensity on the incidence of various oilseed rape diseases, obtained by various authors, are contradictory, therefore similar research is essential seeking to specify the effects of various crop cultivation and management practices on the incidence and severity of various diseases.

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References

1. Coelho P. S., Monterio A. A. (2003) Inheritance of downy mildew resistance in mature broccoli plants. Euphytica, 131, 65–69.
2. Conn K. L., *et al* (1990) A disease assessment key for Alternaria blackspot in rapeseed and mustard. Canadian Journal of Plant Disease, 70, 19–20
3. Evans E. J., Gladders P. (1981) Diseases of oilseed rape and their control, East and South-Last England, 1977–1981. In: Proceedings 1981 British Crop Protection Conference – Pests and Diseases. 2, 505–512
4. Gupta R., *et al* (2003) Influence of sowing dates and weather factors on development of Alternaria blight on rapeseed-mustard. Indian Phytopathology, 56 (4), 398–402.
5. Jensen B. D., *et al* (1999) Seedling and adult plant resistance to downy mildew (*Peronospora parasitica*) in cauliflower (*Brassica oleracea convar. Botrytis var. botrytis*). Plant Pathology, 48, 604–612.
6. Kadian A. K., Saharan G. S. (1988) Progress of Alternaria blight of mustard in relation to cultural practices. Oil Crops Newsletter, 5, 32–33.
7. Kennedy R., Graham M. (1995) Infection on oil-seed rape by *Alternaria brassicae* under varying conditions of temperature and wetness. In: 9th Inter. Rapeseed congress, Cambridge. 2, 601–603.
8. Krüger W. (1991) Efficiency of specific fungicidal treatments in autumn and / or in spring. In: Bulletin OILB SROP. 14 (6), 89–90.
9. Sadowski C. *et al.* (2002) Health status of spring rape plants as affected by the sowing date and fertilisation with sulphur, boron and magnesium. In: IOBC WPRS Bulletin. 25, 2, 93–102.
10. Sadowski C. *et al.* (2002) Occurrence of fungal diseases on spring oilseed rape in Poland. In: IOBC WPRS Bulletin 25 (2), 1–12.
11. Saharan G. S. (1991) Assessment of losses, epidemiology and management of black spot disease of rapeseed-mustard. In: GCIRC 8th Inst. Rapeseed Congress. July 9–11, Saskatoon, Canada, Proceedings. 2, 465–470.
12. Sharma S. R., Kolte S. J. (1994) Effect of soil-applied NPK fertilizers on severity of black spot disease (*Alternaria brassicae*) and yield of oilseed rape. Plant and Soil. 167, 313–320.
13. Söchting H. P., Verreet J. A. (2004) Effects of different cultivation systems (soil management and nitrogen fertilization) on the epidemics of fungal diseases in oilseed rape (*Brassica napus* L. var. *napus*). Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, 111 (1), 1–29.
14. Stankova J. (1972) Varietal variability of winter rape in its susceptibility to dark leaf spot and the factors influencing the development of the disease. Rostlinna Vyroba, 18, 625–630.

CHENOPODIUM ALBUM AND *RUMEX CRISPUS* SEEDLING BIOMASS, ROOT AND SPROUT FORMATION DEPENDENCE ON DIFFERENT ABIOTIC FACTORS AND THEIR COMBINATIONS

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Abstract

The greenhouse experiments were carried out on basis of the Lithuanian Institute of Horticuture in 2004, analysing the initial growth of two weed species: *Chenopodium album* L. and *Rumex crispus* L. The aim of this work was to evaluate cadmium (Cd), cuprum (Cu) and sulphur acid (H_2SO_4) concentration – substratum acidity pH, temperature (hot and cool chamber) and their combinations influence on selected two biological different weed species seedling roots and sprouts length and biomass formation. Weed seedling growth was strongly influenced by the level of growing substratum pH, concentration of Cu and Cd, and environment temperature. Weed seedling biomass accumulation has tendency to decrease essentially by acidity of the environment, as well as the length of their roots and sprouts. Increased concentration of Cu and Cd inhibited evolution of weed seedlings. However, repeatedly used Cu, Cd or acid has less influenced weed seedlings evolution. Consequently weed has partial adapted to the negative environment influence. In some cases Cu operates as microelement and stimulates growth of *Chenopodium album* L. and *Rumex crispus* L.

Key words: *Chenopodium album*, *Rumex crispus*, root and sprout length, seedling biomass, adaptation, abiotic factors

Introduction

Investigated weed species are widely spread in Europe, Asia and etc. (*Rumex crispus* L.) or even belong to cosmopolitan group of plants (*Chenopodium album* L.). They are spread in agricultural lands and set–aside all over the world (Aleksandraviciute *et al.*, 1961; Holm *et al.*, 1979; Galinis *et al.*, 1980). *Chenopodium album* is an annual hardly exterminated weed because one plant can give about 100000 or till 200000 seeds which germinate not all at once (Aleksandraviciute *et al.*, 1961; Grigas, 1986). *Rumex crispus* is a perennial weed which is mostly propagated by seeds which grows in no-acid or slightly acid clay and sandy loam soils of normal humidity (Aleksandraviciute *et al.*, 1961). Additional amount of heavy metals gets into the system soil-plants using mineral calcareus maters intensively (Соловьев, Голубев, 1981; Алексеев, 1987). The amount of heavy metals in plants in Lithuania is various. (Mazvila, 2001). Heavy metals in plants usually accumulate from the soil. Later these elements can get into the organism of animals and humans (Mazvila *et al.*, 2001).

Adaptation possibility of separate plant species is different and can vary their competition as environment conditions change. It can cause serious agricultural problems. Undesirable change of plant species follow when environment conditions vary in ecosystems. Usually weeds signify by higher plasticity.

The aim of our experiment was to evaluate initial growth possibilities in vegetative-greenhouse conditions of *Chenopodium album* and *Rumex crispus* by the given different acidity (H_2SO_4 concentration), Cu and Cd concentrations, temperatures and their combinations.

Materials and Methods

Site and treatments. The experiment was conducted at the Lithuanian Institute of Horticulture. The seeds of investigated weed species were collected at the Research Station of the Lithuanian University of Agriculture in the summer and autumn of 2003. Seeds were cleaned and stored in darkness at room temperature until use.

Weed seed viability evaluation. Weed seed viability of *Chenopodium album* and *Rumex crispus* was tested in four replications using method of the acid fuchsin (Ермаков *et al.*, 1952). 25 seeds in each covered Petri dish (9 cm in diameter) were watered by 5 mL of distilled water and laid for 24 hour to bloat. Bloated seeds were watered for 15 minutes by 5 mL of 0.1% concentration acid fuchsin ($C_{19}H_{13}N_3O_9S_3Na_2$), then washed by distilled water and crushed using forceps. White, uncoloured seeds were considered as viable.

pH (acidity) and Cd evaluation for the initial growth of weed seedlings. For the evaluation of pH influence for the initial growth of *C. album* and *R. crispus* seedlings vegetative – greenhouse experiment was conducted. Substratum of turf was used in the plastic pots (capacity of 5 L). For the achieving different turf substratum pH acidity sulphur acid was used. Two days before experiment substratum of turf was watered by the 3 L sulphur acid solution of 0,5; 1; 2; 4; 6 and 8 mL L^{-1} concentration. Therefore, acidity of turf substratum reached 6.2, 6.0, 5.4, 4.9, 2.6 and 2.4 pH. Control treatment pots were watered by the water where pH level was 6.4. Till the weed emergence and one week after emergence pots were kept in greenhouse and lasted two weeks (14 days) – were moved to the phytotron (Table 1).

For the evaluation of *Cadmium (Cd)* influence for the initial growth of *Chenopodium album* and *Rumex crispus* seedlings conducted vegetative – greenhouse experiment as for the pH evaluation. Only for the achievement of different cadmium concentration in the substratum for each pot 3 L of cadmium saline ($CdSO_4 \cdot 8H_2O$) was used with concentration of 0.01M, 0.05M, 0.1M and 0.5M. Substratum pH was 6.1 (Table 2).

Emerged weeds were thinned out to left 30 seedlings per pot. Results were evaluated after 21 days from weed emergence. Length of roots and sprouts were measured (mm) and weed biomass (g per pot) was established oven-dried at 105 ^{0}C. The experiment was conducted in three replications. At the end of experiment over-ground weed biomass and its length were evaluated.

pH, Cd and Cu complex evaluation for the initial growth of weed seedlings. In the second step of the experiment complex effect of pH, Cd and Cu was evaluated for the initial growth of weed seedlings. For the experiment turf substratum with pH 6.4 was used. 1 month after weed emergence was used Cu 2.0 M, Cd 0.16 M and concentrated sulphur acid 5 mL L^{-1} to evaluate effect on its growth. Pots were watered by the 1.5 L of solution. After 14 days initial effect of Cu, Cd and acid on weed growth was evaluated (Tables 3 and 4). Left pots were watered repeatedly with the solutions of Cu, Cd and sulphur acid the same concentrations and amount as for the first impact. Effect on weed growth was evaluated after 8 days (Tables 5, 6, 7 and 8). The experiment was conducted in three replications.

Photoperiod and regime of temperature. Photoperiod of 14/10 h was used. Regime of temperature 24/17^{o}C was used. For the separate stages of the experiment two regimes of temperature were distinguished – hot chamber – 27/20 ^{o}C and cool chamber – 21/17 ^{o}C.

Data analysis. The research data of vegetative-greenhouse experiment were analysed by means of ANOVA. The treatment effects and standard errors (SE) were tested for significance using the Sigma Stat software (SPSS Science, 1997).

Results and Discussion

Viability of investigated weed seeds was 84% for *Chenopodium album* and 89% for *Rumex crispus*. Investigating different substratum acidity influence on *Chenopodium album* growth, it was established that plant growth was mostly inhibited by the highest concentration of sulphur acid (8 mL L^{-1}) which acidified substratum till pH 2.4 (Table 1).

Table 1. Sprout length and over-ground biomass of *Chenopodium album* seedlings, grown insubtratum under different pH levels achieved by the influence of concentrated sulphur acid

Indexes	Sprout length, mm	Crude biomass, g	Air-dry biomass, g
Control, pH 6.4 (0.0 mL L^{-1}acid was not used,)	109.51	49.73	4.90
pH 6.2 (0.5 ml L^{-1})	100.47*	35.13*	3.00**
pH 6.0 (1.0 ml L^{-1})	101.82*	43.10	3.73*
pH 5.4 (2.0 ml L^{-1})	120,10**	58.10*	5.27
pH 2.6 (4.0 ml L^{-1})	119.24*	64.20*	5.60
pH 2,4 (8.0 ml L^{-1})	69.94**	12.00**	1.23**
±SE	1.046	4.27	0.377
P	<0.001	<0.001	<0.001

pH – substratum acidity. ±SE – standard error; P – level of significance. * Significant differences from control treatment at P<0.05; ** Significant differences from control treatment at P<0.01.

The same tendencies were established for the dry biomass. This supplemented our former experiments (Pilipavicius *et al.*, 2004) that *Chenopodium album* are naturalized to emerge and grow in wide range of soil and substratum acidity.

Evaluating Cd of different concentrations influence on *Chenopodium album* (Table 2), it was established that *Chenopodium album* are sensitive to the effect of Cd and even the smallest concentration of Cd (0.01 M Cd SO_4) suppressed their growth more than 50%. *Chenopodium album* did not grow at all when concentration of Cd was 0.5M.

Table 2. Sprout length and over-ground biomass of *Chenopodium album* seedlings, grown in subtratum under different levels of Cd concentration

Indexes	Sprout length, mm	Crude biomass, g	Air-dry biomass, g
Control (Cd was not used)	109.51	49.73	4.90
Cd 0.01 M	52.42**	4.73**	0.47**
Cd 0.05 M	42.18**	1.80**	0.17**
Cd 0.1 M	30.92**	0.20**	0.067**
Cd 0.5 M	0.00**	0.00**	0.00**
±SE	1.13	4.997	0.447
P	<0.001	<0.001	<0.001

Cd – cadmium; ±SE – standard error; P – level of significance; * – significant differences from control treatment at P<0.05; ** – significant differences from control treatment at P<0.01.

Established influence of substratum acidity and concentration of Cd on growth of *Chenopodium album* was evaluated level of effect of *Chenopodium album* and additionaly of *Rumex crispus* using different concentration of sulphur acid, cadmium and cuprum (Tables 3 and 4) and level of adaptation using antropogenical chemicals repeatedly (Tables 5, 6, 7 and 8). After initial proceed with Cu, Cd and acid on *Chenopodium album* essential differences were not established between treatments in both temperature regimes – hot and cool chambers (Table 3).

Table 3. Sprout length and biomass of *Chenopodium album* seedlings grown in subtratum under different levels of Cd, Cu and acid concentrations

Indexes	Hot chamber			Cool chamber		
	sprout length, mm	crude biomass, g	air-dry biomass, g	sprout length, mm	crude biomass, g	air-dry biomass, g
Control	52.92	10.28	1.63	53.58	10.89	1.96
Cu (2 M)	54.33	13.14	2.06	46.42	13.74	1.95
Cd (0.16 M)	48.33	10.65	1.42	52.17	14.94	2.12
Acid (5 mL L^{-1})	50.17	13.87	2.44	42.33	9.31	1.59
±SE	1.877	0.840	0.163	1.901	0.866	0.139
P	0.684	0.372	0.133	0.127	0.053	0.441

Cu – cuprum; Cd – cadmium; ±SE – standard error; P – level of significance.

Carrying out analogical experiment on *Rumex crispus* in cool chamber essential differences were not established as in hot chamber essential increase of sprout length and biomass was got (Table 4).

Table 4. Sprout length and biomass of *Rumex crispus* seedlings grown in subtratum under different levels of Cd, Cu and acid concentrations

Indexes	Hot chamber			Cool chamber		
	sprout length, mm	crude biomass, g	air-dry biomass, g	sprout length, mm	crude biomass, g	air-dry biomass, g
Control	33.08	18.60	1.18	41.33	36.19	2.84
Cu (2.0 M)	40.33**	43.53**	2.61*	42.67	50.18	3.03
Cd (0.16 M)	43.67**	42.33**	2.27*	43.75	41.31	2.58
Acid (5mL L^{-1})	38.67*	36.40*	2.42*	40.50	32.57	2.47
±SE	0.914	2.618	0.198	0.728	2.818	0.226
P	<0.001	<0.001	0.043	0.416	0.136	0.823

Cu – cuprum. Cd – cadmium, ±SE – standard error. P level of significance. * significant differences from control treatment at P<0.05. ** significant differences from control treatment at P<0.01.

Weed sprout length and seedling biomass change tendencies were established after *Chenopodium album* and *Rumex crispus* adaptation period when they were influenced by acid, cadmium and cuprum repeatedly by various their combinations (Tables 5 and 6). *Chenopodium album* seedling length and biomass growth was mostly stopped by repeated acid and cadmium effect in both regimes of temperature. Root growth was inhibited analogically as over-ground plant part; however, there was already essential growth inhibition.

Table 5. Sprout length and biomass of *Chenopodium album* seedlings grown in substratum repeatedly using Cd, Cu and sulphur acid

	Hot chamber					Cool chamber				
	sprouts			roots		sprouts			roots	
Indexes	length, mm	crude biomass, g	air-dry biomass, g	crude biomass, g	air-dry biomass, g	length, mm	crude biomass, g	air-dry biomass, g	crude biomass, g	air-dry biomass, g
Control	44.03	91.37	15.38	29.55	3.84	44.03	122.93	16.88	19.97	3.07
Control+acid	52.33	92.37	13.82	19.76*	3.18	54.37*	104.57	16.58	14.47	2.75
Control+Cu	52.09	88.67	11.15	20.82*	2.12*	48.71	107.63	15.38	12.57	2.12
Control+Cd	54.00*	109.33	16.16	20.46*	2.38*	52.57*	99.33*	15.53	11.67	2.15
Acid	46.82	105.50	14.39	23.55	3.24	47.14	103.07	15.56	11.37	2.02
Acid+ acid	37.34*	51.50**	6.73	9.06**	0.97**	43.81	72.93*	13.45	9.00*	1.59
Acid+Cu	46.94	88.17	12.47	21.66*	2.97	38.24	84.47	11.34	8.87*	1.36
Acid+Cd	44.63	101.00	13.28	20.24*	2.69*	36.25*	104.10	15.14	14.93	2.38
Cu	48.20	99.77	14.87	27.14	2.903	41.60	100.10	14.45	14.13	2.67
Cu+ acid	47.80	95.00	11.890	19.74*	2.35*	42.97	74.97**	11.16	16.13	3.52
Cu+Cu	50.54	98.50	13.70	24.63	2.83	51.71*	102.37	14.06	17.83	3.08
Cu+Cd	50.46	85.17	11.81	25.02	2.72*	42.63	83.73*	12.74	17.50	2.61
Cd	43.43	89.17	12.21	20.43*	2.72*	46.91	101.97	16.02	22.17	3.57
Cd+acid	49.97	93.33	13.63	25.90	3.84	37.58	69.20**	7.87	15.83	2.11
Cd+Cd	39.14*	95.13	10.87	21.45*	2.58*	46.00	98.70*	13.86	17.93	3.15
Cd+Cu	41.97	100.07	10.54	20.07*	2.20*	45.66	104.13	13.55	20.23	3.01
±SE	0.700	2.462	0.466	0.810	0.124	0.622	2.796	0.493	0.816	0.162
P	<0.001	0.014	0.055	0.001	0.002	<0.001	0.013	0.094	0.073	0.477

Cu – cuprum; Cd – cadmium, ±SE – standard error; P – level of significance: * Significant differences from control treatment at $P < 0.05$; ** Significant differences from control treatment at $P < 0.01$.

Table 6. Sprout length and biomass of *Rumex crispus* seedlings grown in substratum repeatedly using Cd, Cu and sulphur acid

	Hot chamber						Cool chamber					
	sprouts			roots			sprouts			roots		
Indexes	length, mm	crude biomass, g	air-dry biomass, g	length, mm	crude biomass, g	air-dry biomass, g	length, mm	crude biomass, g	air-dry biomass, g	length, mm	crude biomass, g	air-dry biomass, g
Control	38.67	95.37	4.34	19.67	7.53	0.71	44.40	117.47	5.54	23.00	12.17	1.59
Control+acid	40.40*	60.77	3.06	20.60	5.57	0.49	44.67	42.03*	2.04*	20.33	12.93	0.59
Conrol+Cu	42.00*	71.23	4.06	18.50	7.43	0.92	50.25	124.03	6.27	24.25	7.43	1.79
Control+Cd	40.00	90.03	4.34	20.83	8.73	0.96	36.00	58.30	2.70	19.00	6.23*	0.72
Acid	46.67	111.27	5.38	20.00	11.40	1.08	41.20	93.00	5.13	26.40	10.73	1.13
Acid+acid	43.29	95.10	3.46	23.33	8.37	0.73	37.50	48.67	1.74*	23.25	4.47*	0.46
Acid+Cu	46.60	98.10	4.74	25.00	9.47	0.88	44.67	94.83	4.74	19.33	12.20	1.20
Acid+Cd	38.80	87.30	4.37	18.80	9.13	0.79	40.60	79.13	3.85	25.00	10.40	1.33
Cu	48.75*	125.03	6.51	26.00*	10.80	1.10	44.00	56.63	4.01	22.80	9.57	0.78
Cu+acid	49.20*	106.70	5.61	23.00	9.40	1.05	44.00	77.40	3.47	21.00	7.40	0.68
Cu+Cu	41.17	95.83	5.68	19.67	8.37	0.84*	58.00*	110.60	5.05	23.00	8.13	1.14
Cu+Cd	46.40	136.66	7.13	22.00	10.23	1.15	43.33	90.37	4.27	25.33	6.97	83.73**
Cd	47.20*	120.93	5.77	22.60	10.40	1.03	41.50	107.23	4.96	21.00	8.60	1.00
Cd+acid	38.67	55.50	2.83	20.83	5.90	0.50	45.67	113.63	5.11	24.83	10.60	1.03
Cd+Cd	43.80	105.13	5.36	22.40	8.70	0.85	43.60	136.23	5.86	24.60	11.47	1.07
Cd+Cu	48.00*	106.4	4.86	20.60	9.07	0.67	49.00	149.90	6.50	23.33	12.80	1.31
±SE	0.701	5.780	0.277	0.506	0.496	0.0616	0.873	6.282	0.286	0.493	0.541	0.0694
P	0.015	0.609	0.295	0.427	0.875	0.864	0.013	0.029	0.046	0.196	0.098	0.001

Cu – cuprum; Cd – cadmium, ±SE – standard error; P – level of significance: * Significant differences from control treatment at $P < 0.05$;
** Significant differences from control treatment at $P < 0.01$.

Interesting results were obtained with *Chenopodium album* effected it by Cu and Cd in control pots. Here length of *Chenopodium album* seedlings had tendency to increase and over-ground and root biomass to decrease. However, repeatedly used acid, Cd and Cu just cuprum although not essentially induced seedling growth. Likely, Cu could effect as required microelement for plants (Table 5). Analogically Cu induced growth of *Rumex crispus* in both regimes of temperature, when cadmium growth inhibited and acid effect was not asserted except two time use of acid. Evaluating regimes of temperature, *Rumex crispus* better grew in cool chamber than in hot one (Table 6). *Chenopodium album* effected contrary – their growth was more intensive under condition of higher temperature. Roots formation was adequately weed over-ground part (Table 5). During short time period weeds cannot adapt to the anthropogenic elements (Cu, Cd and sulphur acid) though partial adaptation occurs; repeated use of Cu, Cd and sulphur acid inhibited *Chenopodium album* and *Rumex crispus* growth not so intensively. Besides, weeds at early growth stages reacted more sensitively to used chemical matters. It happened due to accumulated less amounts of nutrition matters in weed seedlings at early growth stages.

Conclusions

Performed researches showed that *Chenopodium album* is adapted to grow in wide diapason of substratum acidity (pH 6.4–2.6). It was established that *Chenopodium album* growth was inhibited only by the highest acid concentration (8 mL L^{-1} concentrated sulphur acid), which formed pH 2.4.

Chenopodium album showed high sensitivity to cadmium. Their growth was suppressed more than 50% even by the lowest concentration of cadmium solution (0.01 M $CdSO_4$) and by the 0.5 M $CdSO_4$ *Chenopodium album* did not grow at all.

Investigating complex influence of sulphur acid, cadmium and cuprum sulphates separately and jointly were established only partial adaptation of *Chenopodium album* and *Rumex crispus* for used anthropogenic chemicals.

Weed watered by Cu sulphate established tendency of *Chenopodium album* and *Rumex crispus* growth intensification. It could occur when Cu effected as microelement in both regimes of temperature.

Evaluating regimes of temperature, it was established that *Rumex crispus* grew better in cool chamber (21/17 ^{o}C) and *Chenopodium album* contratry – their growth intensified in environment of higher temperature regime (27/20 ^{o}C).

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References

1. Aleksandraviciute B., Apalia D., Brundza K. *et al.* (1961) Lietuvos TSR flora, Vol. III (ed. A Minkevicius). Mokslas, Vilnius, Lithuania.
2. Galinis V., Jankeviciene R., Kiziene B. *et al.* (1980) Lietuvos TSR flora, Vol. VI (ed. A Minkevicius). Mokslas, Vilnius, Lithuania.
3. Grigas A. (1986) Lietuvos augalu vaisiai ir seklos. Mokslas, Vilnius, Lithuania.
4. Holm L. G., Pancho J. V., Herberger J. P., Plucknett D. L. (1979) *Geographical Atlas of World* Weeds. John Wiley & Sons, New York, USA.
5. Mazvila J. (2001). Sunkieji metalai Lietuvos dirvozemiuose ir augaluose. Monografija. Kaunas, 163–174.
6. Mazvila J., Adomaitis T., Eitminavicius L., Lubyte J., Antanaitis A., Matusevicius K. (2001) Sunkieji metalai Lietuvos dirvozemiuose ir augaluose. Zemdirbyste. Mokslo darbai, 73, 64–90.
7. Pilipavicius V., Romaneckiene R., Ramaskeviciene A., Sliesaravicius A. (2004) Weed seed germination, root and sprout formation Dependence on different acidity environment. EWRS XII^{eme} Colloque International sur la biologie des mauvaises herbes. Dijon, France, 305–312.
8. Spss Science (1997) SigmaStat® Statistical Software Version 2.0. User's Manual. USA.
9. Алексеев Ю. В. (1987) Тяжелые металлы в почвах и растениях. – Л., 141.
10. Ермаков А. Н., Арасимович В. В., Смирнова-Иконникова М. И., Мурри И. К. (1952) Методы биохимического исследования растений. Москва – Ленинград.
11. Соловьев Г., Голубев М. (1981) Влияние минеральных удобрений на содержание тяжелых металлов в растениях. Агрохимия, 11, 114–119.

ACTIVITY OF α – AMYLASE IN RYE GRAIN AND ITS RELATIONSHIP WITH OTHER TRAITS

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Abstract

The prime task set for the up-to-date winter rye breeding is to improve grain yield and bread-making qualities. To achieve a high quality of bread, an optimal α-amylase activity is required. The activity of α-amylase in rye grain and its relationship with protein and starch content, thousand grain weight and volume weight were studied in a field experiment set up at the Lithuanian Institute of Agriculture during 2001–2003. The tests involved 14 new, advanced rye breeding numbers and the check variety 'Duoniai'. The experimental findings suggest that the falling number ranges from 165 to 263 s, protein content from 11.2 to 14.6, starch content from 57.7 to 59.7 g kg^{-1}. A thousand grain weight is within the range 34.1–40.4 g, volume weight – 692–752 g l^{-1}, which is common for Lithuanian rye. The best falling number index 263 s was obtained for the breeding number LIA 463, high falling numbers were identified for LIA 395, 423 and 424. The germplasm of these breeding numbers included parental varieties from West European countries 'Amilo', 'Motto', and 'Hacada', as well as the local variety 'Kombaininiai'. The analysis of paired regression revealed a high significant negative correlation between protein content and falling number, and a positive correlation between falling number and starch content. A less significant positive correlation was identified between a thousand grain weight and protein content and falling number and volume weight.

Key words: winter rye, varieties, grain quality

Introduction

In Lithuania, winter rye occupies 60,000–70,000 ha annually. The total annual production is 150,000–170,000 t, average yield amounts to 2.3–2.5 t ha^{-1}. From the economic point of view winter rye is one of the most important crops, especially in the regions of low soil productivity or in low input farming systems.

The air humidity in Lithuania during the harvest time is relatively high. Rye grains have a general tendency to rapid sprouting in the spikes when the air humidity is a little higher. Pre-harvest sprouting, which is determined by high activity of amylases, resulted in low quality of rye grain. On the other hand, α-amylase is one of the important components that determines the technological structure of rye dough as well as protein content (Wannerberger, 1996).

The prime task set for the up-to-date winter rye breeding is to improve grain yield and bread-making qualities. To achieve a high quality of bread, an optimal α-amylase activity is required (Drews and Seibel, 1976; Juodeikienė and Repečkienė, 2003).

Generally, a high falling number of rye flour (above 200 s) results from the low α-amylase activity, whereas low falling number (below 100 s) is connected with higher α-amylase activity. The range between 100 and 200 s is of technological interest for rye (Brummer, 2003). According to Lithuanian standards, the falling number has to be not lower than 100 and not higher than 270 s (LST 1580-99). Nevertheless, milling industry prefers rye grain with a higher falling number index, because in Lithuania there is often risk that part of purchased rye grain will be harvested in not optimal conditions, and a feasibility to improve grain quality of milling lots is always attractive.

Other authors report that starch content is important for winter rye grain quality (Scierbum *et al.*, 1991) as well as for protein content (Eliasson, 1995). Studies of literature and personal observations enable to make the conclusion that actual rye grain quality is a proper proportion among the main chemical components.

The activity of α-amylase in rye grain and its relationship with protein and starch content, thousand grain weight and volume weight were studied in a field experiment set up at the Lithuanian Institute of Agriculture during 2001–2003.

Material and Methods

The field experiments were set up at the Lithuanian Institute of Agriculture in the replicated yield test. The test plots were 15 m^2 planted in 4 replications. $N_{90}P_{24}K_{43}$ was applied annually. The experiment included 14 newly developed advanced rye breeding numbers and the check variety "Duoniai", which is well adapted to the Lithuanian conditions and accounts for 50% of the total rye cultivation area in Lithuania.

The harvesting conditions in 2001–2003 were favourable (Table 1). The air temperature was higher than the average in the observation period 1924–2003. The precipitation level was low.

Table 1. The air temperature and precipitation during pre-harvest period 2001–2003

Conditions		2001	2002	2003	Average, 1924–2003
Mean air temperature, ^{0}C	in 10-day period before harvest	21.0	22.1	23.3	
	in 3-day period before harvest	17.5	18.6	22.8	
	in July	17.3	20.3	21.0	16.6
Total precipitation, mm	in 10-day period before harvest	3.0	4.7	15.0	
	in 3-day period before harvest	1.0	1.3	0	
	in July	66.5	35.7	71.5	73.2

The new breeding numbers contain germplasm from different East and West European countries as well as local breeding material in their pedigree. Number LIA 339 was developed from the cross Duoniai/Rosilika; LIA 391: Ilmen/Duoniai; LIA 395: Kombainiai/Immering //Sanile /3/Kombaininiai; LIA 423: Ilmen/Hacada// Motto; LIA 424: LIA 395/Motto; LIA 426: LIA 395/Joniai; LIA 463: Amilo/Motto; LIA 469 Amilo/3/Motto/LIA395//Joniai; LIA431:Duoniai/Exprit; LIA432:LIA 395/ Eksprit; LIA440: LIA 395//Borba/ Duoniai /3/Wibro; LIA455 LIA 395/ Zduno; LIA 468 Amilo/3/LIA 395//Ilmen/Hacada.

Analyses of grain quality were done at the Analytical Laboratory of LIA using conventional methods and facilities. The protein content was determined by Kjeldahl method, starch content by GOST 10845, amylase activity by Perten's Falling Number 1800 (standard ICC No 107). Statistical data processing was performed by the software ANOVA and STAT-ENG using the programme "Selekcija" (Tarakanovas, 1999).

Results and Discussion

In this study we analysed amylase activity, protein and starch content, and two grain characteristics – a thousand grain weight (g) and volume weight (g l^{-1}), important traits for milling industry. The experimental results (Table 2) show that the falling number ranges from 165 to 263 s, protein content from 11.2 to 14.6, starch content from 57.7 to 59.7 g kg l^{-1}. A thousand grain weight is within the range of 34.1–40.4 g, volume weight – 692–752 g l^{-1}, which is characteristic of Lithuanian rye. The best falling number index 263 s was identified for the breeding number LIA 463, high falling numbers were identified in LIA 395, 423 and 424. The germplasm of these selections included parental varieties from West European countries 'Amilo', 'Motto', 'Hacada' as well as the local variety 'Kombaininiai'.

Table 2. Quality characteristics of winter rye varieties and breeding numbers, Dotnuva, 2001–2003

Varieties and breeding numbers	Falling number, s	Protein content, g kg $^{-1}$	Starch content, g kg $^{-1}$	1000 grain weight, g	Volume weight, g l^{-1}
Duoniai	176	12.3	57.7	37.4	752
Joniai	224	11.9	58.8	38.0	739
LIA 339	217	12.1	59.0	37.2	744
LIA 391	206	11.8	58.3	36.7	747
LIA 395	232	12.4	58.1	38.9	745
LIA 423	229	12.2	59.7	38.4	736
LIA 424	222	12.1	58.9	35.7	733
LIA 426	218	12.0	58.1	37.5	748
LIA 463	263	11.2	59.3	37.2	740
LIA 469	202	12.5	58.0	37.3	719
LIA 431	173	12.6	58.2	34.1	707
LIA 432	187	14.6	57.8	35.8	692
LIA 440	178	14.3	58.2	40.4	698
LIA 455	182	13.2	58.7	37.7	737
LIA 468	165	14.3	58.5	39.7	737
LSD 05	15.86**	0.81**	2.06	2.06	31.87**

The analysis of paired regression between protein content and falling number revealed a negative correlation (Fig. 1). The hyperbolic regression was: $Y = 7.022 + 1130.838 / X$. Determination coefficient XY $R^2 = 0.544$, Fisher's test $F = 15.51$ **.

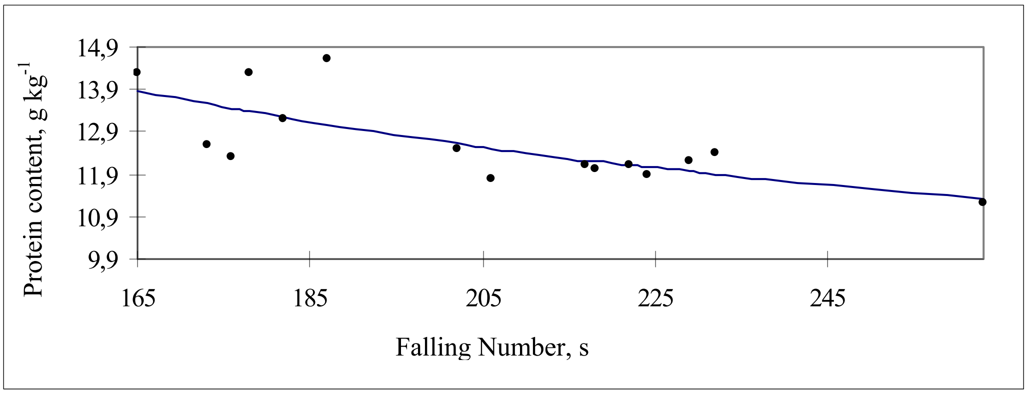

Figure 1. Correlation between the grain protein content and falling number index in winter rye (Dotnuva, 2001–2003)

A positive correlation between starch content and falling number was identified among investigated rye varieties and breeding numbers (Fig. 2). The hyperbolic regression was: Y= 64.791–1363.165/X. Determination coefficient $R^2 = 0.587$; Fisher's test F = 18.45** which showed a high significance of data.

These findings revealed that the focus of Lithuanian breeders on the improvement of grain protein content resulted in an inferior falling number index. The falling number index of Lithuanian rye varieties varied between 120 and 160 s in favourable growing conditions. If harvesting period is characterised by a high level of precipitation, falling number of many varieties is not acceptable. The protein content in Lithuanian varieties is rather high (Ruzgas, Plycevaitiene, 2003).

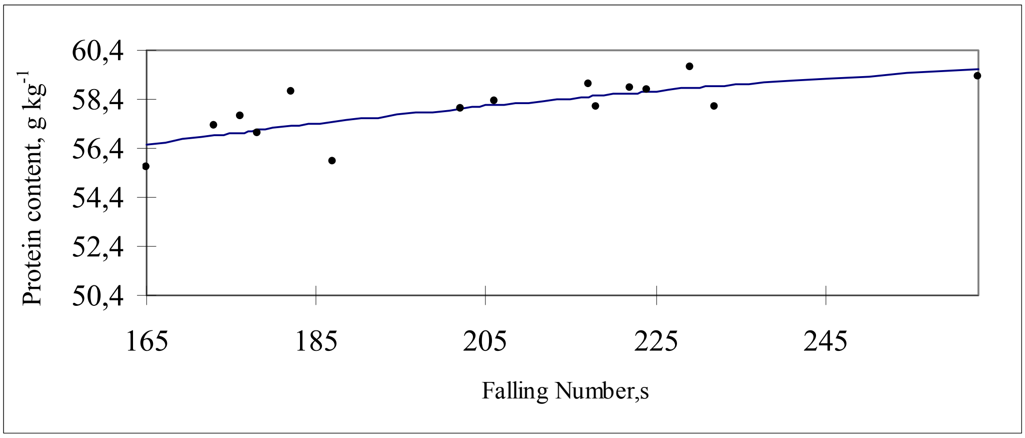

Figure 2. Correlation between the starch content and falling number index in winter rye (Dotnuva, 2001–2003)

On the other hand, the rye growing regions in Lithuania and neighbouring countries are situated in hilly regions with severer winter conditions. Therefore winterhardiness of winter rye varieties should be sufficiently high. To improve the winter hardiness, parental varieties from Eastern Europe were included in Lithuanian rye breeding programmes. These varieties are characterised by a rapid sprouting, which is typical of drier climate conditions.

To improve the bread-making quality of rye grain, most of the new advanced rye populations developed at LIA included West European varieties that were developed in the countries with higher air humidity and stricter requirements for grain quality.

Correlation matrix of the relationship between the falling number and the other 4 parameters: grain protein content, starch content, thousand grain weight (TGW) and specific weight showed (Table 3) a strong negative correlation with the protein content and a positive correlation with starch content. A less significant correlation exists between the falling number and specific weight. TGW has no impact on the falling number index.

Table 3. Relationship between the falling number and protein content, starch content, thousand grain weight (TGW) and specific weight

Quality characteristics	Correlation coefficients				
	Falling number	Protein content	Starch content	TGW	Volume weight
Falling number	1	–0.733	0.745	–0.033	0.417
Protein content		1	–0.827	0.314	–.676
Starch content			1	–0.116	0.532
TKW				1	0.202
Volume weight					1

It was determined that grain protein content positively correlated with TGW and negatively with specific weight. Specific weight has a positive effect on starch content.

Conclusions

To develop winter rye varieties with desirable technological qualities, it is essential to obtain breeding material characterised by a low amylase activity which highly correlates with Perten Falling number index. To achieve this it is recommended to include varieties bred in the countries with a relatively high air humidity in the crossing combinations.

The analysis of paired regression revealed a high significant but negative correlation between the protein content and falling number, and a positive correlation between the falling number and starch content. A less significant positive correlation was identified between a thousand grain weight and protein content, as well as between the falling number and volume weight.

References

1. Brummer J. – M. (2003) Problems with the characterization of rye for bread production in Germany. In: Juodeikiene G. (ed) Proceedings of Conference 1st Baltic Conference on Rye in the EU Context. ICC, Kaunas University of Technology, 79–96.
2. Drews E., Seibel W. (1976) Bread-baking and other uses around the world. In. Bushuk (ed) Rye: production, chemistry and technology, W. St. Paul, Minesota, 127–180.
3. Eliasson A. – C. (1995) Rye proteins at the air/ water interface. In: International rye symposium: technology and products. – Espoo, 131–136.
4. Juodeikienė G. Repeckienė A. (2003) Influence of raw material properties and technological factors on rye bread quality. In: Juodeikiene G. (ed) Proceedings of Conference 1st Baltic Conference on Rye in the EU Context. ICC, Kaunas University of Technology, 116–125.
5. LST 1580-99. Rugiai. (1999) Supirkimo ir tiekimo reikalavimai. – Vilnius, 6.
6. Ruzgas V. Plycevaitienė V. (2003) The key objectives in winter cereals breeding at the Lithuanian Institute of Agriculture. Biologija, 1, 78–79.
7. Scierbum F. *et al.* (1991) Studies on rye starch properties and modification. Part I. Composition and properties of rye starch granules. In: Starch/Starche. Vol. 43, No 9, 331–339.
8. Tarakanovas P. (1999) Statistinių duomenų apdorojimų programų paketas „Selekcija“. – Akademija, Lithuania, 59.
9. Wannerberger L. (1996) Cereal proteins.Interfacial and physiological properties. In: doctoral thesis. – Sweden, 64.

APHIDS AND THIPS OCCURRENCE AND CONTROL MEASURES IN WINTER RYE

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Abstract

Studies were carried out at the Lithuanian Institute of Agriculture during the period 2001–2004. Contact and systemic insecticides were used for pest control in winter rye. Pesticide application timing was determined according to thrips and aphids threshold of harmfulness. In Lithuania, the threshold of thrips harmfulness is 1–2 pests per stem, and that of aphids – 5–10 pests per stem. The experimental results suggest that thrips and aphids were the main pests occurring in winter rye crops during the experimental years. The occurrence of thrips was intensive each experimental year. The occurrence of aphids was intensive in 2002 and 2004. Thrips reached the threshold of harmfulness at winter rye stem elongation stage in 2001, 2002 and 2004, and at booting stage in 2003. Aphids reached the threshold of harmfulness at grain development stage in 2002 and 2004. Both insecticides significantly decreased the occurrence of thrips and aphids. Winter rye yield was higher in the plots applied with insecticides.

Key words: winter rye, thrips, aphids, insecticides, grain yield

Introduction

Since the middle ages rye bread has been a staple food and the most common flour used for baking breads in Lithuania. Nowadays winter rye is primarily grown for food and forage production. The decline in the rye cultivation area at the end of last century resulted from a lower yielding ability of rye compared with wheat. One of the factors responsible for the diminution in rye grain yield is pests. Major pests of cereal crops in Lithuania are frit fly (*Oscinella spp*.), aphids (*Rhopalosiphum padi* L. and *Sitobion avenae* F.), sawfly (*Pachynematus clitellatus* Lep.), lemma (*Lema spp*.) and thrips (*Thysanoptera*) (Šurkus, 1997). Of all winter cereals, the highest occurrence of thrips was found on winter rye in Lithuania (Šmatas, 2002b). Polish experimental evidence suggests that the abundance of thrips tends to increase annually (Kąkol and Kucharczyk, 2004). Through the use of insecticides against thrips, winter rye yield increased by 11.4–12.5% (Šmatas, 2002 a). The research data on the occurrence and damage done by aphids in winter rye are scarce. The aim of our study was to estimate the abundance of aphids and thrips in winter rye and to compare the efficacy of contact and systemic insecticides against sucking pests, using the insecticides according to thrips and aphids thresholds of harmfulness.

Materials and methods

The field trial was conducted at the Lithuanian Institute of Agriculture in Dotnuva during 2001–2004. The winter rye variety 'Duoniai' was sown at a rate of 4.5 million seed ha^{-1} with 12 cm row spacings. P_{60} and K_{60} fertilizers were applied in the autumn before drilling. Nitrogen was applied twice: N_{90} – at the beginning of the growing season, and N_{30} at the stem elongation stage.

Experimental design:

1. untreated;
2. Karate 0.2 l ha^{-1} at an average infestation level of 1–2 thrips per stem (in tables marked as KT);
3. Actara 0.06 kg ha^{-1} at an average infestation level of 1–2 thrips per stem (in tables marked as AT);
4. Karate 0.2 l ha^{-1} at an average infestation level of 5–10 aphids per stem (in tables marked as KA);
5. Actara 0.06 kg ha^{-1} at an average infestation level of 5–10 aphids per stem (in tables marked as AA).

The trial was carried out in four replicates, with randomly arranged treatments. The initial size of an experimental plot was 25 m^2 (2.5 × 10 m), of a record plot – 22 m^2 (2.2 × 10). Contact insecticide Karate (active ingredient lamda-cyhalothrin 50 g l^{-1}) and systemic insecticide Actara (active ingredient thiamethoxam 250 g kg^{-1}) were used for the spray application. Insecticide application timing was determined according to thrips and aphids thresholds of harmfulness. In Lithuania, the threshold of thrips harmfulness is 1–2 pests per stem and that of aphids – 5–10 pests per stem. Infested stems must account for not less than 50 percent (Šurkus, 2002). The assessments of pests were made according to EPPO guidelines. The assessment of pest infestation before the spray application was made by inspecting 25 main stems in the protection bands. The first assessment was made 3–4 days after the spray application, and the other assessments were repeated weekly. Ten main stems per plot, selected randomly, were assessed. Aphids were counted on ears, leaves and stems of each plant, thrips were counted by opening leaf sheaths. After winter rye heading, thrips were counted on ears too. Plant growth stages were estimated according to the BBCH scale. The plots were harvested and the grain yield (t ha^{-1}) was adjusted to 15% moisture content. The profit per-treatment was calculated by deducting the cost of spray applications per 1 ha (20 Lt) and insecticide price per 1 ha (Karate 19.00 Lt, Actara 30.18 Lt) from the value of extra yield (310 Lt t^{-1}). The significance of data was determined by the Fisher's criterion with a significance level of $P \leq 0.01$ and 0.05. Prior to the statistical analysis, the data of thrips and aphids counts per tiller were transformed to Sqr(X); percentages were transformed to Asin(Sqr(X%)). Significant differences from untreated in tables are marked as **($P \leq 0.01$) and *($P \leq 0.05$).

Results

The occurrence of thrips was intensive each experimental year. The occurrence of aphids was intensive in 2002 and 2004. In 2001 and 2003, aphids did not reach their threshold of harmfulness and insecticides were used only according to thrips threshold of harmfulness. We did not provide the data of aphids spread in 2001 and 2003, since just a few aphids were found in winter rye crop. In 2001, the occurrence of thrips reached their threshold of harmfulness at the stem elongation stage – 1.72 thrips per stem and 72% of infested stems. The occurrence of thrips was intensive at the stem elongation to beginning of heading stage – 2.03–4.95 thrips per stem and 75–92.5% of infested stems (Table 1).

Table 1. Reduction in the occurrence of thrips as affected by the use of contact and systemic insecticides in winter rye. Dotnuva, 2001

Treatment[1]	Occurrence of thrips after spray application									
	4 d.[2]	11 d.	18 d.	25 d.	32 d.	39 d.	46 d.	53 d.	60 d.	67d.
	32-33[3]	34	51	55	59	65	71	71-73	73	77
Percent of infested stems										
Untreated	92.5	85.0	75.0	62.5	60.0	50.0	97.5	100	72.5	35.0
KT	37.5**	10.0**	27.5**	27.5	12.5**	30.0	55.0**	47.5**	40.0*	25.0
AT	25.0**	12.5**	27.5**	10.0**	17.5**	27.5*	50.0**	67.5**	42.5	12.5
Number of thrips per stem										
Untreated	4.95	2.45	2.03	1.15	0.98	1.00	8.45	13.05	2.98	0.58
KT	0.50**	0.23**	0.40**	0.28*	0.15*	0.45**	2.03**	2.75**	1.75	0.35
AT	0.35**	0.18**	0.30**	0.13**	0.20**	0.50*	2.10**	3.90**	1.38	0.13

[1] treatment details in materials and methods; [2] number of days after spray application;
[3] growth stage by BBCH.

The occurrence of thrips reached its maximum at the watery ripe and early milk stages. During that period 13.05 thrips per stem were found in untreated plots and all stems were infested. The application of contact and systemic insecticides significantly reduced the occurrence of thrips in winter rye crop. Four days after the spray application, the number of thrips per stem was 10 times lower than in the plots sprayed with contact insecticide and 14 times lower than in the plots sprayed with systemic insecticide, percent of infested stems was 2.5 times lower in the plots sprayed with contact insecticide and 3.7 times lower in the plots sprayed with systemic insecticide. Fifty-three days after the spray application, when the occurrence of thrips had reached its maximum, the number of thrips per stem was 4.7 times lower in the plots sprayed with contact insecticide and 3 times lower in the plots sprayed with systemic insecticide.

In 2002, the occurrence of thrips reached the threshold of harmfulness at the booting stage – 1.36 thrips per stem and 64% of infested stems. The occurrence of thrips was most intensive at the full flowering to medium milk stage – 5.2–12.6 thrips per stem and 87.5–95 percent of infested stems (Table 2).

Four days after the spray application, the number of thrips per stem was 14 times lower in the plots sprayed with contact insecticide. No thrips were found in the plots sprayed with systemic insecticide. Spraying winter rye according to the thrips threshold of harmfulness significantly decreased thrips occurrence for 37 days till the early and medium milk stage. At that time the number of thrips per stem was 11 times lower in the plots sprayed with contact insecticide and 5 times lower in the plots sprayed with systemic insecticide. Percent of infested stems was 3 times lower in the plots sprayed with contact insecticide and 1.5 times lower in the plots sprayed with systemic insecticide. Spraying winter rye according to the aphids threshold of harmfulness significantly decreased thrips occurrence for 4 days.

Table 2. Reduction in the occurrence of thrips as affected by the use of contact and systemic insecticides in winter rye. Dotnuva, 2002

Treatment[1]	Occurrence of thrips after spray application								
	4 d.[2]	11 d.	18 d.	25 d.	32 d.	37 d. 4 d.[3]	45 d. 12 d.	51 d. 18 d.	58 d. 25 d.
	51-55[4]	59	65	71	73	73-75	77	77	77-83
	Percent of infested stems								
Untreated	70.0	57.5	87.5	95.0	87.5	87.5	32.5	5.0	5.0
KT	10.0**	17.5*	52.5*	50.0**	35.0**	27.5**	32.5	7.5	5.0
AT	0**	12.5**	50.0**	70.0**	57.5*	55.0**	10.0	5.0	0
KA	n.a.[5]	n.a.	n.a.	n.a.	n.a.	42.5**	25.0	0	0
AA	n.a.	n.a.	n.a.	n.a.	n.a.	50.0**	42.5	2.5	2.5
	Number of thrips per stem								
Untreated	1.80	1.55	7.20	12.60	6.75	5.20	0.55	0.08	0.08
KT	0.13**	0.23**	1.20**	2.83**	0.50**	0.48**	0.40	0.10	0.05
AT	0**	0.13**	2.20**	2.73**	1.55**	1.10**	0.23	0.05	0
KA	n.a.	n.a.	n.a.	n.a.	n.a.	1.40**	0.38	0	0
AA	n.a.	n.a.	n.a.	n.a.	n.a.	1.15**	0.80	0.03	0.03

[1] treatment details in materials and methods; [2] number of days after spray application, when spray application was made according to thrips threshold of harmfulness; [3] number of days after spray application, when spray application was made according to aphids threshold of harmfulness; [4] growth stage by BBCH; [5] not assessed.

In the plots sprayed with contact insecticide according to the thrips threshold of harmfulness no aphids were found for 18 days (Table 3).

Table 3. Reduction in the occurrence of aphids as affected by the use of contact and systemic insecticides in winter rye. Dtonuva, 2002

Treatment[1]	Occurrence of aphids after spray application								
	4 d.[2]	11 d.	18 d.	25 d.	32 d.	37 d. 4 d.[3]	45 d. 12 d.	51 d. 18 d.	58 d. 25 d.
	51-55[4]	59	65	71	73	73-75	77	77	77-83
	Percent of infested stems								
Untreated	7.5	10.0	5.0	42.5	95.0	40.0	15.0	25.0	5.0
KT	0	0*	0	10.0**	22.5**	17.5*	22.5	42.5	7.5
AT	2.5	7.5	5.0	17.5*	45.0**	22.5	10.0	17.5	17.5
KA	n.a.[5]	n.a.	n.a.	n.a.	n.a.	10.0*	0	5.0	2.5
AA	n.a.	n.a.	n.a.	n.a.	n.a.	5.0**	2.5	7.5	12.5
	Number of aphids per stem								
Untreated	0.20	0.38	0.08	2.98	8.03	1.28	0.73	0.75	0.05
KT	0	0	0	0.50**	0.48**	0.33**	0.55	0.98	0.13
AT	0.05	0.08	0.08	0.58**	1.30**	0.53	0.38	0.23*	0.20
KA	n.a.	n.a.	n.a.	n.a.	n.a.	0.15**	0	0.05**	0.03
AA	n.a.	n.a.	n.a.	n.a.	n.a.	0.05**	0.08	0.08**	0.13

[1] treatment details in materials and methods; [2] number of days after spray application, when spray application was made according to thrips threshold of harmfulness; [3] number of days after spray application, when spray application was made according to aphids threshold of harmfulness; [4] growth stage by BBCH; [5] not assessed.

Aphids reached the threshold of harmfulness a month later than thrips at the early milk stage (all stems were infested, 8.28 aphids per stem were found). Insecticides sprayed at that time significantly decreased the occurrence of aphids for 18 days.

In 2003, the occurrence of thrips reached the threshold of harmfulness at the stem elongation stage – 1.96 thrips per stem and 88% of infested stems. The occurrence of thrips reached its maximum at full and end of flowering – 21.73 thrips per stem and all stems were infested (Table 4).

Table 4. Reduction in the occurrence of thrips as affected by the use of contact and systemic insecticides in winter rye. Dtonuva, 2003

Treatment[1]	Occurrence of thrips after spray application								
	4 d.[2] 51-55[3]	11 d. 59	18 d. 65	25 d. 71	32 d. 73	37 d. 73-75	45 d. 77	51 d. 77	58 d. 77-83
	Percent of infested stems								
Untreated	77.5	55.0	82.5	95.0	100	100	100	60.0	37.5
KT	7.5**	20.0*	45.0*	62.5**	92.5	97.5	100	52.5	32.5
AT	12.5**	17.5*	52.5*	80.0**	97.5	97.5	95.0	50.0	22.5
	Number of thrips per stem								
Untreated	1.55	1.45	2.53	15.75	21.73	18.30	11.75	1.63	0.63
KT	0.08**	0.20**	0.63**	2.70**	7.83**	8.15**	9.38	1.23	0.35
AT	0.28**	0.20**	0.80**	4.50**	9.80**	8.45**	8.38*	1.20	0.38

[1] treatment details in materials and methods; [2] number of days after spray application; [3] growth stage by BBCH.

The occurrence of thrips in the plots sprayed with contact and systemic insecticides was significantly lower for 25 days. The number of thrips per stem was significantly lower for up to 39 days after the spray application, but the percent of infested stems was not significantly lower.

In 2004, the occurrence of thrips reached the threshold of harmfulness at the stem elongation stage (1.60 thrips per stem and 68% of infested stems). The occurrence of thrips reached its maximum at the watery ripe stage (19.3 thrips per stem and 100% of infested stems) (Table 5).

Table 5. Reduction in the occurrence of thrips as affected by the use of contact and systemic insecticides in winter rye. Dotnuva, 2004

Treatment[1]	Occurrence of thrips after spray application									
	3 d.[2]	10 d.	17 d.	24 d.	30 d.	37 d.	43 d.	50 d.	56 d. 3 d.[3]	63 d. 10 d.
	39[4]	47	53–55	59–61	65	69	71	73	75	77
	Percent of infested stems									
Untreated	60.0	47.5	45.0	52.5	65.0	100	100	97.5	75.0	35.0
KT	0**	0**	2.5**	17.5**	12.5**	25.0**	57.5**	40.0**	47.5*	30.0
AT	2.5**	10.0**	7.5**	30.0**	27.5*	52.5**	75.0**	80.0**	60.0	17.5**
KA	n.a.[5]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	77.5	20.0*
AA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	82.5	17.5**
	Number of thrips per stem									
Untreated	1.28	0.95	0.60	0.93	3.55	15.90	19.30	11.30	4.35	0.80
KT	0**	0**	0.10**	0.20**	0.25**	0.90**	3.25**	2.28**	2.08*	0.80
AT	0.03**	0.10**	0.08*	0.45*	0.48**	4.40**	7.25**	6.05**	1.60**	0.38*
KA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.78	0.48
AA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.68	0.28*

[1] treatment details in materials and methods; [2] number of days after spray application, when spray application was made according to thrips threshold of harmfulness; [3] number of days after spray application, when spray application was made according to aphids threshold of harmfulness; [4] growth stage by BBCH; [5] not assessed.

The application of contact insecticide according to the thrips threshold of harmfulness significantly decreased the occurrence of thrips in winter rye crop for 56 days till medium milk stage. The use of the systemic insecticide according to thrips threshold of harmfulness significantly decreased the occurrence of thrips for 63 days till late milk stage.

In 2004, aphids started to spread at the end of heading and beginning of flowering and reached the threshold of harmfulness at the early and medium milk (7.32 aphids per stem and 84% of infested stems). The use of insecticide according to thrips threshold of harmfulness significantly decreased the occurrence of aphids in winter rye crop till the watery ripe stage in the plots treated with systemic insecticide and till early milk stage in the plots treated with contact insecticide (Table 6).

Table 6. Reduction in the occurrence of aphids as affected by the use of contact and systemic insecticides in winter rye. Dtonuva, 2004

Treatment[1]	Occurrence of aphids after spray application									
	3 d.[2]	10 d.	17 d.	24 d.	30 d.	37 d.	43 d.	50 d.	56 d. 3 d.[3]	63 d. 10 d.
	39[4]	47	53-55	59-61	65	69	71	73	75	77
Percent of aphid-infested stems										
Untreated	0	0	0	2.5	25.0	40.0	37.5	62.5	55.0	12.5
KT	0	0	0	0	0**	5.0**	0**	10.0**	25.0*	5.0
AT	0	0	0	0	7.5*	2.5**	15.0*	32.5	32.5	15.0
KA	n.a.[5]	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	17.5**	2.5*
AA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	30.0*	7.5
Number of aphids per stem										
Untreated	0	0	0	0.23	0.55	2.73	2.08	2.93	1.50	0.18
KT	0	0	0	0	0	0.05**	0**	0.15**	0.75	0.05
AT	0	0	0	0	0.13	0.10**	0.43**	0.95	0.83	0.18
KA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.83	0.03
AA	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.63	0.28

[1] treatment details in materials and methods; [2] number of days after spray application, when spray application was made according to thrips threshold of harmfulness; [3] number of days after spray application, when spray application was made according to aphids threshold of harmfulness; [4] growth stage by BBCH; [5] not assessed.

The use of the insecticides according to aphids threshold of harmfulness did not significantly decrease the number of aphids per stem compared with the untreated plots, since the occurrence of aphids in untreated plots decreased, too.

Spraying winter rye with contact and systemic insecticides according to thrips threshold of harmfulness significantly increased grain yield every experimental year (Table 7).

Table 7. Effect of insecticides on winter rye grain yield Dotnuva, 2001–2004

Treatment[1]	Yield and yield increase, t ha^{-1}				2001–2004			2002 and 2004		
	2001	2002	2003	2004	Average, t ha^{-1}	Relative val., %	Profit, Lt ha^{-1}	Average, t ha^{-1}	Relative val., %	Profit, Lt ha^{-1}
Untreated	4.73	5.66	4.35	7.26	5.50	100	–	6.46	100	–
KT	+0.44	+0.28	+0.54	+0.46	+0.43	107.8	94.30	+0.37	105.7	75.70
AT	+0.54	+0.53	+0.67	+0.49	+0.56	110.2	121.80	+0.51	107.9	106.30
KA	–	+0.27	–	+0.36	–	–	–	+0.32	104.9	60.20
AA	–	+0.27	–	+0.33	–	–	–	+0.30	104.6	41.20
LSD_{05}	0.380	0.266	0.460	0.404	0.384	7.107	–	0.327	4.917	–

[1] treatment details in materials and methods.

The application of contact insecticide increased the grain yield by 4.9–5.7%, systemic insecticide – by 4.6–7.9%. Spraying winter rye with contact and systemic insecticides according to aphids threshold of harmfulness significantly increased the grain yield in 2002. Yield increase resulting from the use of insecticides according to aphids threshold of harmfulness was not significant in 2004. The use of insecticides in winter rye crop was profitable. The highest profit was obtained while using insecticides according to thrips threshold of harmfulness: 94.30 Lt ha^{-1} using contact insecticide, and 121.80 Lt ha^{-1} using systemic insecticide. A lower profit – 41.20–60.20 Lt ha^{-1} – was obtained using insecticides according to aphids threshold of harmfulness.

Discussion

The occurrence of thrips on winter rye was intensive during all experimental years. Thrips reached the threshold of harmfulness (1–2 thrips per stem) at the stem elongation stage, except for 2003. In 2003, thrips reached the threshold of harmfulness at the booting stage. The general trends of thrips occurrence in the insecticide-untreated winter rye crops were similar in each experimental year. Thrips occurrence gradually decreased from the stem elongation stage in 2001, 2003 and 2004 and from heading stage in 2002. Then the abundance of thrips started to increase differently at different growth stages in separate years. The occurrence of thrips reached its maximum at the watery ripe stage in 2001, 2002 and 2004 and at full and end of flowering stage in 2003. At that time 95–100% of stems were infested with thrips and there were 12.60–21.73 thrips per stem. Similar results were obtained in Sweden. The number of thrips at their peak moment was 13.9–15.4 per stem (Larsson, 1988). According to the studies carried out in Norway, the number of thrips was less than 1 per stem (Kobro *et al.*, 2000). The occurrence of thrips sharply decreased at the late milk stage. At that time there were 0.55–1.63 thrips per stem. The occurrence of thrips in the plots sprayed with contact and systemic insecticides was significantly lower for 53 days in 2001, 37 days in 2002, and 25 days in 2003 compared with untreated plots. The occurrence of thrips in the plots sprayed with contact insecticide was significantly lower for 56 days and in the plots sprayed with systemic insecticide was significantly lower for 63 days in 2004. While using insecticides for winter rye protection against thrips, a yield increase of 3–13% was obtained (Larsson, 1988). Our findings suggest that spraying rye according to the thrips threshold of harmfulness gave a yield increase of 7.8–10.2%.

Aphids reached the threshold of harmfulness (5–10 aphids per stem) at grain development stage in 2002 and 2004. More intensive spread of aphids occurred in 2002. That year a significant 4.8% yield increase was obtained when spraying rye according to aphids threshold of harmfulness at early milk stage. Studies conducted by other authors indicate that a significant yield increase was obtained when spraying winter wheat at the early milk stage at abundance of 6.2–6.8 aphids per stem (Oakley and Walters, 1994). In 2004, aphids spread was intensive (7.32 aphids per stem were found before the spray application), but 3 days after the spray application the number of aphids sharply decreased in untreated plots. Consequently, a significant yield increase was not obtained. Both systemic and contact insecticides significantly decreased the number of pests in rye crop. In terms of efficacy, no marked differences were found between the tested systemic and contact insecticides.

The extent of pest damage to plants depends on the abundance of pests and time of their onset. Based on our experimental evidence we can conclude that thrips spread abundantly each experimental year from the stem elongation stage to the late milk stage. In 2002–2004, the spread of aphids was intensive at the end of flowering and watery ripe stage, but they did harm for a shorter period than thrips. When spraying rye according to thrips threshold of harmfulness the occurrence of aphids significantly decreased, too. When rye was sprayed according to aphids threshold of harmfulness, the occurrence of thrips had already reached its maximum and had done the harm for the rye crop. As a result, spraying of winter rye according to aphids threshold of harmfulness did not significantly increase the winter rye grain yield (according to averaged data from 2002 and 2004). Spraying of winter rye according to the thrips thresholds of harmfulness significantly increased the grain yield each experimental year.

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References

1. Kąkol E., Kucharczyk H. (2004) The occurrence of thrips (*Thysanoptera*, Insecta) on winter and spring wheat in chosen regions of Poland. Acta Phytopathologia et Entomologica Hungarica, 39, 263–269.
2. Kobro S. *et al.* (2000) Cereals as host plants for thrips (Thysanoptera) in Norway. Norwegian Journal of Entomology, 47, 1–6.
3. Larsson H. (1988) Economic damage caused by cereal thrips in winter rye in Sweden. Acta Phytopatologica et Entomologica Hungarica, 23, 291–293.
4. Oakley J. N., Walters K. F. A. (1994) A field evaluation of different criteria for determining the need to treat winter wheat against the grain aphid *Sitobion avenae* and the rose-grain aphid *Metopolophium dirhodum*. Annals of Applied Biology, 124, 195–211.
5. Šmatas R. (2002a) Harmfulness of thrips in winter rye. In: Žiogas A., Pilipavičius V. and Šaluchaitė A. (eds) Plant protection in the Baltic region in the context of integration to EU. Proceeding of the scientific international conference, Kaunas, Akademija, LT, 129–130.
6. Šmatas R. (2002b) Spread of thrips on winter cereals in Lithuania. In: Klāsens V., Špogis K., Lypsik A., Waller K. P., Hulgren J., Tuherms H., Valters J. and Bernhard A. (eds) Research for rural development 2002. International scientific conference proceedings, Jelgava, LV, 42–44.
7. Šurkus J. (1997) Insecticides against pests on spring barley. Agriculture. Scientific articles, 60, 142–152.
8. Šurkus J. (2002) Varpinių javų kenkėjai. In: Šurkus J., Gaurilčikienė I. (eds) Žemės ūkio augalų kenkėjai, ligos ir jų apskaita, Dotnuva-Akademija, LT, 66–79.

PEST AND DISEASE MANAGEMENT IN WINTER RYE CROP

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Astract

The main foliar diseases in winter rye crops were powdery mildew (*Blumeria graminis* (DC.) Speer), brown rust (*Puccinia recondita* Rob. ex Desm.) and scald (*Rhynchosporium secalis* (Oud.) Davis). Fungicides decreased the incidence and severity of foliar diseases in winter rye crops. The fungicides Falcon *(tebuconazole+triadimenol+spiroxamine 167+43+250 g l^{-1})* and Tilt *(propiconazole 250 g l^{-1})* were moderately effective against powdery mildew. Falcon provided high efficacy against brown rust. Tilt was less effective against severe brown rust infection. This fungicide did not have any effect on the disease incidence but reduced the severity of the disease. The tested fungicides showed a moderate efficacy against scald. During the experimental period the main pests in winter rye stands were thrips and aphids. The occurrence of thrips was abundant annually. The spread of aphids was abundant only in 2002. The pyretroid insecticide Fastac (*alfa-cipermetrin 100 g l^{-1})* significantly decreased the incidence of pests in winter rye. Owing to the use of insecticide, fungicides and their mixtures a significant grain yield increase was obtained. Average yield increase due to the insecticide was 0.41 t ha^{-1}, due to fungicides – 0.38–0.40 t ha^{-1}, and due to their mixtures – 0.52-0.62 t ha^{-1}. The annual and average yield increase was higher for the treatments applied with a mixture of fungicides and insecticide.

Key words: winter rye, foliar diseases, pest, fungicide, insecticide, grain yield

Introduction

Since the middle ages rye bread has been a traditional in Lithuania. Nowadays winter rye is primarily grown for food and feed consumption. The decline in the area of rye at the end of last century resulted from lower rye productivity compared with wheat. The main factors responsible for the reduction in rye grain yield are pests and diseases. Scald (*Rhynchosporium secalis* (Oud.) Davis, powdery mildew (*Blumeria graminis* Perss.) and brown rust (*Puccinia recondita* Rob.ex. Desm.) occurred on winter rye crops annually. In south-eastern and western regions of Lithuania, where rye is grown in the largest area, scald infection can be severe 'Gaurilčikienė (1998)'. In the case of abundant spread of powdery mildew, grain yield might decline by 42%, of scald by 26–60%, of brown rust by 25–29% '(Bielka, 1982; Andriuschenko et. al., 1990)'. Through fungicidal applications against winter rye diseases the yield increased by up to 21.2% 'Lisova (2002)'. Major pests of cereal crops in Lithuania are frit fly (*Oscinella* spp.), aphids (*Rhopalosiphum padi* L. and *Sitobion avenae* F.), sawfly (*Pachynematus clitellatus* Lep.), lemma (*Lema* spp.) and thrips (*Thysanoptera*) 'Šurkus (1997)'. Of all winter cereals the highest occurrence of thrips was found on winter rye in Lithuania 'Šmatas (2002b)'. Through the use of insecticides against thrips winter rye yield increased by 11.4–12.5% 'Šmatas (2002a)'. The management of pests and diseases on winter rye could be beneficial only when the spry application has been made before their dramatic increase in the crop. The aim of our experiments was to investigate the regularities of the occurrence of the main pests and diseases on rye and to test the feasibility to control pests and diseases by a single application of mixtures composed of fungicides and insecticides.

Materials and Methods

The pest and disease assessments were conducted during the 1999–2002 growing seasons at the Trial Department of the Lithuanian Institute of Agriculture in Dotnuva. The winter rye variety 'Duoniai' was sown at a rate of 4.5 million ha^{-1} with 12 cm interrow spacing. Fertilisers P_{60} and K_{60} were applied in the autumn before drilling. Nitrogen was applied twice: N_{90} – at the beginning of growing season, and N_{30} at the stem elongation stage. The plots for pest and disease assessment were 10 m long and 2.5 m wide with four replicates. The insecticide, fungicides and their mixtures were applied at the end of booting – beginning of heading stage (BBCH 47-51). The insecticide Fastac (*alfa-cipermetrin 100 g l^{-1})* and fungicides Falcon *(tebuconazole+triadimenol+ spiroxamine 167+43+250 g l^{-1})* and Tilt *(propiconazole 250 g l^{-1})* and their mixture were used. Plant growth stages were assessed according to the BBCH scale. The leaf positions on tillers were numbered relative to the uppermost leaf the flag leaf. Thus the leaf immediately below the flag leaf (F) was designated F-1, the second leaf below the flag leaf was F-2 and so on. The leaf disease assessments were made at anthesis, early milk and at milk ripening stages. The percent of leaf area showing symptoms of leaf diseases was used to quantify disease severity. Disease severity was assessed on each plot at five randomly selected places on three adjacent tillers F, F-1 and F-2 leaves using a percentage scale 0, 1, 5, 10, 25, 50, 75. Percent of diseased leaves was used to quantify the disease incidence. The assessment of pest infestation before the spray application was made by inspecting 25 main stems in the protection bands. Assessments were made 6 days after the spray application and repeated every weak. 10 main stems per plot, selected randomly, were assessed. Aphids were counted on ears, leaves and stems of each plant, thrips were counted by opening leaf sheaths. The plots were harvested and yields in t ha^{-1} were adjusted to 15% moisture content. The significance of data was determined by the Fisher's criterion with a significance level of $P \leq 0.01$ and 0.05. Prior to the statistical analysis the data of disease incidence, severity and percent of pest-infested stems were transformed to Asin(Sqr(X%). Pests counts per tiller were transformed to Sqr(X); percentages. Significant differences from untreated in tables are marked as **($P \leq 0.01$) and *($P \leq 0.05$).

Results

Early appearance of powdery mildew on winter rye stands was observed annually. On flag leaves at the end of booting – beginning of heading initial spots of mildew appeared only in 2000 and 2002, but lower leaves at this stage were diseased annually. On F-1 leaves the incidence of mildew covered 8–65%, the disease severity was 0.08–0.85%, and on F-2 35–68% and 0.88–1.72%, respectively. The incidence of mildew on untreated plots at anthesis – early milk (BBCH 65-73) was varied over years. During the whole experimental period the most severe occurrence of mildew was in 1999, and the lowest in 2002 (Table 1). In the case of heavy mildew infection in 1999 the fungicides highly suppressed the incidence and severity of powdery mildew on flag leaves. The disease incidence and severity on F-1 was significantly suppressed annually (except for the incidence in Tilt treatment in 1999). But on F-2 significant efficacy of fungicides against mildew was recorded in 1999, and only in Falcon treatment in 2000 and 2001.

Table 1. Reduction in the incidence and severity of powdery mildew as affected by the use of fungicides on winter rye crops, Dotnuva, 1999–2002

Treatment	Dose		Incidence	%		Severity	%
	l ha^{-1}	F	F-1	F-2	F	F-1	F-2
1999 BBCH 73							
Untreated	–	26.6	50.0	75.9	1.03	2.63	5.12
Falcon	0.4	3.3**	23.3*	49.2*	0.03**	0.63*	1.30**
Tilt	0.5	3.3**	28.3	41.0**	0.03**	0.83*	1.42**
2000 BBCH 65							
Untreated	–	5.0	35.0	55.6	0.12	0.88	1.82
Falcon	0.4	0	15.0*	36.9	0	0.28**	0.57**
Tilt	0.5	1.7	15.0*	43.6	0.02	0.22**	0.92
2001 BBCH 65							
Untreated	–	1.7	32.3	76.7	0.02	0.30	2.10
Falcon	0.4	0	1.7**	46.6**	0	0.02**	0.53**
Tilt	0.5	0	5.0**	55.0*	0	0.05**	1.43
2002 BBCH 73							
Untreated	–	8.3	55.0	82.5	0.08	0.55	0.82
Falcon	0.4	0**	16.7**	50.6*	0**	0.17**	0.51
Tilt	0.5	1.7*	21.6**	61.2	0.02*	0.22**	0.61

Brown rust in 1999 appeared on winter rye crop late, at the beginning of grain filling stage. At early milk only initial pustules on upper three leaves were found. Fungicide-treated plots were free of brown rust. In 2000 the occurrence of brown rust was earlier than in 1999 and at milk ripe stage became severe. At the beginning of heading disease symptoms were found on 5% F-1 and 50% on F-2 leaves. At anthesis on untreated plots brown rust incidence was on 30–58.2% upper three leaves, the disease severity was 0.37–1.88% of the leaf surface, but at milk stage on flag leaves it amounted to 11.68% (Table 2). Hot weather promoted rapid and severe infection of rust. In 2001 and 2002 brown rust was abundant, but not so severe. Fungicides significantly decreased the severity of brown rust. In the case of severe spread of rust in 2000 and 2002, the decrease in the disease incidence in Tilt- applied plots was insignificant.

Table 2. Reduction in the incidence and severity of brown rust as affected by the use of fungicides on winter rye stands, Dotnuva, 1999–2002

Treatment	Dose		Incidence	%		Severity	%
	$l\ ha^{-1}$	F	F-1	F-2	F	F-1	F-2
1999 BBCH 73							
Untreated	–	1.7	1.7	3.8	0.02	0.02	0.12
Falcon	0.4	0	0	0	0	0	0
Tilt	0.5	0	0	0	0	0	0
2000 BBCH 65							
Untreated	–	30.0	40.0	58.2	0.37	1.10	1.88
Falcon	0.4	0**	15.0*	28.3*	0**	0.22*	0.58**
Tilt	0.5	3.3**	13.4*	35.3	0.03**	0.27*	0.35**
2000 BBCH 75							
Untreated	–	90.0	–	–	11.68	–	–
Falcon	0.4	53.3**	–	–	0.68**	–	–
Tilt	0.5	88.4	–	–	2.35**	–	–
2001 BBCH 75							
Untreated	–	43.3	81.6	77.7	0.64	2.18	1.88
Falcon	0.4	1.7**	1.7**	18.0**	0.02**	0.02**	0.18**
Tilt	0.5	20.0*	20.0*	30.3**	0.20**	0.12**	0.30**
2002 BBCH 77							
Untreated	–	50.0	83.3	–	2.43	4.18	–
Falcon	0.4	13.4**	40.0**	–	0.14**	0.40**	–
Tilt	0.5	26.7	58.3*	–	0.55*	1.37*	–

The incidence of scald developed differently over years. At the end of booting in 1999 and 2000 the flag and F-1 leaves were free of scald symptoms, but 30–40% F-2 and 75–80% F-3 leaves were infected. At the same stage in 2001 and 2002 only initial spots of scald were found on F-3. Late in the season scald injured upper rye leaves annually. Fungicides applied at the end of booting-beginning of heading sufficiently decreased the incidence and severity of scald, but only in 2001 and 2002 the reduction in the severity of the disease was significant (Table 3).

The spread of insects in winter rye crop was different during all experimental years. High occurrence of thrips on winter rye crop was observed annually. The spread of thrips before the use of insecticide was intensive in each experimental year – almost all stems were infected (78–96%) and 1.53–3.64 thrips per stem were found. In 1999the occurrence of thrips was most intensive at the early milk and milk ripe stage – 2.25–3.05 thrips per stem and 95–87% of infested stems (Table 4). Winter rye spraying with the insecticide Fastac resulted in a significant suppression of thrips during the period from the end of heading to late milk stage. The occurrence of thrips in sprayed plots was on average no higher than 0.50 thrips per stem and the percent of infested stems was 42.5 and less. In 2000 and 2001 the occurrence of thrips gradually declined during the period from heading to grain development. In 2000 the maximum number of thrips (9.18 thrips per stem and 97.5 percent of infested stems) on untreated plots occurred in the milk ripe stage.

Table 3. Reduction in the incidence and severity of scald as affected by the use of fungicides on winter rye stands, Dotnuva, 1999–2002

Treatment	Dose		Incidence	%		Severity	%
	l ha^{-1}	F	F-1	F-2	F	F-1	F-2
1999 BBCH 73							
Untreated	–	6.7	26.7	82.0	0.13	0.97	3.94
Falcon	0.4	3.3	36.7	83.6	0.03	0.58	3.72
Tilt	0.5	8.3	20.0	68.3	0.08	0.47	2.51
2000 BBCH 75							
Untreated	–	48.3	–	–	0.75	–	–
Falcon	0.4	48.3	–	–	0.48	–	–
Tilt	0.5	46.7	–	–	0.66	–	–
2001 BBCH 75							
Untreated	–	1.7	53.3	76.1	0.02	1.86	4.01
Falcon	0.4	1.7	36.6	68.0	0.02	0.57*	2.01**
Tilt	0.5	5.0	27.0**	75.1	0.05	0.74*	2.50*
2002 BBCH 73							
Untreated	–	0	28.3	55.8	0	0.55	1.66
Falcon	0.4	0	15.0*	42.9	0	0.15*	1.14
Tilt	0.5	0	16.7*	47.4	0	0.17*	0.96
2002 BBCH 77							
Untreated	–	46.7	95.0	–	0.74	3.74	–
Falcon	0.4	16.6**	50.0**	–	0.16**	0.76**	–
Tilt	0.5	30.0	71.7**	–	0.30*	1.78**	–

In 2001 the maximum (18.70–18.43 thrips per stem and 100 percent of infested stems) occurred at the watery ripe to milk ripe stage. Thrips occurrence on sprayed plots significantly declined. In 2000 the number of thrips per stem on sprayed plots increased to 1.15 (while on untreated plots 9.18), in 2001 – 0.80 (while on untreated plots 18.70).

Table 4. Reduction in the distribution of thrips as affected by the use of insecticide in winter rye Dotnuva, 1999–2002

Treatment[1]		Year	Number of days after spray application / growth stage by BBCH					
		1999	6/59	14/65	20/73	26/75	33/77	40/77
Untreated	Infested stems %		92.5	90.0	95.0	87.5	85.0	50.0
Fastac	Infested stems %		37.5**	10.0**	40.0**	40.0**	42.5**	22.5**
Untreated	Thrips per stem		1.50	1.90	2.25	3.05	1.95	0.53
Fastac	Thrips per stem		0.40**	0.38**	0.50**	0.50**	0.45**	0.23**
		2000	6/59-61	14/65	21/69	31/75		
Untreated	Infested stems %		95.0	87.5	82.5	97.5	n.a.[2]	n.a.
Fastac	Infested stems %		25.0**	27.5**	40.0**	45.0**	n.a.	n.a.
Untreated	Thrips per stem		2.23	1.68	1.40	9.18	n.a.	n.a.
Fastac	Thrips per stem		0.25**	0.28**	0.48**	1.15**	n.a.	n.a.
		2001	6/51	12/55	19/65	26/69	33/71	40/75
Untreated	Infested stems %		85.2	80.0	35.0	55.0	100	100
Fastac	Infested stems %		32.5**	2.5**	10.0*	25.0*	35.0**	25.0**
Untreated	Thrips per stem		5.20	2.18	0.45	1.35	18.70	18.43
Fastac	Thrips per stem		0.53**	0.03**	0.10*	0.30**	0.80**	0.60**
		2002	6/55-57	12/61-65	19/71	26/71	33/73	39/77
Untreated	Infested stems %		75.0	87.5	97.5	97.5	95.0	42.5
Fastac	Infested stems %		10.0**	37.5**	65.0**	65.0**	52.5**	20.0
Untreated	Thrips per stem		1.60	6.23	13.58	13.35	5.58	0.58
Fastac	Thrips per stem		0.10**	0.88**	2.98**	3.10**	1.58**	0.20

[1] Fastac was used at the dosage 0,15 l ha^{-1}; [2] not assessed.

In 2002 the most intensive spread of thrips was identified in watery ripe stage (13.58 thrips per stem 97.5 percent of infested stems). The insecticide Fastac significantly protected winter rye crop against thrips for 33 days.

In 1999 and 2001 the spread of aphids on untreated plots was not intensive (Table 4). The differences in the number of aphids in sprayed and unsprayed plots were not sharp due to the low aphids occurrence. In 2000 no aphids were found in winter rye crop. The spread of aphids in 2002 was the most intensive in watery ripe stage – 8.65 aphid per stem and 67.5% of infested stems. Spraying of winter rye with the insecticide Fastac significantly declined the occurrence of aphids from the early milk to late milk stage. The number of aphids on sprayed plots was no higher than 0.68 aphid per stem and the percent of infested stems no higher than 32.5.

Table 5. Reduction in the distribution of aphids as affected by the use of insecticide in winter rye, Dotnuva, 1999, 2001 and 2002

Treatment[1]		Year	Days number after spray application / growth stage by BBCH					
		1999	6/59	14/65	20/73	26/75	33/77	40/77
Untreated	Infested stems %		5.0	15.0	55.0	67.5	65.0	27.5
Fastac	Infested stems %		2.5	5.0	25.0*	37.5**	25.0**	5.0*
Untreated	Aphids per stem		0.05	0.65	1.38	1.98	0.95	0.28
Fastac	Aphids per stem		0.03	0.23	0.38**	0.48**	0.25*	0.05
		2001	6/51	12/55	19/65	26/69	33/71	40/75
Untreated	Infested stems %		5.0	12.5	20.0	15.0	10.0	22.5
Fastac	Infested stems %		0*	0*	2.5**	2.5	0*	10.0
Untreated	Aphids per stem		0.05	0.20	0.50	0.20	0.15	0.43
Fastac	Aphids per stem		0*	0**	0.05**	0.05	0	0.25
		2002	6/55-57	12/61-65	19/71	26/71	33/73	39/77
Untreated	Infested stems %		5.0	7.5	37.5	67.5	57.5	22.5
Fastac	Infested stems %		0	2.5*	0**	12.5**	32.5*	10.0
Untreated	Aphids per stem		0.05	0.28	2.43	8.65	2.63	0.53
Fastac	Aphids per stem		0	0.08	0**	0.68**	0.65*	0.28

[1] Fastac was used at the dosage 0,15 l ha^{-1}.

The annual and average yield increases were higher when mixtures of fungicides and insecticide were applied. In 1999, 2001 and 2002 in all treatments grain yield increased significantly (except of Falcon treatment in 2001), but in 2000 only in Falcon+Fastac treatment the increase was significant, in the other treatments the trend of increasing was observed (Table 6). Due to the hot weather at milk ripe only flag leaf was still green. Average yield increase in all cases was significant. Due to the insecticide it was 0.41 t ha^{-1}, due to fungicides 0.38–0.40 t ha^{-1}, and due to their mixtures 0.52–0.62 t ha^{-1}.

Table 6. Influence of insecticide and fungicide mixtures on winter rye grain yield, Dotnuva, 1999–2002

Treatment	Dose l ha^{-1}	Yield and yield increase t ha^{-1}					Rel. values %
		1999	2000	2001	2002	average	
Untreated		5.39	3.94	4.48	5.75	4.89	100
Fastac	0.15	+0.43	+0.21	+0.53	+0.48	+0.41	108.4
Falcon+Fastac	0.4+0.15	+0.57	+0.62	+0.54	+0.75	+0.62	112.7
Falcon	0.4	+0.40	+0.37	+0.35	+0.48	+0.40	108.2
Tilt+ Fastac	0.5+0.15	+0.50	+0.21	+0.82	+0.54	+0.52	110.6
Tilt	0.5	+0.50	+0.22	+0.46	+0.36	+0.38	107.8
LSD_{05}		0.403	0.407	0.361	0.313	0.313	7.38

Discusion

Our results emphasise the importance of managing pests and diseases in winter rye stands. Yield responses to the application of foliar fungicides and insecticides to winter rye are variable. The requirement for treatment is to make the spry application only when the value of the yield benefit will exceed the cost. According to our experimental data the best yield responses on winter rye were given by using fungicide and insecticide mixtures. Powdery mildew, brown rust and scald were the main diseases on winter rye, while thrips and afhids were the main threat to the yield. According to our observations the progress of these harmful organisms on winter rye stands occurs at booting or ear emergence stage. Little published information is available on the fungicidal control of rye mildew and brown rust and application timing. On winter wheat the best results and the highest yield response to mildew were associated with sprays applied at the flag leaf emerged-early booting, or ear emergence, before the rapid increase in disease occurred 'Hardwick et al., 1994'.

Brown rust commonly occurred on winter rye crops more intensively than on winter wheat. At milk ripe stage of winter wheat an increase in damaged leaf area by 1%, resulted in grain yield losses of 0.25–0.30% and grain weight losses – 0.25–0.08% 'Milus (1994)'. Brown rust epidemic on winter wheat could be prevented by a single spry application before the rust infection exceeds 5–10% on upper three leaves. The optimal time was heading 'Fuzi (1997)'. The causal agents of wheat and rye rust and mildew differed one from the other only by *forma specialis* the infection characteristics and environmental requirements are similar. Unlike mildew and rust airborne infection, scald is spread by rain-splash. A system for optimizing fungicide application to control scald on winter rye has been developed in Germany. The data from weekly disease assessments, hourly temperatures, and leaf wetness were used. No significant differences in yield or profit were found between the three tested systems, but all three were superior to the prophylactic and untreated variants. All three systems recommended only one spry application 'Werres, Hindorf (1993)'.Thrips spread on winter rye was intensive during all experimental years. *Limothrips denticornis* Hol. is dominant on winter rye 'Samersov and Yachene (1978)'. To efficiently reduce *Limothrips denticornis* populations in the leaf sheathes, the rye must be treated before heading since females entered and start egg-laying when the last leaf sheath is opening. Once the eggs have been laid, they cannot be killed with a contact insecticide 'Larsson (1988)'. Our findings suggest that spraying winter rye by insecticide before heading significantly declined the number of thrips on sprayed plots. In 2000-2002, when thrips had reached the maximum of their occurrence their number was 9.18–18.70 per stem. Similar results were obtained in Sweden. The number of thrips at their peak moment was 13.9–15.4 per stem 'Larsson (1988)'. According to the studies carried out in Norway, the number of thrips was less than 1 thrips per stem 'Kobro, et al., 2000'. Using insecticides for winter rye protection against thrips a yield increase of 3–13% was obtained 'Larsson (1988)'. Experimental evidence suggests that insecticides are responsible 8.4% yield increase. According to our results the best pest and diseases control on winter rye might be achieved by a single spry application with a mixture of insecticide and fungicide at the end of booting stage.

References

1. Bielka F., Rosberg R., Neuhaus W. (1982) Schadwirkungen von Erysiphe graminis und Puccinia recondita bei Winterrogen in DDR. Tagung Berlin Akademie Landwirtschaft Wissenschaften DDR. 198, 2, 521–524.
2. Fuzi I. (1997) Control of Leaf Rust of winter wheat, *Triticum aestivum*, in Hungary. Pesticide Science, 49, 389–399.
3. Gaurilčikienė I. (1998) Investigation of the occurrence of fungal diseases on various sowing time and density tetraploid winter rye stands in different agroclimatic zones of Lithuania. Agriculture. Scientific articles, 62, 142–154
4. Hardwick N. V., Jenkins J. E. E., Collins B., Groves S. J. (1994) Powdery mildew (*Erysiphe graminis*) on winter wheat: control with fungicides and the effects on yield. Crop Protection 13, 2, 93–98.
5. Kobro S., Teksdal A. E. and Andersen A. (2000) Cereals as host plants for thrips (Thysanoptera) in Norway. Norwegian Journal of Entomology, 47, 1–6.
6. Larsson H. (1988) Economic damage caused by cereal thrips in winter rye in Sweden. Acta Phytopatologica et Entomologica Hungarica, 23, 291–293.
7. Lisova R. (2003) Effect of fungicide tango application time on the occurrence of winter rye foliar diseases and on grain yield. Agriculture. Scientific articles, 2, 82, 100–113.
8. Milus (1994) Effect of leaf rust and Septoria leaf blotch on yield and test weight of wheat in Arkanas. Plant disease. 78, 1, 55–59.
9. Šmatas R. (2000a) Harmfulness of thrips in winter rye. In: Žiogas A., Pilipavičius V. and Šaluchaitė A. (eds) Plant protection in the Baltic region in the context of integration to EU. Proceeding of the scientifics international conference, Kaunas, Akademija, LT, 129–130.
10. Šmatas R. (2000b) Spread of thrips on winter cereals in Lithuania. In: Klāsens V., Špogis K., Lypsik A., Waller K. P., Hulgren J., Tuherms H., Valters J. and Bernhard A. (eds) Reseach for rural development 2002. International scientific conference proceedings, Jelgava, LV, 42–44.
11. Šurkus J. (1997) Insecticides against pests on spring barley. Agriculture. Scientific articles, 60, 142–152
12. Werres G., Hindorf H. (1993) Evaluation of a system for optimizing fungicide application to control *Rhynchosporium secalis* on winter rye. EPPO Bulletin, 23, 565–576.
13. Андрющенко А. Б., Винничюк Т. С., Тополкова Л. И. (1990) Фитосанитарное состояние посевов зерновых культур, возделываемым по интенсивным технологиям, в условиях северной лесостепи и Полесья УССР // Защита растений в условиях интенсификации с-х. Украинской ССР. Сборник научных трудов. Киев, 41–43.
14. Самерсов В. Ф., Яченя С. В. (1978) Агротехнические меры борьбы со злаковыми трипсами. Защита растений, Сборник научных работ, 3, 94–99.

RELATIONSHIPS BETWEEN SPRING OILSEED RAPE DENSITY, ASSIMILATING LEAF AREA, LIGHTING AND YIELD

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Abstract

In the period of 2002–2003, at the Experimental Station of the Lithuanian University of Agriculture, the influence of spring oilseed rape (*Brassica napus* L. ssp. *oleifera annua* Metzg.) “Sponsor” density on plant assimilating leaf area, lighting of crop layers, plant yield at the flowering stage, and seed yield was investigated, as well as relationships between these indicators were determined. The data show that at increasing crop density (from 50.1 to 350 plants m^{-2}), the leaf area index increased ($r = 0.99$, $P \leq 0.01$), while assimilating leaf area per plant decreased ($r = -0.89$, $P \leq 0.01$) and depended on the light flux reaching soil surface ($r = 0.98$, $P \leq 0.01$) and also ¼ and ½ crop layers ($r = 0.93$ and $P \leq 0.01$; $r = 0.83$, $P \leq 0.05$). At increasing crop density, the seed yield per plant significantly decreased from 33.1 to 78.5% and depended on assimilating leaf area per plant ($r = 0.99$, $P \leq 0.01$) and yield of one plant at the flowering stage ($r = 0.95$, $P \leq 0.01$). At an increasing number of plants per m^{-2} (up to 259), rapeseed yield significantly increased from 28.6 to 58.8%, as compared with thinnest crop, and when the crop reached average density of 347 plants m^{-2}, the seed yield significantly decreased due to reduction of plant size and productivity. Significant parabolic relationship ($r = 0.92$, $P \leq 0.05$) was established between rapeseed yield and crop productivity at the flowering stage.

Key words: *Brassica napus* L., density, assimilating leaf area, lighting, yield

Introduction

Spring oilseed rape growth, development and yield formation are determined by the number of plants, which depends on the peculiarities of the chosen variety, agrometeorological factors, seed norm and the technology applied (Буряков *et al.*, 1988; Al-Barzinjy *et al.*, 1999; Velička, 2002). In the course of experiments Ogilvy (1984) observed the following features in thinner crops: stronger branching of plants, unequal maturing, growth of lower less productive side branches, increased competition among different parts of a plant for light, nutrients and water. In denser rape crops, plants produce fewer side branches therefore use of nutrients is more effective and crop maturity is more equal, but due to strong competition the plants tend to lodge. Al-Barzinjy *et al.* (2003) have established the number of seeds per pod and seed mass to be bigger in upper branches of a plant than those in lower less productive ones.

According to literature sources, optimal spring oilseed rape crop density should be 100–150 plants per m^{-2} (Буряков *et al.*, 1988). Šidlauskas (2000) has established that at increasing spring oilseed rape crop density from 20 to 160 plants per m^{-2} the seed yield increases. Besides, bigger crop density provides greater possibility to produce high rapeseed yields by applying nitrogen fertilizers before beginning of flowering. According to the data provided by Heikkinen (1991), the shorter is the plant development period, the bigger seed rate is required to get maximum yield.

Grosse *et al.* (1992) state that the bigger assimilating leaf area falls to the unit of soil surface and time, the more solar energy is accumulated in biomass and the bigger rapeseed yield is produced. Assimilating leaf area depends on genetical, biological and morphological characteristics of plants, the stage of their development, and its maximum is reached in different vegetation periods of various plants (Eisele, Köpke, 1990). The literature sources also indicate that optimal index of rape leaf area is at the beginning of flowering. Later significant decrease of leaf area index and increase of pod area index are observed (Diepenbrock, Grosse, 1995).

Diepenbrock (2000) indicates that rape density is a very important factor, influencing productivity of an individual plant. Equal distribution of plants in an area unit is indispensable condition for stable productivity. Besides, equally distributed rape plants are less sensitive to environmental stress (Sierts *et al.*, 1987). Therefore, not only choice of an optimal spring oilseed rape crop density under concrete agroclimatic conditions but also determining the influence of the number of plants, as one of regulated factors, on quantitative and qualitative indices of plants growth and yield size is important. In this respect, under Lithuanian agroclimatic conditions spring oilseed rape has been investigated for the first time.

The aim of the work – to determine optimal spring oilseed rape crop density by evaluating relationships between the number of plants, lighting efficiency, leaf area index, crop productivity at the flowering stage and seed yield.

Materials and Methods

The investigations were carried out at the Experimental Station of the Lithuanian University of Agiculture (54°53′N, 23°50′E) in the period of 2002–2003. Soil – carbonated shallow gleyic luvisol (*Calc(ar)i-Epihypogleyic Luvisols*). Soil texture: medium clay loams on heavy clay loams and clays. Soil moisture is regulated by means of closed drainage.

Soil pH – 6.9–7.3, hydrolytic soil acidity – 0.9–7.5 μekv kg^{-1}, base saturation of soil – 77–96%, organic carbon – 1.35%. The content of total nutrients in the soil: 86–111 mg kg^{-1} of phosphorus, 100–134 mg kg^{-1} of potassium, 148 mg kg^{-1} of sulphur, and 1.30 mg kg^{-1} of boron.

The scheme of the experiment is presented in Table 1. Spring oilseed rape crops of different density were formed by a seeding machine of exact distribution taking into consideration seed germinability and 1000 seed mass.

Soil tillage was applied according to the usual agrotechnics. Spring oilseed rape "Sponsor" was sown on 30 April 2002 and 2 May 2003. Fertilization – $N_{90}P_{60}K_{120}$. Predecessor – spring barley. After sowing, rape was sprayed with herbicide butizan 400 (2.5 l ha^{-1}), against pests – 2 times with fastack (0.1 l ha^{-1}). Size of accounting plot – 41.4 m^{-2}, replications – 4. The yield was harvested on 19 August in 2002 and on 18 August in 2003. The experimental data was statistically estimated by using Fisher protected LSD test, correlation and regression analyses.

Spring oilseed rape crop density was determined in 4 places of each plot by counting plants within the frame of 0.25 m^2.

Leaf area index was determined at the flowering stage of rape with scanner HP SHANJET 3500C and computer system ROOTEDGE (1998).

Crop lighting was measured at the flowering stage with luximeter Ю 116 (range of measurement 0–100000 lx) (Тооминг, Гуляев, 1967; Lithuanian Hygiene norm HN 98:2000, 2000). Lighting was measured at soil surface, at ¼, ½, ¾ crop layers and rape apices.

Coefficient of rape apices lighting: $\tau_r = 100\%$.

Lighting of a certain crop layer: $\tau_l = E_l \times E_r^{-1} \times 100\%$,

here E_l – lighting in a certain crop layer, E_r – lighting of rape apices.

Five plants were taken from each experimental plot to determine the yield of dry matter of overground part of plants at the flowering stage. Separate morphological parts of plants (leaves, stems, flowers) were weighed and dried for 24 hours in thermostate at the temperature of 105 °C. Dry matter (DM) yield of all plants and their separate morphological parts (g m^{-2} and t ha^{-1}) and yield per plant (g) were calculated.

Meteorological conditions. In the period of spring rape vegetation in 2002, the sum of active temperatures (≥ 10 °C) was 2011.2 °C, precipitation was 191.3 mm, HTC (hydrothermal coefficient) – 0.95.

During spring rape vegetation in 2003, the sum of active temperatures (≥ 10 °C) was 1770.8 °C, precipitation was 227.9 mm, HTC – 1.29.

In 2002 and 2003, agrometeorological conditions were similar at the flowering stage and rapeseed harvesting.

Results and Discussion

The carried out experiments show that the rape leaf area index is closely related to crop density ($y = 2.61 + 0.009x$, $r = 0.99$, $P \leq 0.01$). The lowest rape area index is established in the thinnest crop – 3.13 m^{-2} (Fig. 1). At the increasing number of plants to 200 per m^{-2}, the leaf area index increases but no significant differences are established. At rape crop density of 200.1–350 plants per m^{-2}, in comparison with the thinnest crop, a significant increase of leaf area index from 54.6 to 80.2% is observed.

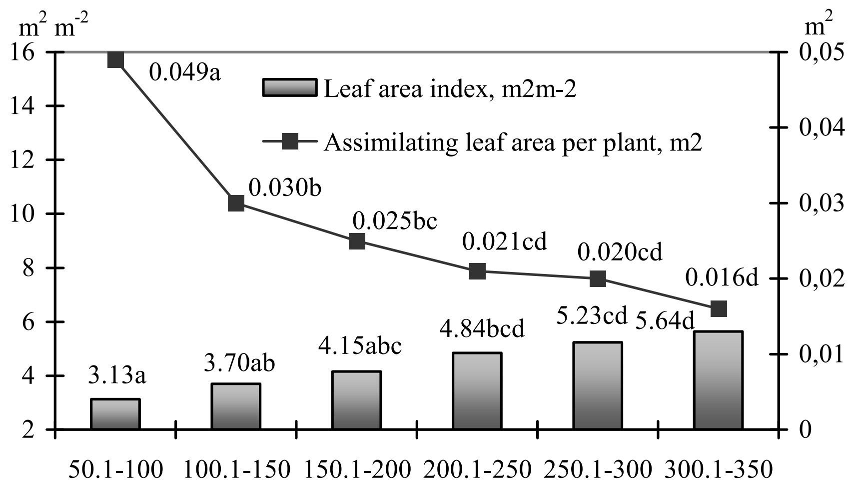

Figure 1. Assimilating leaf area of spring oilseed rape in different density crops at the flowering stage, 2002–2003. Averages that do not share a common letter are significantly different ($P \leq 0.05$)

At increasing rape crop density, the assimilating leaf area per plant decreases ($y = 0.05–0.001x$, $r = –0.89$, $P \leq 0.05$). The biggest assimilating leaf area per plant (0.049 m^2) is determined in the thinnest rape crop (Fig. 1), where plants have formed the biggest number of branches and leaves. At the rape density increase from 100.1 to 350 plants per m^{-2}, the assimilating leaf area per plant, in comparison with the thinnest crop, significantly decreases, while in the thickest rape crop it is 3 times smaller. Assimilating leaf area of plants depends on lighting conditions (lighting coefficient τ). Direct strong and very strong positive significant correlations between assimilating leaf area per plant and lighting at soil surface ($r = 0.98$, $P \leq 0.01$), ¼ rape crop layer ($r = 0.93$, $P \leq 0.01$), and ½ rape crop layer ($r = 0.83$, $P \leq 0.05$) are established. Lighting of rape crop layers is closely related to crop density and assimilating leaf area of plants. At increasing crop density, decreasing solar light flux falls to soil surface ($y = 9.11–0.03x$, $r = –0.85$, $P \leq 0.05$), to ¼ crop layer ($y = 26.71–0.05x$, $r = –0.87$, $P \leq 0.05$) and to ½ crop layer ($y = 8.92–0.11x$, $r = –0.93$, $P \leq 0.01$). Strong negative significant correlations are established between the rape leaf area index and lighting at soil surface ($r = –0.87$, $P \leq 0.05$), at ¼ crop layer ($r = –0.85$, $P \leq 0.05$), and at ½ crop layer ($r = –0.88$, $P \leq 0.01$).

Comparison of lighting of different layers in rape crops of different density shows that a significantly bigger (from 2.5 to 6.6 times) solar energy flux falls to soil surface in the thinnest crop with the smallest leaf area index if compared with denser crops (Table 1). Significant decrease of the solar energy flux that falls to the ¼ and ½ layers of rape crop is observed only in the thickest (average 347 plants per m^{-2}) rape crop. Similar regularities have been established in the ¾ layer of rape crop, but lighting of this layer is bigger than that of lower layers of the crop where the main mass of rape branches is concentrated.

Table 1. Lighting of different density spring oilseed rape crops at the flowering stage, 2002–2003. Averages that do not share a common letter are significantly different ($P \leq 0.05$)

Crop density, plants m^{-2}	Lighting, lx / Lighting coefficient τ, %				
	At soil surface	At ¼ crop layer	At ½ crop layer	At ¾ crop layer	At rape apices
50.1–100	7225	25250	69500	83750	93750
(aver. 64)	9.90a	27.1a	74.6a	89.4a	100
100.1–150	3750	16500	60750	7850	93750
(aver. 123)	4.00b	17.6ab	65.0	83.7ab	100
150.1–200	3750	15500	56500	86000	95000
(aver. 164)	3.89b	16.3ab	59.2a	90.4a	100
200.1–250	3250	17000	57500	81250	93750
(aver. 227)	3.47b	18.2ab	61.4a	86.8ab	100
250.1–300	1750	15250	55250	86250	96000
(aver. 259)	1.82b	15.7ab	57.4ab	89.9a	100
300.1–350	1375	9750	35750	68750	93000
(aver. 347)	1.48b	10.5b	38.5b	74.0b	100

Rape like many annual plants reach the highest intensity (optimum) of photosynthesis at the beginning of flowering when the leaf area index is maximal. Grosse *et al.* (1992) has determined close dependence between the leaf area index before flowering and the seed yield. The present experimental data and statistical analysis bring to the statement that photosynthesis, which has taken place under various conditions in spring oilseed rape crops of different density, results in the formation of different yields of overground plant mass (Table 2). The presented experimental data shows that at average rape crop density increase from 64 to 227 plants per m^{-2}, a significant increase in the mass of leaves (133.43–275.12 g m^{-2}), stems (174.05–323.69 g m^{-2}) and flowers (18.58–39.60 g m^{-2}) is observed. When rape crop reaches the average density of 259 plants per m^{-2} the mass of leaves and stems significantly decreases, respectively by 17.4% and 9.4%, while that of flowers significantly increases by 33.6%. It has been determined that in still denser rape crops (average 347 plants per m^{-2}), the mass of separate morphological parts of a plant changes: that of leaves and stems significantly increases, while that of flowers tends to decrease. This might be influenced by a significantly decreased average assimilating leaf area per plant in dense rape crop. At rape crop density increase from 50.1 to 350 plants per m^{-2}, the rape yield (DM g m^{-2}) increases while the yield of one plant (DM g) significantly decreases – from 5.09 g in the thinnest crop to 2.13 g in the thickest crop. Similar regularities were also determined by Al-Barzinjy *et al.* (1999).

Table 2. Spring oilseed rape productivity in different density crops at the flowering stage, 2002–2003. Averages that do not share a common letter are significantly different ($P \leq 0.05$)

Indices	Average crop density, plants m^{-2}					
	64	123	164	227	259	347
Rape yield, DM g m^{-2}	326.06a	387.87ab	458.39b	638.41c	573.32c	738.20d
Of which:						
Leaves, DM g m^{-2}	133.43a	152.81ab	194.35bc	275.12de	227.13cd	280.36e
Stems, DM g m^{-2}	174.05a	212.38b	233.08b	323.69c	293.29d	409.86e
Flowers, DM g m^{-2}	18.58a	22.68ab	30.96b	39.60c	52.90d	47.98d
Yield per plant, DM g	5.09a	3.15b	2.80b	2.81b	2.21c	2.13c

Correlation and regression data analysis shows the existence of a significant relationship between rape productivity and crop density ($y = 224.58 + 1.50x$, $r = 0.97$, $P \leq 0.01$), leaf area index ($y = -181.21 + 157.72x$, $r = 0.96$, $P \leq 0.01$), lighting at soil surface ($y = 814.69x^{-0.402}$, $r = 0.85$, $P \leq 0.05$), ¼ crop layer ($y = 5287.53x^{-0.834}$, $r = 0.84$, $P \leq 0.05$) and ½ crop layer ($y = 53889.53x^{-1.151}$, $r = 0.95$, $P \leq 0.05$).

The experiments have established that mass per plant and its separate morphological parts depend on assimilating leaf area per plant. Very strong positive significant correlations between assimilating leaf area per plant and mass per plant ($y = 0.62 + 89.78x$, $r = 0.99$, $P \leq 0.01$), mass of flower ($y = 0.09 + 3.95x$, $r = 0.92$, $P \leq 0.01$), stem ($y = 0.29 + 48.83x$, $r = 0.98$, $P \leq 0.05$) and leaves ($y = 0.24 + 37.00x$, $r = 0.97$, $P \leq 0.01$) per plant are established.

The experimental results show that conditions of spring oilseed rape growth and development in crops of different density have influence on the seed yield (Fig. 2). Donald (1963) determined the important comparison of three indices: rape density, dry matter, and seed yield.

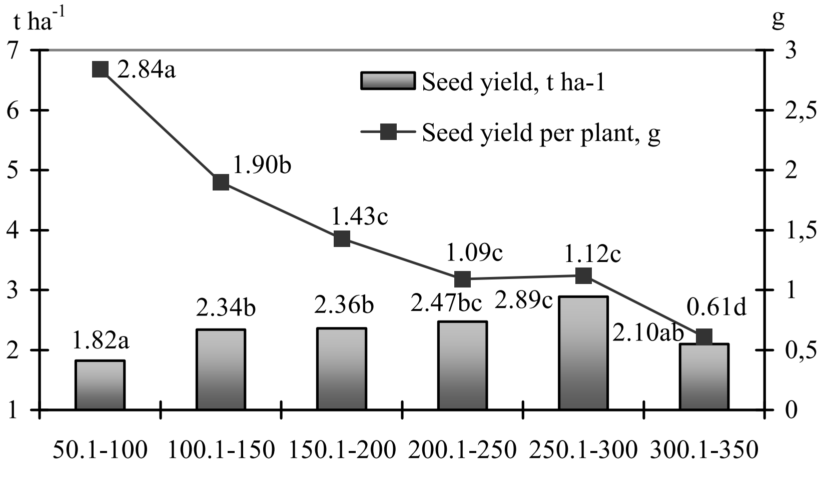

Figure 2. Rapeseed yield in crops of different density, 2002–2003. Averages that do not share a common letter are significantly different ($P \leq 0.05$)

The lowest seed yield (1.82 t ha^{-1}) is received in the thinnest rape crop (50.1–100 plants per m^{-2}), although seed yield per plant is the biggest (2.84 g). Plants in thin rape crops are branchier, which is the reason of unequal maturing of seeds, and the number of plants does not ensure a higher seed yield. At increasing rape crop density from 100.1 to 300 plants per m^{-2}, the seed yield per plant significantly decreases from 33.1 to 61.6% if compared with seed yield per plant in the thinnest crop, but rapeseed yield per ha^{-1} significantly increases from 28.6 to 58.8%. Rapeseed yield is closely related to crop productivity at the flowering stage (Fig. 3) and the following agrotechnical and environmental factors that influence plant growth at that time: crop density, assimilating leaf area and lighting at ½ crop layer in particular ($y = -3.34+0.22x-0.002x^2$, $r = 0.89$, $P\leq0.05$).

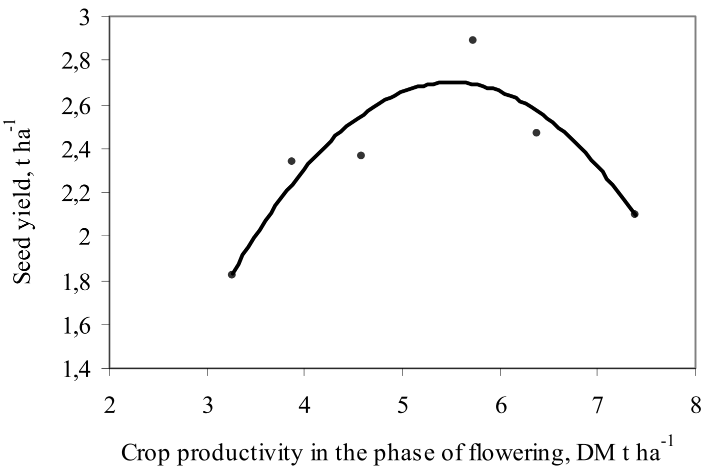

Figure 3. Dependence of rapeseed yield on crop productivity at the flowering stage

When rape crop density reaches the limit of 300.1–350 plants per m^{-2} in comparison with 250.1–300 plants per m^{-2} crop density and significant seed yield decrease of 27.3% is observed. This may be determined by reduction of plant size and productivity (insufficient lighting of separate morphological parts of a plant, small average assimilating leaf area per plant and crop productivity at the flowering stage), and for these reasons the seed yield per plant significantly decreases down to 0.61 g. Seed yield per plant is directly influenced by assimilating leaf area per plant ($y = -0.25+65.06x$, $r = 0.99$, $P\leq0.01$) and yield per plant (DM g) in the phase of flowering ($y = -0.59+0.69x$, $r = 0.95$, $P\leq0.01$).

Conclusions

At rape crop density increase from 100.1 to 350 plants per m^{-2}, in comparison with the thinnest crop (50.1–100 plants per m^{-2}), the leaf area index increases from 18.2 to 80.2% and assimilating leaf area per plant decreases from 38.8 to 67.3%. A very strong positive significant correlation ($r = 0.99$, $P\leq0.01$) between leaf area index and rape crop density is observed.

Assimilating leaf area per plant depends on the light flux falling on soil surface ($r = 0.98$, $P\leq0.01$) and also ¼ and ½ crop layers ($r = 0.93$, $P\leq0.01$; $r = 0.83$, $P\leq0.05$).

At rape crop density increase from 100.1 to 350 plants per m^{-2}, in comparison with the thinnest crop, seed yield per plant significantly decreases from 33.1 to 78.5%. This is most influenced by assimilating leaf area per plant ($r = 0.99$, $P\leq0.01$) and yield per plant at the flowering stage ($r = 0.95$, $P\leq0.01$).

At an increasing number of plants per m^{-2} up to 259, the rapeseed yield significantly increases from 28.6 to 58.8% in comparison with the thinnest crop (64 plants per m^{-2}), and when the crop reaches the average density of 347 plants per m^{-2} the seed yield significantly decreases due to reduction of plant size and productivity.

A significant parabolic relationship ($r = 0.92$, $P\leq0.05$) is established between rapeseed yield and crop productivity at the flowering stage. In this stage, rape productivity is influenced by crop density ($r = 0.97$, $P\leq0.01$), plant leaf area index ($r = 0.96$, $P\leq0.01$) and light flux falling to soil surface ($r = 0.85$, $P\leq0.05$) and also to ¼ and ½ crop layers ($r = 0.84$ and $r = 0.95$, $P\leq0.05$).

References

1. Al-Barzinjy M. *et al.* (2003) Comparison of growth, pod distribution and canopy structure of old and new cultivars of oilseed rape (*Brassica napus* L.). Acta Agric. Scand., Sect. B, Soil and Plant Sci., 53, 138–146.
2. Al-Barzinjy M. *et al.* (1999) Relationship between plant density and yield for two spring cultivars of oilseed rape (*Brassica napus* L.). Acta Agric. Scand., Sect. B, Soil and Plant Sci., 49, 129–133.
3. Diepenbrock W., Grosse F. (1995) Rapeseed (*Brassica napus* L.) physiology. In: Diepenbrock W., Becker H. C. (eds.) Physiological Potentials for Yield Improvement of Annual Oil and Protein Crops, Adv. Plant Breeding, UK, 21–53.
4. Diepenbrock W. (2000) Yield analysis of winter oilseed rape (*Brassica napus* L.). Field Crops Research, 6, 35–49.
5. Donald C. M. (1963) Competition among crop and pasture plants. Adv. Agron., 159, 1–118.
6. Eisele J. – A., Köpke H. (1990) Licht als Faktor der Konkurenzkraft gegenüber Unkräutern in Beständen morphologisch unterschiedlicher Winterweizensorten. Mitteilungen der Gesellschaft für Pflanzenbauwissenschaften, 3, 229–232.
7. Grosse F. *et al.* (1992) Ertragsbildung und Ertragsstruktur bei Winterraps (*Brassica napus* L.). II. Vergleich zwischen Elternlinien und deren F1- und F2- Generationen. J. Agron., 169, 94–103.
8. Heikkinen M. K., Auld D. L. (1991) Harvest index and seed yield of winter rapeseed grown at different plant population. The 8th International Rapeseed Congress, Canada, Saskatoon, UK, 1235–1240.
9. Ogilvy S. E. (1984) The influence of seed rate on population structure and yield of winter oilseed rape. Aspects of Applied Biology, 6, 59–66.
10. Sierts H.-P. *et al.* (1987) Stability of yield components from winter oil-seed rape (*Brassica napus* L.). J. Agron. Crop Sci., 158, 107–113.
11. Šidlauskas G. (2000) Vasarinių rapsų pasėlio tankumo įtaka azoto, fosforo ir kalio kiekiui augaluose, sėklų derliui bei žalių baltymų ir riebalų išeigai. Žemdirbystė, 70, 176–185.
12. Velička R. (2002) Rapsai (monografija), Kaunas, UDK, 320.
13. Буряков Ю. П. *et al.* (1988) Рапс озимый и яровой, Москва, УКД, 43.
14. Тооминг Х. Г., Гуляев Б. И. (1967) Методика измерения фотосинтетически активной радиации, Москва, Наука, УКД, 143.

VARIABILITY OF SOIL PARAMETRS AND WINTER TRITICALE AND WHEAT YIELDING ON PRODUCTION PLANTATIONS

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Abstract

In the years 2001–2003 an experiment on the 5 production plantations of winter triticale and 4 plantations of winter wheat was conducted. Variability of soil parameters (pH_{KCl}, P_2O_5, K2O, MgO contents) and correlation relationships between soil characteristics and grain yield were studied. The content of phosphorus in soil ranged from 1,5 to 28,0 mg P_2O_5 $100g^{-1}$ soil among specified plots of winter triticale and 11,3–25,6 mg P_2O_5 $100g^{-1}$ soil among winter wheat ones; potassium 4,3–29,8 mg K_2O 100 g^{-1} soil (triticale) and 3,4–22,4 mg K_2O $100g^{-1}$ soil (wheat); magnesium MgO 3,2–13,6 mg MgO 100 g^{-1} soil (triticale) and 3,1–14,4 mg MgO $100g^{-1}$ soil (wheat). Acidity of analyzed fields expressed in pH ranged from 4,1 to 7,5 (triticale) and 4,5–6,9 (wheat).

Variation coefficients for tested characteristics of soil on particular plantations varied from 20,0 to 49% (triticale) and from 17,0% to 34,0% (wheat) for potassium content and from 24,0 to 66,0% and from 10,0 to 19,0% for phosphorus, resp. while from 23,0 to 37,0% and from 16,0 to 28,0%, resp. for magnesium content. Soil acidity characterized with less variability in the fields and its variation coefficients varied from 8,0 to 12,0% for triticale plantations and from 5,0 to 11,0% for wheat.

Key words: wheat, triticale, grain yield, production plantations, soil parameters, variability

Introduction

Winter wheat and winter triticale are species that provide the highest grain yield from among all cereals cultivated in Poland. However, yield variability in our country is big one and is mostly caused by site factors as well as applied production technologies (Klepacki 1998). Possibilities of yielding variability limitation in the agricultural practice through providing of optimum level of production technology factors is not always carried out (Wyszyński *et al.* 2004, Rozbicki, Mądry 2000). Soil is the most affecting crop yielding factor from the all settlement ones, thus in the precise agricultural system identification of soil conditions is important in an attempt to decrease yielding variability. There is big care assigned to assess variability of soil parameters in the field in this system as mineral nutrients are applied in terms of recognized variability of soil nutrient content (Hołownicki 2003). Limitation of yielding variability leads to raising level of cereals yield.

The aim of this work was an assessment of soil parameters variability within production plantation of winter cereals – wheat and triticale and finding relationship between these cereals yielding and soil parameters variability.

Material and Methods

Research was conducted on the 5 production plantations of winter triticale and 4 plantations of winter wheat in the central Poland (middle part of Great Valleys Region). Area of plantations varied from 2 to 5 ha. Both cereal species were cultivated on the similar soils belonged to the ones from IIIa to IV b soil classes. To assess variability of soil conditions individual fields were divided into plots (800–1000 m^2). Thus 24–48 plots on the triticale plantation and 24–30 on wheat ones were traced. Just before harvesting some samples of soil and plants were taken at random.. Grain yield from 1 m^2, pH and P_2O_5, K_2O and MgO content (mg $100g^{-1}$ soil) were determined. For each plantation it was established the range and variability of soil parameters and average values. Also a contribution (%) of plots that characterized with pH and P_2O_5, K_2O and MgO content falling into interval value of these parameters taken according to applied in Poland classification was determined. To simplify the process of evaluation three ranges of scale for each soil parameter were used (Tab.2). For each plantation a variation coefficient of analyzed soil parameters and simple correlation coefficients between grain yield and soil parameters were calculated. Average yield on each plantation and the share of plots having given yielding interval was assessed. Then distinguished 5 class intervals: 91–110, 111–130, >130 and 71–90, <70% of average yield on the plantation.

Results

Variability of pH on investigated fields is presented on the Tab. 1. Lower average values and major pH variability appeared more often on triticale plantations than on wheat ones. Average value of pH found on triticale plantation was 4,9–5,8 while in wheat 5,8–6,1. Range of pH values variability among plantations was wide. Plots of the highest acidity displayed pH in the range 4,1–4,8 (triticale) and 4,5–5,5 (wheat). Maximum values were 6,2–7,5 (triticale) and 6,5–6,9 (wheat). Share of plots of low pH (<5,5) was bigger in the triticale fields than wheat ones and ranged from 18,5% (II plantation) to 84,8% (IV plantation). In the case of wheat it varied from 0 to 26,7% (I and IV plantation). Wheat plantations characterized with much more share of neutral (pH> 6,5) and weak acid (pH= 5,6- 6,5) plots.

P_2O_5, K_2O and MgO contents in the soil are presented on the Tab.1. It was characterized by significant variability of parameters between plantations and within them. The lowest contents of these nutrients on analyzed plots of particular plantations were by about 100% to hundreds percents less than the highest ones found in other plots of the same fields.

Table 1. The pH and content of main mineral nutrients in soil on cereals production plantations

Soil parameters and their values		Triticale					Wheat			
		I	II	III	IV	V	I	II	III	IV
pH	mean	5,6	5,8	5,7	5,2	4,9	6,1	6,1	5,8	5,9
	min	4,3	4,5	4,8	4,6	4,1	5,5	5,2	4,6	4,5
	max	6,8	7,5	6,2	6,4	6,2	6,9	6,6	6,5	6,9
coefficient of variation (%)		12	9	8	8	14	5	7	9	11
K_20 [mg100g^{-1} soil]	mean	11,5	10,6	14,2	14,1	13,5	5,6	7,5	14,7	6,5
	min	4,9	4,3	8,0	5,1	10,6	3,4	4,6	9,9	4,5
	max	22,8	15,1	18,6	29,8	18,5	9,9	13,2	22,2	8,8
coefficient of variation (%)		35	20	24	49	20	32	34	21	17
P_20_5 [mg100g^{-1} soil]	mean	15,9	9,4	12,0	3,2	4,8	16,3	19,2	19,3	16,6
	min	9,0	6,3	6,4	1,5	2,1	13,1	14,1	15,9	11,3
	max	25,4	16,3	28,0	8,4	8,8	21,2	22,4	25,6	22,4
coefficient of variation (%)		25	24	61	66	41	12	11	10	19
MgO [mg100g^{-1} soil]	mean	7,6	8,8				4,7	8,2	9,5	4,5
	min	3,6	3,2				3,1	4,7	5,2	3,2
	max	13,6	12,1				8,0	14,4	12,8	6,8
coefficient of variation (%)		37	23				24	28	16	17

Variation coefficients of analyzed soil parameters in investigated fields were high and their values varied since 20,0 to 49,0% (potassium content for triticale), 17,0–34,0% (wheat), 24–66% (phosphorus). Variability of magnesium reachness was similar.

On particular plantations share of plots of mineral nutrients content corresponding to distinguished class intervals was diverse (Tab.2). For four of five tested fields of triticale dominating plots it was under 12,5 mg K_2O and 10 mg P_2O_5 100g^{-1} soil. Wheat plantations I and II of big contribution of low potassium content characterized with big share of plots of high phosphorus content, above 15 mg P_2O_5 100g^{-1} soil. Plantations III and IV of high contribution of plots with average level of K_2O content had the former 100% share of plots with high level of P_2O_5 while on the latter a level was low.

Table 2. The share of plots in pH classes and soil parameters on cereals production plantations, %

Soil parameters and their clases		Triticale					Wheat			
		I	II	III	IV	V	I	II	III	IV
pH	<5,5	33,3	18,5	35,7	84,8	70,8	0,0	8,3	20,8	26,7
	5,6–6,5	56,3	77,8	64,3	15,2	29,2	91,7	70,8	75,0	50,0
	>6,5	10,4	3,7	0,0	0,0	0,0	8,3	20,8	4,2	23,3
K_2O [mg 100g^{-1} soil]	<12,5	58,3	85,2	14,3	51,7	57,1	100,0	91,7	25,0	10,0
	12,6–20,0	39,6	14,8	85,7	27,6	42,9	0,0	8,3	70,8	80,0
	>20,1	2,1	0,0	0,0	20,7	0,0	0,0	0,0	4,2	10,0
P_2O_5 [mg 100g^{-1} soil]	<10,0	6,3	74,1	57,1	100,0	100,0	0,0	0,0	0,0	100,0
	10,1–15,0	41,7	22,2	28,6	0,0	0,0	20,8	8,3	0,0	0,0
	>15,1	52,1	3,7	14,3	0,0	0,0	79,2	91,7	100,0	0,0
MgO [mg 100g^{-1} soil]	<5,0	14,6	7,4				62,5	4,2	0,0	76,7
	5,1-7,0	35,4	7,4				33,3	29,2	4,2	23,3
	>7,1	50,0	85,2				4,2	66,7	95,8	0,0

In Tab. 3 there are presented average yields on the production plantations and contribution (%) of plots on particular fields of grain yield classified to each interval in comparison to the mean yield on the plantation. Distribution of yields showed that only on two triticale plantations (II and V) were dominating plots where grain yield was in the range of 91–110% of mean yield from fields. On remaining fields dominated plots where yield differed by ±10–30% or more than ±30% from the average yield. Yield matching in the wheat fields were higher. Plots with yield in the range of 91–110% of average yield dominated, while plots with more than ±30% difference have not been found at all.

Table 3. Average grain yield (g m^{-2}) and share (%) of plots in classes of yield on production plantations

	Triticale					Wheat			
	I	II	III	IV	V	I	II	III	IV
Grain yield (g m^{-2})	595	624	368	368	473	887	913	646	404
Yield grain clases*									
<70	16,7	7,4	7,1	12,1	8,3	0,0	0,0	0,0	0,0
71–90	18,8	11,1	50,0	18,2	8,3	20,8	25,0	37,5	20,0
91–110	18,8	63,0	0,0	39,4	58,3	54,2	50,0	37,5	56,7
111–130	29,2	14,8	21,4	21,2	20,8	25,0	25,0	25,0	23,3
>131	16,7	3,7	21,4	9,1	4,2	0,0	0,0	0,0	0,0

Soils where yields of wheat and triticale were high characterized with the highest average values of pH. Only on the I plantation of high yielding triticale the high phosphorus content in the soil was notified. On the others where the level of yield was higher soil nutrients content was low in comparison to plantations where yield was lower. Simple correlation coefficients between grain yield, pH and phosphorus and potassium contents in soil point to a little direct dependence between grain yield and soil characteristics (Tab. 4).

Table 4. Simple correlation coefficients between grain yield and soil parameters on production plantations

Soil parameters	Plantation	I	II	III	IV	V
pH	Triticale	0,49**	0,20	–0,12	–0,09	0,07
	Wheat	–0,11	0,34*	–0,22	0,06	
content of K_2O	Triticale	–0,17	–0,14	0,41*	0,40**	0,20
	Wheat	0,24	0,13	0,09	–0,03	
content of P_2O_5	Triticale	–0,08	–0,46**	0,10	0,32*	0,57*
	Wheat	0,05	0,27	–0,07	0,15	

Positively significant simple correlation coefficients were achieved between yield and pH only on the one plantation of wheat and one of triticale while between yield and contents of phosphorus and potassium only on two plantations of triticale.

Discussion

Investigation conducted on the production plantations of winter triticale and wheat showed major diversification of soil conditions within individual fields. High variation of soil parameters (level of pH, reachnes in main nutrients) might be the reason of high yield diversification on these plantations. Mineral nutrients content in soil is determined mainly by correct fertilization. It is very important to sow fertilizers evenly that cause a long term effect on soil conditions. It is responsible of nutrients homogeneity in the field (Kalinowska-Zdun 1997), which was not found on the plantations. Lack of significant correlation between grain yield and soil parameters (pH and nutrients content) proves that their major variability is not the only and base reason of major yielding variability of wheat and triticale on the production fields. Aiming at eveness of the wheat and triticale yields on plantations requires beside accurate testing soil environment also some focusing on technological factors, especially the most varying yielding. Proper production technology is based among others upon the use of qualified even grains, even grain seeding in soil, steady application grains in the field, lowest proper density of plants, dose and term of nitrogen application, (Piech, Stankowski 1989; Kuś, Jończyk 1997; Mercik 1997).

References

1. Hołownicki R. (2003) Rolnictwo precyzyjne szansą na ograniczenie zagrożeń dla środowiska przyrodniczego. Fragmenta Agronomica, 3(79), 52–64.
2. Kalinowska – Zdun M. (1997) Zmiany technologiczne i ich konsekwencje w uprawie roślin. Zesz. Probl. Post. Nauk Rol. 439, 261–266.
3. Klepacki B. (1998) Przestrzenne zróżnicowanie technologii produkcji roślinnej w Polsce i jego skutki. Fundacja 'Rozwój SGGW', Warszawa.
4. Kuś J., Jończyk K. (1997) Oddziaływanie wybranych elementów agrotechniki na plonowanie pszenicy ozimej. Fragmenta Agronomica, 3(55), 4–16.
5. Mercik S. (1997) Nawożenie i jego wpływ na plonowanie roślin oraz na środowisko glebowe. Zesz. Probl. Post. Nauk Rol. 439, 97–102.
6. Piech M., Stankowski S. (1989) Wpływ terminu siewu i ilości wysiewu na plonowanie i jakość ziarna pszenicy ozimej. Biuletyn IHAR 169, 137–147.
7. Rozbicki J., Mądry W. (2000) Poprawność technologii uprawy pszenżyta ozimego na plantacjach produkcyjnych Mazowsza i Podlasia. Fol. Univ. Agric. Stetin. 206, Agricultura 82, 243–248.
8. Wyszyński Z., Michalska B., Piotrowska W. and Kucharczyk D. (2004) Ocena poprawności technologii produkcji na plantacjach produkcyjnych zbóż ozimych w rejonie Polski Centralnej. Annales UMCS, Sec.E, 59, 2, 941–949.

Field management

EFFECT OF PRE-SOWING SOIL PREPARATION ON THE SOIL AGROPHYSICAL PROPERTIES AND SPRING CEREALS YIELD

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Abstract

The influence of different pre-sowing soil preparation means on seedbed quality, soil physical properties and yield of spring wheat and triticale had been studied in the field experiments at the Lithuanian Institute of Agriculture in 2000–2003. The Endocalcari-Endohypogleyic Cambisols light loam soil was prepared for spring wheat and spring triticale by harrowing with heavy tine harrows with a precision seedbed cultivator and S – shape coulters cultivator by different intensities and depth. The amount of structural aggregates, >5 mm in seedbed after sowing, decreased by 14.2–16.4% in treatments, where harrowing and tillage with precision soil preparation equipment to 3–4 cm depth and tillage with S – shape coulters cultivator in two passes were made. It was determined, that soil bulk density decreased and total porosity increased at depth 0–10 cm, when soil for spring wheat and spring triticale drilling was prepared by precision seedbed cultivator to 5–6 cm depth, and with S – shape coulters cultivator to 8–10 cm depth in two passes. The total soil porosity at 0–20 cm depth was from 49.5 to 56.0%, and about 70% of pores were air filled.

Key words: soil tillage, seedbed, spring cereals

Introduction

Spring wheat in Lithuania is grown in area about 80 thousand hectare and spring triticale in 20 thousand hectare (Statistical…, 2002). Crop establishment largely depends on the methods for seedbed preparation and sowing. Several research experiments on seedbed preparation and sowing methods for spring grain cereals, mainly in spring barley, has been done during the last few decades. Early studies concentrated on the intensity and depth of harrowing (Kadžiauskas, 1974). Some research was done on reduced pre-sowing seedbed preparation (Arlauskas, 1999; Jovaišienė, 1980; Maikštėnienė, 1980). Various implements and intensities for seedbed preparation have been compared on sandy loam and clay loam soils. It has been shown that the high influence on establishment of spring cereals had time of harrowing and sowing (Petraitis; 1994; Petraitis, Baniūnas, 1996). Harrowing with a precision seedbed cultivator for peas had an advantage over S – shape spring harrows on sandy loam (Auškalnis, 1999). In dry springs very important factor for uniform cereals emergence is good seed-soil contact (Satkus, 2001). It was assumed that the seeds should be placed directly on a firm and moist seedbed base and covered by a layer of fine aggregates (Heinonen, 1985). In different trials it was found that the finer the aggregate size of the plowed layer the better the cereals emergence (Brown *et al.*, 1996; Hakkanson *et al.*, 2002). The new precision seedbed cultivators are used very often in recent years. One of them is Kongskilde Germinator, a precision seedbed cultivator to create a perfect seedbed – in many cases in only one pass. It consists of narrow working sections with a roller in the front and at the rear for depth control. The Germinator is equipped with specially designed straight tines at a uniform tine spacing of only 5 cm for a very intensive soil preparation (www.kongskilde.com). Important indicator of soil properties is bulk density. The optimal bulk density for plant growth is different for each soil. In general, less than optimal bulk density leads to poor water relations, and high bulk density reduces aeration and increases penetration resistance, limiting root growth (Cassel, 1982) The effect of soil tillage on bulk density is temporary, and after tillage the soil rapidly settles, recovering its former bulk density (Campbell, Henshall, 1991; Franzen *et al.*, 1994). In the objectives of the present work were to investigate soil physical and seedbed properties after different secondary soil tillage for spring wheat and triticale.

Materials and Methods

Experiments were conducted in 2000–2003 on a sandy loam soil, at the Lithuanian Institute of Agriculture in Dotnuva. In autumn ploughed soil for seeding of spring wheat and triticale in spring has been prepared by different soil tillage equipment: heavy harrows BZST-1.0, precision seedbed cultivator (Kongskilde Germinator), and cultivator KP-2 with S – shape coulters according the experiment design.

Experimental design:

1. Harrowing with heavy tine harrows two passes.
2. Harrowing with heavy tine harrows and tillage with a precision seedbed cultivator to the 3–4 cm depth.

3. Tillage with a precision seedbed cultivator to the 3–4 cm depth.
4. Tillage with a precision seedbed cultivator to the 5–6 cm depth.
5. Tillage with S – shape coulters cultivator to the 8–10 cm depth one pass.
6. Tillage with S – shape coulters cultivator to the 8–10 cm depth two passes.
7. Tillage with S – shape coulters cultivator to the 12–14 cm depth two passes.

Each experiment was arranged as a complete randomized block design with four replicates. Gross plot size was 4 × 20 m and net plot size – 2.3 × 15 m.

Spring wheat variety 'Munk' and triticale variety 'Wanad' were sown with a drill with wedge-shaped coulters to 3–4 cm depth. The amount of soil structural aggregates at soil seedbed was evaluated just after sowing according Swedish method (Hakkanson *et al.,* 2002). Soil samples to determine soil bulk density, moisture, and porosity were taken in the beginning of growing season and after harvesting of spring cereals. Two cylinders (100 cm^2) from each plot were used to take undisturbed soil samples. The samples to determine soil bulk density were taken at depths of 0–5, 5–10, 10–15 and 15–20 cm to determine content of soil structural aggregates from 0–10 and 10–20 cm depth (Вадюнина u.др., 1986). The yield of spring wheat and triticale was calculated at 85% dry matter content. Analysis of variance (ANOVA) was conducted on soil physical and the yield data for each year (Dospechov, 1985; Tarakanovas, 1996).

Results and Discussion

In autumn soil was mould board ploughed to 22–24 cm depth. In spring soil was tilled for sowing according to experiment design. The findings of the soil structural aggregates in seedbed just after sowing have shown that different tillage methods have some effect (Table 1).

Table 1. Effect of pre-sowing tillage on the indices of seedbed quality, Dotnuva, 2001–2003

Soil tillage	Amount of structural aggregates, %					
	<2 mm		2–5 mm		>5 mm	
	0–2 cm depth	2–5 cm depth	0–2 cm depth	2–5 cm depth	0–2 cm depth	2–5 cm depth
Harrowing two passes	26.5	23.8	31.4	42.9	42.1	33.3
Harrowing and tillage with precision soil preparation equipment to 3–4 cm depth	28.2	26.4	36.6	45.4	35.2	28.2
Tillage with precision soil preparation equipment to 3–4 cm depth	25.1	30.1	31.8	38.9	43.1	31.0
Tillage with precision soil preparation equipment to 5–6 cm depth	28.4	27.0	30.3	46.1	41.3	26.9
Tillage with S – shape coulters cultivator to 8–10 cm depth one pass	24.3	27.0	28.9	42.4	46.8	30.6
Tillage with S – shape coulters cultivator to 8–10 cm depth two passes	26.8	27.1	37.1	41.4	36.1	31.5
Tillage with S – shape coulters cultivator to 12–14 cm depth two passes	25.4	22.5	36.8	46.1	37.8	31.4
LSD_{05}	4.61	5.25	5.35	5.02	5.89	5.26

The amount of structural aggregates, >5 mm in seedbed after sowing, decreased by 14.2–16.4% in treatments, where harrowing and tillage with precision soil preparation equipment to 3–4 cm depth and tillage with S – shape coulters cultivator in two passes was made. Soil bulk density was close to optimum. Least soil bulk density was at 0–10 cm depth was in treatments, where tillage with precision soil preparation equipment to 5–6 cm depth and tillage with S – shape coulters cultivator to 8–10 cm depth in two passes (Table 2).

In general the braking of soil clods more depended on occasions of passes than type of tillage equipments and tillage depth. The total soil porosity was high – from 49.5 to 56.0%, and about 70% of pores were air filled. The highest soil porosity at 0–10 cm depth was in treatments tilled by precision soil preparation equipment to 5–6 cm depth, with S – shaped coulters cultivator to 8–10 and 12–14 cm depth tilled in two passes (Table 2).

Table 2. Effect of pre-sowing tillage on soil physical properties, Dotnuva, 2000–2003

Soil tillage	Soil bulk density Mg m^{-3}		Soil moisture, %		Soil total porosity, %		Soil air-filled porosity, %	
	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth	0-–0 cm depth	10–20 cm depth
Harrowing two passes	1.24	1.33	11.6	12.1	52.7	49.7	38.3	33.4
Harrowing and tillage with precision soil preparation equipment to 3–4 cm depth	1.21	1.33	12.4	12.6	54.0	49.6	39.3	32.9
Tillage with precision soil preparation equipment to 3–4 cm depth	1.22	1.33	11.9	12.3	53.6	49.5	39.0	33.2
Tillage with precision soil preparation equipment to 5–6 cm depth	1.16	1.30	11.8	12.4	56.0	50.7	42.8	34.6
Tillage with S – shape coulters cultivator to 8–10 cm depth one pass	1.22	1.31	11.8	12.5	53.6	50.2	39.2	33.9
Tillage with S – shape coulters cultivator to 8–10 cm depth two passes	1.18	1.33	11.9	12.3	55.1	49.6	40.1	33.3
Tillage with S – shape coulters cultivator to 12–14 cm depth two passes	1.19	1.32	11.9	12.3	55.9	50.1	40.6	33.9
LSD_{05}	0.055	0.058	0.67	0.71	2.05	2.20	2.81	3.07

The amount of soil structural aggregates per growing season in plough layer of spring cereals was similar in all treatments. The different pre-sowing soil tillage not always has different influence on soil aggregates stability (Velykis *et al.,* 1996). The tendency to increase amount of structural aggregates larger than 5 mm was found in treatment where soil was tilled with cultivator with S – shape coulter to 8–10 cm depth in one pass compare to harrowing with heavy tine type harrows in two passes (Table 3).

Table 3. Effect of various pre-sowing tillage methods on soil structural aggregates content per growing season, Dotnuva, 2000–2003

Soil tillage	Content of soil structural aggregates, %						Water stable structural aggregates, %			
	>5.0 mm		5.0-0.25 mm		<0.25 mm		>0.25 mm		>1 mm	
	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth	0–10 cm depth	10–20 cm depth
Harrowing two passes	51.5	57.5	41.6	36.8	6.9	5.7	48.3	49.9	9.5	11.2
Harrowing and tillage with precision soil preparation equipment to 3–4 cm depth	55.2	60.7	39.1	34.2	5.7	5.1	49.4	50.5	9.8	11.2
Tillage with precision soil preparation equipment to 3–4 cm depth	48.1	59.4	44.2	34.7	7.7	5.9	47.3	51.1	9.2	10.9
Tillage with precision soil preparation equipment to 5–6 cm depth	47.5	60.1	44.9	34.5	7.6	5.4	49.1	51.0	9.7	11.7
Tillage with S – shape coulters cultivator to 8–10 cm depth one pass	49.3	59.2	43.1	35.3	7.6	5.3	48.7	50.4	9.2	11.2
Tillage with S – shape coulters cultivator to 8–10 cm depth two passes	47.3	61.0	44.0	33.2	8.7	5.7	48.9	50.1	9.4	10.8
Tillage with S – shape coulters cultivator to 12–14 cm depth two passes	45.8	57.2	46.3	37.0	7.9	5.8	48.1	51.5	8.3	11.7
LSD_{05}	8.86	8.48	8.34	7.71	1.86	1.58	2.18	2.95	2.01	2.04

The averaged yield of spring wheat and triticale in the year 2000–2003 was similar in all soil tillage treatments. Some tendency of yield of spring wheat and triticale increase was in treatments where soil for sowing of spring cereals was prepared by precision soil preparation equipment (Table 4).

Table 4. Influence of pre-sowing soil tillage on yield of spring wheat and triticale, Dotnuva, 2000–2003

Treatments	Spring wheat		Spring triticale	
	t ha^{-1}	%	t ha^{-1}	%
Harrowing two passes	3.63	100.0	4.14	100.0
Harrowing and tillage with precision soil preparation equipment to 3–4 cm depth	3.80	104.8	4.39	106.0
Tillage with precision soil preparation equipment to 3–4 cm depth	3.77	103.9	4.19	101.1
Tillage with precision soil preparation equipment to 5–6 cm depth	3.74	103.0	4.23	102.2
Tillage with S – shape coulters cultivator to 8–10 cm depth one pass	3.57	98.4	4.00	96.6
Tillage with S – shape coulters cultivator to 8–10 cm depth two passes	3.72	102.3	4.21	101.6
Tillage with S – shape coulters cultivator to 12–14 cm depth two passes	3.67	101.0	4.18	100.8
LSD_{05}	0.315		0.302	

Conclusions

The lowest amount of soil structural aggregates in seedbed at 0–2 cm depth >5 mm size was found in treatment where harrowing and tillage with precision soil preparation equipment was done. The highest amount of 2–5 mm size aggregates after sowing of cereals in 0–2 cm depth was in treatments, where soil was tilled by cultivator with S – shape coulters to 8–10 cm and 12–14 cm depth in two passes.

The lowest soil bulk density, and the highest total porosity in 0–10 cm depth was in treatments where soil for sowing was prepared by precision soil preparation equipment to 5–6 cm depth and tillage with S – shape coulters cultivator to the depth 8–10 cm in two passes.

The averaged yield over the years 2000–2003 of spring wheat and triticale was similar in all treatments

References

1. Arlauskas M. (1999) Prospects for soil tillage minimization in Lithuania. Agriculture, Scientific articles, 67, 142–156.
2. Auškalnis A. (1999) Effect of pre-sowing soil preparation and sowing on the pea yield and on soil physical properties. Agriculture, Scientific Articles, 68, 50–61.
3. Berntsen R., Berre B. Soil fragmentation and the efficiency of tillage implements. Soil and Tillage Research, 64, 23–40.
4. Brown A. D. *et al* (1996) Effect of macroporosity and aggregate size on seed-soil contact. Soil and Tillage Research, 38, 203–216.
5. Campbell D. J., Henshall M. F. (1991) Bulk density. In.: Unger P. W. and Van Doren D.M. (Eds.) Soil analysis.. Physical methods. Marcel Dekker, New York. USA., 329–366.
6. Cassel D. K. (1982) Tillage effects on soil bulk density and mechanical impedance. In.: Unger P.W. and Van Doren D. M. (Eds.) Predicting tillage effects on soil physical properties and processes. ASA-SSSA, Madison USA, 45–67.
7. Franzen H. *et al* (1994) Tillage and mulching effects on physical properties of a tropical Alfisols. Soil and Tillage Research, 28, 329–346.
8. Germinator specifications www.kongskilde.com
9. Hakanson I. *et* al (2002) A review of research on seedbed preparation for small grains in Sweden. Soil and Tillage Research, 64, 23–40.
10. Heinonen R., (1985) Soil Management and Crop Water Supply, 4th Edition. Department of Soil Science, Swedish University of Agricultural Sciences, Uppsala, 105.
11. Jovaišienė E. (1980). Priešsėjinio dirvos paruošimo ir sėjos tankumo įtaka derliui lengvuose priemoliuose. LŽMTI mokslinių straipsnių rinkinys. 41, 16–22.
12. Kadžiauskas P. (1974) Priešsėjinis dirvų dirbimas vasarojui. LŽMTI darbai. – Vilnius., 18, 57–93.
13. Maikštėnienė S. (1980) Priešsėjinio dirvos ruošimo būdai ir miežių sėklų įterpimo gylis sunkiuose priemoliuose. LŽMTI mokslinių straipsnių rinkinys. – Vilnius, 41, 23-27.
14. Petraitis V. (1994) The theory and practise of spring barley management on loamy soils in central Lithuania: The work of doctor habilitatis. – Dotnuva, 158.
15. Petraitis V., Baniūnas V. (1996) Spring wheat cultivation on light and heavy loams. Agriculture, Scientific Articles, 52, 225–247.
16. Satkus A. (2001) Effect of rolling methods on spring barley seedbed preparation on a clay loam soil. Agriculture, Scientific Articles, 75 3–13.
17. Statistical Yearbook of Lithuania 2001. 2002. Vilnius, 106.
18. Tarakanovas P. (1996) Selekcinių – genetinių tyrimų rezultatų apdorojimo ir įvertinimo sistema „Selekcija“.– Dotnuva-Akademija, 76.
19. Velykis A., et al (1996) Methods of loosening and pre-sowing soil tillage on heavy clay loam. Agriculture, Scientific Articles 51, 53–69.
20. Вадюнина А., Корчагина З. (1986) Методы исследования физйческих своиств почв. – М., 5–204.
21. Доспехов Б. А. (1985) Методика полевого опыта. М., 351.

THE INFLUENCE OF NO-TILLAGE, REDUCED TILLAGE, STRAW AND GREEN MANURE ON LUVISOL PHYSICAL PROPERTIES AND EARTHWORM POPULATIONS

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Abstract

Many studies in European and other countries have showed positive effects of reduced tillage and no-tillage systems on physical properties of various soils. However, some data also show that the results are less positive under humid conditions. There's also lack of information about the effect of green manure and straw management under no-tillage and reduced tillage systems. Stationary two-factor experiment was carried out in the Experimental station of Lithuanian University of Agriculture. Continuous spring barley (*Hordeum vulgare* L.) was grown over the period of 2000–2003. Soil physical properties: bulk density, porosity, moisture content, water infiltration rate and earthworm numbers were measured under the following tillage systems – deep ploughing (15–25 cm), shallow ploughing (10–12 cm), shallow cultivation with heavy cultivator and disc harrows (8-10 cm), shallow spring rotavation (5–6 cm), shallow grass-clover (*Trifolium pratense* L. and *Phleum pratense* L.) green manure incorporation with rotavator in spring (5–6 cm) and no-tillage. Straw, green manure and tillage systems had no significant influence on soil bulk density and porosity. Shallow green manure incorporation significantly increased moisture content in barley at tillering stage. No-tillage and reduced tillage treatments significantly increased the amount of water stable aggregates. No-tillage, shallow spring rotavation and green manure increased water infiltration rate and had highly positive effect on numbers and biomass of earthworm populations.

Key words: no-tillage, reduced tillage, straw, green manure, bulk density, porosity, moisture, infiltration rate, earthworms

Introduction

Less energy and labour consuming tillage systems such as deep or shallow loosening and no-tillage recently become more and more popular in Lithuania. Many trials showed that persistent deep ploughing has negative effect on most of soil features and leads to soil organic matter reduction, nitrogen and pesticide leaching, (Gedvilas, 1978; Arlauskas, 2000), especially when the straw and plant residue is removed and there's large area of uncovered soil. Surface organic residue makes protective cover, which prevents soil from erosion and silt up (Sommer *et al.*, 1985). However, straw residue may cause problems both in sowing and later on in growing season. It may present a physical barrier to moisture uptake under dry conditions or accumulation of phytotoxins under wet conditions and decrease early season soil temperatures (Børresen, 1986). Reduced tillage systems, especially no-tillage, protects natural biodiversity, increases soil biological activity and aggregate stability in upper arable layer and increases the amount and biomass of earthworms in soil (Joshko *et al.*, 1996). Success of minimum tillage partly depends on weather and climatic conditions. In some trials better results are achieved in dry years and in wet conditions reduced tillage can be less effective (Riley, 1983). Other scientists in Denmark didn't investigate this dependence (Djurhus, 1985). Trials in Norway showed that reduced tillage is less effective in heavy wet soils (Riley, 1983). Bulk density is inversely related to total porosity (Carter and Ball, 1993). Many trials showed controversial effect of reduced and no-tillage on soil bulk density. According to the conclusions of some scientists, reduced tillage significantly increases soil bulk density and compaction in upper arable layer (Ellis *et al.*, 1982; Tebrügge, During, 1999). Some authors concluded that bulk density does not depend on tillage system (Arshad *et al.*, 1999; Blevins *et al.*, 1983; Logsdon, Cambardella, 2000), while other trials showed, that no-tillage significantly decreased bulk density. According to the results of long-term trials in Norway, the highest soil porosity and lowest bulk density was in no-tilled soil. No-tillage significantly increased the amount of macro-pores (>30 μm) and middle sized (3–10 μm) pores (Ekeberg and Riley, 1997). Bulk density and porosity also varies over the year due to seasonal thawing-freezing processes (Blevins *et al.*, 1983) and it can also be affected by kinetic rainfall energy. Decrease of soil bulk density is one of the main tillage goals. However this effect is temporal, cause after tillage soil rapidly settles, returning to its former state (Franzen *et al.*, 1994; Franzluebbers *et al.*, 1995).

Many trials in Lithuania showed inconstant effect of reduced tillage systems on soil physical properties (Jodaugiene 2002; Arlauskas, 2000; Pranaitis, 1999). Therefore there is lack of knowledge about crop residue effect on soil physical properties under reduced tillage systems and there are only few trials on no-tillage.

The aim of this research was to investigate the influence of no-tillage, reduced tillage and plant residue on soil physical properties and earthworm populations.

Materials and Methods

Stationary two-factor field experiment was established in the Experimental station of Lithuanian University of Agriculture. Soil at the site is *Endocalcaric Endohipogleyic Luvisol* (FAO), moderately heavy sandy clay loam on sandy light loam. Soil pH – 7.6 (potentiometric determination), humus content – 28.6 g kg^{-1} (aparatus Heraeus), K_2O – 134 mg kg^{-1}, P_2O_5 – 266 mg kg^{-1} (A-L-Egner-Riehm-Domingo). Continuous spring barley (*Hordeum vulgare* L.) in experimental field has been sown annually since 1999. The straw from the one part of experimental field was removed (N) and from another part – chopped and spread (S) at harvesting. The following tillage systems were investigated in both backgrounds: 1) DP – deep ploughing (control), 2) SP – shallow ploughing (10cm), 3) SL – shallow loosening with a heavy cultivator and disc harrows (8–10 cm) in autumn, 4) SR – shallow rotavation (5–6 cm) in spring, 5) GMR – green manure incorporation with rotavator (5–6 cm) in spring, 6) NT – no-tillage, direct drilling. Only the stubble of the first treatment was deep ploughed later in autumn. The stubble of the forth and fifth treatments was rotavated only in spring before barley sowing. Red clover (*Trifolium pratence* L.) and timothy (*Phleum pratence* L.) were undersown in GMR treatment. This catch crop sprouted up after barley harvesting and was incorporated as the green manure next spring. White mustard (*Sinapis alba* L.) for the green manure was undersown in the stubble with chopped straw of NT treatment after barley harvesting. Only treatments DP, SP and SL were secondary cultivated in spring. Barley sowing was performed with no-till air drill John Deere 750 A. The stubble of treatment GMR in 2000 and the stubble of treatments SR, GMR and NT in 2001–2002 were sprayed with roundup 4 l ha^{-1}.

The trials were carried out in four replicates. The treatments were arranged by split-plot method. Calculable area of each test plot was 34.5 m^2.

Soil samples (200 cm^3) for bulk density, moisture content, and pore size investigations were taken with Nekrasow borer from the upper layer (3–13 cm) and lower layer (15–25 cm) of each plot in May. Samples were dried 2 days under 105 ºC and weighed. Soil moisture percent was calculated from dry soil weight (Вадюнина, Карчагина, 1986).

Water infiltration was investigated right after barley harvesting by the two rings method. Two metallic rings were hammered into the soil and filled with water. Water infiltration was measured in the inner ring 50 minutes in three places of each plot. The readings on the float of inner ring were recorded 10 times every 5 minutes (Martin, Carter, 1983).

The number and biomass of earthworms was investigated after barley harvesting by method of chemical repellents (0.55% formalin solution) in 0.25 m^2 metallic frames. The frames were hammered in three places of each plot and filled with solution. After solution infiltrated into the soil, all earthworms were collected, weighed and expressed in units and grams per square meter (Martin, Carter, 1983).

The data of the trials were evaluated in two-way ANOVA and three-way ANOVA. Levels of significance are marked as follows: * – $P \leq 0.05$; ** – $P \leq 0.01$*** – $P \leq 0.001$.

Results and Discussion

Bulk density of soil. Soil water and air balance, soil biological activity, seed germination, distribution of plant roots and crop yields highly depends on soil bulk density. Many trials showed the increase of bulk density and compaction on conventionally ploughed soils with high traffic, which appears due to many tillage operations (Tebrügge and During, 1995; Lampurlanes and Cantero-Martinez, 2003).

Three year data of our experiment didn't show significant effect of straw residue on bulk density, also bulk density was slightly – 0.8–1.4% lower in plots were straw was spread than without straw residue (Table 1). This result contributed to conclusion of Børresen (1999), who stated that there is no significant effect of straw on bulk density even after 8 years of straw incorporation. Bulk density more differed in upper and lower arable layers than in tillage systems.

Table 1. The influence of no-tillage, reduced tillage and plant residue on soil bulk density and moisture content at barley tillering stage

Treatment	Bulk density, g m^{-3}						Moisture content, %					
	2000		2001		2002		2000		2001		2002	
Factor A: straw												
N	1. 40		1. 48		1. 32		17. 11		19. 02		16. 60	
S	1. 38		1. 46		1. 31		17. 16		20. 64***		17. 20	
Factor B: tillage system												
depth, cm	3–13	15–25	3–13	15–25	3–13	15–25	3–13	15–25	3–13	15–25	3–13	15–25
DP	1.28	1.44	1.46	1.49	1.22	1.32	15.18	20.2	18.85	20.36	15.35	18.10
SP	1.34	1.42	1.50	1.52	1.22	1.35	14.91	18.45	18.40	20.83	15.81	17.89
SL	1.41***	1.42	1.48	1.50	1.34	1.42	14.16	19.42	19.30	20.52	15.54	18.72
SR	1.42***	1.46	1.45	1.49	1.31	1.41	15.73	18.41	20.74	20.42	16.57	16.53
GMR	1.42	1.42	1.45	1.43	1.31	1.39	15.73	19.71	20.74	21.42	16.57	17.35
NT	1.41	1.38	1.44	1.44	1.32	1.26	14.89	20.36	18.10	20.85	16.13	18.17

Tebrügge (1999) and Cavalaris (2002) investigated higher soil density in upper arable layer. However similar results in our experiment were obtained only in the first experimental year. According to the data of 2000, 10.2% higher bulk density was investigated in SR, 10.9% higher in GMR and 10.2% higher in NT treatment. There were no significant differences between different tillage systems in lower 15–25 cm arable layer, averagely 0.7–6.6% higher bulk density in all experimental years was observed in lower than in upper 3–13 cm layer. In upper soil layer in all tillage treatments soil bulk density ranged from 1.22 to 1.50 g cm^{-3}, while in lower – from 1.26 to 1.52 g cm^{-3}.

Soil moisture content. Optimum moisture content is one of the main conditions for high cereal yields. According the results of some trials, reduced tillage especially when straw residue is spread on the surface, reduces water evaporation. However, this effect of residue is more observable in spring at sowing time and early plant growth stages. Straw cover partly reflects the sun radiation and causes later soil surface heating and slower moisture evaporation. The amount of moisture in soil without straw ranged from 16.60 to 19.02% while in plots with straw it was averagely 5.7% higher and ranged from 17.16 to 20.64%. The significant effect of straw on soil moisture content was obtained only in 2001, when soil moisture in all tillage treatments was 1–3.6 percent units higher than optimum for barley growth (17–18%). The results showed that moisture content in plots with straw was 1.62 percent unit higher than without straw (*P<0.001*). Tillage systems had no significant influence on soil moisture content. Highest moisture content was obtained in 3–13 cm layer of GMR treatment. Evaporation decreased due to green manure application as investigated by Clark (1997). The experiment of Cavalaris (2002) showed highest content of moisture in upper (0–10 cm) soil layer of no-tilled plots. According to our experiment higher moisture content was observed in lower 15–25 cm arable layer of GP and NT treatments than in the same layer of shallow or spring loosened plots.

Soil porosity. Soil porosity strongly depends on soil particle size and mineral structure, humus content and etc. (Chenu *et al.*, 2000). Higher soil density decreases total porosity. Straw incorporation had no significant influence on soil total porosity over the period 2000–2002 (*P = 0.400*, *P = 0.577* and *P = 0.110*). In fact, soil porosity depended more on sampling depth than on tillage system. Therefore the interaction between tillage (*P = 0.005*) and soil sampling depth was obtained on the first experimental year, so tillage systems will be discussed separately in upper (3–13cm) and lower (15–25cm) layers.

Significant influence of tillage systems on soil total porosity was investigated only in 2000 (Table 2). In all treatments it was significantly – 5.6% higher in upper (3–13cm) than in lower soil layer, except NT treatment, where it was slightly – 2.8% higher in lower layer. Compared to DP, total porosity in this treatment was 5.3% higher, but this difference is not essential. Similar tendency of total porosity was noticed in 2001, while the data of 2002 showed the controversial results – the highest total porosity was observed in lower soil layer of DP treatment.

Table 2. The influence of no-tillage, reduced tillage and plant residue on soil porosity at barley tillering stage in 3–13 cm and 15–25 cm soil arable layers

Treatments	Total porosity of 3–13 cm layer, %			Total porosity of 15–25 cm layer, %		
	2000	2001	2002	2000	2001	2002
Factor A: straw						
N	48.04	43.08	50.53	44.51	42.78	47.66
S	47.55	44.11	51.56	46.09	43.62	47.76
Factor B: tillage system						
DP	50.69	43.83	52.94	44.65	42.48	49.53
SP	48.44	42.31	52.99	45.51***	41.70	48.98
SL	50.95	43.36	52.96	45.42***	42.50	47.89
SR	45.62***	43.09	48.43	43.97***	42.85	46.32
GMR	45.48***	44.12	49.72	45.22***	44.92	46.30
NT	45.72	44.71	49.24	47.02*	44.72	47.25

SR, GMR and NT treatments decreased total porosity in soil upper 3–13 cm layer average by 5.0–5.2%. All reduced tillage systems, including shallow ploughing (SP) significantly increased total porosity in 15–25 cm layer average by 0.6–0.8 percent units, while in NT treatment this difference was 2.4 percent units (*P<0.05*), compared to deep ploughing. However, these results were obtained only in the first experimental year. According to the results of Clark (2002), the amount of the largest pores in no-tillage treatment was 2 times smaller than in cultivated soil.

Water infiltration. According to Zuzel *et al.* (1987), water infiltration increases in tillage systems which stimulates the increase of organic matter content and soil porosity. Water infiltration in field conditions was investigated right after barley harvesting. According to the data of two years (Fig.), straw incorporation had no significant influence on average infiltration rate in 50 min of observation (*P = 0.123* and *P = 0.963*). Significant influence of straw was obtained only in 2002, at first 5 minutes of observation, when infiltration rate in plots with straw totalled 1.24 cm min^{-1}, and in plots without straw – 0.98 cm min^{-1} or 21% higher (*P = 0.021*). Infiltration rate in plots without straw was also 13.3% higher in 2003, but this difference is not significant (*P = 0.319*).

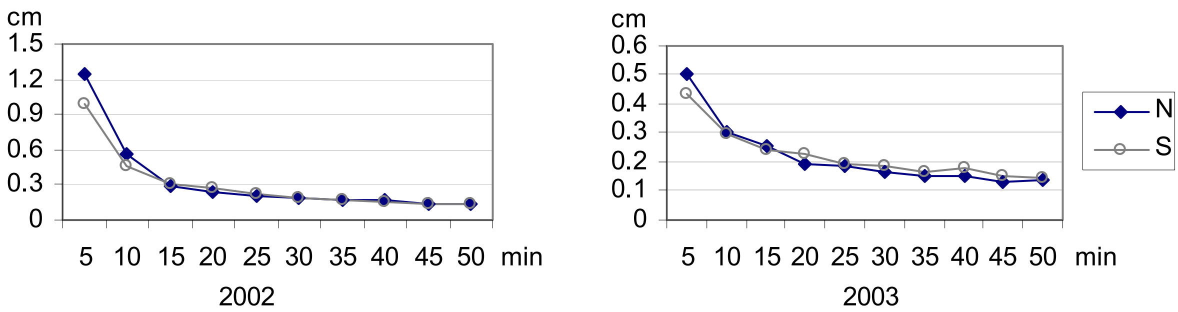

Figure 1. The influence of straw (factor A) incorporation on water infiltration rate, 2002–2003

Tillage systems in 2002 had significant influence on water infiltration at the beginning of observation (Table 3). According to average data of 50 min. observation, lowest water infiltration was in DP and SP treatments – respectively 0.19–0.29 cm min^{-1} and 0.19–0.25 cm min^{-1}. Significantly higher infiltration, compared to DP, was investigated at first 5 observation minutes in SR, GMR and NT. Highest infiltration rate – 0.56–1.65 cm min^{-1}, or 29.0–135.7% was found in GMR treatment. Respectively 30.0–85.7% and 25–70% higher, compared to DP, infiltration rate was established in SR and NT treatments. However, significant differences in these tillage systems were established only in 2002 (*P = 0.003* and *P = 0.011*). There were no significant differences after another 5 min. of observation.

Table 3. The influence of reduced tillage and no-tillage (factor B) on water infiltration rate, 2002

Treatments	Infiltration, cm min^{-1} after									
	5 min	10 min	15 min	20 min	25 min	30 min.	35 min	40 min	45 min	50 min
DP	0.70	0.44	0.26	0.26	0.23	0.21	0.24	0.22	0.16	0.18
SP	0.65	0.40	0.26	0.23	0.20	0.19	0.18	0.16	0.14	0.11
SL	1.18*	0.53	0.34	0.30	0.23	0.19	0.18	0.16	0.16	0.16
SR	1.30**	0.48	0.31	0.24	0.22	0.16	0.17	0.12	0.16	0.13
GMR	1.65***	0.47	0.34	0.30	0.20	0.19	0.14	0.15	0.11	0.12
NT	1.19*	0.44	0.28	0.20	0.18	0.17	0.12	0.12	0.10	0.08

Significant differences in 2003 were established after 15–20 min. of observation (Table 4). Significantly – 52.4 and 38.1% higher infiltration rate, compared to DP, was investigated in SR and GMR treatments. Infiltration rate was also 19.4% in NT plots, but this difference is not significant (*P = 0.269*). Similar results where obtained after 20 minutes of observation, when infiltration rate was 58.8 and 47.1% in SR and GMR, than in DP treatment. After 25 min of observation infiltration slowed down and there was no significant differences between tillage systems.

Table 4. The influence of reduced tillage and no-tillage (factor B) on water infiltration rate, 2003

Treatments	Infiltration, cm min^{-1} after									
	5 min	10 min	15 min	20 min	25 min	30 min.	35 min	40 min	45 min	50 min
DP	0.40	0.25	0.21	0.17	0.16	0.15	0.14	0.16	0.12	0.13
SP	0.41	0.23	0.23	0.18	0.20	0.15	0.15	0.13	0.13	0.13
SL	0.43	0.25	0.20	0.17	0.15	0.16	0.17	0.15	0.15	0.14
SR	0.52	0.36	0.32**	0.27**	0.24	0.21	0.18	0.20	0.16	0.15
GMR	0.56	0.35	0.29*	0.25*	0.20	0.20	0.18	0.20	0.15	0.14
NT	0.50	0.33	0.25	0.21	0.18	0.17	0.15	0.15	0.15	0.17

Earthworms. Quantity of earthworms in soil depends on many factors. Some data show that one of the limiting factors is quantity of organic residue, suitable for earthworm food and moisture content in soil (Lauringson *et al.*, 1999), tillage intensity (Bargett *et al.*, 1998), and humous soil layer thickness (Pupaliene, 2004). The lowest earthworm numbers were investigated in DP (Table 5). More earthworms, compared to ploughed soil, were found in other tillage systems. The earthworm numbers in SR, GMR and NT treatments were respectively 119, 118 and 128 times higher than in DP ($P<0.001$). According the investigation of Pupaliene (2004), three year of continuous barley cropping reduced the amount of earthworms, regardless tillage system applied. Therefore our experiment showed highly positive effect of reduced and no-tillage systems despite four years of continuous cropping.

Table 5. The influence of no-tillage, reduced tillage and plant residue on number and biomass of earthworms

Treatments	Earthworms, number m^{-2}	Total earthworm biomass, g m^{-2}	Average mass of earthworm, g
Factor A: straw			
N	110.6	69.9	0.56
S	102.0	74.4	0.63
Factor B: tillage system			
DP	1.7	0.6	0.22
SP	4.0	1.9	0.43
SL	11.2	7.9	0.69*
SR	202.2***	131.5***	0.46
GMR	200.8***	149.7***	0.84**
NT	218.1***	141.1***	0.93**

Total earthworm biomass also highly depended on tillage system. Highest total earthworm biomass was found in NT – 149.7 m^{-2}, and somewhat lower in GMR – 141.1 g m^{-2} and SR – 131.5 g m^{-2}, while total biomass of earthworms in DP was only 0.6 g m^{-2}. According to experimental data, highest average mass of earthworm was in NT – 0.93 g, more than three times higher than in DP. Similar average earthworm mass was found in GMR treatment – 0.84 g. The mulch of green manure applied in this treatment provided better moisture conditions and contributed to straw residue decomposition favouring earthworm growth. Therefore in SR treatment average earthworm mass was only two times higher (0.46 g) compared to average mass of earthworm in DP (0.22 g).

Deep soil loosening is one of the best tools to incorporate and mix plant residue, stimulating decomposition and herewith providing food for earthworms. This fact could contribute to high average earthworm mass in SL treatment. Compared to ploughed soil, average earthworm in SL treatment was significantly – 3.1 times higher ($P<0.05$).

Conclusions

Straw incorporation and tillage systems have no significant influence on bulk density and soil moisture content at barley tillering stage. The effect of straw residue incorporation and tillage systems on soil total porosity is inconsistent.

No-tillage and reduced tillage didn't change soil porosity in 0–15 cm layer. Reduced and no-tillage increased soil porosity in 15–25 cm layer, but the differences are only marginal.

The worst water infiltration is in autumn ploughed soil. No-tillage and reduced tillage significantly increases infiltration rate. Straw residue incorporation significantly decreases water infiltration. There are no significant differences after 25 min. of observation.

The amount and biomass of earthworms didn't depend on straw incorporation. No-tillage, shallow rotavation and shallow green manure incorporation with rotavator significantly increases the amount and total biomass of earthworms. No-tillage, green manure incorporation and shallow loosening with heavy cultivator in autumn significantly increased average earthworm mass, compared to deep autumn ploughing.

References

1. Arlauskas M. (2000) Armens storio įtaka dirvos savybėms ir vasarinių miežių derliui. Žemdirbystė. Mokslo darbai, LŽI. LŽŪU, 69, 56–70.
2. Arshad M. A., Lowery B., Grossman B. Physical tests form monitoring soil quality // Soil Science Society of America Journal, 1996, vol. 49, 123–141.
3. Bardgett R. D. and Cook R. (1998) Functional aspects of soil animal diversity in agricultural grasslands. Applied Soil Ecology, 10 (3), 3–13.
4. Blevins L., Smith M.S., Thomas G. W, Frye W. W. (1983) Influence of conservation tillage on soil properties // Journal of Soil and Water Conservation, 38, 301–304.
5. Børresen T. (1986) Effects of Three Tillage Systems Combined with Different Compaction and Mulching treatments on Cereal Yields, soil temperature and Physical Properties on Clay Soil in South Eastern Norway. Dr. Sci. thesis, Agriculture University of Norway.
6. Børesen T. (1999) The effect of straw management and reduced tillage on soil properties and crop yields of spring-sown cereals on two loam soils in Norway. Soil and Tillage Research, 51 (1–2), 91–102.
7. Carter M. R. and Ball B. C. (1993) Soil porosity. Soil sampling methods of soil analysis, 581–588.
8. Cavalaris C. R. and Gemtos T. A. (2002) Evaluation of four conservation tillage methods in the sugar beet crop. Agricultural Engineering International. The CIGR Journal of Scientific Research and Development, 4, 3–23.
9. Clark, Decker A.M., Meisinger J. J., Mulford F. R., McIntoch M. S. (1997) Kill day of vetch-rye mixture: Soil moisture and corn yield // Agronomy Journal, 89, 434–441.
10. Chenu C., Le Bissonnais Y. Arrouays D. (2000) Organic Matter Influence on Clay Wettability and Soil Aggregate Stability. Soil Science Society of America Journal, 64, 1479–1486.
11. Djurhus J. (1985) Actual Evapotranspiration in Spring Barley in Relation to Soil Tillage and Straw Incorporation. Danish Journal of Plant Soil Sciences, 47–59.
12. Ekeberg E. and Riley H.C.F. (1997) Tillage intensity effects on soil properties and crop yields in a long-term trial on morainic loam soil in southeast Norway. Soil and Tillage Research, 42, 227–293.
13. Ekeberg E. (1987) Reduced Tillage on Loam Soil. I. Cereals. Norwegian Journal of Agriculture Research, 1, 1–6.
14. Ellis F., Christian D., Cannel R. (1982) Direct drilling, shallow tine cultivation and mouldboard ploughing on a silt loam. Soil and Tillage Research, 2, 115–130.
15. Franzluebbers A.J., Hons P.M., Zuberer D.A. (1995) Tillage and crop effects on seasonal dynamics of soil CO_2 evaluation, water content, temperature and bulk density. Applied Soil Ecology, 2, 95–109.
16. Franzen H., Lal R., Ehlers W. (1994) Tillage and mulching effects on physical properties of a tropical Alfisol. Soil and tillage research, 28, 329–346.
17. Gedvilas B. (1978) Gilaus arimo periodiškumas kalvoto reljefo dirvose. Lietuvos žemdirbystės mokslinio tyrimo instituto darbai. Agronomija, V., 5–11.
18. Joschko M. and Höflich G. (1996) Einfluß konservierender Bodenbearbeitung auf das Bodenleben in Sandböden.Bornimer Agrartechnische Berichte 9, 41–56.
19. Jodaugienė D. Ilgamečio arimo ir purenimo įtaka dirvožemiui ir žemės ūkio augalų pasėliams supaprastinto žemės dirbimo sistemoje. Daktaro disertacija, LŽUU, Akademija, 2002, 166.

20. Lauringson E., Kuil.T., Talgre L., Hirsnik L., Vette M. (1999) Effect of agrotechnology on the number of earthworms. In: Agroecological optimization of husbandry technologies. Jelgava, 57–65.
21. Lampurlanes J. and Cantero-Martinez C. (2003) Soil bulk density and penetration resistance under different tillage and crop management systems and their relationship with barely root growth. Agronomy Journal, 95(3), 526–533.
22. Logsdon S. D. and Cambardella C.A. (2000) Temporal Changes in Small Depth – Incremental Soil Bulk Density. Soil Science Society of America Journal, 64, 710–714.
23. Marti M. (1984) Cereal Monoculture without Ploughing in South-East Norway – Effects on Yields and Soil Physical and Chemical Properties. Dr. Sci. thesis. Ås: Agricultural University of Norway.
24. Pranaitis K. (1999) Minimalus žemės dirbimas javų sėjomainoje velėniniame jauriniame priesmėlio dirvožemyje. Žemdirbystė. Mokslo darbai, 67, 157–164.
25. Pupalienė R. (2004) Įvairaus intensyvumo žemdirbystės sistemų poveikis vasarinių miežių agrocenozei. Daktaro disertacija. Kaunas, 126.
26. Rydberg T. (1987) Studies in Ploughless Tillage in Sweeden 1975-1986. Division of soil Management, Uppsala, Sweden, report 76, 35.
27. Riley H. (1983) Reduced Cultivations and Straw Disposal Systems with Spring Cereals on Various Soil Types. I. Yields and Weed Incidence. Research of Norwegian Agriculture, 34, 209–219.
28. Riley H. (1985) Reduced Tillage for Spring Cereals. Different Seed Drills and Sowing Dates. Research of Norwegian Agriculture, 36, 61–70.
29. Sommer C., Zach M., Dambroth M. (1985) Konservierende Bodenbearbeitung, Ergebnisse und Erfahrungen aus der Praxis. Agrar-Übersicht 5. 12–15.
30. Tebrügge F. and During R. A. (1999) Reducing tillage intensity – a review of results from long term study in Germany. Soil and Tillage Research, 53, 15–28.
31. Zuzel, J. F. and Pikul J. L. (1987) Jr. Infiltration into a seasonally frozen agricultural soil. J. of Soil and Water Conserv. 42:447–449.
32. Вадюнина А. Ф., Карчагина З. А. (1996) Методы исследования физических свойств почв. Москва. Агропромиздат, 410.

THE INFLUENCE OF PLOUGHING AND PLOUGHLESS SOIL TILLAGE ON SOIL PROPERTIES IN WINTER WHEAT CROP

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Abstract

The investigation of ploughing and ploughless soil tillage have been carried out in the field experiment at the Experimental Station of Lithuanian University of Agriculture on drained medium loam *Endohypogleyic-Eutric Planosol – Ple-gln-w* soil and started in 1988. Chemical properties of arable horizon: pH_{KCL} – 7.1–7.5, humus content 16.5–18.0 g kg^{-1}, available phosphorus content 211–227 mg kg^{-1}, available potassium content 104–120 mg kg^{-1}. Crop rotation: spring barley + under-sow, perennial grasses I year, perennial grasses II year, winter wheat, fodder beets, spring rape. Treatments: 1) conventional ploughing 23–25 cm, 2) shallow ploughing 12–14 cm, 3) deep chisel loosening 23–25cm, 4) shallow chisel loosening 12–14 cm. Data of 1995–2000 years are presented in this paper. The results indicate that shallow ploughing and ploughless soil tillage had no significant influence on soil bulk density and total porosity at different growth stages of winter wheat as compared with conventional ploughing. One of the reasons was greater amount of earthworms (numbers 46–68%, biomass 14–41%) when reduced soil tillage, especially ploughless soil tillage was used. Reduced tillage significantly increased soil structure stability in the entire arable horizon: in the upper layer by 8.7–12.8 percentage units and in the lower layer by 4.2–8.1 percentage units. After two crop rotations (12 years) arable horizon according to nutrient content differentiated into the upper more fertile and lower less fertile layers. Highest fertility differentiation of arable horizon was in the ploughless tilled plots: the difference of humus content between upper and lower layers was 21–26%, phosphorus – 31–41%, potassium – 43–47%. After two crop rotations humus content in all arable horizons was higher 5.4–9.1% when reduced soil tillage was implemented as compared with conventional ploughing.

Keywords: reduced tillage, soil properties, winter wheat

Introduction

Conventional ploughing is the most time consuming and having lowest labor productivity soil tillage process, which requires approximately 40% of expenditures for soil tillage operations (Tebrügge, Böhrnsen, 1997). Reduced soil tillage enables not only to increase efficiency of crop production, but also to reduce detrimental effect to soil and environment. Results of many investigations conducted in different countries indicate that continuous conventional ploughing has negative influence on most soil properties and beside that it stimulates formation of thicker soil layer in the interface between arable horizon and lower soil layer (Koeller, 1993; Derpsch, 1999). Reduced soil tillage, which is in the intermediate position between conventional ploughing and direct drilling, has positive influence on soil structure stability and enables stability of other soil agrophysical properties. Organic residues being left near soil surface make protective layer, which prevents soil from erosion and silt up (Sommer, Brunotte, 1997; Epperlein, Metz, 1998). Many authors indicate that reduced soil tillage (especially ploughless) increases accumulation of organic matter; reduction of tillage operations and tillage depth has positive influence on humus content and quality (Ball *et al.*, 1998; Seyfarth *et al.*, 1999; Ausmane *et al.*, 2000).

Earthworm numbers and their biomass in soil increases when reduced soil tillage is applied (Joschko, Höflich, 1996). Composition of earthworm species is changing, numbers of deep burrow earthworms (*Lumbricus terrestris)* is increasing because of this soil tillage type (Epperlein, Metz, 1998).

There are contradictory statements in the scientific literature as to influence of reduced soil tillage on fertility differentiation of arable layer. In most cases it is indicated that reduced soil tillage stimulates accumulation of nutrients in the soil surface: higher contents of humus, mobile phosphorus and potassium are in the 0–10 cm layer as compared with 10–20 cm layer. Because of that the plant roots are approximately two times more abundant in the upper soil layer when reduced tillage is applied in comparison with conventional ploughing (Schrötter, 1999).

The aim of our investigation was to compare the influence of conventional (23–25 cm) and shallow (12–14 cm) ploughing, deep (23–25 cm) and shallow (12–14 cm) chisel loosening on soil agrophysical, agrochemical properties and earthworm abundance in winter wheat crop.

Materials and Methods

The field experiment on investigation of reduced soil tillage started in 1988 at the Experimental Station of Lithuanian University of Agriculture. Soil of the experimental site was medium loam on sandy loam over the moraine clay *Endohypogleyic-Eutric Planosol – Ple-gln-w.* The arable horizon 27–30 cm, pH_{KCl} – 7.5–7.9, humus content – 15.2–16.0 g kg^{-1}, available phosphorus P_2O_5 – 214–238 mg kg^{-1}, available potassium K_2O – 100–112 mg kg^{-1}.

The following crop rotation was used in the experimental site: spring barley with undersow, 1st year perennial grasses (red clover and timothy), 2nd year perennial grasses, winter wheat, fodder beet, spring rape.

Treatments of primary soil tillage: 1) conventional mouldboard ploughing at the depth of 23–25 cm (deep ploughing), 2) shallow ploughing at the depth of 12–14 cm, 3) deep loosening with chisel cultivator at the depth of 23–25 cm, 4) shallow loosening at the depth of 12–14 cm with the same cultivator. The same seedbed preparation was applied on all plots – twofold cultivation + harrowing.

The initial plot size was 126 m^2. Observations were done on plots 70 m^2 of size. There were three plots per treatment. Randomized block design was applied. Only mineral fertilizers were used for all crops. Fertilizers rate was calculated according to the nutrient content in the soil and target grain yield 5.5 t ha^{-1} – $N_{90}P_{20}K_{130}$. Seed rate was 220 kg ha^{-1}. Herbicide roundup was applied on perennial grasses stubble before deep and shallow loosening (3 and 4 treatments). Winter wheat crop was sprayed by herbicide logran extra in 1995–1997 and by herbicide duplozan super in 1998–2000.

Soil agro-physical properties (soil bulk density, moisture content, and total porosity) were measured five times per season: after sowing, at the end of vegetation in autumn, at the beginning of vegetation in spring, at ear formation stage and after harvesting. The undisturbed soil samples were taken with Necrasov′s borer. Soil structure stability was estimated in 1996–1998 after crop harvest by Savinov method (Vadiunina, Korciagina, 1996). Soil samples for testing agrochemical soil properties were taken by agrochemical borer at the end of second crop rotation (after 12 years) after winter wheat harvesting. The following methods of agrochemical analyses were used: pH_{kcl} – potentiometric; available P_2O_5 and K_2O – A-L; humus content was calculated according to estimated carbon content, determined by Hereaus apparatus. Given carbon content was multiplied by coefficient 1.724. Analyses were done at the Center of Agrochemical Investigations of Lithuanian Institute of Agriculture.

Numbers and biomass of earthworms was estimated after crop harvest by the method of chemical repellents. Assumptions for analyses of variance were checked and data of earthworm sampling before ANOVA was transformed in the following way: $\sqrt{x+1}$ (Tarakanovas, 1999).

Results and Discussion

Agro-physical properties. The aim was to determine the influence of different primary soil tillage on soil agrophysical properties – bulk density, moisture, total porosity and numbers of pores filled with moisture and air at different stages of winter wheat growth. The obtained data show, that soil bulk density did not significantly change neither after sowing of winter wheat nor at different stages of winter wheat growth (Fig. 1). However, the tendencies of increasing soil bulk density in lower arable horizon were observed after harvesting. In 1997 the soil bulk density determined in soil layer 15–25 cm was significantly bigger than that in the plots of shallow ploughing or deep loosening. Literature sources provide various statements about changes of soil bulk density in the case of reduced soil tillage. Some scientists state that soil bulk density does not changes greatly (Arlauskas, 1994; Simanskaite, 2000), while others express the opinion that having refused deep mould-board ploughing the soil bulk density increases and total porosity decreases. For this reason yield losses are expected (Rasmussen, 1999; Fulajtar, 2000; Hakansson, Lipiec, 2000).

Soil moisture analysis revealed that reduced tillage contributed to preservation of moisture, which was particularly important in dry years (Fig. 2).

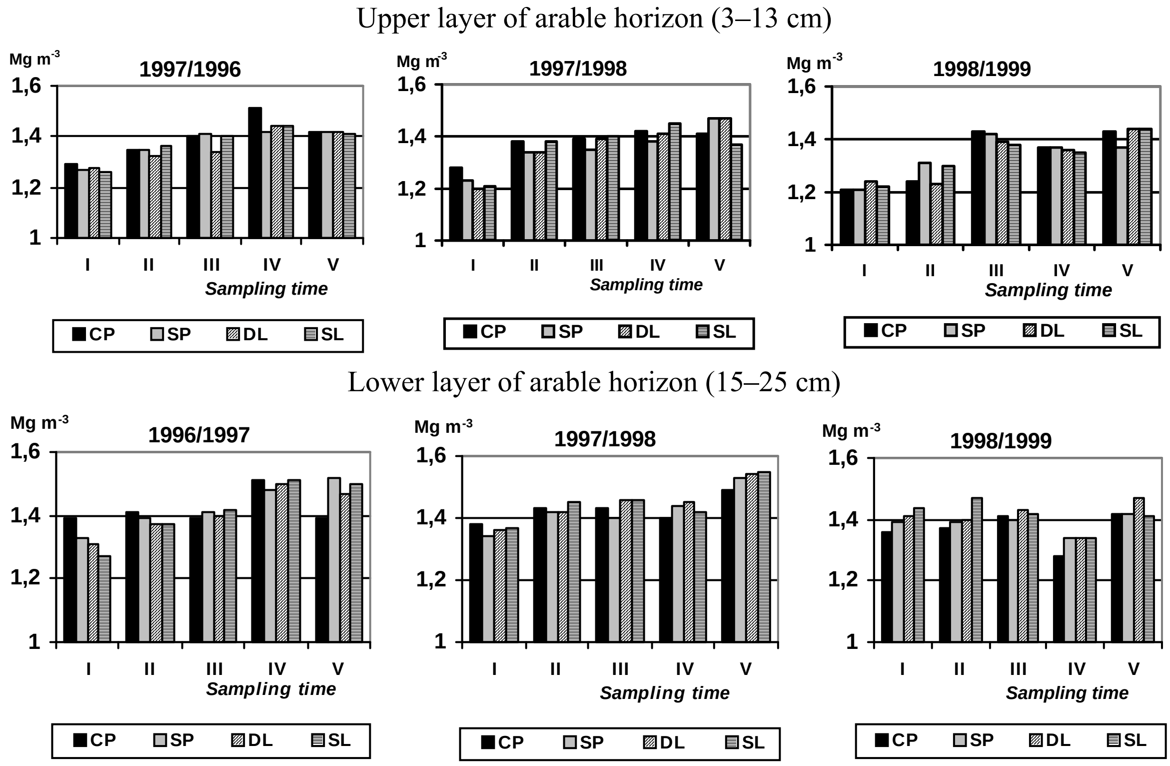

Figure 1. The influence of long-term ploughing and reduced soil tillage on soil bulk density Mg m^{-3} in winter wheat crop, 1997–1999 (CP – conventional ploughing, SP – shallow ploughing, DL – deep loosening, SL – shallow loosening; I – after sowing, II – at the end of vegetation in autumn, III – after renewal of vegetation in spring, IV – ear formation stage, V – after harvesting), $P < 0.05$

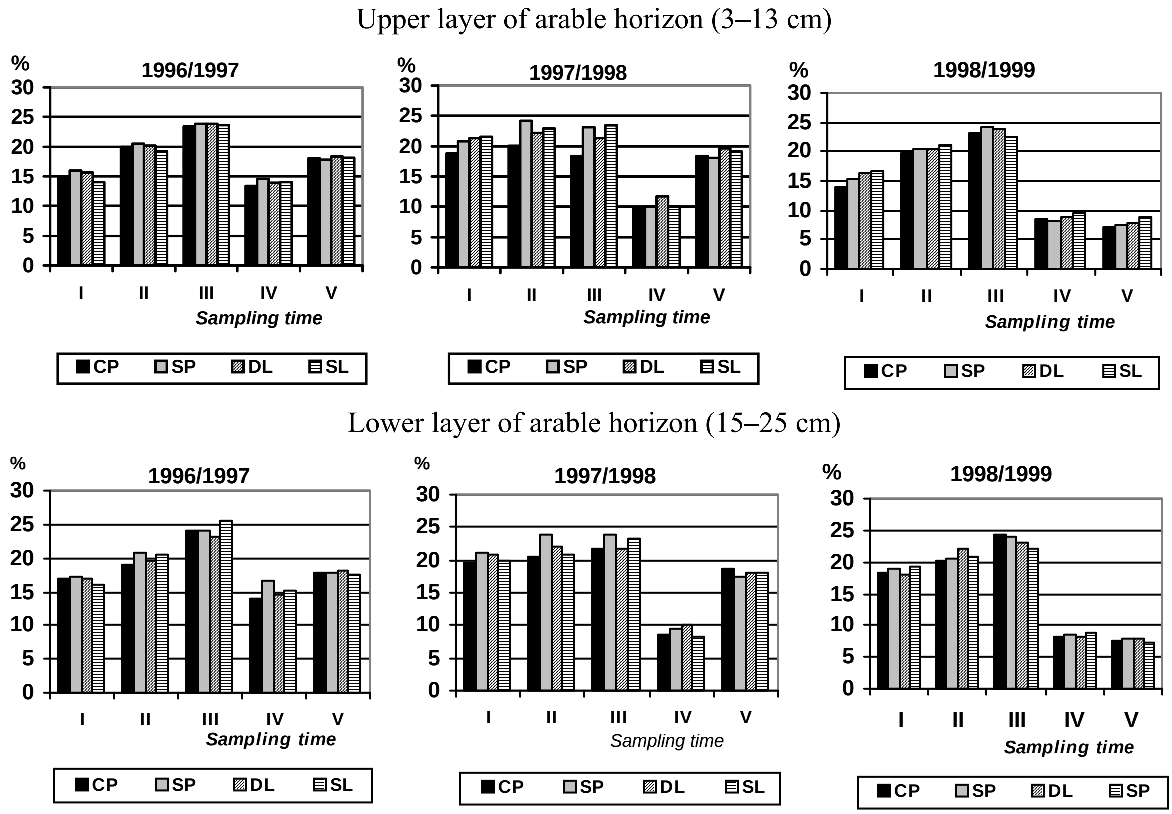

Figure 2. The influence of long-term ploughing and reduced soil tillage on soil moisture content, % in winter wheat crop, 1996–1999 (CP – conventional ploughing, SP – shallow ploughing, DL – deep loosening, SL – shallow loosening; I – after sowing, II – at the end of vegetation in autumn, III – after renewal of vegetation in spring, IV – ear formation stage, V – after harvesting), $P < 0.05$

According to the data presented by USA Soil Protection Agency more than 50% of moisture contained in soil can be preserved by means of reduced tillage (Dekker et al., 1998). Experiments in Germany show that ploughless soil tillage (with heavy cultivator in particular) provides more favourable conditions for maintaining higher amount of moisture in soil, which is very important in dry years. Opposite results are often obtained in wet years (Weisskopf *et al.*, 2000; Wierman, Horn, 2000; Hartage, 2000).

When using shallow ploughing and deep and shallow loosening with heavy cultivator instead of conventional ploughing, the stability of soil structure changed significantly. The obtained data shows that turning over of arable horizon worsened the stability of soil structure (Table 1). Meanwhile, in the case of ploughless soil tillage application the stability of soil structure increased.

Table 1. The influence of long-term ploughing and ploughless soil tillage on soil structure stability after winter wheat harvesting, 1996–1998

Soil tillage treatments	Arable layer, cm	1996	1997	1998
Conventional ploughing	0–15	39.5	37.4	36.6
	15–25	43.6	44.8	41.2
Shallow ploughing	0–15	38.0	38.5	42.2*
	15–25	47.7*	47.8	46.8*
Deep loosening	0–15	47.3*	52.4*	39.9*
	15–25	46.6	52.1*	52.2*
Shallow loosening	0–15	46.8*	52.0*	53.1*
	15–25	48.4*	52.8*	52.6*
LSD_{05}	0–15	5.86	4.67	2.66
	15–25	3.86	3.61	4.38

* Significant differences as compared with conventional ploughing.

In comparison with deep ploughing higher stability of soil structure was determined in the upper layer of arable horizon (3–13 cm): in 1996 – 19–20%, in 1997 – 39–40%, in 1998 – 43–44%, while in the lower layer of arable horizon (15–25 cm) it was as follows: in 1996 – 7–11%, in 1997 – 16–18%, in 1998 – 27–28%. In the case of shallow ploughing improved stability of soil structure was observed in the lower layer of arable horizon (7–14%). Other researchers present similar data. Accumulation of organic residues (including humus) on the soil surface is one of the most important reasons of increased soil structure stability in the case of reduced tillage (Ball *et al.*, 1998; Tebrugge, During, 1999).

Earthworms. Some researchers state that having reduced soil tillage the soil bulk density does not increase, the stability of its structure and infiltration improve because of increased numbers of earthworms (Edwards, Shipitalo, 1998; Potthoff, 1999; Joschko *et al.*, 1999). In 2000, number of earthworms and their biomass after winter wheat harvesting were estimated to determine the influence of soil tillage on earthworm abundance (Table 2).

Table 2. The influence of long-term ploughing and ploughless soil tillage on numbers of earthworms and their biomass after winter wheat harvesting, 2000

Soil tillage treatments	Numbers of earthworms		Biomass of earthworms		Weight of one earthworm	
	numbers m^{-2}	%	g m^{-2}	%	g	%
Conventional ploughing	100.8	100	54.4	100	0.41	100
Shallow ploughing	168.0	166.7	61.9	113.8	0.40	97.6
Deep loosening	169.3	168.0	76.5	140.6	0.46	112.2
Shallow loosening	147.1	145.9	72.8	133.8	0.50	122.0

The obtained data prove that reduced soil tillage created favourable conditions for spreading of earthworms: their numbers increased by 46–68%, and biomass – by 14–41%. Meanwhile, the biomass of one earthworm was established to increase by 12–22% when ploughless soil tillage was applied.

Agrochemical characteristics. These long-term experiments aimed to find out whether overturning of arable horizon influences differentiation of its fertility as literature sources provide contradictory statements. Some authors state that having reduced soil tillage significantly higher amounts of humus, available phosphorus, and potassium are accumulating in the upper layer of arable horizon (Hutsch, Steffens, 1992; Pranaitis, 1999). Other researchers express the opinion that differentiation of layers of arable horizon is not distinct (Kuhn, Werner, 1999; Rasmussen, 1999; Lauringson *et al.*, 2001). According to some scientists differentiation of layers of arable horizon does not become apparent having reduced soil tillage because of greater numbers of earthworms and their impact (Stockfisch, 1997; Sommer, 1998). At the same time M. Arlauskas (1994) states that the upper layer of arable horizon is more fertile irrespective of the applied method of soil tillage. The obtained data show that having reduced soil tillage differentiation of the layers of arable horizon with respect to nutrients becomes apparent (Table 3).

Table 3. The influence of long-term ploughing and ploughless soil tillage on soil agrochemical characteristics, 2000, after winter wheat harvesting

Soil tillage treatments	Arable layer, cm	pH_{KCl}	Humus, g kg^{-1}	Available phosphorus, P_2O_5, mg kg^{-1}	Available potassium, K_2O, mg kg^{-1}
Conventional ploughing	0–15	7.1	17.8	241	120
	15–25	7.2	14.5	213	92
Shallow ploughing	0–15	7.3	19.7	265	157
	15–25	7.3	15.6	184	84
Deep loosening	0–15	7.5	20.1	277	136
	15–25	7.4	14.8	163	72
Shallow loosening	0–15	7.5	20.2	255	138
	15–25	7.5	15.8	166	79
LSD_{05}		0.21	2.01	33.5	26.8

In the case of deep ploughing the upper layer of arable horizon was more fertile than the lower layer: amount of humus was higher by 18.5%, available phosphorus – by 11.6%, available potassium – by 23.4%. However, having reduced soil tillage the difference of soil fertility was more expressed. The upper layer of arable horizon contained higher amounts of humus – by 20.8–26.4%, available phosphorus – by 30.6–41.2% and available potassium – by 42.8–47.1% in comparison with the lower layer. For this reason the distribution of roots in arable horizon changes. Having reduced soil tillage 33–61% of roots are accumulating at the soil surface (0–5 cm), while the amount of roots that accumulates in the arable horizon layers of 5–15 cm and 15–25 cm is significantly smaller, 15–46% and 35–45% respectively (Jodaugiene, 2002). Therefore in such a case during dry years plants may feel lack of nutrients because they are concentrated at the soil surface.

Conclusions

Long-term shallow ploughing and ploughless soil tillage have no significant influence on the bulk density of arable horizon at different growth stages of winter wheat. However, after harvesting the tendency of soil density increase in the lower layer of arable horizon is observed.

Reduced soil tillage does not worsen moisture regime in the period of winter wheat vegetation.

Ploughless soil tillage significantly improves the stability of soil structure in the entire arable horizon. In the case of shallow ploughing the soil structure stability is improved only in the lower layer of arable horizon.

Reduced soil tillage creates more favourable conditions for the spread of earthworms. Having refused conventional ploughing numbers of earthworms increase by 46–68%, and their biomass – by 14–41%.

Using shallow ploughing and ploughless soil tillage instead of conventional ploughing the arable horizon differentiates according to the amount of nutrients into the upper more fertile and the lower less fertile layers during two crop rotations. The upper layer contains more humus – by 21–26%, available phosphorus – by 31–41% and available potassium – by 43–47% than the lower layer.

References

1. Arlauskas M. (1994) Žemės dirbimo minimalizavimas. Žemės ūkio mokslai, 1, 39–-43.
2. Ausmane M., Guzane V., Krogere R., Liepins J., Melngalvis I., Rubenis E. (2000) Results on investigations of ploughing depth in crop rotation. The Results of long – term Field Experiments in Baltic States. Proceedings of the International Conference Jelgava, Latvia, 19–25.
3. Ball B. C, Tebrügge F., Satori L. *et al.* (1998) Influence of no-tillage on physical, chemical and biological soil properties. Experrience with the application of no-tillage crop production in the West-European countries. Final EU-Report of concerted Action No Air3-CT93-1464, Fachverlag Köhler, Giessen, 7–27.
4. Dekker L. W., Ritsema C. J., Oostindie K., Boersma O.H. (1998) Effect of drying temperature on the severity of soil water repellency. Soil Science, 163, 780–796.
5. Derpsch R. (1999) Direktsaatfläche in Südamerika wächst . Landwirtschaft ohne Pflug, 12, 13–15.
6. Dirsė A. (2001) Žemės ūkio augalų vegetacijos laikotarpių drėgmingumas. Žemės ūkio mokslai, 3, 51–56.

7. Epperlein J., Metz R. (1998) Unverzichtbare Helfer im Boden. Landwirtschaft ohne Pflug, 11, 13–15.
8. Fulajtar E. (2000) Assessment and determination of the compacted soils in Slovakia. Advances in GeoEcology 32, Reiskirchen, 384–387.
9. Hakansson I. and Lipiec J. (2000) A review of the usefulness of relative bulk density values in studies of soil structure and compaction. Soil & Tillage Research, 53, 71–85.
10. Hartage K.H. (2000) The effect of soil deformation on physical soil properties – a discourse on the common background. Advances in GeoEkologie 32, Reiskirchen, 32–43.
11. Jodaugienė D. (2002) Ilgamečio arimo ir purenimo įtaka dirvožemiui ir žemės ūkio augalų pasėliams supaprastinto žemės dirbimo sistemoje. Daktaro disertacijos santrauka, Akademija, – 35.
12. Joschko M. und Höflich G. (1996) Einfluß konservierender Bodenbearbeitung auf das Bodenleben in Sandböden. Bornimer Agrartechnische Berichte, 9 (in German).
13. Köller K. (1993) Erfolgreiche Ackerbau ohne Pflug, Frankfurt/Main (DLG-Verlag), 119.
14. Lauringson E., Talgre L., Kuill T., Vipper H., Hirsnik L. (2001) The effect of the minimisation of autumn tillage on Soil priperties and yield In: Conference on Sustainable Agriculture in Baltic States. Proceedings of the International Conference, Tartu, 104–112.
15. Martin R., Carter (1983) Soil Sampling and Methods of Analysis, 359–371.
16. Potthoff M. (1999) Synchronisation des Stoffkreislaufs durch Förderung bodenbiologischer Prozesse im Ackerbau. Dissertation Universität Göttingen, 195.
17. Pranaitis K. (1999) Minimalus žemės dirbimas javų sėjomainoje velėniniame jauriniame priesmėlio dirvožemyje. Žemdirbystė: mokslo darbai 67, 157–165.
18. Rasmussen K. J. (1999) Impact of ploughless soil tillage on yield and soil quality. Soil & Tillage Research 53, 3–14.
19. Schrötter S. (1999) Einfluß konservierender Bodenbearbeitungsintensität auf Pflanzenentwicklung, Ertragsbildung und Verfahrensgestaltung: Bodendurchwurzelung. In: Bodenökologische und pflanzenbauliche Effekte konservierender Bodenbearbeitung auf sandigen Böden. ZALF – Bericht, Müncheberg, 39, 62–64.
20. Seyfarth W., Joschko M., Rogasik J. (1999) Bodenökologische und pflanzenbauliche Effekte konservierender Bodenbearbeitung auf sandigen Böden. ZALF- Bericht, Müncheberg, 39–136 (in German).
21. Sommer C. (1998) Konservierende Bodenbearbeitung – ein Konzept zur Lösung agrarrelevanter Bodenschutzprobleme. Landbau Völkenrode SH 191, – 127.
22. Sommer C. und Brunotte J. (1997) Kriterien für eine bodenschutzorientierte Landbewirtschaftung. Umweltverträgliche Pflanzenproduktion, Fachtagung 11./12.7.96, Wittenberg, 55–79.
23. Šimanskaitė D. (2000) Efektivnost čizelnoj obrabotki na legkosūglinistych počvach. The Results of long-term Field Experiments in Baltic States. Proceedings of the International Conference Jelgava, Latvia, 147–154.
24. Tarakanovas P. (1999) Statistinių duomenų apdorojimo programų paketas „Selekcija", LŽI-Akademija, 57 Tebrügge F., Böhrnsen A. (1997) Crop yields and economic aspects of no-tillage compared to plough tillage, 25–43.
25. Tebrügge F., Düring R. A. (1999) Reducing tillage intensity – a review of results from long-term study in Germany. Soil & Tillage Research 1432, 1–14.
26. Vadiunina A. F., Korčiagina Z.A. (1986) Metody isledovanija fizičeskich svoistv počv. M., – 415.
27. Weisskopf P., Zihlmann U., Wiermann C., Horn R., Anken Th. and Diserens E. (2000) Influences of convention and onland-ploughing on soil structure. Advances in GeoEkologie 32, Reiskirchen, 73–81.
28. Wiermann C. & Horn R. (2000) Effect of different tillage systems on the recovery of soil structure following a single compaction event. Advances in GeoEkologie 32, Reiskirchen, 339–350.

SOIL RESISTANCE IN WINTER WHEAT SOWINGS AS DEPENDENT ON SOIL TILLAGE AND SOWING TECHNOLOGIES

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Abstract

Field trials were carried at the Latvia University of Agriculture (LLU) Study and Research Farm (SRF) 'Vecauce' during 2001 to 2004. The effect of chisel ploughing and sowing technologies on yield and quality of winter wheat were studied on sod-podzolic sandy loam soils. Winter wheat was grown after clover – timothy mix. Fields were treated with herbicide Glifoss 3 l ha^{-1} after harvest of previous crop.

The following treatments were investigated in trial: Factor A – chisel ploughing with 'Kverneland CLE' at the depth of 0 m (untreated), 0.25, 0.35 or 0.50 m; factor B – soil tillage with autumn ploughing at the depth of 0.22–0.25 m or sowing without soil reversion; factor C – sowing technologies: using disc driller with incorporation of mineral fertilizers ('Rapid 400 C') or using anchor-type driller with rototiller and application of mineral fertilizers before sowing ('Amazone AD-403 super'). Sward of a fore-crop was treated with serrate disc harrow 5–7 cm deep in treatments where driller 'Rapid 400 C' was used in direct sowing.

Resistance of soil was determined on the third decade of April at the end of winter wheat tillering stage or at the beginning of heading stage. Certified device of the company Ejkalkampf was used. A variant of measurements included five observations. Obtained data were processed by correlation, regression and dispersion analysis using Fischer's criterion.

Results of research showed significant effect of chisel ploughing, depth of measurements on soil resistance data variability, but less effect was observed with sowing technologies using different seeding equipment. The depth of soil layers' layout as a factor increasing data variability increased in case measurements which were done farther from the zone of the action of a digger tine. Effect of chisel ploughing on soil resistance was significant only on the place of action of a digger tine and in the distance of 0.1 m from it.

Increased soil resistance in soil layer 0.3 to 0.5 m deep was observed in treatments with soil reversion as compare with treatments without ploughing thus indicating the formation of plough pan. Significant increase of the soil resistance in subsoil was observed in cases when chisel ploughing was not performed and was substituted only by ploughing. It was found that soil resistance 0.6 m distant from the action zone of a digger tine in treatment with ploughing was insignificantly different from neither that observed in the treatment where neither soil ploughing nor chisel ploughing was performed.

Key words: winter wheat, soil tillage, chisel ploughing, sowing, soil resistance

Introduction

Direct sowing of spring barley or minimal soil tillage becomes a very popular method worldwide. Such sowing technology allows economizing resources hereto not decreasing yields of cereals. This fact has also been approved in earlier researches made by the scientists of the Department of Soil management of the Latvia University of Agriculture (LLU) (Lapins D. *et al.*, 2001 a, b). More and more drillers appear recently in farms in Latvia, which allow reduction of soil tillage in winter or spring cereals but often these drillers are used in traditional soil tillage system – after soil ploughing. Several researches have been made in Lithuania (Maikstiene S., 2000; Stancevicius A. *et al.*, 2000) and Estonia (Lauringson E. *et al.*, 2001) in this direction. Long-term trials on chisel ploughing effect on changes of soil agrochemical properties have been made also in Germany (Schröder D., Schulte – Karning H., 1984).

The aim of this work was to evaluate the effect of different soil tillage and sowing technology treatments on the yield and quality of winter wheat.

Materials and Methods

Field trials were carried out at the Latvia University of Agriculture (LLU) Study and Research farm (SRF) 'Vecauce' during the years 2001 to 2004. The effect of chisel ploughing and sowing technologies on yield and quality of winter wheat were studied on sod-podzolic sandy loam soils with organic matter content from 20 g kg^{-1} to 28 g kg^{-1}; soil reaction from pH_{KCl} 6.5 to 7.0, phosphorus content from 161 to 306 mg kg^{-1}, potassium content from 119 to 418 mg kg^{-1}. Soil agrochemical properties were determined at Agrochemical Research Centre. Winter wheat cv. 'Kontrast' was grown after clover – timothy mix. Fields were treated with herbicide Glifoss 3 L ha^{-1} after harvest of previous crop. Pre-plant mineral fertilizer $N_6P_{26}K_{30}$ was applied at 300 kg ha^{-1} but in top-dressing NH_4NO_3 at the rate of 70 kg ha^{-1} was added early in spring and 70 kg ha^{-1} at

GS 37 of winter wheat. Mineral fertilizers dispersed by pneumatic diffuser 'Amazone'. The yield was harvested with trial harvester 'Hege-140', adjusted to 14% moisture content and 100% purity.

The following treatments were investigated in trial:

Factor A – chisel ploughing with 'Kverneland CLE': A1 – at the depth of 0 m (untreated); A2 – at the depth of 0.25 m; A3 – at the depth of 0.35 m; A4 – at the depth of 0.50 m.

Factor B – soil tillage: B1 – autumn ploughing at the depth of 0.22–0.25 m with 'Overum'; B2 – sowing without soil reversion.

Factor C – sowing technologies: C1 – using disc driller with incorporation of pre-plant mineral fertilizers ('Rapid 400 C'); C2 – using anchor-type driller with rototiller and application of mineral fertilizers before sowing ('Amazone AD-403 super'). Sward of the fore-crop was treated with serrate disc harrow at the depth of 0.05 – 0.07 m in treatments where driller 'Rapid 400 C' was used in direct sowing.

Resistance of soil was determined in the third decade of April at the end of tillering stage or at the beginning of heading stage. Certified device of the company Ejalkampf was used. A variant of measurements included five observations. Obtained data were processed with ANOVA, correlation and regression analysis using Fischer's criterion. There was a lack of precipitation from the second decade of April till the second decade of May in all trial years (Fig. 1).

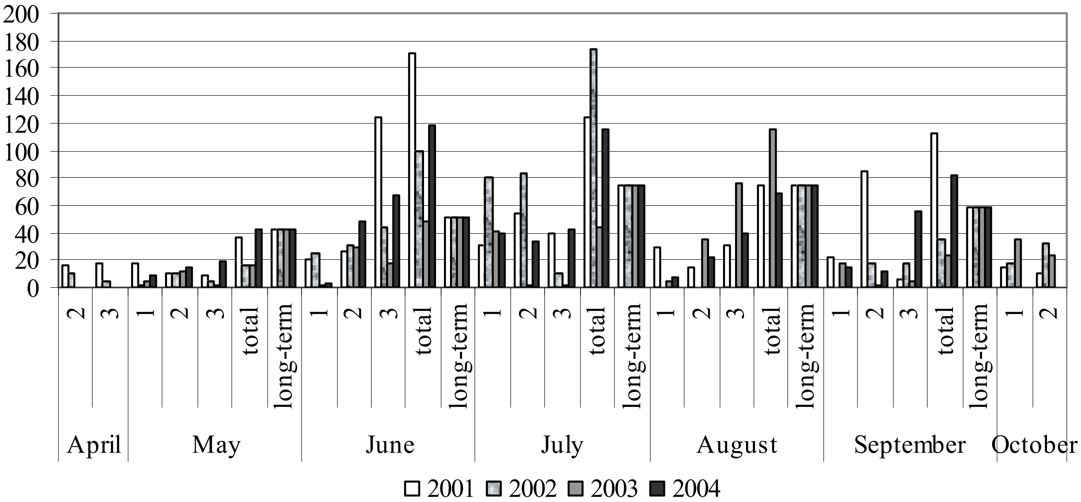

Figure 1. Amount of precipitation, LLU SRF 'Vecauce', 2001–2004, mm

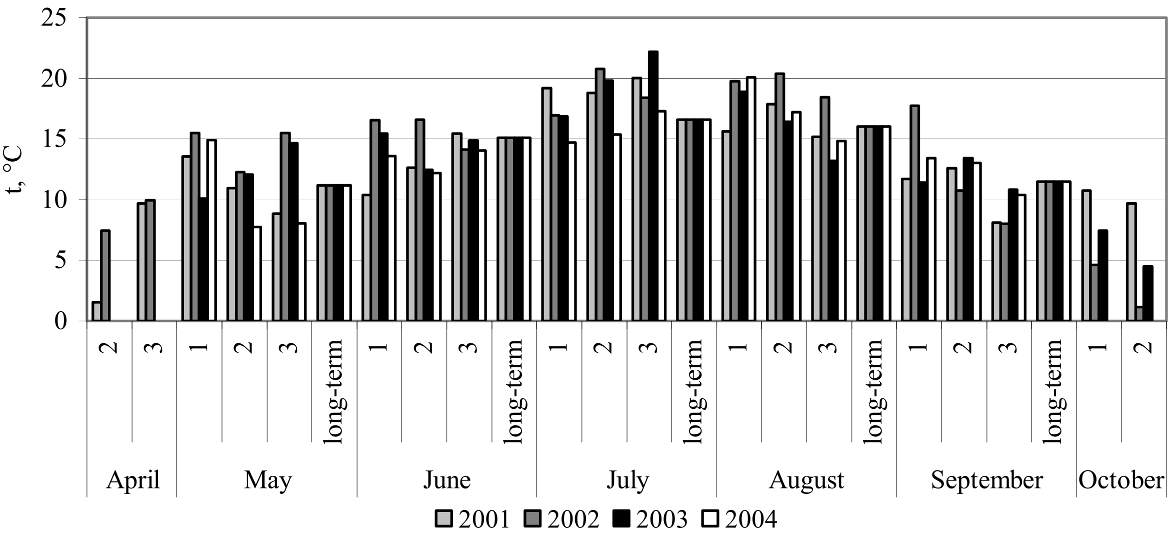

Figure 2. Mean temperatures, LLU SRF 'Vecauce', 2001–2004, °C

Very dry weather occurred in 2002 when from the third decade of July till the end of October total amount of precipitation was less than 40 mm. The vegetation period in 2004 was characterized by increased amount of precipitation. Differences in the average temperatures were not so remarkable. Average temperatures at the end of September and at the beginning of October were higher in the year 2001.

Particularly dry weather in the autumn of 2002 was complemented by rapid decrease in temperature from the second decade of September onward (Fig. 2).

Results and Discussion

Results show that the significantly highest influence on soil resistance change had the depth of measurement of soil resistance and chisel ploughing, but less influence was observed with sowing technologies using different drillers. The influence of the depth of soil layers on diversity of results increased if measurements were done farther from the locale of chisel plough tine action (Fig 3).

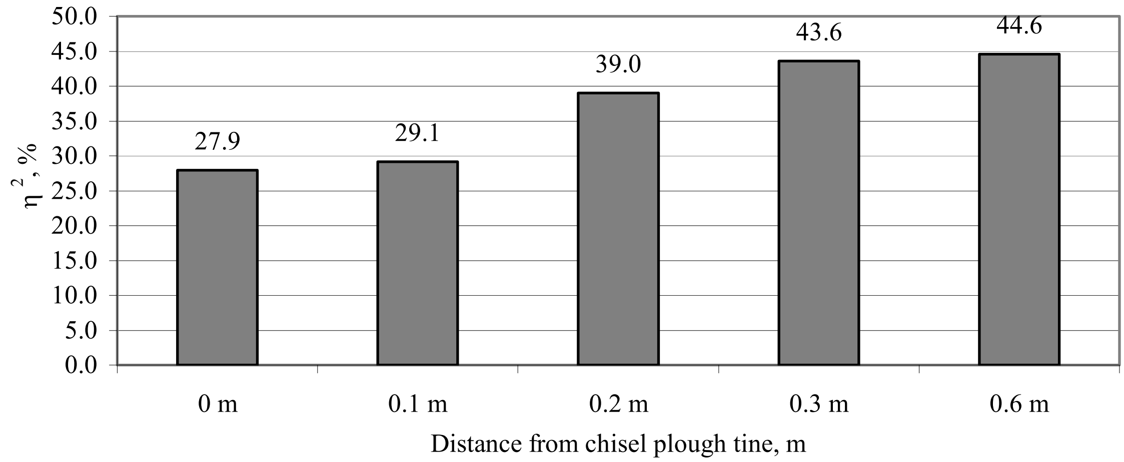

Figure 3. Influence of the depth of soil layers on soil resistance diversity depending on distance from the locale of chisel plough tine on average in all treatments, η^2, %

The depth of chisel ploughing made significant influence on soil resistance change only at the locale of chisel plough tine and 0.1 m from it. A significant second-degree polynomial coherence was established between depths of chisel ploughing and changes of soil resistance at different distance from the locale of chisel plough tine averagely in three years (Fig 4).

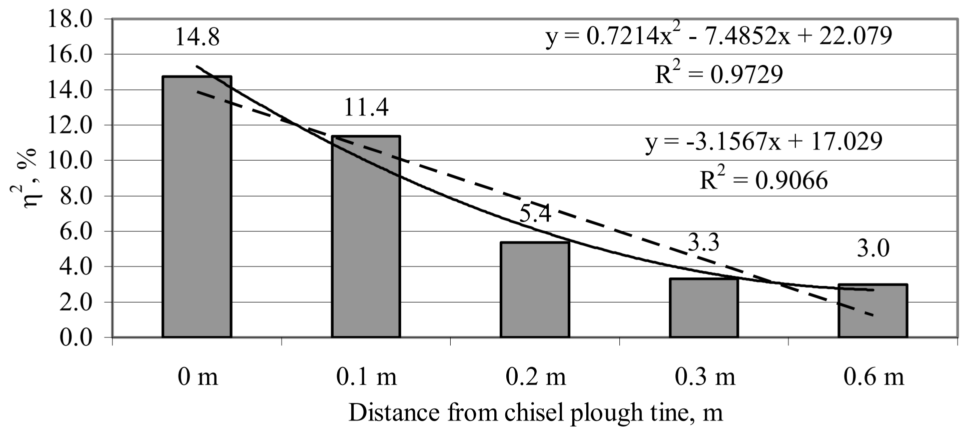

Figure 4. Influence of chisel ploughing depth on soil resistance change at different distances from the locale of chisel plough tine averagely in three years, η^2, %

Significant decrease of chisel ploughing influence was established only in the first 0.1 m from the locale of chisel plough tine. That made 0.2 m or 11% from the total working width (1.8 m) of chisel plough and the area where chisel ploughing was done. Soil resistance in subsoil at the depth of 0.3–0.5 m on the locale of chisel plough tine was 265 kPa, at the distance 0.6 m from the locale of chisel plough tine – 549 kPa, but in the treatment without chisel ploughing – 529 kPa averagely in three years in treatments with direct sowing. Significant differences in soil resistance were established only between average values from all measurements on the locale of chisel plough tine, at distance 0.6 m from it and in treatments without chisel ploughing.

The changes of soil resistance in subsoil compare to treatments with chisel ploughing at depth 0.5 m and treatment without chisel ploughing certified that significant decrease of soil resistance was gained only on the locale of chisel plough tine in all trial years (Table1). Soil resistance in subsoil at distance 0.6 m from the locale of chisel plough tine was increased significantly in the years 2002 and 2004 but showed tendency to decrease in the year 2003 although changes were insignificant. It could be explained by low rainfall in autumn 2002 (Fig. 1) at the time of chisel ploughing what caused the increase of soil resistance.

Table 1. Soil resistance changes in subsoil compare to treatments with chisel ploughing at depth 0.5 m and without chisel ploughing, ± kPa

Year	Depth of measurements, m			$\gamma_{0.05}$
	0.2–0.3 m	0.3–0.4 m	0.4–0.5 m	
On the locale of chisel plough tine				
2002	–223	–130	–182	100.9
2003	–176	–336	–296	136.7
2004	–379	–398	–262	130.2
0.6 m from the locale of chisel plough tine				
2002	–100	203	102	100.9
2003	64	–4	–84	136.7
2004	–151	12	136	130.2

Significant changes of soil resistance in subsoil were determined in all trial years if we compare treatments with and without soil ploughing (Fig. 5).

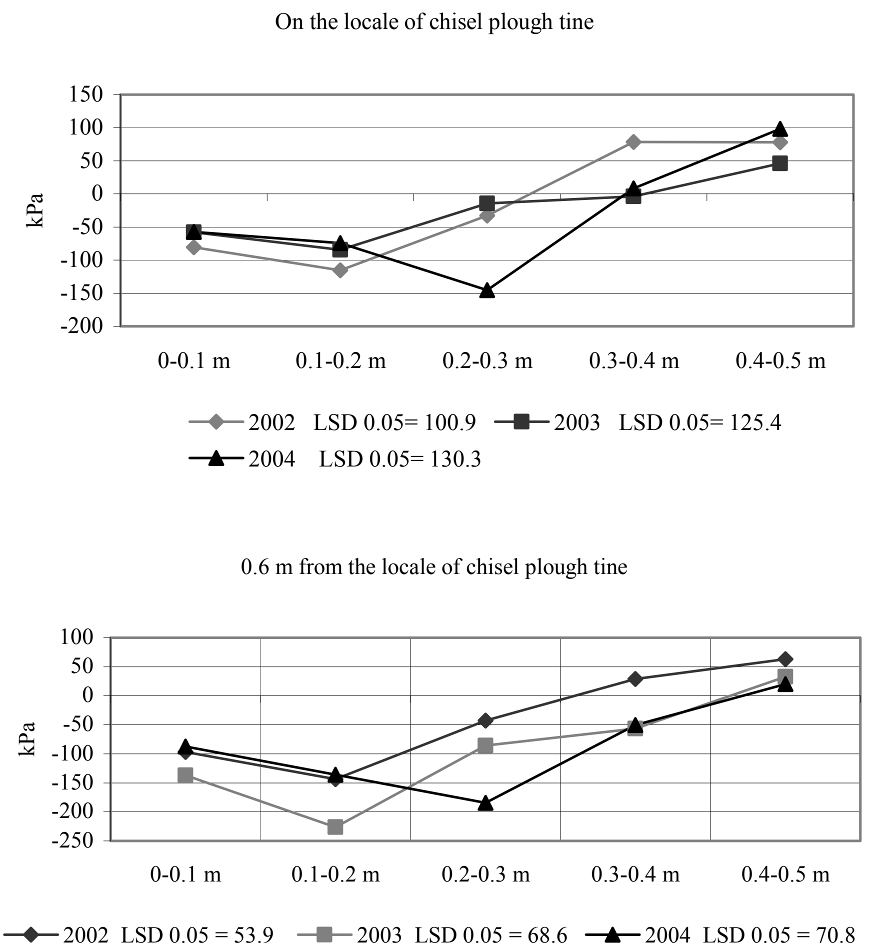

Figure 5. The changes of soil resistance in treatments with and without soil ploughing

The most decrease of soil resistance change on the locale of chisel plough tine and 0.6 m from the locale after soil ploughing were determined at depth 0.1–0.2 m but in the year 2004 also at depth 0.3 m. Results from data analysis show that these changes on the locale of chisel plough tine are statistically significant in the year 2002 at depth 0.1–0.2 m and in the year 2004 at depth 0.2–0.3 m.

There were significant differences of soil resistance in all trial years 0.6 m from the locale of chisel plough tine. Significantly higher soil resistance was determined in subsoil at depth 0.3–0.5 m in treatments with soil ploughing compare to treatments with direct sowing what showed the formation of plough pan. Significant increase of soil resistance could be observed in treatments without chisel ploughing but with soil ploughing. Data shows that soil resistance 0.6 m from the locale of chisel plough tine in treatments with ploughing was similar to that in treatment without any soil tillage.

Sowing technologies had insignificant influence on soil resistance. A tendency was observed to increase soil resistance at depth 0–0.3 m in treatments with ploughing and at depth 0–0.1 m in treatments without ploughing using disc driller 'Rapid 400 C' compare to anchor-type driller with vertical rototiller 'Amazone' AD-403'.

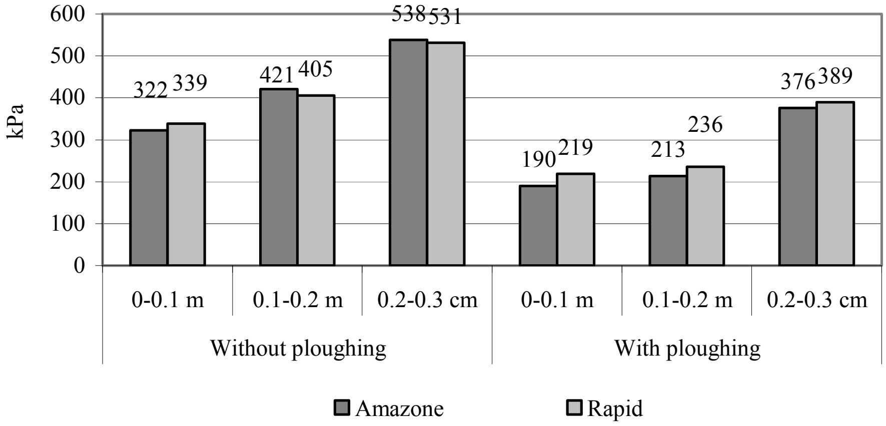

Figure 6. Effect of sowing technologies on soil resistance in treatments without chisel ploughing averagely in three years

Conclusions

The significantly highest influence on soil resistance change had the depth of measurement of soil resistance and chisel ploughing but less impact – sowing technologies using different drillers. The influence of soil layers depth on diversity of results increased if measurements were done farther from the locale of chisel plough tine.

Significant influence of chisel ploughing on soil resistance was established only on the locale and first 0.1 m from the locale of chisel plough tine what made 11% from the total 1.8 m working width of chisel plough.

Significantly higher soil resistance was determined in subsoil at depth 0.3–0.5 m in treatments with soil ploughing compare to treatments with direct sowing what showed the formation of plough pan. Significant increase of soil resistance could be observed in treatments without chisel ploughing but with soil ploughing. It was established that soil resistance 0.6 m from the locale of chisel plough tine in treatments with ploughing were similar to that without any soil tillage.

Sowing technologies had insignificant influence on soil resistance.

References

1. Lapiņš D. *et al.* (2001 a) Augsnes apstrādes un sējas tehnoloģiju ietekme uz ziemas kviešu ražību. Agronomijas Vēstis, Nr. 3. – Jelgava, LLMZA, LLU, 108.–111.
2. Lapiņš D. *et al.* (2001 b) Effect of Soil Tillage and Sowing Technologies on Winter Wheat. Proceedings of the 3rd International Conference 'Environment. Technology. Resources.' Rezekne 2001, 61–64.
3. Lauringson E., *et al.* (2001) The Effect of the Minimisation of Autumn Tillage on Weediness and Yield. Baltic States Banch of Istro – 1st International Conference of BSB of Istro & Meeting of Working Group 3 of the INCO – COPERNICUS Concerted Action on Subsoil Compaction. Modern Ways of Soil Tillage and Assessment of Soil Compaction and Seedbed Quality., 21–24 August 2001 EAU Tartu Estonia, 81–92.
4. Maiksteniene S. (2000) Possibilities of primary tillage reduction on clay loam soil. Proceedings of the International Conference 'The Results of Long-Term Field Experiments in Baltic States', Jelgava, Latvia, November 22–23, 2000, 106–114.
5. Stancevicius A., *et al.* (2000) Reduced Primary soil Tillage of the Light Loamy Soils. Proceedings of the International Conference 'The Results of Long-Term Field Experiments in Baltic States', Jelgava, Latvia, November 22–23, 2000, 133–147.
6. Schröder D., Schulte – Karning H. (1984) Nachweis 20-jährigen Wirksahmkeit von Tieflockerungsmabnahmen in lössbeeinflussten Graulehm- Pseudogleyen. – Pflanzenernährung und Bodenkunde, Band 147, Heft 7, 540–552.

POSSIBILITIES OF SOIL TILLAGE AND SOWING TECHNOLOGIES OPTIMISATION IN SPRING BARLEY

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Abstract

Field trials were organized at Study and Research Farm 'Vecauce' during 2002 to 2004. The effect of soil tillage and sowing techniques on grain yield and yield structure elements of spring barley were studied on sod-podzolic loamy high-cultivated soils with high potassium and phosphorus contents.

It is ascertained that grain yield was 3–6% higher in treatments with soil deep loosening. This difference was significant in treatment with soil loosening at 0.25 m depth. However the grain yield was 4–17% lower in treatments with sowing in stubble than in treatments with ploughing. The results of investigation show that sowing in stubble with application of Glifoss (glyphosate, 360 g L^{-1}) at dosage 2 L ha^{-1} gave similar results as in treatment with ploughing. The sowing with disk seeders Rapid gave higher grain yield than sowing with Amazone but differences were not significant. The highest influence on grain yield showed the number of perennial weeds per 1 m^{-2}.

Key words: spring barley, sowing technologies, soil tillage, soil deep loosening

Introduction

Minimal soil tillage or no-tillage with direct sowing are used more often and often for cereals growing. That allows reduction of expenses by saving fuel and time not decreasing grain yield at the same time. Such results were also obtained in Latvia before now (Korolova J. *et al.*, 2001; Lapins D. *et al.*, 2001). Increasing density of energy saving soil tillage technologies in cereals growing resulted in soil compaction prevented by soil deep loosening.

Minimun soil tillage has been investigated also in Lithuania (Maiksteniene S., 2000; Satkus A. and Velikis A., 2001) and Estonia (Lauringson E. et al., 2001).

The aim of this article was to evaluate effect of different soil tillage and sowing technologies on spring barley grain yield and weed infestation in a sowing.

Materials and Methods

Field trials were carried out in Latvia University of Agriculture (LLU) Study and Research farm (SRF) 'Vecauce' during 2002–2004. Effects of soil tillage, sowing technologies and weed control on yield of spring barley were studied on sod-podzolic (2002 and 2004) and sod-calcareous leached (2003) loam soils with humus content 14–20 g kg^{-1}, soil reaction pH_{KCl} 5.9–6.6, P content 193–207 mg kg^{-1}, K content 96–156 mg kg^{-1}. Spring barley was grown in repeated sowing.

The following treatments were investigated in trial:

Factor A – soil deep ploughing with 'Kverneland CLE': A1 – at depth 0 m (untreated); A2 – at depth 0.25 m; A3 – at depth 0.35 m, the distance between tines – 0.9 m; A4 – at depth 0.35 m, the distance between tines 1.8 m; A5 – at depth 0.50 m.

Factor B – soil tillage and usage of herbicide Glifoss (glyphosate, 360 g L^{-1}) in autumn in treatments with direct sowing (done before trial year): B1 – direct sowing without Glifoss application (untreated); B2 – direct sowing and application with Glifoss 0.5 L ha^{-1}; B3 – direct sowing and application with Glifoss 2.0 L ha^{-1}; B4 – soil ploughing at depth 18–22 cm;

Factor C – sowing technologies: C1 – using anchor-type driller 'Amazone AD-403 super' with rototiller at depth 0.05–0.07 m and dispersion of mineral fertilizers before sowing; C2 – using anchor-type driller Amazone AD-403 super with rototiller at depth 0.07–0.10 m and dispersion of mineral fertilizers before sowing; C3 – using disc driller and local deposition of mineral fertilizers (except ammonium fertilizers) ('Rapid 400 C', hereafter 'Rapid').

Technologies used in growing spring barley. Soil was ploughed by Overum-6 DVL combined with Pakomat DK-205-335 CM. Herbicide Glifoss was applied on 6 September 2001, 19 September 2002 and 5 September 2003. Fields were sown to spring barley cv. Klinta at the rate of 400 germinating seeds per m^2. Mineral fertilizers were used according to soil agrochemical properties: $N_6P_{26}K_{30}$ at the rate of 300 kg ha^{-1} and NH_4NO_3 at the rate of 150 kg ha^{-1} were applied in the year 2002, $N_4P_{20}K_{20}$ at the rate of 300 kg ha^{-1} and NH_4NO_3 at the rate of 200 kg ha^{-1} in the year 2003, but $N_6P_{26}K_{30}$ at the rate of 300 kg ha^{-1} and NH_4NO_3 at the rate of 150 kg ha^{-1} were given in the year 2004. Pneumatic diffuser 'Amazone' dispersed mineral fertilizers. Herbicide Duplozans super 2 L ha^{-1} was applied on 23 May 2002, tank mixture Granstars 10 g ha^{-1} + Primuss 60 ml ha^{-1} + Kontakts (adjuvant) 100 ml per 100 L water was applied on 28 May 2003, but the herbicide Harmonijs ekstra 15 g ha^{-1} + Kontakts (adjuvant) 100 ml per 100 L water was applied on 4 June 2004. Insecticide Fastaks 0.15 L ha^{-1} was used in the year 2002 because of serious aphid infestation. Yield was harvested with trial harvester 'Hege-140' and adjusted to 14% moisture content and 100% purity.

Meteorological conditions. Low-rainfall conditions were observed from the second decade of April till the second decade of May in the first two trial years. Very dry weather with total rainfall below 40 mm was occurring from the third decade of July till the end of October in the year 2002. There was no precipitation in August! Differences in average temperatures were not so remarkable. Particularly dry weather in the autumn of 2002 was complemented with rapid decrease in temperature from 12° in the second decade of September to 2° in the second decade of October. Temperatures in 2003 were similar to long-term averages but amount of precipitation in May and July was lower accounting for 50% of long-term averages in August.

Temperatures in May and June of 2004 were lower but in July and August higher compare to long-term averages. In spring 2004 amount of rainfall was similar to that of long-term averages but June and July were characterized with high amount of precipitation.

Methods used in research and data analysis. Weed plants and number of shoots were counted in three places per plot using a frame 0.1 m^{-2} in size. Dry weight of spring barley shoots was determined for 30 plants from each treatment. Data analysis was done using analyses of variance and correlation.

Results and Discussion

Results of spring barley grain yield show that the lowest yield was obtained in 2002 because of meteorological conditions – exceedingly wet June and July followed by dry August.

Table 1. Grain yield of barley and its dispersion using different soil deep loosening treatments

Treatments	Years			
	2002	2003	2004	average
Grain yield, t ha^{-1}				
A_1 – untreated	2.42	4.32	4.19	3.64
A_2 – 0.25 m	2.43	4.81	4.32	3.86
A_3 – 0.35 m, distance between tines 0.9 m	2.33	4.38	4.40	3.74
A_4 – 0.35 m, distance between tines 1.8 m	2.58	4.50	4.40	3.79
A_5 – 0.5 m	2.62	4.33	4.33	3.76
$\gamma_{0.05}$	0.18	0.14	0.13	0.16
Coefficient of variation, S %				
A_1 – untreated	17.4	8.8	10.0	12.1
A_2 – 0.25 m	13.4	6.3	4.9	8.2
A_3 – 0.35 m, distance between tines 0.9 m	23.2	9.9	6.1	13.1
A_4 – 0.35 m, distance between tines 1.8 m	23.2	6.4	7.9	12.5
A_5 – 0.5 m	13.2	7.7	7.8	9.6

The 3-year results show that yield increase by 6% was achieved in treatment with soil loosening at the depth of 0.25 m (Table 1). This increase of yield is statistically significant. In other treatments yield differences were not significant. The highest differences can be observed among trial years. The highest increase of spring barley grain yield was reached with soil deep loosening at the depth of 0.50 m in a very wet growing season as it was observed in the year 2002, but in the year 2004 the highest yield was obtained in treatment with soil loosening at the depth of 0.35 m.

The highest dispersion of yield data is observed in 2002 when evaluating yield stability between years. The highest yield fluctuations were observed in treatments with soil deep loosening at the depth of 0.35 m in the year 2002. The most stable yields were obtained in treatments with traditional soil tillage using autumn ploughing.

Table 2. Grain yield of barley and its dispersion using different soil tillage-herbicide treatments

Treatments	Years			
	2002	2003	2004	average
Grain yield, t ha^{-1}				
Direct sowing	1.82	4.04	4.23	3.36
Direct sowing + Glifoss 0.5 L ha^{-1}	2.61	4.41	4.23	3.75
Direct sowing + Glifoss 2.0 L ha^{-1}	2.81	4.52	4.32	3.88
Autumn ploughing	2.68	4.91	4.54	4.04
$\gamma_{0.05}$	0.15	0.13	0.11	0.14
Coefficient of variation, S %				
Direct sowing	25.1	9.3	7.4	13.9
Direct sowing + Glifoss 0.5 L ha^{-1}	22.3	8.3	9.4	13.3
Direct sowing + Glifoss 2.0 L ha^{-1}	12.7	8.8	6.9	9.5
Autumn ploughing	12.7	4.9	5.6	7.7

Treatments with direct sowing gave significant lower average grain yield of spring barley in all three trial years (Table 2). Decrease of grain yield made 0.683 t ha^{-1} or 20.3%. Application of herbicide Glifoss at dosage 2 L ha^{-1} caused smaller decrease of grain yield compare to sowing after traditional soil tillage – 0.16 t ha^{-1} or 4%. Both treatments with Glifoss application are statistically similar although the lowest yield was obtained in treatment with spraying Glifoss 0.5 L ha^{-1}.

Table 3. Grain yield of barley and its dispersion using different sowing machines

Treatments	Years			
	2002	2003	2004	average
Grain yield, t ha^{-1}				
'Amazone AD-403 Super'; 0.05–0.07 m	2.26	4.41	4.19	3.62
'Amazone AD-403 Super', 0.07–0.10 m	2.57	4.65	4.25	3.82
'Rapid 400 C '	2.61	4.35	4.55	3.84
$\gamma_{0.05}$	0.13	0.11	0.10	0.12
Coefficient of variation, S %				
'Amazone AD-403 Super', 0.05–0.07 m	21.4	7.3	8.0	12.2
'Amazone AD-403 Super', 0.07–0.10 m	17.4	8.3	7.5	11.1
'Rapid 400 C '	15.4	8.1	6.6	9.9

In all trial period, the average highest spring barley grain yields were produced in treatments where driller 'Rapid' was used (Table 3). Similar yields were obtained also in treatments where driller 'Amazone' with rototiller at working depth 0.07–0.10 m was used. Sowing with driller 'Amazone' and rototiller at depth 0.05–0.07 m resulted in decrease of spring barley yield by 0.206 t ha^{-1} or 6%. Such coherence can be observed in all trial years except the year 2003 when significant higher yield was obtained in treatment 'Amazone' with rototiller at depth 0.05–0.07 m compare to treatment with 'Rapid'. The highest stability of yield between years was observed in treatments where driller 'Rapid' was used (Table 3).

Evaluation has been done for efficacy of autumn soil tillage and application of Glifoss in all three trial years. Obtained results show that application of Glifoss resulted in 3- to 20-fold decrease of perennial weed numbers (Table 4).

Table 4. Effect of different soil tillage – herbicide treatments on perennial weed numbers, p m^{-2}

Treatments	Years			
	2002	2003	2004	average
Direct sowing	7.56	15.23	4.56	9.12
Direct sowing + Glifoss 0.5 L ha^{-1}	2.67	5.11	1.00	2.93
Direct sowing + Glifoss 2.0 L ha^{-1}	0.00	0.45	0.67	0.37
Autumn ploughing	0.45	0.89	1.11	0.81
$\gamma_{0.05}$	1.57	2.32	1.35	5.25

Almost all perennial weeds were eliminated in treatments with Glifoss applied at 2 L ha^{-1}. Perennial weeds by 72% less were found in treatment with traditional autumn ploughing compare to treatment with Glifoss application at dosage 0.5 L ha^{-1}, and by 119% more compare to treatment with Glifoss applied at dosage 2.0 L ha^{-1}. Such coherence is observed also between trial years except the year 2004 when application of reduced dosage of Glifoss gave the same results as autumn ploughing. Correlation between perennial weed numbers in spring and spring barley grain yield vary between years – r_{xy} = –0.63 in the year 2002, r_{xy} = –0.36 in the year 2003; $r_{0.05}$ = 0.253.

The highest number of perennial weeds before harvesting was observed in treatment with direct sowing and without application of Glifoss – 21.2 plants per square meter on average in three years (Table 5). Application of Glifoss resulted in significant decrease of number of perennial weeds before harvesting but the smallest number of these weeds was observed in treatment with autumn ploughing.

Table 5. Different soil tillage – herbicide treatments and effect of drillers on perennial weed numbers before harvesting, p m^{-2}

Treatment	Years			
	2002	2003	2004	average
Soil tillage – herbicide application				
Direct sowing	21.4	15.2	27.	21.2
Direct sowing + Glifoss 0.5 L ha^{-1}	11.2	5.1	23.5	13.3
Direct sowing + Glifoss 2.0 L ha^{-1}	6.7	0.7	22.6	10.0
Autumn ploughing	2.1	0.9	17.5	6.8
$\gamma_{0.05}$	4.03	2.32	6.66	5.54
Drillers				
‘Amazone AD-403 Super’, 0.05–0.07 m	13.7	5.5	22.2	13.6
‘Amazone AD-403 Super’, 0.07–0.10 m	10.2	5.0	22.3	12.5
‘Rapid 400 C‘	12.4	6.4	23.4	14.1
$\gamma_{0.05}$	3.49	2.01	5.77	2.25

Data in the year 2004 differed from those obtained in other trial years regarding greater amount of perennial weeds. Application of Glifoss in the year 2004 gave no significant effect on perennial weed numbers. Whereas use of dosage 2 L ha^{-1} gave significantly higher control of perennial weeds in the years 2003 and 2003 compare to treatment with reduced dosage of Glifoss. Correlation between number of perennial weeds before harvesting and spring barley grain yield is medium high – r_{xy} = –0.71 in the year 2002 and r_{xy} = –0.69 in the year 2003; $r_{0.05}$ = 0.253.

Driller ‘Amazone’ with rototiller did not promote increase of perennial weed numbers compare to different sowing technologies (Table 5).

There were no significant differences in number of spring barley shoots per square meter in spring when comparing different soil tillage – herbicide treatments (Table 6). The highest number of shoots was observed in treatment with traditional soil tillage – 399 per m^{-2}.

The smallest number of spring barley shoots was observed in treatment with driller ‘Rapid’ when comparing different sowing technologies (Table 6).

Table 6. Different soil tillage – herbicide treatments and driller effect on number of spring barley shoots in spring, p m^{-2}

Treatment	Years			
	2002	2003	2004	average
Soil tillage herbicide application				
Direct sowing	331	400	393	375
Direct sowing + Glifoss 0.5 L ha^{-1}	336	403	418	386
Direct sowing + Glifoss 2.0 L ha^{-1}	328	397	403	376
Autumn ploughing	367	414	415	399
$\gamma_{0.05}$	18.9	20.9	17.6	59.7
Drillers				
‘Amazone AD-403 Super’, 0.05–0.07 m	343	400	422	388
‘Amazone AD-403 Super’, 0.07–0.10 m	375	407	421	401
‘Rapid 400 C ‘	306	403	378	362
$\gamma_{0.05}$	16.4	18.1	17.6	41.4
Coefficient of variation, S %				
‘Amazone AD-403 Super’, 0.05–0.07 m	19.2	15.6	15.3	16.7
‘Amazone AD-403 Super’, 0.07–0.10 m	17.1	16.4	12.9	15.5
‘Rapid 400 C‘	23.7	19.4	16.1	19.7

Also coefficient of variation was higher in treatments with driller 'Rapid'. Sowing with driller 'Amazone' made increase of number of shoots by 7–11%.

Table 7. Different soil tillage – herbicide treatments and drillers effect on dry weight of spring barley shoots, g

Treatment	Years			
	2002	2003	2004	average
Soil tillage – herbicide application				
Direct sowing	0.047	0.169	0.062	0.093
Direct sowing + Glifoss 0.5 L ha^{-1}	0.053	0.163	0.060	0.092
Direct sowing + Glifoss 2.0 L ha^{-1}	0.051	0.175	0.061	0.097
Autumn ploughing	0.053	0.179	0.058	0.096
$\gamma_{0.05}$	0.0020	0.0090	0.0020	0.0095
Drillers				
'Amazone AD-403 Super', 0.05–0.07 m	0.050	0.175	0.059	0.095
'Amazone AD-403 Super', 0.07–0.10 m	0.049	0.195	0.062	0.102
'Rapid 400 C'	0.053	0.145	0.059	0.086
$\gamma_{0.05}$	0.0200	0.0080	0.0020	0.0342

There were no significant differences in dry weight of spring barley shoots among different soil tillage – herbicide treatments on average in three years (Table 7). That means that usage of Glifoss in autumn in previous year made no negative impact on growth and development of spring barley.

There were no significant differences in dry weight of spring barley shoots between used drillers although increase by 11–19% was observed in treatments with driller 'Amazone'.

Conclusions

Soil deep loosening on cultivated sandy loam and loam soils gave spring barley grain yield increase by 6%.

Direct sowing caused decrease of spring barley grain yield but the smallest decrease by 4% was observed in previous autumn in treatment with Glifoss applied at dosage 2 L ha^{-1}.

Increase of working depth of 'Amazone' rototiller from 0.05–0.07 m to 0.07–0.10 m gained increase of spring barley grain yield by 6%.

The smallest number of perennial weeds in springtime was observed in treatment with Glifoss application at dosage 2 L ha^{-1}.

Application of Glifoss made insignificant change in number and weight of spring barley shoots.

Sowing with driller 'Amazone' complemented with rototiller did not cause increase in number of perennial weeds.

References

1. Koroļova J., *et al.* (2001) Influence of the soil tillage and sowing technologies on the yield of spring barley grain. Proceedings of International Conference 'Sustainable Agriculture in Baltic States', Tartu, Estonia, 61–67.
2. Lapiņš D., *et al.* (2001) Soil tillage and Sowing Technologies for Spring Barley and Winter Wheat. Baltic States Branch of Istro – 1stInternational Conference of BSB of Istro & Meeting of Working Group 3 of the INCO-COPERNICUS Concerted Action on Subsoil Compaction. Modern Ways of Soil Tillage and Assessment of Soil Compaction and Seedbed Quality, 21–24 August 2001. EAU, Tartu, Estonia, 150–160.
3. Lauringson E., *et al.* (2001) The effect of the Minimisation Autumn Tillage on Weediness and Yield. Baltic States Branch of Istro- 1stInternational Conference of BSB of Istro & Meeting of Working Group 3 of the INCO-COPERNICUS Concerted Action on Subsoil Compaction. Modern Ways of Soil Tillage and Assessment of Soil Compaction and Seedbed Quality, 21–24 August 2001. EAU, Tartu, Estonia, 81–92.
4. Maiksteniene S. (2000.) Possibilities of primary tillage reduction on clay loam soil. Proceedings of the International Conference 'The results of Long – Term Field Experiments in Baltic States', Jelgava, Latvia, November 22–23, 2000, 106–114.
5. Satkus A., Velikis A. (2001) Effect of primary and pre- sowing soil tillage on the formation of seedbed for spring barley in clay loam. Baltic States Branch of Istro- 1stInternational Conference of BSB of Istro & Meeting of Working Group 3 of the INCO-COPERNICUS Concerted Action on Subsoil Compaction. Modern Ways of Soil Tillage and Assessment of Soil Compaction and Seedbed Quality, 21–24 August 2001. EAU, Tartu, Estonia, 57–65.

THE INFLUENCE OF DIFFERENT CROP MANAGEMENT PRACTICES ON SOIL FERTILITY AND CROP ROTATION PRODUCTIVITY

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Abstract

Complex research was carried out at the Lithuanian Institute of Agriculture Joniskelis Research Station on an *endocalcari-endohypogleyic cambisol* to identify the effects of undersown crops – red clover, Italian ryegrass (*Lamium multiflorum* Lamk.) grown as catch crops and succession crop – white mustard (*Sinapis alba* L.) as well as the effects of their biomass incorporated as green manure on the intensity of nutrient circulation cycle in the agrocenoses and on minimisation of soil degradation and filtration water pollution. Red clover grown as a catch crop accumulated in the aboveground and underground biomass 114.6 kg ha^{-1} of biological nitrogen or 76.4 kg ha^{-1} of nitrogen fixed from the atmosphere, which had a positive effect on the quality of filtration water. Here the soil contained much less N_{min} – 36.7 and 21.4% than after *Poaceae* (Bernhart) or *Brassicaeae* (Burnett) family plants that do not fix nitrogen and for the intensification of vegetation of which small nitrogen rates (N_{30}) were used in the form of mineral fertiliser.

Key words: heavy loam brown soil, filtration water, catch crops, nitrogen

Introduction

Biologization in agriculture is one of the chief factors maintaining soil productivity and assisting in finding solutions to environmental problems (Filip, 2002; Bučienė, 2003). A balance between organic matter synthesis and decomposition settles down in natural ecosystems, however due to anthropogenic action mineralization of organic matter intensifies (Pupalienė R. and Stancevičius A., 2003; Crews and Peoples, 2004). Perennial legumes are one of the crops stabilizing decomposition processes. By fully exploiting the whole growing season perennial legumes withhold nutrients in the surface layer of soil and accumulate a high potential of biogenic elements in the phytomass (Schubert, 1995; Ambus and Jensen, 2001). Janušienė and Žekonienė suggest that the use of aboveground biomass of perennial plants as green manure is much more effective than that of annual plants, since a lot of nutrients are introduced in the soil with the well-developed root system (Žekonienė and Janušienė; 1999). Moreover, legume plants fix atmospheric nitrogen and can dispense with mineral nitrogen fertilizers, which consequently results in lower ground water pollution (Wallgren and Linden, 1994). Legumes can be used as catch crops to prevent or minimize post-harvest leaching of nutrients (Baniuniene *et al.*, 2004). The content of nutrients in the filtration water percolated through the soil is largely dependent on plant development, soil type, and texture. One of the ways to minimize nutrient leaching, especially that of nitrates, into ground water is cultivation of plants with a longer growing season and introduction of catch crops after main crops harvesting into agrosystems (Hamel *et al.*, 2004).

Materials and Methods

Two experiments were conducted to ascertain the effects of legumes grown as the main crops and catch crops on soil fertility and cereal productivity. The research "The effects of legumes grown as the main crop and their biomass on the accumulation of biogenic elements and productivity in cereals grown after legumes and in the soil" was conducted following the experimental design: factor A. Preceding crops for cereal sequence (winter wheat – winter wheat-spring barley): red clover (*Trifolium pratense* L.), sown lucerne (*Medicago sativa* L.), vetch and oat mixture (*Vicia sativa* L., *Avena sativa* L.), factor B. Organic manure: 1. No manure; 2. 1st crop – no manure applied; 3. 1st crop – green manure applied, 4. 1st crop – 40 t ha^{-1} farmyard manure applied (Table 2).

The research "The effects of legume catch crops differing in biological characteristics on the accumulation of biogenic elements in cereals, soil and filtration water" following the experimental design: A factor: cereal backgrounds: winter wheat (*Triticum aestivum* L.), spring barley (*Hordeum vulgare* L.). Treatments of factor B – catch crops biomass of which was incorporated as green manure are presented in Table 3. Red clover (*Trifolium pratense* L.) and Italian ryegrass (*Lolium multiflorum* Lamk) were undersown in a winter wheat crop upon resumption of vegetative growth, and in spring barley – shortly after sowing, white mustard (*Sinapis alba* L.) as a post-crop was direct drilled by a stubble drill after cereal harvesting (on the same day). The next year spring barley was grown on both backgrounds after incorporation of catch crops biomass as green manure.

N_{min} content was analysed in soil samples, which were taken from the soil layer 0–40 cm deep in the main crops in spring upon resumption of winter wheat vegetative growth and before spring barley sowing, in catch crops after cereals harvesting, prior to incorporation of catch crops biomass as green manure and after biomass incorporation in spring before barley sowing. Mineral nitrogen (NO_3 + NH_4) was measured by distillation and colorimetry method (in 1 N KCl extraction). To measure nutrient leaching, wells-piezometers were set up after cereal harvesting on each background in two replications to collect filtration water. In water samples N-NO_3 and N-NH_4 and total nitrogen contents were determined calorimetrically by the analyser 'FIA Star 5012 system', NH_4-N – by gas diffusion, total N (having performed organic matter mineralization with potassium persulfate) and N-NO_3 – by cadmium reduction methods. The concentration of carbon in plant underground and aboveground biomass was analysed by the analyser "Heraeus". The share of nitrogen fixed by legume bacteria from the atmosphere in plant biomass was calculated by multiplying nitrogen content by the coefficient (0.63) provided by Chopkins – Piters.

Results and Discussions

The effects of legumes grown as the main crops on the retention of biogenic elements in the soil. The largest amount of nutrients in the agrocenoses was returned into the circulation cycle with the heaviest underground lucerne and clover biomass, while the lowest amount with the mixture of annual plants (Table 1). The importance of legumes in agrocenoses is paramount due to biological nitrogen fixation (Crews and Peoples, 2004). In the phytomass of clover and lucerne nitrogen fixed from the atmosphere accounted for the largest share 66.2 and 156.5 kg ha^{-1}. Seeking to balance nutrient transport in the ecosystem, the soil was additionally incorporated with overground biomass of legumes for green manure. Incorporation of these nutrients is significant in compensating for the amount of nutrients removed with the yield. The content of atmospherically fixed symbiotic nitrogen in plant aboveground mass incorporated as green manure was lower than that in underground mass. The highest content of symbiotic nitrogen was introduced with lucerne and clover aboveground biomass 72.1 kg and 50.5 kg ha^{-1}, respectively, or 3.2 and 2.2 times more than with annual plants mixture.

Table 1. The role of legumes in introducing biogenic elements in the biological circulation of matters, kg ha^{-1}

Crop	Dry matter (DM), t ha^{-1}	N		N:P:K	C:N
		total	fixed		
Underground mass					
Red clover	9.2±1.04	99.6±14.9	66.2±10.0	1:0.2:1.1	24
Sown lucerne	13.7±1.12	234.8±35.1	156.5±23.4	1:0.1:0.7	18
Vetch and oats mixture	5.3±0.51	38.8±7.5	25.9±5.0	1:0.2:2.2	35
Aboveground mass and farmyard manure					
Red clover	3.2±0.58	80.1±5.7	50.5±3.6	1:0.1:0.9	12
Sown lucerne	3.9±0.32	114.2±10.9	72.1±6.9	1:0.1:0.9	10
Vetch and oats mixture	3.8±0.21	36.0±3.4	22.7±2.1	1:0.2:2.5	32
Farmyard manure (FYM)	47.9±0.92	152.0±19.6	–	1:0.2:1.4	18

Carbon to nitrogen ratio determining transformation direction and intensity of incorporated organic matter in the soil differed between individual plant species and within the same species in aboveground and underground parts. For lucerne residues this ratio was the narrowest – 18, and for vetch and oats mixture this ratio was the widest – 35. Having incorporated in the soil nitrogen-rich plant aboveground mass, which C to N ratio was narrower, organic matter mineralization sped up.

Having incorporated nitrogen-rich lucerne and clover aboveground mass as green manure, mineral nitrogen content in the soil in the first year of cereal growing was 9.1 and 6.5% higher than in unfertilised soil (Table 2). Statistical analysis suggests that in the first year with incorporated organic fertilizer the content of N_{min} depended both on incorporated dry matter, nitrogen content, C to N ratio, and soil total nitrogen and humus content.

Moreover, in heavy loam cambisols organic matter mineralization was significantly affected by soil bulk density and aeration porosity. Correlation relationship between N_{min} and C to N ratio of the incorporated organic matter is strong $r = -0.97$ as described by a relationship $y = 48.88 - 0,40x$. The content of free humic acids (ha^{-1}) in the soil had a significant effect on mineral nitrogen increase.

Table 2. The effects of legumes and their aboveground mass incorporated in the soil on N_{min} variation in soil, mg kg^{-1}

Fertilisation	Red clover		Sown lucerne		Vetch and oats mixture	
	Ist member	IInd member	Ist member	IInd member	Ist member	IIInd member
	w. wheat	w. wheat	w. wheat	w. wheat	w. wheat	w. wheat
Without fertilisers	6.2	5.7	6.6	6.1	5.7	5.6
Ist crop without fertilisation 2nd, 3rd – according to $N_{min.}$	6.3	5.6	6.5	6.1	5.7	5.7
Ist crop – green manure, 2nd, 3rd – according to N_{min}	6.6	6.2	7.2	6.8	5.7	6.3
Ist crop – FYM 40 t ha^{-1} 2nd, 3rd – according to $N_{min.}$	6.6	6.4	7.0	6.8	5.9	6.5
1st member LSD_{05} fact. A-0.42; B-0.49; AB-0.85; 2nd member LSD_0 fact. A-0.36; B-0.42; AB-0.72						

Winter wheat produced the highest grain yield (5.58 t ha^{-1}) in all fertilization treatments after lucerne. After all preceding crops a significant grain yield increase was observed through organic fertilization. Averaged data suggest that cereals grown after legumes for three years resulted in large amounts of nitrogen (220.5 kg ha^{-1}) removed with cereal grain and straw yield from the agrocenoses (Fig. 1).

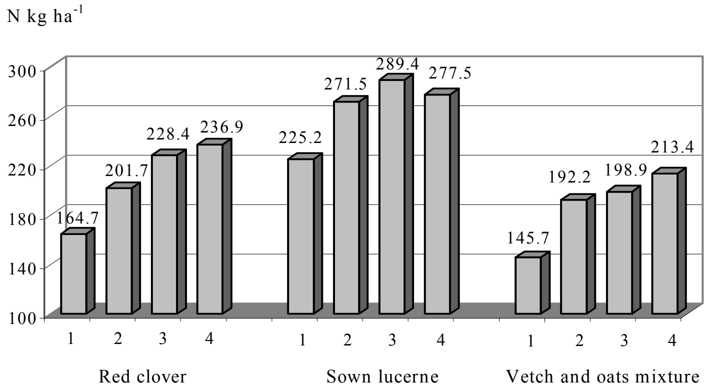

Figure 1. Effects of legumes and their biomass incorporated as green manure on nitrogen accumulation in cereal yield

The highest increase in nitrogen that occurred through organic fertilisers was identified when cereals had were grown in the first year. A more abundant removal of nutrients after lucerne with cereal yield was determined by a higher content of nitrogen accumulated in the soil. Comparison of unfertilised treatments of individual preceding crops revealed that after lucerne the content of nitrogen removed with cereal yield was 36.7 and 54.6% higher than after clover and vetch and oats mixture. Assessment of nitrogen circulation cycle of unfertilised cereal agrocenoses (legumes – winter wheat – winter wheat – spring barley) showed that after lucerne nitrogen was 69.5% compensated by atmospheric nitrogen, while after clover and annual plant mixture nitrogen compensation was lower (40.2 and 17.8%, respectively). When fertilising with organic and mineral nitrogen fertiliser, nutrient removal from agrocenose increased. Having incorporated plant biomass as green manure, the difference of accumulated nitrogen in cereal yield, compared with treatments fertilised only with mineral nitrogen, made up: after clover 16.2%, after lucerne 7.9%, after mixture 4.6%. Nitrogen accumulated in cereal yield by atmospherically fixed nitrogen was compensated as follows: by clover biomass 51.1%, by lucerne 79.0%, and by mixture 24.4%.

After 3 years of cereals cultivation, soil organic carbon content declined. This was influenced by less amount of plant residues left in the soil by cereals as compared with perennial grasses. Moreover, increased soil aeration during soil preparation for cereals activated soil microbiological processes and readily decomposed humic substances accumulated on the backgrounds of perennial grasses were mineralised.

The effects of catch crops differing in biological characteristics on the accumulation of biogenic elements in the soil and filtration water. Catch crops increased the total productivity of both agrosystems: on the background of wheat dry matter content increased from 21.4 to 41.3%, on the background of barley even more – 41.0–85.5%. Of all catch crops red clover increased the productivity of agrocenoses most appreciably, dry matter yield of clover biomass was the highest 1.8 and 1.3 times higher than that of white mustard or Italian ryegrass (Table 3).

Table 3. Effect of catch crops having different biological properties on the cycle of biogenic nitrogen metabolism

Crops (F_B)	Underground biomass			Aboveground biomass		
	incorporation DM t ha^{-1}	N kg ha^{-1}		incorporation DM t ha^{-1}	N kg ha^{-1}	
		total	fixed		total	fixed
White mustard	1.28	16.3	–	1.134	32.0	–
Red clover	2.49	55.7	37.2±2.64	2.03	58.9	39.2±11.53
Perennial ryegrass	1.84	30.1	–	1.59	26.9	–
LSD_{05} fact. B	0.943	17.81		0.779	14.04	

The underground mass of all catch crops (white mustard, red clover, and Italian ryegrass) was higher by 13.3, 22.7, and 15.7%, respectively than aboveground mass, unlike for most crops grown as the main crops. This resulted from the fact that when root system of catch crops had fully formed, the growing period for the development of aboveground biomass was too short (Baggs *et al.*, 2000). Catch crops differed in the accumulation of biogenic elements in underground and aboveground plant parts. The highest contents accumulated were those of nitrogen and potassium, while the lowest content was that of phosphorus. Out of all catch crops grown, clover phytomass was significantly distinguished for nitrogen accumulation 114.6 kg ha^{-1} or 76.4 kg ha^{-1} atmospherically fixed nitrogen. Such amount of biological nitrogen is valuable from the ecological viewpoint, since it can meet N needs of cereals grown after clover. However, white mustard and Italian ryegrass applied with low starter rates of nitrogen fertiliser (N_{30}) accumulated twice as less nitrogen in their biomass (48.3 and 57.0 kg ha^{-1}, respectively).

In the 0–0.4 m soil layer after harvesting of cereals significantly higher concentrations of all forms of available nitrogen compounds and total mineral nitrogen were identified on the background of spring barley, compared with that of winter wheat (Table 4).

Table 4. Effect of the catch crops with different biological properties on the change of $N_{min.}$ in the soil, mg kg^{-1}

Intercrops (F)	Winter wheat (F_A)			Spring barley (F_A)		
	after harvesting of cereals	Before incorporation of catch crops	before barley sowing in spring	after harvesting of cereals	before incorporation of catch crops	before barley sowing in spring
Without catch crops	2.99	3.59	14.95	3.72	4.07	17.40
White mustard	2.99	5.05	15.60	3.72	3.63	17.15
Red clover	2.72	1.71	11.95	4.59	2.89	14.85
Perennial ryegrass	2.69	4.37	18.20	3.78	5.84	16.75
LSD_{05} fact. A	0.434	0.851	1.355	–	–	–
LSD_{05} fact. B	0.6114	1.200	1.916	–	–	–
LSD_{05} fact. AB	0.868	1.700	2.710	–	–	–

Such results were determined by a higher nitrogen removal with winter wheat yield and undersown crops had only negligible effect. In the autumn, upon completion of catch crops growing season, the content of mineral nitrogen in the soil was 0.49 mg kg^{-1} or 14.5% higher, compared with the previous level, however, no marked differences between cereals backgrounds remained. The highest mineral nitrogen content was identified in the soil sown to white mustard and fertilised with N_{30} (averagely on the backgrounds 4.34 mg kg^{-1}) and Italian ryegrass (averagely in the backgrounds 5.11 mg kg^{-1}). The lowest nitrogen content (2.3 mg kg^{-1}) in the soil was found in the treatments grown with nitrogen-fixing red clover as a catch crop. Similar results were obtained in Sweden and other countries (Wallgren and Linden, 1994). In spring in the following year, incorporation of catch crops biomass in the soil resulted in considerably higher mineral nitrogen content (15.86 mg kg^{-1} or 71.4 kg ha^{-1}) compare with the autumn period.

Averaged data suggest that out of all catch crops clover and its biomass were responsible for the highest increase in barley yield (23.2%), a lower yield increase was obtained through white mustard and Italian ryegrass (18.6 and 12.2%, respectively), compared with the control treatment (Table 5).

The highest content of nitrogen was accumulated in barley yield when it was grown after clover and mustard – 21.1 and 18.2% more compared with the control treatment and 14.1 and 11.6% more having incorporated biomass of Italian ryegrass. Nitrogen content removed by cereals after red clover was 83.3% compensated by atmospheric nitrogen, whereas white mustard and ryegrass biomass covered nitrogen expenditure by 54.0 and 70.5%. Catch crops increased organic carbon reserves, especially after red clover, where they increased by 3.5%, compared with the control treatment.

Table 5. Effect of the catch crops with different biological properties on the amount of nitrogen accumulated in cereals yield (grain and straw)

Intercrops (F_B)	Winter wheat (F_A)			Spring barley (F_A)		
	grain yield, t ha^{-1}	N		grain yield, t ha^{-1}	N	
		kg ha^{-1}	increase, %		kg ha^{-1}	Increase, %
Without catch crops	4.15	72.1	–	4.74	79.2	–
White mustard	5.20	89.8	+24.6	4.91	89.1	+12.5
Red clover	5.01	84.2	+16.7	5.28	99.2	+25.2
Perennial ryegrass	4.82	78.9	+9.4	4.81	82.9	+4.6
Grain yield LSD_{05} fact. A-0.133; B-0.188; AB-0.266; N yield LSD_{05} fact. A-3.08; B-4.36; AB-6.16						

Irrespective of the type of catch crops, winter wheat reduced soil nitrogen level, a more significant reduction occurred in total and mineral nitrogen concentration in filtration water, compared with spring barley. Moderately strong correlation between N_{min} content in the soil (x) mg kg^{-1} (0–0.4 m) and total N concentration in filtration 0–0.8 m depth water mg l^{-1} (y_1) $y_1 = 33.87 – 3.606x + 0.211x^2$; $\eta = 0.65$; D = 42%; x extr. = 8.6. Catch crops differed in their effects on nutrient leaching. On barley background these differences were especially distinct: both white mustard and Italian ryegrass grown as catch crops and fertilised with N_{30} increased the concentration of all forms of nitrogen in filtration water, compared with unfertilized treatment. On the background of winter wheat a more marked increase in mineral nitrogen content was identified only for the Italian ryegrass treatment. Averaged data indicate that white mustard or Italian ryegrass when grown as catch crops and fertilised with N_{30}, N_{min} concentration in filtration water (at 0–0.8 m depth) increased by 21.3 and 49.7%, respectively.

Conclusions

Sown lucerne was best at compensating by bioegenic elements the nutrients removed with cereal yield: nitrogen – 69.5% fixed from the atmosphere and 108.8% biological nitrogen incorporated with underground plant mass. This coefficient for red clover and vetch and oats mixtures was significantly lower – 40.2 and 17.8%, respectively.

Catch crops differed in their effects on nutrient leaching: both white mustard and Italian ryegrass grown as catch crops and fertilised with N_{30} increased the concentration of all forms of nitrogen in filtration water, compared with unfertilized treatment.

Catch crops contributed to a higher nitrogen accumulation in the yield of barley grown after them, the largest amount of nitrogen 91.7 kg ha^{-1} was accumulated after red clover and its biomass incorporation as green manure.

References

1. Ambus P., Jensen E.S. (2001) Crop residue management strategies to reduce N-losses – Interaction with crio N supply. Communications in Soil Science and Plant Analysis, 32 (7–8), 981–996.
2. Baggs E. *at al.* (2000) The fate of nitrogen from incorporated cover crop and green manure residues. Nutrien Cycling in Agroecosystems, 56 (2), 153–163.
3. Baniūnienė A. *at al* (2004) Sideracinių augalų veikimas bulvių sėjomainoje. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 87, 61–72.
4. Bučienė A. (2003) Žemdirbystės sistemų ekologiniai ryšiai, Klaipėda, Lietuva, 178. Crews T. E., Peoples M. B. (2004) Legume versus fertilizer sources of nitrogen: ecological tradeoffs and human needs. Agroculture Ecosystems & Environment, 102 (3), 279–297.
5. Filip Z. (2002) International approach to assessing soil quality by ecologically – related biological parameters. Agriculture, Ecosystems and Environment, 88, 169–174.
6. Hamel Ch., *et al.* (2004) Nutrient dynamics: Utilizing biotic-abiotic interactions for improved management of agricultural soils. Journal of crop improvement TM progress in production and productivity, 11, 209–239.
7. Pupalienė R., Stancevičius A. (2003) Įvairaus intensyvumo žemdirbystės sistemų poveikis dirvožemio agrocheminėms savybėms. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 83, 19–29.
8. Schubert, S. (1995). Nitrogen assimilation by legumes-processes and ecological limitations. Fertilizer Research, 42; 99–107.
9. Wallgren B., Linden B. (1994) Influence of different catch crops and ploughing times on soil mineral nitrogen. In: Proceedings of 13th International Conference, Aalborg, Denmark, 215–220.
10. Žekonienė V., Janušienė V. (1999) Intensyvios ir tausojančios žemdirbystės agrobiologinis vertinimas lengvos granuliometrinės sudėties dirvožemiuose. Žemdirbystė: mokslo darbai LŽI, LŽŪU. Akademija, 66, 61–70.

STUDIES ON HOGWEED (*HERACLEUM*) RESTRICTION IN LATVIA IN 2002–2004

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Abstract

Heracleum sosnowskyi was introduced in Latvia as a silage plant. It has since escaped in wild to become one of the most dangerous invasive plants in native flora. Totally there are fixed 13 thousand hectares of land polluted with *H. sosnowskyi* (Berzins A. *et al.*, 2002, Bērziņš A. *et al.*, 2003).

Trials on the possible restriction of hogweed distribution were established in Madona, Talsi and Riga districts. Methods used in restriction of hogweed distribution were divided into the following groups: mechanical, chemical, biological, and combination of these methods. Results showed that the best methods for *H. Sosnowskyi* restriction were as follows: cutting in flower stage, twofold use of glyphosate herbicide in one vegetation season, tribenuron-methyl herbicide applied in early growth stage, mulching with black plastic film and return of polluted lands to agricultural use for crop production.

Key words: *Heracleum*, invasive species, glyphosate, tribenuron-methyl, mulching

Introduction

Heracleum sosnowskyi Manden. is an invasive plant species very rapidly entering flora of Latvia.*H. sosnowskyi* is a native of the Caucasus. Some botanists consider *H. sosnowskyi* Manden. To be only a variety of *H. mantegazzianum* Sommier et Levier or *H. pubescens* (Hoffm.) Marsch. Bieb. That plant species was introduced in Latvia as a cultivated plant in the middle of the 20th century for silage. In wild, *H. sosnowskyi* started escape in 80ies of the last century. At that time, with the change of land property forms from collective to private ones, usual land management system started to change as well. Spread of *H. sosnowskyi* in Latvia became uncontrollable, particularly in wastelands, along roadsides, in bushewood, on riversides etc. Rough estimate of total polluted area in Latvia is about 13 thousand hectares (Lapins D. *et al.*, 2002).

Sap of *H. sosnowskyi* is phytotoxic, which is one of the main and compelling reasons for its control. The sap of the leaves and steams contains furocoumarins. Coming into contact with man's skin that is then exposed to ultraviolet light, usually in the form of sunlight, the furocoumarins are activated to phototoxic derivatives resulting in skin burning. According to some botanists *H. sosnowskyi* is much more dangerous than *H. mantegazzianum* because of higher concentration of photoactive compounds (Lapiņš D. *et al.*, 2002).

The aim of this work was to find most suitable methods for *H. sosnowskyi* restriction.

Materials and Methods

The field trials were carried out from 2002 to 2004 at three locations in Latvia: Barkava (56°45'N, 26°30'E), Kekava (56°49'N, 24°16'E), and Gibuli (57°14'N, 22°25'E). All fields were covered with natural *H. sosnowskyi* stands. The soils of Barkava and Kekava test plots are sandy loams but those in Gibuli loams.

Study treatments were grouped into 4 groups:

Mechanical methods: different soil tillage methods, depths and timing of soil tillage (ploughing, milling, sharing-ploughing, rotary harrowing and plough harrowing) in Kekava and Gibuli; cutting in Kekava and Barkava; mulching in Barkava.

Chemical methods: different rates, concentrations, spraying time, combinations and applications of herbicides (Roundup 3; 5; 6; 9 l ha^{-1}, Roundup 5 l ha^{-1} + Banvel 4S 0.8 l ha^{-1}; MCPA 3 l ha^{-1} + Banvel 4S 0.8 l ha^{-1}; Milagro 1.5 l ha^{-1}). Using of rope wiper with Roundup and aqua at the ratio 1:2; 1:3; and 1:5 and Milagro and aqua 1:5 (Barkava). In spring 2004, effects of soil herbicides: Piramin Turbo, Stomp and Zenkor on *H. sosnowskyi* were tested.

Biological methods: sowing of annual ryegrass, fodder radish, buckwheat (Barkava).

Complex methods: soil tillage + spraying of Roundup (Kekava), spraying of herbicides + cutting (Barkava).

In all trial sites different plot size and machinery were used.

Weed cover was detected in percentage and converted into 9-point system: 0% = 1 point, 0–2.5% = 2 points, 2.5–5% = 3 points, 5–10% = 4 points, 10–55% = 5 points, 15–25% = 6 points, 25–35% = 7 points, 35–67.5% = 8 points, 67.5–100% = 9 points. Field trials were successful if *H.sosnowskyi* cover was estimated 0–1 points.

In Barkava plot the following crop rotation was practised: natural stand of *H. sosnowskyi* → green manure plants → barley → spring wheat.

In trials the following herbicides were applied: Roundup (glyphosate 360 g l^{-1}), MCPA (750 g l^{-1}), Banvel 4S (dicamba 480 g L^{-1}), Granstar (tribenuron-methyl 750 g kg^{-1}), Piramin Turbo (chloridazon 520 g L^{-1}), Stomp (pendimethalin 330 g l^{-1}), Milagro (nicosulfuron 40 g L^{-1}), Zencor (metribuzin 700 g kg^{-1}).

Collected data were processed with a mathematical method and namely the one-factor.

Results and Discussion

Cutting. Plants of *H. sosnowskyi* after first cut in 4–6 leaf stages in the first decade of May were growing and producing seeds. These plants were not different from those in the control plot. Estimated plant density in the control plot during three trial years was 9 points, after a single cutting 8.9 points (Table 1). Seedlings covered 25–30% of the soil surface. Twofold cutting (first in May, second in July) reduced plant density to 8.0 points. Green mass was 50–60% of the control and plants produced seeds, but seedlings covered 40% from the soil surface. Third cutting (end of August) reduced plant density to 8.0 points and plants did not produce seeds (Table 1).

Table 1. Impact of different control methods on *H. sosnowskyi* adult plant cover and seedlings in Barkava field, 9 point system, 2002–2004

Control methods	Years						Average	
	2002		2003		2004			
	adult	seedlings	adult	seedlings	adult	seedlings	adult	seedlings
Roundup 5 L·ha^{-1}	1.0	9.0	1.0	5.9	1.2	6.3	1.1	7.1
Roundup 5 L·ha^{-1} + 3 L·ha^{-1}	–	–	1.0	1.4	1.0	1.2	1.0	1.3
Roundup 5 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1}	4.8	8.2	8.0	3.9	6.3	3.6	6.4	5.2
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1}	9.0	8.0	8.9	4.9	7.9	3.3	8.6	5.4
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1} + Cutting 1x	8.0	8.0	8.9	4.2	7.5	4.6	8.1	5.6
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1} + Cutting 2x	8.8	8.0	7.4	3.5	6.4	4.3	7.5	5.3
Milagro 1.5 L·ha^{-1}	9.0	4.6	8.3	5.3	8.8	4.5	8.7	4.8
Cutting 1x	8.8	7.8	8.8	5.8	9.0	5.8	8.9	6.5
Cutting 2x	8.8	8.0	7.8	4.0	7.4	4.6	8.0	5.5
Cutting 3x	9.0	8.0	7.0	3.8	–	–	8.0	5.9
Cutting in flower time	–	–	7.0	2.3	7.3	4.3	7.2	3.3
Control	9.0	6.2	9.0	3.1	9.0	3.4	9.0	4.2
$LSD_{0.05}$	0.41	0.39	0.25	0.34	0.40	0.47	1.22	1.92

Green mass was 20–25% from the control and plants did not form floral shoots. Third cut in 2004 was not possible due to cold weather. Plants after second cut did not form herbage and floral shoots. In 2003 and 2004 plants of *H. sosnowskyi* were cut in flower stage (early July). Density of plants was reduced to 7.2 points and plants formed some floral shoots from basal axillary's buds, which produced negligible quantity of seeds (Table 1). After flowering and seed production plants were lost. In 2004, repeated cutting was performed in one half of the area, which was cut in 2003. Plant density was reduced to 8.8 points after 1st cut and to 7.8 points after 2nd cut (Table 2). In place with estimated plant densities 8.9 and 8.0 points, density was reduced to 8.0 points after 3rd cut (Table 1).

Table 2. Impact of control methods on *H. sosnowskyi* adult plant cover and seedlings in Barkava field, 9-point system, 2004

Control methods	Adult	Seedlings
Roundup 5 L·ha^{-1}	1.0	3.4
Roundup 5 L·ha^{-1} + 3 L·ha^{-1}	1.0	1.2
Roundup 5 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1}	7.2	3.3
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1}	8.5	4.5
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1} + Cutting 1x	8.7	3.9
MCPA 3 L·ha^{-1} + Banvel 4S 0.8 L·ha^{-1} + Cutting 2x	6.7	3.6
Milagro 1.5 L·ha^{-1}	7.2	4.4
Cutting 1x	8.8	5.5
Cutting 2x	7.8	3.9
Cutting in flower time	6.1	3.0
Control	9.0	3.5
$LSD_{0.05}$	0.51	0.57
Influence of treatment, %	96.5	73.1

When cutting plants of *H. sosnowskyi* by hand using hand scythe or trimmer, precautionary measures should be observed.

Treatments with spraying mix of herbicides MCPA 3 l ha^{-1}+ Banvel 4S 0.8 L ha^{-1} and in combination with a single or twofold cutting were unsuccessful. The plant cover was reduced to 8.1 and 7.5 points (Table 1).

Herbicidal control. Herbicides were applied in different ways and combinations. In small plots, there were tested rope wiper and aqua mix with herbicides Roundup and Milagro. Treatment with of Roundup and aqua in ratios 1:2, 1:3 and 1:5 gave similar results. Estimated cover of *H.sosnowskyi* plants was 1.3, 1.5 and 1.6 points, respectively. From economical and technological aspects, application of Roundup and aqua solution 1:5 was more efficient particularly in places with thinned plants, but only adult plants were killed by that method. Seedlings recovered very fast and occupied free places, and in the 2nd year after herbicides application the plot was similar to that of control. Milagro solution with aqua was unsuccessful. Plant cover was reduced only to 6.0 points (Table 3).

Table 3. Impact of rope wiper use with different solutions and black plastic film on *H. sosnowskyi* adult plant cover, Barkava field, 9-point system, 2002–2004

Control methods	Year			Average
	2002	2003	2004	
Roundup-aqua 1:2	1.7	1.0	1.2	1.3
Roundup-aqua 1:3	2.0	1.0	1.4	1.5
Roundup-aqua 1:5	2.0	1.0	1.9	1.6
Milagro-aqua 1:5	–	3.3	8.7	6.0
Black plastic film	1.0	1.0	1.0	1.0
Control	8.1	8.8	8.8	8.6
$LSD_{0.05}$	–	–	–	2.0

A single Roundup application in spring at 3, 5, 6, 9 l ha^{-1} reduced plant cover to 7.2, 7.1, 7.3 and 6.4 points, respectively. These doses practically killed adult plants, and seedlings and young plants occupied empty spaces in autumn. In Barkava in 2002–2004 treatment with Roundup 5 l ha^{-1} resulted in adult plant cover reduction to 1.1 point but the cover of seedlings in autumn was reduced only to 7.1 points. It suggests that a single application of Roundup is not recommended (Tables 1 and 4).

Table 4. Impact of different control methods on *H. sosnowskyi* cover in Kekava field, autumn, 9-point system, 2002–2004

Control methods	Year			Average
	2002	2003	2004	
Control	7.8	8.8	8.7	8.4
Roundup 3 L·ha^{-1} 1x	7.0	7.7	6.8	7.2
Roundup 3 L·ha^{-1}2x	4.5	5.9	2.0	4.1
Roundup 3 L·ha^{-1} 3x	4.5	1.7	0.8	2.3
Roundup 6 L·ha^{-1} 1x	5.4	8.7	7.7	7.3
Roundup 9 L·ha^{-1} 1x	5.4	8.5	5.2	6.4
Roundup 3 L·ha^{-1} 1x + soil milling 1x	3.8	2.4	1.0	2.4
Roundup 3 L·ha^{-1} 2x + soil milling 2x	3.8	2.3	1.0	2.4
LSD $_{0.05}$	1.05	0.53	0.80	2.38
Influence of treatment, %	35.6	95.1	93.1	78.6

Treatments with repeated application of Roundup in combinations 3+3, 5+3 and 3+3+3 L ha^{-1} reduced the cover of *H. sosnowskyi* to 4.1, 1.3, and 2.3 points, respectively. The last two treatments practically killed all old plants and the second spraying killed seedlings. The soil was practically completely free from plants and ready for growing grasses or cereals.

Tests on different Roundup concentrations (1.5%, 2%, 3%, 6%) showed that the best results were obtained with 2, 3 and 6% concentrations and efficiency of the first two treatments was similar. Less effective was the use of 1.5% concentration.

Good results were reached with Roundup application in combination with soil milling. Spraying of Roundup 3 l ha^{-1} and a single soil milling resulted in plant cover reduction to 2.4 points but twofold spraying of Roundup 3+3 L ha^{-1} reduced plant cover to 2.4 points too. From economical aspect the first treatment was better.

Effect of herbicides Roundup 5 l ha^{-1} and Banvel 4S 0.8 l ha^{-1} mix was unsuccessful. The cover of adult plants was reduced only to 6.4 points but the application of Roundup alone reduced the adult plant cover to 1 point (Table 1). This mix was antigen.

Mix of MCPA 3 L ha^{-1} and Banvel 4S 0.8 L ha^{-1} reduced plant cover to 8.6 points. Plants were under stress only for two weeks and afterwards grew normally like those in the control plots. This treatment was combined with a single and twofold cuttings. The plant cover in this process was reduced to 8.1 and 7.5 points respectively, but this combination was unsuccessful (Table 1).

Application of herbicide Milagro 1.5 l ha^{-1} reduced plant cover only to 8.7 points. In 2002, the treated plants did not produce seeds, and the developed flower buds were drying up. Possibly weather conditions (sunny and warm) occurring in that year increased the efficiency of the applied herbicide (Table 1).

Test of soil herbicides Piramin Turbo 5 l ha^{-1}, Stomp 6 l ha^{-1} and Zenkor 0.7 kg ha^{-1} in 2004 on former soil tillage treatments was unsuccessful.

In Barkava plots in 2003 and 2004 herbicide Granstar 15 g ha^{-1} was tested in barley sowing with green manure plants as previous crop, which were natural *H. sosnowskyi* society. After barley in 2004 Granstar application was repeated on spring wheat. Results showed that Granstar contributed to the reduction of *H. sosnowskyi* cover from 4.0–8.9 points, in previous crops to 3.5–3.7 points after barley cropping. Next year after barley, application of Granstar 15 g ha^{-1} in spring wheat field resulted in hogweed cover reduction to 2.6–2.8 points. Application of Granstar showed that the effect of green manure plants was small because the impact on natural *H.sosnowskyi* society after soil tillage was similar (Table 5). After treating plants, they slowly turned yellow green, floral shoots were short and seeds were setting abnormal. Seedlings after spraying slowly died off.

Table 5. Impact of crop rotation on *H. sosnowskyi* cover in Barkava field in 9-point system, 2002–2004

Crop	Green manure plants,	Spring barley,	Spring wheat,

	2002	2003	2004
Buckwheat	4.8	2.9	2.7
Annual ryegrass	6.0	3.3	2.6
Fodder radish	4.8	2.6	2.6
Control, soil tillage in autumn	9.0	2.7	2.8
Control	9.0	8.8	8.7
$LSD_{0.05}$	0.60	0.31	0.54

Mulching. Soil mulching with black plastic film gave the best results. After a year of treatment all plants died off and soil was completely free from any plants and was ready for grasses or cereals (Table 3). This method did not destroy soil seed bank in one year and from economical aspect was costly.

Soil milling. Soil milling was performed 12–15 cm deep in Kekava field. A single soil milling in 10 May 2002 reduced *H. sosnowskyi* cover from 9 to 5 points but contributed to the growth of *Agropyron repens* (L.) P. Beauv. from 4.1% to 26.2%. The second milling treatment in similar depth with a month interval reduced *H. sosnowskyi* cover to 2 points and that of *Agropyron repens* was 25.7%. Soil milling in combination with herbicide Roundup 3 L ha^{-1} reduced hogweed cover to 1.0–3.8 (average 2.4) points and destroyed *Agropyron repens* cover to 0% (Table 4).

Similar results were achieved in Gibuli plot with *H.sosnowskyi* cover reduced to 4 points. Soil milling in combination with ploughing 20–22 cm deep after a month interval and following sharing-ploughing reduced *H.sosnowskyi* cover to 1 point, so the field was practically free from hogweed. However this method was costly.

Conclusions

Successful restriction of *H. sosnowskyi* should be based on biological and ecological habits. In open areas, the best results were achieved by herbicidal methods with twofold application of glyphosate herbicides and use of tribenuron-methyl herbicide in early stages of plant growth.

In protected areas, mulching with black plastic film and cutting of adult plants in full flower stage could be used but these methods were time-consuming and costly.

Areas free from hogweed must be returned to natural plant societies or to agricultural use for crop production.

References

1. Bērziņš A. u.c. (2002) Latvāņu izplatības ierobežošana Latvijā. Līguma Nr. 300402/S83 ar Zemkopības un Satiksmes ministrijām zinātniskā atskaite. – Jelgava, LLU, 98
2. Berzins A. *et al.* (2003) Study of Hogweed (*Heracleum)* Distribution and Possibilities of Restriction in Latvia. In: Proceedings of International Conference 'EcoBalt', Riga, Latvia, 83–85.
3. Bērziņš A. u.c. (2003) Latvānis *(Heracleum*) un tā izplatība Latvijā. Agronomijas Vēstis, Nr. 5, LLU, Jelgava, 86.–93.
4. Lapiņš D. u.c. (2002) Latvāņi, to izplatības ierobežošana. LLKC, LLU, Ozolnieki, 28.

IMPACT OF THE SOWING DEPTH AND TIME ON SUGAR BEET GERMINATION ON SOILS LOW IN HUMUS

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Abstract

Research objective – to assess the impact of sowing time and depth and their interaction on sugar beet germination on loamy, low in humus soils. The trials on sugar beet germination were carried out over 2000–2002 in the Plant breeding collections at Lithuanian University of Agriculture.

Soil on trial fields – carbonate shallow gracious *IDg8–k(LVg–p–w–ec).* Soil textural class is a medium heavy loam, pH_{KCl} – 6.8–7.2, humus content – 14–17 g kg^{-1}.

The obtained data indicated that on soils low in humus soil crust was formed in almost all cases and had a negative impact on germination of sugar beet seeds. The greatest impact was identified in variants of later sowing when at optimum sowing depth 50–67% of seeds germinated.

Sowing depth, sowing time and their interaction had statistically significant impact on sugar beet germination whereas sowing depth affected sugar beet germination by 66.1–84.2%. In terms of agronomy the highest beet field germination was obtained when sown early at 3 cm depth.

Key words: Sugar beet, germination, sowing depth, variance analysis, regression analysis

Introduction

There also is a relationship between seed germination and seed quality, and method and time of sowing. The most complicated situation occurs when sugar beets are grown on soils low in humus and of heavy textural class. In spring even after slight rain strong and almost not permeable to air crust is formed what results in low germination.

There is evidence to suggest that sugar beet yield and crop quality are in close relationship with crop density and uniformity parameters. Plant scientists in Lithuania and neighbouring countries speculate that the highest sugar beet yields are obtained when crop density at the time of harvesting makes 70–90 thou ha^{-1} of plants (3, 6, 8, 10, 12, 14). The optimum amount of sugar in roots in most cases is obtained when average root weight is 650–900 g (3, 5, 14). However, it is very hard to form sugar beet crop exhibiting the set parameters on a concrete field. There is a direct relationship among seed ratio, field germination and crop thinning during the vegetation period. Seed quality parameters, sowing methods and time, physical and agrochemical soil characteristics have been shown to affect seed germination (1, 2, 6, 7, 13, 11). From the sowing methods sowing depth has the greatest impact on sugar beet germination (12, 14). The methods of soil preparation for sowing (6, 8, 12), moisture and temperature regimes (3, 14), application of growth stimulators and other factors also contribute to seed germination. Thus, in order to develop mathematic modelling system of productive sugar beet crop density detailed multi-factorial trials were started at LUA.

Materials and Methods

The trials on sugar beet germination were carried out over the period 2000–2002 in plant breeding collections at Lithuanian University of Agriculture.

Soil on trial fields are carbonate shallow gracious IDg8 – k(LVg-p-w-ec). Soil textural class is medium heavy loam, pH_{KCl} 6.8–7.2, humus content 1.4–1.7%, phosphorus content 142–157 mg kg^{-1}, potassium content 117–39 mg kg^{-1} of soil.

Meteorological conditions. Data obtained from Kaunas meteorological station were used.

The weather in April 2000 was by 5.7 °C warmer and amount of precipitation made 55% of the long-term averages. The weather in May was warmer than the norm. The amount of precipitation made 76% of the norm. The conditions for sugar beet germination were mean due to lack of moisture especially when sowing was done later.

In April 2001 the amount of precipitation was also lower and the weather was warmer. However, the moisture resources in soil were higher than in 2000. In May the weather was warmer and rainier if compared with long-term averages.

The spring in 2002 was earlier, the weather was warm, and moisture resources in soil after the rainy summer and autumn of 2001 were high. The conditions for sugar beet germination were optimum.

Trial scheme. Four sugar beet sowing dates (10 April, 20 April, 30 April, 10) and seven sowing depths (0; 1; 2; 3; 4; 5; 6 cm) were compared in the trails. The trial included 28 variants. To increase the statistic reliability of trial data 10 replications were made.

The plot size was 4 m^2. 50 seeds were hand-sown on a small trial field. Field germination in all variants and all investigation years was computed 4 weeks after sowing.

Research methods. To analyze research results the investigation methods of stochastic relationships – methods of disperssive – regressive analysis were employed. Equality of variable variances was checked by ANOVA/MANOVA module using the criterion constructed by the American statistician Harvard Levene. This criterion has been chosen due to not so high sensitivity to the disturbance of the normality assumption. To compute the parameters b0, b1, b2 of the chosen module Quasi-Newton method was used (4, 9).

Results and Discussion

Estimation of data from plant breeding point of view. In accepted sugar beet growing technologies recommended sowing depth is 2 cm (3, 6, 12, 14). However, at such a depth frequently moisture content is not sufficient what results in seed germination decrease. The increase in sowing depth reduces field germination, as sugar beet seeds do not exhibit strong germination power (14). Our research data were in full agreement with these assumptions. In 2000 due to lack of moisture in soil, in treatments with sowing depth 1 and 2 cm, respectively 9.6–33.1 and 24.7–50.2% of seeds germinated. When sown at 3 cm depth sugar beet seed germination ranged from 40.8 to 53.6% (Table 1).

Table 1. The impact of interaction between sowing depth and sowing time on mean germination of sugar beets

Sowing time	Sowing depth, cm	Average germination, %			Sowing time	Sowing depth, cm	Average germination, %		
		2000	2001	2002			2000	2001	2002
10 April	0	16.3	26.3	18.7	30 April	0	3.3	6.8	10.8
10 April	1	29.6	63.0	60.3	30 April	1	9.6	21.2	20.3
10 April	2	50.2	66.9	63.5	30 April	2	24.7	45.6	35.1
10 April	3	53.6	62.1	66.2	30 April	3	40.8	50.6	44.7
10 April	4	46.0	52.9	64.1	30 April	4	38.5	47.5	41.0
10 April	5	28.8	39.8	53.7	30 April	5	22.4	37.4	31.3
10 April	6	16.3	23.0	32.1	30 April	6	8.7	15.2	21.3
20 April	0	6.6	22.7	14.1	10 May	0	7.7	5.9	21.1
20 Apri	1	21.3	62.0	23.9	10 May	1	33.1	17.0	44.1
20 Apri	2	29.9	67.4	47.7	10 May	2	41.8	23.9	50.4
20 Apri	3	42.1	67.0	52.1	10 May	3	46.7	44.0	54.7
20 Apri	4	41.3	59.7	45.6	10 May	4	43.0	42.7	51.8
20 Apri	5	27.3	46.3	32.1	10 May	5	33.2	26.4	26.7
20 Apri	6	12.9	27.9	20.5	10 May	6	16.0	16.4	18.1

Whereas in 2001 trial sown on 10 April and 20 April sugar beet exhibited the most abundant germination in treatment with 2 cm sowing depth: 66.9 and 67.4%. Sown on 30 April and 10 May sugar beets exhibited higher germination in treatments with sowing depth 3 and 4 cm. It could be explained by the lack of moisture at the and of April and the first part of May.

In 2002 trial sugar beets exhibited the highest germination at 3 cm depth for all sowing times. With later sowing time (30 April and 10 May) the negative impact of soil moisture deficit on sugar beet germination was recorded. That is why in treatments with 1 and 2 cm sowing depth only 17.0–45.6% of seeds germinated.

In all research years, sowing at 4 cm depth resulted in 42.2–50.6% seed germination. Such germination parameters still satisfy the requirements of industrial workers (12, 15). However, further sowing depth increase resulted in substantial reduction of sugar beet germination and crop uniformity.

Statistic data estimation. It was determined that in all cases probability p to make a first variety mistake is less than chosen significance level $\alpha = 0.05$. Due to this there is no basis to reject the formed zero hypothesis about the equality of variable variance.

Table 2. Levene's test for Homogeneity of Variances

Index	Year 2000				Year 2001				Year 2002			
	04.10.	04.20.	04.30.	05.10.	04.10.	04.20.	04.30.	05.10.	04.10.	04.20.	04.30.	05.10.
F - test	1.487	1.707	2.108	1.734	2.200	1.871	1.268	1.966	2.213	1.778	2.153	2.185
P - level	0.197	0.134	0.065	0.128	0.054	0.100	0.285	0.084	0.053	0.118	0.059	0.056

Having checked the equality of variable variances two-factorial analysis was completed. The results obtained are presented in Table 3.

Table 3. Statistics of ANOVA two factor dependence on germination, depth and time of sugar beet sowing

Source of variation	Mean square	Degrees of freedom	F - ratio
		Year 2000	
Sowing depth	2456.966	6	71.9354
Sowing time	8040.933	3	235.4237
Interaction	171.013	18	5.0069
Error	34.155	252	x
		Year 2001	
Sowing depth	10399.400	6	269.6918
Sowing time	9766.410	3	253.2763
Interaction	665.510	18	17.2590
Error	38.560	252	x
		Year 2002	
Sowing depth	6312.771	6	114.8390
Sowing time	8401.812	3	152.8418
Interaction	396.266	18	7.2087
Error	54.971	252	x

It follows that formed zero hypothesis that sowing depth has no impact on sugar beet field germination has to be rejected, as probability $p<\alpha$ to make a first degree mistake shows, that computed F ratio values are higher than F with 6 and 252 degree of freedom $\alpha = 0.05$ critical level meaning ($F = 71.94$; $F = 269.69$; $F = 114.84$; $p = 0.00$). From this it follows that with probability $P=0.95$ over all investigation years the sowing depth had statistically significant impact on sugar beet germination.

The impact of interaction among sowing time ($F = 235.42$; $F = 253.28$; $F = 152.84$; $p=0.00$; *3* and *252* degrees of freedom), sowing depth and sowing time ($F = 5.01$; $F = 17.26$; $F = 7.21$; $p = 0.00$; 18 and 252 degrees of freedom) on sugar beet germination was statistically significant.

The substantial impact of chosen factors (sugar beet sowing depth and time) and their interaction was detected, however, we have to find the samples of the means that exhibit statistically significant differences. We have chosen one of *post hoc* criteria – Tukey HSD. This criterion is based on the statistics of studentized distance. Evaluating data obtained from the trials by means of this criterion it was determined that differences in sugar beet germination among different treatments of sowing depth and sowing time in most cases were statistically significant ($p<0.05$) in all investigation years. Even comparing the treatments of relatively optimum sowing depth (1, 2, 3 cm) the statistically significant differences were determined (Table 4).

Table 4. Statistically significant differences between sugar beet germination means in treatments with optimum sowing depth and sowing time

Year	Sowing depth, cm			
	10 April	20 April	30 April	10 May
2000	1-2; 1-3	1-3; 2-3	1-2; 1-3; 2-3	1-3
2001	x	x	1-2; 1-3	1-3; 2-3
2002	x	1-2; 1-3	1-2; 1-3	x

Having loaded on a computer quantitative trial data for each year – 280 independent (sowing depth) and 280 dependent (seed germination) variables and analyzed variance diagrams on the relationships between sugar beet field germination and sowing depth to describe estimation function second degree parabola regression model was chosen (Table 5).

Table 5. Statistics of regression analysis of relationship between germination and sowing depth of sugar beets

Sowing time	η^2 Variance explained, %	η Index of correlation	$H_o : b_i = 0$ Coeffi-cients	t – test	Regression model $\hat{y}_x = b_0 + b_1 x + b_2 x^2$
Year 2000					
10 April	75.6	0.86936	b_1	13.710	$\hat{y}_x = 14.78 + 24.08x - 4.05x^2$
			b_2	14.393	
20 April	81.1	0.90076	b_1	16.969	$\hat{y}_x = 4.45 + 21.83x - 3.39x^2$
			b_2	16.440	
30 April	80.6	0.89790	b_1	16.685	$\hat{y}_x = -2.24 + 22.90x - 3.49x^2$
			b_2	15.861	
10 May	84.2	0.91769	b_1	18.719	$\hat{y}_x = 9.62 + 23.99x - 3.84x^2$
			b_2	18.721	
Year 2001					
10 April	81.7	0.90373	b_1	14.202	$\hat{y}_x = 33.74 + 23.30x - 4.30x^2$
			b_2	16.375	
20 April	82.9	0.91054	b_1	16.719	$\hat{y}_x = 29.36 + 27.47x - 4.72x^2$
			b_2	19.934	
30 April	81.8	0.90448	b_1	17.357	$\hat{y}_x = 3.54 + 28.68x - 4.43x^2$
			b_2	16.727	
10 May	68.3	0.82660	b_1	11.898	$\hat{y}_x = 2.05 + 21.35x - 3.15x^2$
			b_2	10.952	
Year 2002					
10 April	79.3	0.89062	b_1	15.826	$\hat{y}_x = 24.84 + 29.10x - 4.69x^2$
			b_2	15.914	
20 April	66.1	0.81286	b_1	11.367	$\hat{y}_x = 11.36 + 27.72x - 3.75x^2$
			b_2	11.235	
30 April	73.7	0.85874	b_1	13.629	$\hat{y}_x = 8.17 + 19.74x - 2.94x^2$
			b_2	12.660	
10 May	76.4	0.87382	b_1	12.906	$\hat{y}_x = 23.06 + 22.01x - 3.92x^2$
			b_2	14.357	

It appears from the computation data presented in Table 5 that with probability of $P = 0.95$ there is strong and statistically significant curvature dependence ($0.81286 \leq \eta \leq 0.91769$) between sugar beet field germination and sowing depth, sowing depth predetermined the sugar beet germination by 74.5–89.7%. The analyzed factor exhibited the greatest impact in 2001 in the fourth sowing, the least – in 2002 in the second sowing.

The obtained dependences can be statistically significantly (Student criterion t and $p<0.05$) described by the second degree parabola equations, which show that sugar beet germination increases when increases sowing depth up to 3 cm, after this the mentioned factor has negative effect, i.e., when sowing depth increases the germination decreases (Fig. 1).

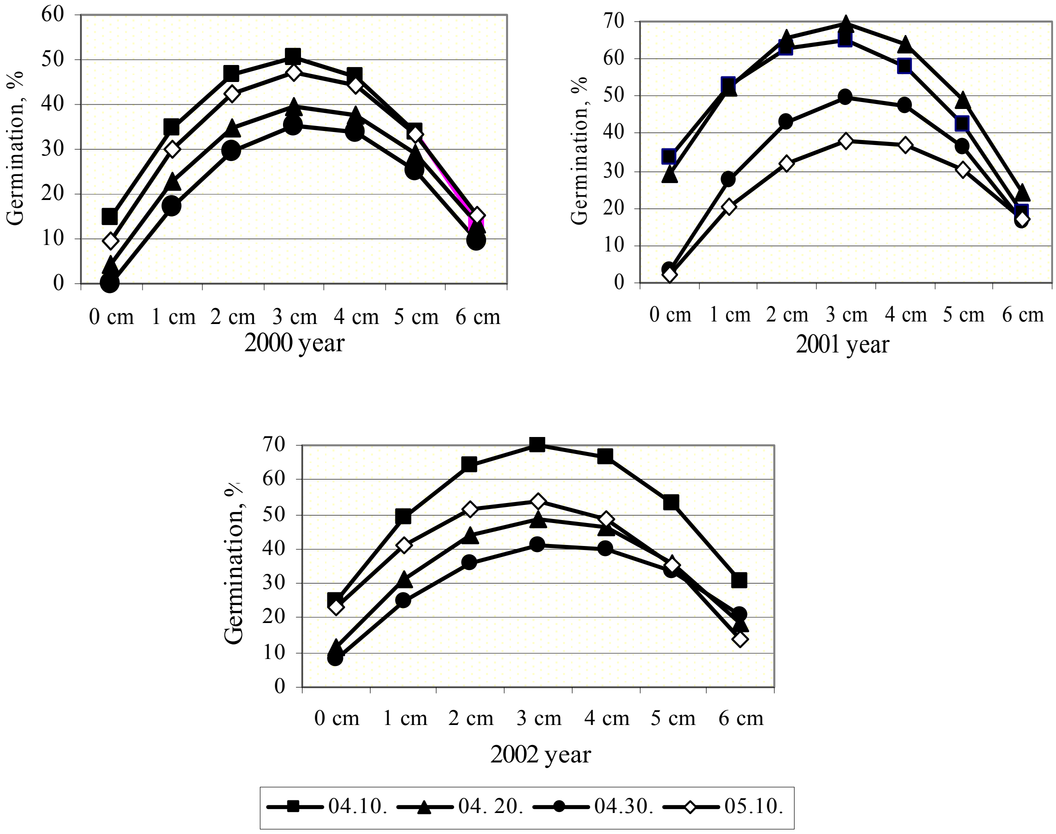

Figure 1. Predicted germination of sugar beet

Conclusions

During trials the weather in April and May was warmer and drier than the long-term averages. Under such conditions sugar beets exhibited higher germination in treatments with sowing depth 3 and 4 cm (45.8–55.9 and 42.2–50.7%) than in treatments with sowing depth 1 and 2 cm.

In all trials sugar beets exhibited the best germination in the first sowing time treatment. The following sowing times resulted in substantial reduction of field germination. In late sowing treatments the positive impact of 3–4 cm sowing depth on seed field germination was recorded if compared with 1–2 sowing depth treatments.

Levene criterion indicates that variable variances of trials are equal, and in further analysis ANOVA model may be applied. F ratio computed applying this model with probability of $P = 0.95$ allows it to state that sowing depth, sowing time and interaction of these two factors had statistically significant impact on sugar beet field germination.

Statistically significant (Student criterion t and $\alpha<0.05$) dependence of sugar beet field germination is well described by means of second degree parabola, indicating that field germination of sugar beet increased with the increase of sowing depth up to 3 cm. With further increase of sowing depth the germination decreased.

References

1. Arlauskas M., Naudžiūnas K. (1994) Kaip atpiginti žemės paruošimą cukriniams runkeliams. Rekomendacijos augalininkystei intensyvinti. Dotnuva. Akademija, 18–20.
2. Arlauskas M. (1998) Cukriniai runkeliai: kaip atpiginti jų auginimą. Augalininkystės ir bitininkystės dabartis ir ateitis. Mokslinių straipsnių rinkinys. Kaunas. Akademija, 37–42.
3. Armstrong M.J. (1997) The structure of UD beet sugar research and development. 60e Congr., Cambridge, 1 Juill., Inst. int. rech. betteravieres. Bruxelles, 9–18.
4. Čekanavičius V., Murauskas E. (2002) Statistika ir jos taikymai (2). Vilnius: TEV, 238.
5. Jakienė E., Mickevičius V., *at al* (2001) Augimo stimuliatorių – stilitų fiziologinio aktyvumo bei poveikio cukrinių runkelių produktyvumui tyrimai. Žemdirbystė: Mokslo darbai. LŽI, LŽŪU. Akademija, 75, 65–72.
6. Romaneckas K., Žulienė R., *at al* (2001) Priešsėjinio dirvos purenimo būdų įtaka fizikinėms dirvos savybėms ir cukrinių runkelių sėklų sudygimai. Žemdirbystė: Mokslo darbai LŽI, LŽŪU. Akademija, 73, 147–158.

7. Šarauskis E., Meironaitė D., *at al* (2001) Cukrinių runkelių sėjos energetiniai tyrimai. Jaunimas siekia pažangos. LŽŪU doktorantų mokslinės konferencijos straipsnių rinkinys. Kaunas, 192–195.
8. Žulienė R., Romaneckas K. (2001) Dirvos volavimo galimybė auginant cukrinius runkelius. Šiuolaikinės augalininkystės technologijos. Mokslinių straipsnių rinkinys. LŽŪU, 111–115.
9. Боровиков В. (2001). Искусство анализа данных на компьютере. STATISTICA. Санкт-Петербург: ПИТЕР, 650.
10. Вундерлих К. Х. (1998) Формируя густоту посева. Сахарная свекла, 5, 22–23.
11. Коломиец А. П. (1984) Приемы повышения полевой всхожести. Сахарная свекла, 2, 13–14.
12. Коломиец А. П. (1990) Правильно выбрать способ предпосевной подготовки почвы. Сахарная свекла, 2, 25.
13. Цаан Г., Фехлер П. (1979) Результаты определения влияния заделки семян на посевную всхожесть семян сахарной свеклы при посеве сеялкой точного высева. Перевод с немецкого: Г. Минчин. – Харьков, 1–10
14. Шпаар Д., Дрегер Д., и. др. (2000) Сахарная свекла. Минск: ФУАинформ, 264.

THE INFLUENCE OF REDUCED PRIMARY SOIL TILLAGE ON SOIL PHYSICAL PROPERTIES, WEED INFESTATION, SUGAR BEET YIELD AND QUALITY

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Abstract

Over the period of 2002–2004 at the Experimental Station of Lithuanian University of Agriculture the possibility to reduce primary soil tillage in the crop of sugar beet was investigated. The aim of the field trial was to investigate the influence of reduced primary soil tillage on physical soil properties, sugar beet yield, roots quality and infestation of weeds. The treatments of primary soil tillage were as follows. 1. Deep (25 cm) ploughing with moldboard plough (DP). 2. Shallow (12–15 cm) ploughing with moldboard plough (SP). 3. Deep (25–30 cm) tillage with chisel cultivator (DC). 4. Shallow (10–12 cm) tillage with disc harrow (SC). 5. No-tilled soil (NT). The reduction of soil tillage intensity had no significant influence on soil bulk density. In top layers of soil the highest amount of moisture was observed in no ploughed or tilled soils. Alternative soil tillage with chisel cultivator or disc harrow had no significant influence on sugar beet yield and quality of roots in comparison with inversion soil tillage. Germination of sugar beet seeds was poor in no tilled soil. That negatively influenced the yield and quality of sugar beet. The highest amount of annual weeds was identified in no-tilled (NT) plots.

Key words: sugar beet, reduced tillage, yield and quality, weed infestation

Introduction

Refusal of intensive soil tillage increases labor efficiency, reduces costs, and improves soil fertility and balance of soil water, nutrients and organic matter (Riley *et al.*, 1998). Application of reduced soil tillage and refusal of deep soil ploughing in autumn are possible in cultivated soils (Arlauskas, 1993; Stancevicius *et al.*, 1990; Velykis *et al.*, 1996). At decreasing volumes of soil tillage works physical properties of the soil are constantly improving, although this is observed only after 4–5 years of this soil tillage system application (Håkanson, 1993). According to the data of the experiments carried out in Norway change of the depth of ploughing to a more shallow has no significant influence on soil and crop yield in the first 7–8 years (Märländer, 1989). After application of reduced method of the main soil tillage soil in spring contains more moisture than in the case of intensive tillage (Cannel, Hawes, 1994). Data of the experiments in Australia tells that the biggest amount of moisture in soil is determined in the case of zero soil tillage system, the smallest one – in the ploughed soils (Brown *et al.*, 1998). Experiments, which were carried out in Nebraska in 1982, aimed to compare physical properties of soil in the case of mould-board ploughing, deep loosening and zero soil tillage application. After zero soil tillage application not only the biggest soil bulk density but also bigger moisture content was determined (Mielke, Wilhelm, 1998). According to the data of Taboada M. A. the comparison of intensive and zero soil tillage shows that after 4 years of investigations the zero soil tillage has no significant influence on soil bulk density and solidity (Taboada *et al.*, 1998).

When reduced soil tillage is applied weeds are spreading. According to the data obtained by Swedish scientists the reduction of ploughing depth to 12 cm is harmful in the year when perennial weeds spread and minimal norm of nitrogen fertilizers are applied (Boström, 1999).

The influence of the main soil tillage on physical properties of soil, productivity of sugar beets and production quality under sufficiently humid climatic conditions in Lithuania has not been comprehensively investigated. Therefore our investigations were aimed to determine the influence of the intensity of soil tillage on soil bulk density and humidity, and productivity and quality of sugar beet root crops. The hypothesis states that decreasing intensity of soil tillage has no important influence on physical properties of soil, germination of sugar beet seeds, crop formation, productivity and quality of root crops, although number of weeds in the crop may increase.

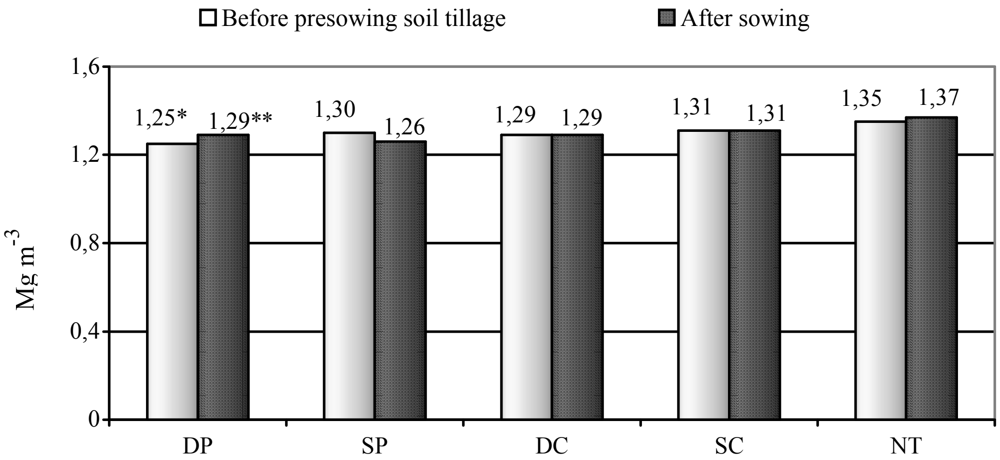
Materials and Methods

The trial was carried out on the light loam soil in the Experimental station of Lithuanian University of Agriculture in 2002–2004. The soil reaction was slightly alkaline with a lot of phosphorus and some potassium. The field experiment was established according to the following scheme: 1. Deep (25 cm) ploughing with moldboard plough (DP). 2. Shallow (12–15 cm) ploughing with moldboard plough (SP). 3. Deep (25–30 cm) cultivation with chisel cultivator (DC). 4. Shallow (10–12 cm) cultivation with disc harrow (SC). 5. No-tilled soil (NT).

The sugar beet varieties 'Anna', 'Juvena', and 'Millenium' were grown. The paper describes the average data of various varieties. There were 4 replications of the test. The initial size of the test plots was 117 m^2, but the estimated plot size was 84 m^2. The location of the plots was randomized. The sugar beet seeds were sown with 45 cm spaces between rows, and with 14.5 cm distances between seeds. The pre-sowing soil tillage was made with compound cultivator. The predecessor of the sugar beets was winter wheat. The crops were fertilized with N_{60+60} P_{80} K_{160}. Stubble of winter wheat was treated with universal herbicides before wintering. Soil bulk density and moisture content were determined before and after soil tillage with the cylindrical method of Nekrasov. Weeds infestation was evaluated by the counting of weeds in 10 different places of plots. The obtained test data were statistically evaluated with ANOVA (LSD_{05}).

Results and Discussions

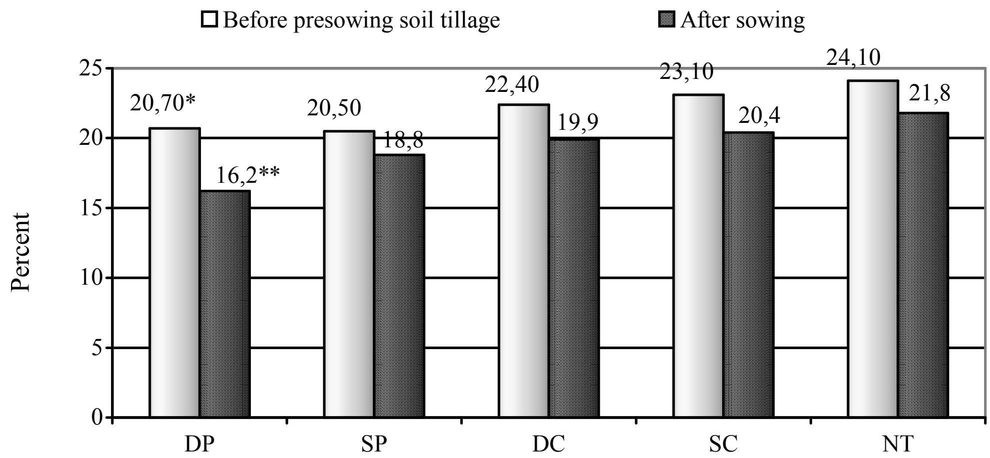
Bulk density and moisture content of soil at 0–10 cm depth. Before soil tillage in spring the bulk density of the soil that had been differently tilled in autumn varied at the depth of 0–10 cm from 1.25 to 1.31 Mg m^{-3}. Bulk density of stubbly soil was somewhat higher (1.35 Mg m^{-3}). No significant difference between treatments was observed. Significantly higher moisture content was determined in un-ploughed soils, while the highest one – 24.1% – in non-tilled soils.



* LSD_{05} = 0.11; * * LSD_{05} = 0.09.

Figure 1. Soil bulk density at 0–10 cm depth

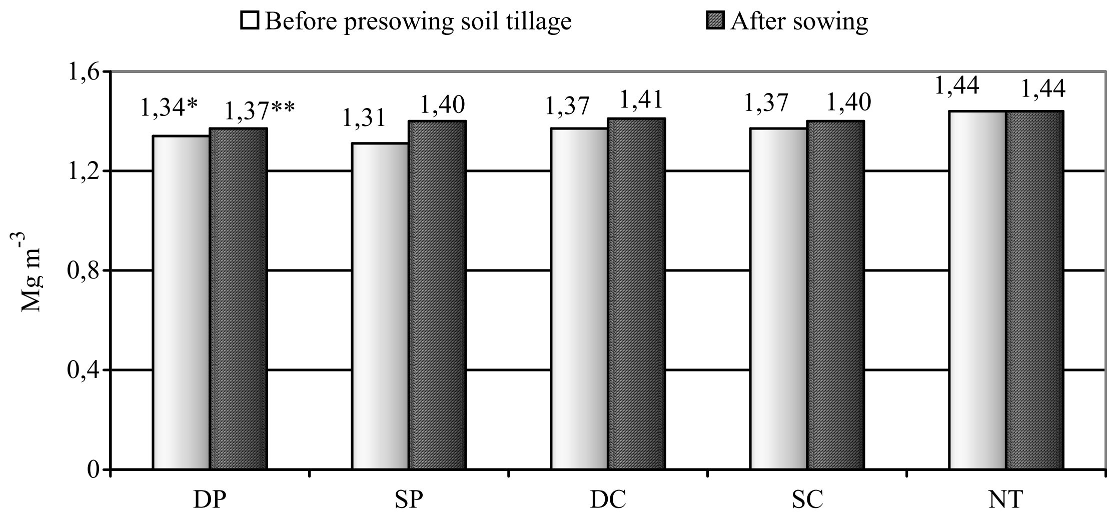
The soil that had been deeply ploughed in autumn was denser after pre-sowing soil tillage and sowing. Bulk density of the soil that had been tilled in other ways did not increase significantly. Deeply ploughed soil dried more rapidly after sowing and in the period of seed swelling it contained 16.2% of moisture. Moisture content of 20–22% in the seedbed provides the most favorable conditions for germination of dressed sugar beet seeds. However, in our experiment soil moisture had no significant influence on seed germination.



* LSD_{05} = 2.4; ** LSD_{05} = 1.8.

Figure 2. Soil moisture content at 0–10 cm depth

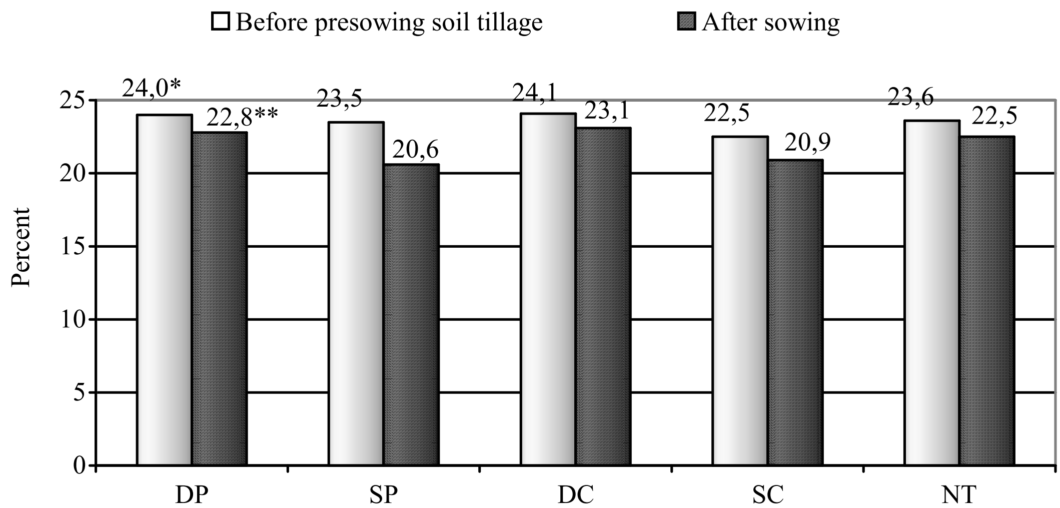
Bulk density and moisture content of soil at 10–20 cm depth. Before pre-sowing soil tillage in spring soil bulk density at the depth of 10–20 cm was higher than in the topsoil layer. However, differences between treatments were not great and ranged from 1.31 to 1.37 Mg m^{-3}. The density of non-tilled stubble was slightly higher, although the difference was not significant. Under the influence of different soil tillage treatments the conditions of soil humidity did not differ significantly.



* LSD_{05} = 0.12; ** LSD_{05} = 0.07.

Figure 3. Soil bulk density at 10–20 cm depth

After sugar beet sowing the bulk density of deeper soil layers increased more than that of surface layers with exception of non-tilled stubble, where the soil bulk density did not change. After sowing the drying of deeper soil layers was slower than that of the surface layers. The highest moisture content was determined in the soil that had been chiseled in autumn.



* LSD_{05} = 2,7; ** LSD_{05} = 2.1.

Figure 4. Soil moisture at 10–20 cm depth

Seed germination and plant growth. Germination of sugar beet seeds in cultivated soil was similar despite different soil moisture conditions in the period of germination. Germination of sugar beet seeds that had been directly sown into stubble was poor as thick layer of straw at the soil surface blocked introduction of seeds during sowing. Some of the seeds remained not introduced. Poor germination of seeds had negative influence on crop formation.

Table 1. Parameters of sugar beets germination and growth

Treatment	Seeds field germination, %	Crop density before harvesting, t ha^{-1}	Yield of roots, t ha^{-1}	Yield of white sugar, t ha^{-1}
DP	50.6	84.3	47.9	6.31
SP	50.7	78.5	46.2	6.30
DC	50.6	81.1	49.2	6.53
SC	52.8	88.2	47.5	6.63
NT	28.5	58.4	41.0	5.19
LSD_{05}	9.7	24.4	10.9	0.82

The sugar beet that had been sown into stubble produced similar yield of root crop irrespective of the crop density. Productivity of root crops was in the range of 41.0–49.2 t ha^{-1} and did not differ significantly. Different methods of soil tillage had no significant influence on the yield of white sugar. Losses of the yield of white sugar were determined only in the treatment of direct sowing.

The quality of sugar beet roots. Neither soil tillage intensity nor depth had important influence on the root crop quality. The sugar beet that had been sown directly into stubble had more ramify root crops and lower saccharine level. The differences were insignificant.

Table 2. Sugar beet roots quality

Treatment	Roots ramify, %	Sucrose content, %	Soluble ash, %	Sugar output, %
DP	10.0	17.2	0.90	13.22
SP	11.5	17.4	0.83	13.64
DC	12.4	17.4	0.87	13.27
SC	11.3	17.8	0.79	13.99
NT	15.8	17.0	0.86	12.67
LSD_{05}	6.4	1.4	0.12	0.90

Higher sugar output was determined in the sugar beet after shallow ploughing or shallow disk-cultivation if compared with that of the sugar beets that had been directly sown into stubble. The difference was not significant.

Weed infestation. Deep soil ploughing was not the most effective method of weed killing. It was slightly advantageous in the control of perennial weeds spreading, while the intensity of annual weeds spreading was similar to that in the soil tilled in other ways.

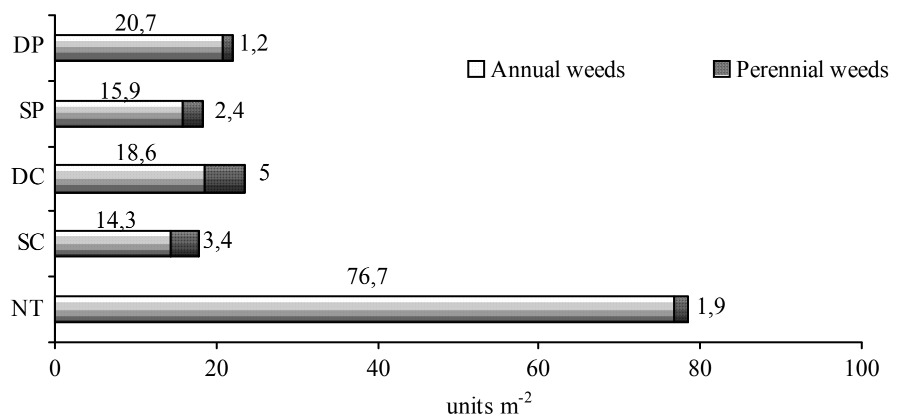


Figure 5. Weed infestation

In non-tilled stubble perennial weeds did not spread due to their intensive control in winter wheat crop and stubble that had existed before sugar beets. This agrees with scientific statements that combination of minimal soil tillage methods and application of herbicides cause lower weed infestation than deep ploughing and avoiding use of herbicides (Stancevicius, Raudonius, 1990). Nevertheless, spreading of short-lived weeds several times exceeded weed infestation in tilled soil.

Conclusions

Reduction of soil tillage intensity had no significant influence on soil bulk density. The highest soil bulk density increase was determined in topsoil layer of the soil that had been ploughed in autumn and became close to that of non-tilled stubble.

At the decreasing soil tillage intensity the soil humidity in the surface layer proportionally increased. This dependency was not revealed in deeper soil layers.

Sugar beets had similar seed germination in field, crop density, indices of root crop productivity and quality irrespective of the method of soil tillage. The sugar beets that had been sown directly into stubble had poor germination, formed thin crop, which had a negative influence on root crop productivity and sugar output.

Spreading of short-lived weeds in stubble soil several times exceeded weed infestation in the soils that had been tilled in autumn. The number of short-lived weeds was similar in differently tilled soils. The lowest number of perennial weeds was determined in soil of deep ploughing and zero tillage.

References

1. Arlauskas M. (1993) The influence of different tillage systems on soil properties and crop yield. Soil Tillage and Envinonment, 88, 289–294.
2. Boström U. (1999) Type and time of autumn tillage with and without herbicides at reduced rates in southern Sweden 1. Yields and weed control. Soil and Tillage Research, 50, 271–281.
3. Brown R. E. *et al.* (1998) Crop production and soil water storage in long – term winter wheat-fallow tillage experiments. Soil and Tillage Research, 49, 19–27.
4. Cannel R. Q., Hawes J. D. (1994) Trends in tillage practices in relation to sustainable crop production with special reference to temperate climates. Soil and Tillage Research, 30, 245–282.
5. Håkansson I. Impact of machinery induced soil compaction on environmental effects of agriculture (1993) Soil Tillage and Environment, 88, 369–370.
6. Märländer B. (1989) Bestandesdichte in vereizelungslosen Zuckerrübenbau. Zuckerrübe, 2, 106–110.
7. Mielke L. N., Wilhelm W. W. (1998) Comparisons of soil physical characteristics in long-term tillage winter wheat-fallow tillage experiments. Soil and Tillage Research, 49, 29–35.
8. Riley H. *et al.* (1998) Long term field experiments with reduced tillage in Norway. Soil and Tillage Research, 124, 15–25.
9. Stancevicius A., Raudonius S. (1990) Pagrindinio žemės dirbimo minimalizavimas ir armens užteršimas piktžolių pradais. LŽUA mokslo darbai, 36, 28–31.
10. Stancevicius A. *et al.* (1990) Pagrindinio žemės dirbimo minimalizavimas ir pasėlių piktžolėtumas. LŽUA mokslo darbai, 36, 43–49.
11. Taboada M. A. *et al.* (1998) Comparision of compaction induced by conventional and zero tillage in two soils of Rolling Pampa of Argentina. Soil and Tillage Research, 49, 57–63.
12. Velykis A. *et al.* (1996) Gilaus purenimo ir priešsėjinio dirbimo būdai sunkaus priemolio dirvoje. Žemdirbystė, 51, 53–69.
13. Крумов Крум И., Райков С. (1992) Влияние на нивото но почвената влажност и обработка върху дружното поникване и началното развитие на захарното цвекло. Растениеьдство науки, 1–2, 28–32.

YIELD OF WINTER WHEAT DEPENDING ON SOIL TILLAGE – SOWING TECHNOLOGIES AFTER DIFFERENT PREVIOUS CROPS

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Abstract

Reduction of soil tillage in cereals becomes more significant recently in Latvia and Baltic countries (Lauringson *et al.*, 2000; Stancevicius *et al.*, 1999). Many new minimum tillage and no-till machines are available to Latvian farmers. Real efficiency and economical aspects to compare these technologies against traditional ploughing are very important.

The research on soil tillage – sowing technologies in winter wheat was done on heavy clay soils in Dobele region of Latvia. Three-year trials were established after two different previous crops – winter wheat and winter rape (factor A). Three different soil tillage – sowing technologies were compared. Traditional tillage with soil ploughing and cultivation was compared to minimum soil surface tillage using Simba Discs 34C 4.6 + Simba double press 4.6 and no-till sowing with direct drilling (factor B). Vaderstad Rapid 600P seed drill was used for all experiments. Impact of weed infestation was investigated comparing herbicide Secator 0.3 kg ha^{-1} application and no-herbicide treatment (factor C).

Meteorological conditions were different in all trial years with great deflection from long-term averages causing great differences in results between three trial years with different impact of various factors.

Data shows that herbicide application had a main impact on winter wheat grain yield. It gave significant higher yields in treatments with minimal soil tillage and especially sowing winter wheat after winter rape. Traditional soil tillage had advantages in years with great amount of precipitation (growing season 2000–2001 and especially 2001–2002) but under dry conditions (autumn 2002) significant higher yield was obtained with direct sowing.

Key words: winter wheat, soil tillage, previous crop, herbicide use

Introduction

Tendency of using reduced soil tillage technologies becomes more important and popular in Latvia and in EU countries (Romaneckas, 1999; Satkus, 2000; Simanskaite, 2000). It is mainly caused by more economical use of production sources in agriculture. Many new agricultural machines, which are designed for minimum soil tillage and no-till are offered by agricultural machinery producers. Wide experiments regarding these methods were done in EU countries in the period 1970–1988 when many different soil cultivation and tillage methods on various crops were compared (Cannel *et al.*, 1980; Drew and Saker, 1980; Finney and Knight, 1973; Hodson, 1977). Presently main part of engineering of agricultural machinery and recommendations for their use are based on these results.

Research and experiments of different technological solutions for soil tillage systems and their impact on productivity of different crops are conducted in many places of Latvia. Research on soil tillage systems in winter wheat production after different previous crops combined with efficiency of herbicide use was not done previously in Latvia. Also efficiency of agricultural machinery used for these experiments such as Simba Discs 34C 4.6 + Simba double press 4.6 were not compared under conditions of Latvia, particularly on heavy clay soils.

The target of scientific work was to clarify benefits or shortcomings of minimal soil tillage and no-till against traditional soil ploughing with stubble reversion as well as to find differences in impact of these technologies on soil parameters, weed infestation in winter wheat sown after winter rape and continued wheat crop rotations. The results could give the possibility of finding optimal way of using these technologies and working out recommendations for practical use.

Materials and Methods

The three-year experiments (2001–2003) were conducted at farm Dobele Agra SIA located in Dobele region of Latvia. The soil at the site is heavy clay. Trials were established in two different crop rotations (Factor A): 1. Winter wheat was sown after winter wheat. 2. Winter wheat sown after winter rape. Three different soil tillage and sowing methods were compared. (Factor B): 1. – minimal conservation soil tillage at the depth of 10–15 cm with mixing of soil, 2. – direct sowing into stubble without soil cultivation before, and 3. – traditional soil tillage with ploughing 25 cm deep with cultivation prior to sowing. Additionally impact of these soil tillage methods on weed infestation in winter wheat was studied. (Factor C): 1. – use of the herbicide Secator 0.3 kg ha^{-1}, 2. – untreated with herbicides.

Winter wheat variety 'Zentos' was sown on 25 September 2000, 29 September 2001 and on 30 September 2002 with a seed drill Vaderstad Rapid 600P. Soil ploughing was done with 6 furrow conventional plough Kwerneland, cultivation was done with equipment Vaderstad Rexius. Minimal soil tillage was performed with heavy disc harrows Simba Discs 34C 4.6 in combination with press Simba double press 4.6. Herbicide Secator at the rate of 0.3 kg ha^{-1} was used during tillering stage of winter wheat. Yield was harvested with Claas combine harvester.

There were variable weather conditions with large fluctuations from long time averages during experiments. That caused large differences in results between experimental years with different impact on various factors.

Autumn 2000 was long and warm with significant amount of precipitations. These conditions were favourable for active growth and development of crops and weeds. In treatment with winter wheat sown after winter rape using minimal soil tillage and direct sowing, there was observed high level of infestation with wintering weeds like *Matricaria perforata* Merat. These conditions effected growth and development of winter wheat because of high weed competitiveness. In spring, these weeds were already big in size and herbicide use efficiency was low. Also high amount of precipitation during June and July of 2001 (115 un 118 mm, SIA Dobele Agra weather station data) contributed to active growth of weeds thus having effect on winter wheat yield.

The second-year trials were established under high soil moisture, caused by high amount of precipitation during summer 2001 (309 mm, SIA Dobele Agra weather station data). These conditions were not favourable for soil tillage works as compare to previous year. Growth and development of winter wheat were different compare to previous year.

Spring 2002 was favourable for growth and development of winter wheat, but summer months were sunny and very dry (rainfall 37 mm in June, 30 mm in July, 0 mm in August) (Dobele Agra weather station data). Under such conditions of growth the herbicide use efficiency was high in treatments with traditional soil cultivation with ploughing.

The third-year experiments were established under very dry soil conditions caused by dry summer 2002. The drought period lasted for 60 days. Under such conditions direct sowing was difficult. Cold winter with great fluctuations in temperatures negatively effected winter hardiness of winter wheat. High temperatures in July and heavy rainfalls in August effected harvesting. These entire variables whether conditions gave us wide experience in using different soil tillage methods under different weather and soil conditions.

Three-factor ANOVA were used for data analysis.

Results and Discussion

Results obtained in 1st experimental year. In the 1st experimental averages of winter wheat yields ranged from 3.23–5.09 t ha^{-1} (Table 1). Significantly highest yield of winter wheat was obtained in treatment with 2nd wheat compare to winter wheat sown after winter rape (factor A). The use of herbicides (factor C) gave significant yield increase in both previous crop situations. Results of the use of different soil tillage methods showed significant differences between all treatments with 2nd wheat and herbicide used (factors A1, C1). The highest yield 5.09 t ha^{-1} was attained in treatment with minimal soil tillage, which was significantly higher compare to other treatments. Otherwise, without herbicide use, significantly highest yield was obtained in treatment with traditional soil tillage (3.70 t ha^{-1}). Differences between treatments with minimal tillage and direct sowing were not significant (A1, B1, C2 and A1, B2, C2).

Results were different in cases with using herbicide on 1st wheat – wheat sown after winter rape. The highest yield 4.96 t ha^{-1} was received in treatment with traditional soil tillage and differences with other treatments (B1, B2) were significant. Yield in treatment with direct sowing was significantly lower compare to minimal tillage.

In the same trials with the 1st winter wheat grown without herbicide use (A2, C2), again the best results were achieved in treatment with traditional soil tillage – 3.37 t ha^{-1}, but there were not observed significant differences in yields of winter wheat.

After first experimental year better results were obtained with 2nd wheat when sown using minimal tillage compare to 1st wheat. It could be explained by the high amount of volunteer rape plants occurring in 1st winter wheat crop.

Table 1. The yield of winter wheat depending on soil tillage and weed control technologies in the year 2001

Previous crop (A)	Soil tillage, sowing (B)	Weed control (C) with herbicide (C1)	Weed control (C) without herbicide (C2)	Average, A $\gamma^{A}_{0.05} = 0.177$	Average, B $\gamma^{B}_{0.05} = 0.217$
Winter wheat (A1)	Minimal tillage (B1)	5.09	3.38		4.11
	Direct drilling (B2)	4.23	3.41		3.80
	Traditional tillage with ploughing (B3)	4.84	4.32		4.37
	Average, A1	4.72	3.70	4.21	x
Winter rape (A2)	Minimal tillage (B1)	4.65	3.33		
	Direct drilling (B2)	4.32	3.23		
	Traditional tillage with ploughing (B3)	4.96	3.37		x
	Average, A2	4.64	3.31	3.98	
Average C; $\gamma^{C}_{0.05} = 0.177$		4.68	3.51	x	
$\gamma_{0.05} = 0.434$ (to separate differences)					

Favourable weather conditions in autumn contributed to the growth of weeds and volunteers. They grew in size and got strength resulting in less herbicide use efficiency in these treatments causing yield reduction by weed and volunteers competition.

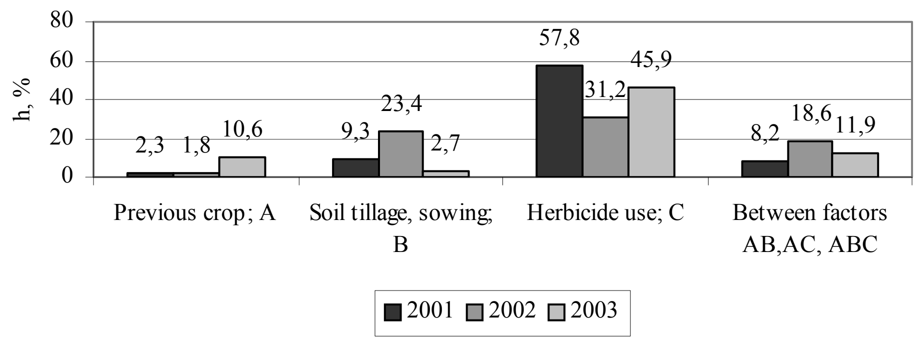

Figure 1. Impact of different factors on winter wheat yield in 2001–2003

Among different factors having influence on the yield of winter wheat (Fig. 1), in the 1st experimental year the highest impact was achieved by herbicide use – 57.8%, 9.3% by soil tillage, and 2.3% by previous crop.

Results obtained in 2nd experimental year. Much higher yields were obtained in the 2nd experimental year being in the range of 3.76–7.53 t ha^{-1} (Table 2). In this experimental year yields were significantly higher in 1st wheat trials (previous crop – winter rape). Beneficial effect of previous crop was exerted on the growth and development of winter wheat. The herbicides use gave significant yield improvement in both treatments with previous crops (A1, A2) showing the significant impact of weeds on yield of winter wheat.

Table 2. The yield of winter wheat depending on soil tillage and weed control technologies in 2002

Previous Crop (A)	Soil tillage, sowing (B)	Weed control (C) with herbicide (C1)	Weed control (C) without herbicide (C2)	Average, A $\gamma^{A}_{0.05} = 0.292$	Average, B $\gamma^{B}_{0.05} = 0.358$
Winter wheat (A1)	Minimal tillage (B1)	5.87	5.21	5.57	5.81
	Direct drilling (B2)	4.70	4.83		4.95
	Traditional tillage with ploughing (B3)	6.73	6.07		6.46
	Average, A1	5.77	5.37		x
Winter rape (A2)	Minimal tillage (B1)	7.41	4.76	5.91	x
	Direct drilling (B2)	6.50	3.76		
	Traditional tillage with ploughing (B3)	7.53	5.52		
	Average, A2	7.15	4.68		
Average C ; $\gamma^{C}_{0.05} = 0.292$		6.46	5.03	x	

$\gamma_{0.05} = 0.714$ (to separate differences)

In trials with 2nd wheat with herbicide use (treatments A1, C1), the highest yield was achieved in treatment with traditional tillage – 6.73 t ha^{-1}, which was significantly different from treatments with minimal tillage and direct sowing (factors B1, B2).

Direct sowing treatment showed s worse results compare to treatments with minimal tillage. Interesting results were obtained in direct sowed treatments in 2nd wheat with yield being greater without herbicide use (A1, B2, C2), however this difference was not significant. It means, that weeds had insignificant impact on yield formation.

The impact of soil tillage methods on the yield of 1st winter wheat in treatments with herbicide use (treatments A2, C1) was as follows: the highest yield was provided by traditional soil tillage being significantly higher than that obtained with direct sowing (B2). There were not observed significant differences between treatments B1 and B2. In the treatments with 1st wheat without herbicide use (treatments A2, C2) results were similar (Table 2) and differences between treatments were not significant.

In the second experimental year, like previous experimental years, the impact on yield formation was highest with herbicide use – 31.2%. Soil tillage method was affecting results by 23.4%, which was significantly higher than in the previous year (Fig. 1).

Results obtained in the 3rd experimental year. Yields obtained in the third experimental year were in the range of 3.76–5.80 t ha^{-1} (Table 3). If in previous experimental years significant impact on the yield of winter wheat was exerted by all three compared factors, then in the 3rd year the impact of soil tillage method (factor B) was insignificant.

Similarly, in the 2nd experimental year significantly highest yields were reached in treatments with 1st wheat. In both cases with previous crops (factor A), significantly higher yields were obtained in treatments with herbicide use.

In 2nd wheat trials with herbicide use (treatments A1, C1), highest yield was got in treatment with minimal soil tillage (B1 – 5.48 t ha^{-1}), the yield being significantly higher than that in treatments with direct sowing and traditional soil tillage (B2, B3). Significantly lowest yield was in case of traditional soil tillage. In treatments without herbicide use (variants C2) significant differences in yield of winter wheat was observed only between treatments B1 and B2. Significantly highest yield was obtained in treatments with direct sowing in both cases of crop rotation (factor A). The lowest yield was in treatments with minimal tillage (Table 3).

Table 3. The yield of winter wheat depending on soil tillage and weed control technologies in 2003

Previous Crop (A)	Soil tillage, sowing (B)	Weed control (C)		Average, A $\gamma^{A}_{0.05} = 0.267$	Average, B $\gamma^{B}_{0.05} = 0.327$
		with herbicide (C1)	without herbicide (C2)		
Winter wheat (A1)	Minimal tillage (B1)	5.48	3.76	4.35	4.63
	Direct drilling (B2)	4.65	4.03		4.78
	Traditional tillage with ploughing (B3)	4.33	3.83		4.44
	Average, A1	4.82	3.87		x
Winter rape (A2)	Minimal tillage (B1)	5.41	3.89	4.89	x
	Direct drilling (B2)	5.80	4.64		
	Traditional tillage with ploughing (B3)	5.64	4.15		
	Average, A2	5.56	4.23		
Average C ; $\gamma^{C}_{0.05} = 0.267$		5.19	4.05	x	
$\gamma_{0.05} = 0.653$ (to separate differences)					

According to monitoring in the growth period of crops better snow cover during period of frosts was recorded in treatment with direct sowing. That made better protection against crop winterkill and affected final results of this experimental year.

In the 3rd experimental year like previous ones, the greatest impact on the yield of winter wheat was exerted by factor C – herbicide use (45.9%). Significantly higher impact compare to previous years was also exerted by factor B – soil tillage methods (10.6%) (Fig. 1).

Results obtained in three experimental years. The averages of three experimental years show significantly highest yields of winter wheat grown in crop rotation after winter rape (1st wheat). Herbicide use in both cases of crop rotation gave significant yield increase compare to untreated case.

Trials with 2nd wheat (wheat after wheat in crop rotation) combined with herbicide use provided the highest yield in treatment with minimal soil tillage. The yield was significantly higher than that obtained in treatments with direct drilling and traditional soil tillage.

In 2nd wheat trials combined with herbicide use the highest yield was in obtained in treatment with minimal soil tillage. The yield was significantly higher than that that obtained in treatments with traditional tillage and direct drilling.

Table 4. The yield of winter wheat depending on soil tillage and weed control technologies, 2001–2003

Previous Crop (A)	Soil tillage, sowing (B)	Weed control (C)		Average, A $\gamma^{A}_{0.05}$ = 0.130	Average, B $\gamma^{B}_{0.05}$ = 0.159
		with herbicide (C1)	without herbicide (C2)		
Winter wheat (A1)	Minimal tillage (B1)	5.48	4.11	4.71	4.85
	Direct drilling (B2)	4.53	4.09		4.51
	Traditional tillage with ploughing (B3)	5.30	4.74		5.09
	Average, A1	5.10	4.31		x
Winter rape (A2)	Minimal tillage (B1)	5.82	4.00	4.93	x
	Direct drilling (B2)	5.54	3.88		
	Traditional tillage with ploughing (B3)	5.98	4.35		
	Average, A2	5.78	4.07		
Average C ; $\gamma^{C}_{0.05}$ = 0.130		5.44	4.19	x	
$\gamma_{0.05}$ = 0.319 (to separate differences)					

Highest winter wheat yield was obtained in case of traditional soil tillage without herbicide use. Yield differences with minimal tillage and direct drilling were lower than critical difference.

The highest yield of 1st wheat combined with herbicide use was got in treatment with traditional soil tillage. The yield was significantly higher than that obtained in other treatments. The same tendencies were observed in treatments without herbicide use. The lowest winter wheat yield was obtained in treatments with direct drilling. In case of herbicide use the yield was significantly lower, and in case without herbicide use – insignificantly lower.

Table 5. Effect of herbicide application depending on previous crop and soil tillage – sowing technologies

Soil tillage, sowing (B)	Effect of herbicide application, ± t ha^{-1}	
	winter wheat as previous crop	winter rape as previous crop
Direct drilling (B2)	0.44	1.66
Minimal tillage (B1)	1.37	1.82
Traditional tillage with ploughing (B3)	0.56	1.71
Average BC; $\gamma^{BC}_{0.05}$ = 0.225	0.79	1.73

Herbicide use showed significant impact on changes of winter wheat yield in all soil tillage – sowing technologies and in treatments with both previous crops (Table 5). The most notable effect was observed when growing winter wheat after winter rape what could be explained by high effect of herbicide applied to germinated rape plants. When comparing different soil tillage systems, significantly higher effect of herbicide application was obtained in treatment with minimal soil tillage and 2nd wheat. That could be explained with ploughing effect, which worked also as weed limiting factor, and presence of stubbles in treatment with direct drilling.

Conclusions

Different soil tillage – sowing technologies used after different previous crops were the reason for diverse situation in weed infestation, which had a significant impact on winter wheat yield. Various weed control technologies had to be applied using minimal soil tillage or direct drilling compare to traditional soil tillage.

Significant lower yields were obtained with direct sowing; moreover there was observed high yield variation although it could be an alternative method in particularly dry autumns how it was observed in 2002.

Obtained yield of winter wheat differed under the influence of meteorological and soil conditions in all treatments of investigated soil tillage – sowing technologies because these factors promoted significantly the influence of other factors. Herbicides applied were the main factor affecting changes of winter wheat yield.

References

1. Cannel R. Q. *et al.* (1980) The growth and yield of winter cereals after direct drilling, shallow cultivation and ploughing on non – calcareous clay soils. J. agric. Sci. Comb. 345–359.
2. Drew M. C., Saker I. R. (1980) Direct drilling and ploughing: their effects on distribution of extractable phosphorus and potassium, and of roots, in the upper horizons of two clay soils under winter wheat and spring barley. J. agric.Sci. Comb. 411–423.
3. Finney J. R., Knight B. A. (1973) The effect of soil physical conditions produced by various cultivation systems on the root development of winter wheat. J. agric.Sci. Comb. 435–442.
4. Hodson D. R. *et al.* (1977) Cultivations systems for spring barley with special reference to direct drilling. J. agric.Sci. Comb. 631–644.
5. Lauringson E. *et al.* (2000) The effect of crop rotation, autumn soil cultivation and chemical herbicides on the productivity and weediness of crops // The results of long term Field Experiments in Baltic States, Jelgava, 71–79.
6. Romaneckas K. (1999) The influence of minimal presowing soil tillage methods on agrophysical soil properties, sugar beet seeds germination and mass of seedlings // Agroecological optimisation technologies. Proceedings of international scientific conference, – Jelgava, 150–154.
7. Satkus A. (2000) The effect of soil tillage on spring barley seedbed preparation on clay loam soil. // Summary of doctoral thesis. Lithuanian Institute of Agriculture, 24–28.
8. Simanskaite D. (2000) Effectiveness of the use of chisel cultivator KČ–5.1 in a crop rotation on light loamy soil // The results of long term Field Experiments in Baltic States, Jelgava, 147–153.
9. Stancevicius A. *et al.* (1999) The effects of reduced tillage on winter wheat yield and agrophysical soil properties. // Agroecological optimisation technologies. Proceedings of international scientific conference, – Jelgava, 157–171.

WEEDINESS OF MIXED CROPS DEPENDING ON WEATHER CONDITIONS AND SOWING RATE OF LEGUMINOUS

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Abstract

The research was conducted at the experimental station of the Department of Field Crop Husbandry of the Estonian Agricultural University. In the research presented here, the influence on weed infestation level in various combinations of mixed crops was estimated in 1999–2004. Increased seed density led to considerable reduction in weed weight (r = 0.925–0.991***). A stronger weed weight reduction effect was observed at the densities of 60–120 seeds per m^{-2}. In a monoculture, leguminous crops proved to be less competitive with weeds. Spring vetch has a weed-suppressing action; owing to its weak stem, however, it inevitably requires a support crop. Vetch monocultures became totally overgrown with weeds. Wheat had a lower competitive power than oats both in a monoculture and a mixed crop. The correlation of the density and weight of weeds with the precipitation level and soil temperatures in April, May and June is moderate. With regard to spring precipitation, weed weight was influenced the most by precipitation in May. Thus, requalled –0.51* in no-crop soil, –0.72** in monocultural wheat and –0.51* in monocultural barley. Higher precipitation was conducive to quick sprouting of cereals and gave them a growth advantage over weeds. Of mixed crops, the weed weight correlation in May was the strongest in an oats-pea mix, r = –0.46–0,66*.

Key words: pea, common vetch, spring cereals, weeds, sowing rate

Introduction

An integral part of field crop husbandry is the use of different plant protection products and mineral fertilisers, which ensure high and quality yields. However, more and more attention is being paid to environment-friendly crop husbandry. One opportunity for improving soil humus balance, producing richer-in protein feeding stuffs and reducing the amounts of mineral fertilisers is the use of legumes. Heavy lodging of some species, however, is a disadvantage of leguminous monocultures. Cereals have been used most commonly as support crops.

Mixed crops are not cultivated very often, but they are used frequently in integrated and organic farming. A number of correlations related to plant production and production ecology are yet to be ascertained.

Mixed crops (established by adding cereal seed to legume seed) have several positive effects, such as a higher competitive ability with weeds (Kimpel-Freund *et al.*, 1998) and reduced soil nitrate leaching after harvest. Favourable interactions have been observed in pea-oat mixes (Rauber *et al.,* 2000). The growing of pea or spring vetch in a mix with cereals is one opportunity for obtaining high-protein yields from low-fertility and unfertilised soils. Accordingly, the growing of mixed crops under organic farming serves to a certain extent as an alternative to mineral nitrogen fertilisers (Lauk and Lauk, 1999). As vetch is highly sensitive to herbicides (Lauk and Lauk, 1998) its use under organic farming could be much more widespread.

In a vetch-cereal mix the support crop leads to shortened growth period of vetch and contributes to more even and faster maturation of seeds (Lauk and Leis, 1996). Pea-vetch mixes improve of carbon to nitrogen ratio in plant residues, accelerating the residue degradation process.

Weeds have a significant effect on the yields of agricultural crops. Mixed crops are competitive with the weeds occurring in the agricultural community. Spring vetch and field bean are considered the best weed-suppressing crops of legumes. In a field overgrown with weeds vetch yield drops by up to 71% (Dimitrova, 2002). The competitiveness of mixed crops with weeds depends on the environmental conditions in vegetation period, on their correspondence to the needs arising from the biological peculiarities of crops (Talgre *et al.,* 2001).

In integrated weed control the goal is not the total destruction of weeds but the keeping of their populations under a certain level by means of combining cultivation methods and herbicide use. As weed populations are in the state of constant change and their structure is always altering weed control methods also need to be changed to keep crops free from weeds. In the present study we attempted to ascertain, under no herbicides, what cereal species and what legume seed densities should be used in a legume–cereal mix to keep the weed content as low as possible.

Materials and Methods

The research was conducted at the experimental station of the Department of Field Crop Husbandry of the Estonian Agricultural University, where the influence on weed infestation level in various combinations of mixed crops was estimated in the environmental conditions of 1999–2004.

The field experiments on mixtures of legumes (pea and vetch) and grains (barley, oat and wheat) were conducted on soils with loamy texture (*albeluvisols* – according to the WRB classification). Cereal seed densities were identical, 250 germinating seeds per m^{-2}, in all the variants. Vetch and pea seed densities varied between 0–120 germinating seeds per m^{-2}. The trial variants were established in one replication, except for the cereal monoculture variant, which was in two replications. The proportion of weeds in the agricultural community was assessed in 4 replications on each trial plot using a 0.25 m^2 frame. The species composition, density and dry weight of weeds were determined. Most of the weed species occurring in the crops belonged to the category of annuals.

Regression and correlation analysis were used in data processing.

Results and Discussion

Reduction in the sprouting and growth of weeds may be due to mechanical obstructions, soil air and water regime, reduction in light radiation reaching the ground and lower daytime soil temperatures (Teasdale and Mohler, 1993) or to the production of allelopathic substances (Weston, 1996). The extent to which weeds are suppressed depends significantly on the cover crop species and the farming system used.

The weed infestation data from the trials are expressed in weight units as the competitive power of the species more related to weight than to density (Boström and Fogelfors, 1999).

It appears from the trial data that leguminous monocultures had lower statistically reliable competitiveness with weeds (Fig. 1). At a low seed density the competitiveness of monocultural pea was smaller than that of monocultural spring cereal species in the period of massive weed sprouting. According to Grevsen the competitiveness of pea increased reliably after its seed density was raised from 90 to 150 seeds per square metre. Higher seed densities reduced weed dry weight by 50% in 1997 and 30% in 1998 however, it was only in one year that the increase in pea yield was reliable (Grevsen, 2004). There are no statistical differences between the results for cereal monocultures and those for mixed crops. However, the competitive ability of oats tended to be higher and that of wheat lower in both a monoculture and a mixed crop (Fig. 2).

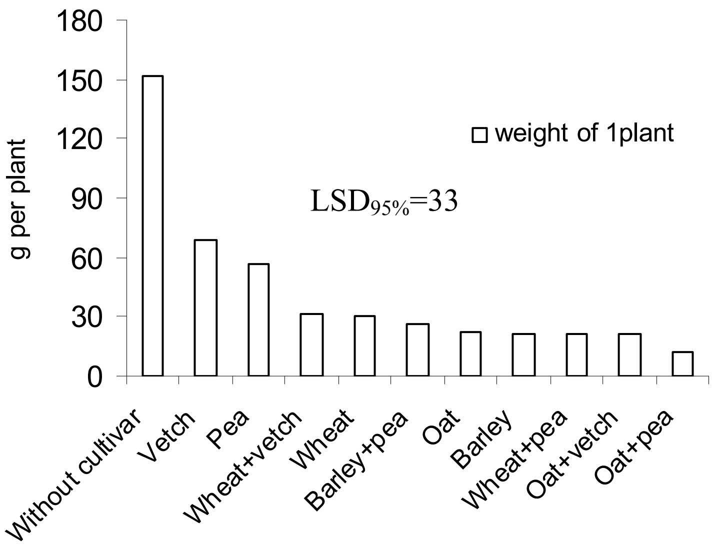

Figure 1. Weed weight (g m^{-2}) in monocultures and mixed crops in 2002–2003

The competitive edge of cereals, particularly oats, is based on their faster initial development and earlier and greater light interception, i.e. they leave weeds and slower growing leguminous in their shade. The competitiveness of oats is also enhanced by higher efficacy in absorbing water and nutrients. According to Shininano (Rauber *et al.,* 2000) oats root weight and length considerably exceeded the corresponding values for pea. In higher-precipitation years oats developed rapidly and vigorously and exhibited high competitiveness with weeds. The competitiveness was further enhanced in mixes with pea.

In pea-oats mixes (50 and 300 germinating seeds per m^{-2}, respectively) pea is the crop of a lower competitive ability (Rauber *et al.*, 2000). The same tendency was also revealed in pea-barley mixes.

Previous studies have shown that when growing vetch with spring wheat then short-stemmed wheat varieties are unsuitable as vetch support crops (Lauk *et al.*, 1998). Growing vetch with a long-stemmed wheat variety the mixes stand better and, at higher vetch seed densities, produce greater yields (Lauk and Lauk, 1999).

Higher legume seed densities led to lower weed densities and weights. More substantial decreasing occurred in weight (Fig. 3). Although the influence of increased seed density on per-plant weight reduction did not exceed the limits of the trial error it is nevertheless certain that higher seed densities tended to lower weed growth capacity. Plants with lower growth capacity produced fewer seeds of lesser viability and this created conditions for better weed control in subsequent years.

In an oats monoculture light transmission is smaller for about 40 days after sprouting in the field compared to a pea monoculture (Rauber *et al.,* 2000). In the subsequent stages the reverse was true. In pea-oats mixes light transmission was similar to that in oats monoculture in the first half of vegetation while subsequently it resembled that in pea monoculture.

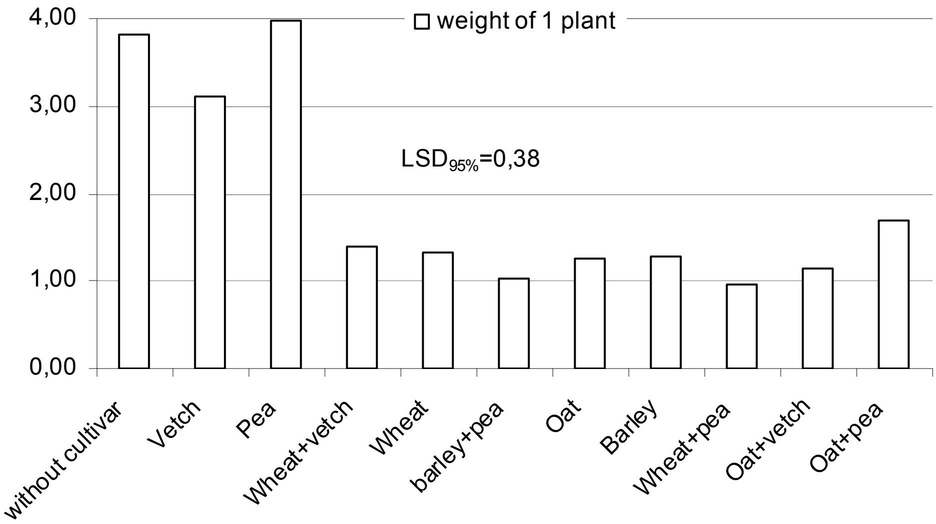

Figure 2. Average weed plant weight (g $plant^{-2}$) in monocultures and mixed crops in 2002–2003

Low precipitation levels fail to significantly influence vetch growth, as it is well adapted to areas of scarce rainfall (Chowdhury *et al.,* 2001). In a high-precipitation year the growth of vetch was very intensive and its competitiveness with cereals and weeds was high.

The dynamics of weed infestation are significantly governed by the primary and secondary weed seed dormancy periods. Depending on the growth conditions weed seeds require either a shorter or a longer time for ripening. Germination of weed seeds over a longer period is ensured by several regulatory mechanisms, such as pericarp water permeability and the existence in pericarp of sprouting-inhibiting substances (Börner, 1995). All above-mentioned processes are related with climatic factors – light, temperature, oxygen, carbon dioxide and water. Water has been considered a most significant agent in terms of both seed germination and the development of vegetative parts of perennial weeds. As well, weed seed germination is largely influenced by soil temperature, particularly in combination with soil moisture regime.

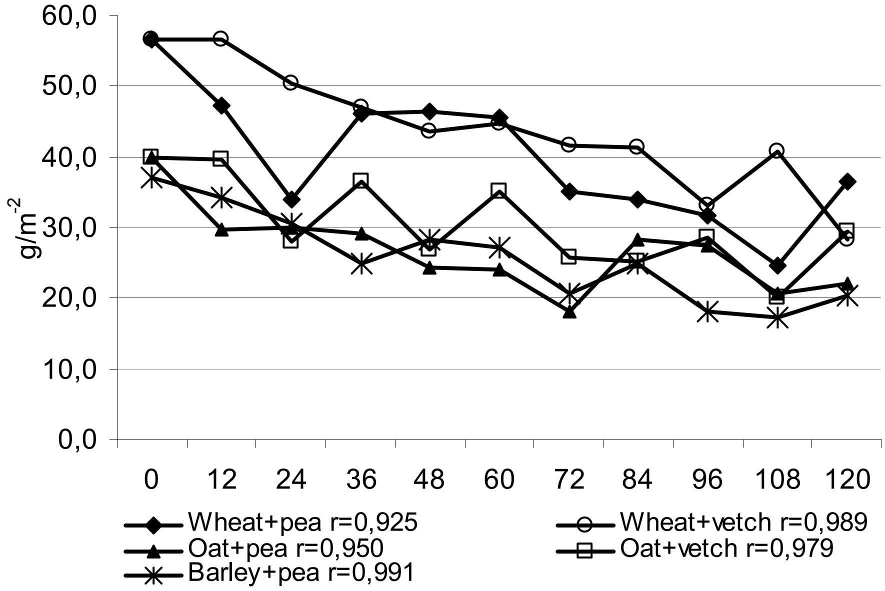

Figure 3. Weed weight g/m^{-2} depending on leguminous seed densities in 1999–2004

It appears from the analysis of the correlation of the density and weight of weeds with the precipitation level and soil temperature in April, May and June in 1999–2004 that the correlation between temperature and weed infestation is moderate. With regard to spring precipitation, weed weight was influenced the most by precipitation in May. Thus, r equalled –0.51* in no-crop soil, –0.72** in monocultural wheat, –0.38 in monocultural oats and –0.51* in monocultural barley. Higher precipitation was conducive to quick sprouting of cereals and gave them a growth advantage over weeds by suppressing their growth. Of the mixed crops, the weed weight correlation in May was the strongest in oats-pea mix, where r = –0.46–0.66*; in wheat-pea mix r = –0.25–0.32. In the remaining mixed crops the correlation between weed infestation and the studied parameters were either non-significant or moderate.

It could be presumed that the correlation is the strongest between annual weed density and spring precipitation. It appeared that April and May precipitation had a relatively small impact on weed sprouting. An environment favourable for weed seed germination was set up by October–December precipitation (r = 0.78** in cereal rotation). The correlation between January–March precipitation and annual weed density was weaker (r = 0.47*). The importance of autumn precipitation lies not only in that it replenishes spring soil water supply but also in that in autumn soils, which are more abundant in moisture the seeds pass their dormancy period more quickly.

Higher spring temperatures were not conducive to the growth of annual species; e.g., April soil temperature is negatively correlated with mayweed density (r = –0.56*), May soil temperature with the density of *Thlaspi arvense* (r = –0.52*) and May soil temperature with the density of annual species taken together (r = –0.47*). Apparently, this is not due to a direct negative effect of temperature on germination but to the fact that at higher soil temperatures there is less water in the soil.

Conclusions

The growing of monocultural cereals and mixed crops revealed a tendency towards a higher competitive power of oats and a lower competitive power of wheat in both a monoculture and a mixed crop. In years with higher precipitation levels oats was observed to have a higher competitive ability with weeds. The competitive power was further enhanced in oats-pea mixes.

Monocultures of legumes had a lower competitive power with weeds. At a low seed density, the competitive power of monocultural pea was smaller than that of monocultural spring cereal species in the period of massive weed sprouting.

Higher legume seed densities led to considerable reductions in the weight of weeds. There was a clear tendency towards reduced weed growth capacity at higher legume seed densities, which creates conditions for better weed control in subsequent years.

Higher precipitation was conducive to quick sprouting of cereals and gave them a growth advantage over weeds by suppressing their growth.

April and May precipitation had a relatively small effect on weed sprouting in spring. An environment favourable for weed seed germination was set up by October–December precipitation.

Acknowledgements

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References

1. Boström, U., Fogelfros, H., (1999) Type and time of autumn tillage with and without herbicides atreducedrates in southern Sweden. 2. Weed flora and diversity. Soil & Tillage Research, 50, 283–293.
2. Börner, H. (1995) Unkrautbekämfung. Jena, 315.
3. Chrowdhury, D. Tate, E., McDonald, G.K. and Hughes, R. (2001) Progress Towards Reducing Seed Toxin Levels in Common Vetch (*Vicia sativa* L.). Proceedings of the 10th Australian Agronomy Conference, Hobart.
4. Dimitrova, T. (2002) Selectivity and effectiveness of some herbicides in vetch (*Vicia sativa* L.). Agrokhimiya y Ekologiya 32 (6), 58–60.
5. Grevsen, K. (2004) Weed competitive ability of green peas (*Pisum sativum* L.) affected by seeding rate and genotype characteristics. Biological Agriculture and Horticulture, 21 (3), 247–261.
6. Kimpel-Freund, H., Schmidtke, K., Rauber, R. (1998) Einfluss von Erbsen (*Pisum sativum* L.) mit unterschiedlichen morphologischen Merkmalen in Reinsaat und Gemenge mit Hafer (*Avena sativa* L.) auf die Konkurrenz gegenüber Unkräutern. Pflanzenbauwissenschaften 2, 25–36.
7. Lauk, E., Leis, J. (1996) Suviviki kasvatamisalase uurimistöö tulemused aastatest 1994–1996. Teaduselt põllule ja aeda, 93–96.
8. Lauk, E., Leis, J., Lauk, R. (1998) Viki-nisu ja viki-kaera segukülvide katsete tulemused. Teaduselt põllule ja aeda, 52–58.
9. Lauk, Ü., Lauk, E. (1998)Viki-nisu segukülvide umbrohutõrje uuringud 1997. aastal. Teaduselt põllule ja aeda, 50–51.
10. Lauk. E., Lauk, R., Lauk, Ü. (1999) Kaunviljade-teraviljde segukülvide katsete tulemusi. Teaduselt põllule ja aeda, 134–141.
11. Rauber, R., Schmidtke, K., Kimpel-Freund, H. (2000) Konkurrenz und Ertragsvorteile in Gemengen aus Erbsen (*Pisum sativum* L.) und Hafer (*Avena sativa* L.). Journal of Agronomy and Crop Science 185, 33–47.
12. Talgre, L., Kuill, T., Lauringson, E. and Lauk, E. (2001) Umbrohtumusest tera ja kaunviljade segukülvides. Transactions of the Estonian Academic Agricultural Society 15, 97–100.
13. Teasdale, J. R., Mohler, C. L. (1993) Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agronomy Journal, 85, 673–680.
14. Weston, L. A. (1996) Utilization of allelopathy for weed management in agroecosystems. Agronomy Journal, 88, 860–866.

DYNAMICS OF PHOSPHORUS ACCUMULATION IN DIFFERENT CROP ROTATIONS

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Abstract

In Priekuli Plant Breeding Station during 40-year period, the influence of nine crop rotation and five fertilization systems on soil fertility properties was fixed. Measurements of soil nutrient content, including phosphorus (P), were performed each year. The use of different fertilizer application systems had a considerable impact on the content of available P in soil. On non-fertilized background P content under the influence of crop rotation changed by 4, under farmyard manure – 51, under NPK – 73, under stable manure + NPK by 53 and under 2 NPK by 214 mg kg^{-1} of soil. Data showed that doses of fertilizers included in investigations were in sharp contrast with the requirements of crops. In fertilizer application systems stable manure + NPK and 2 NPK are unacceptable and in conflict with sustainability of agriculture. The optimal fertilizer system for soil fertility provision is system in which doses of phosphorus are not exceeding 90 kg ha^{-1}.

Key words: crop rotation, phosphorus, soil, fertilizing systems

Introduction

The economical and environmental sustainability of farming is dependent also on the efficient use of phosphorus because the content of available phosphorus in the soil is one of the basic nutrient elements (Ekeberg and Riley, 1995; Mikkelsen, 1998).

The utilization of nutrient elements is largely various by different management systems (Johnston, 1995; Stenberg, *et al.,* 1998). Agricultural management practices and management systems that have continued a long time may have an impact on soil biological and chemical, and physical characteristics (Fortune, *et al.,* 1999; Mashauskiene and Mashauskas, 1994). This may lead to altered soil functions and the changes may be either positive or negative for the agriculture (Barber, 1988).

Nutrient management should aim to maintain chemical soil fertility in an agronomic desired and ecologically acceptable range (non accumulation), supply the crops at the right time with the needed nutrients and minimise the losses of nutrients. In practice, tracing of real changes in soil is not always possible due to great influence of climatic conditions on plant nutrient uptake.

This information can give an indication of the sustainability and agronomic efficiency of the fertilizer application system concerning phosphorus content in the soil in 40-year period in different crop rotations.

Material and Methods

The experiment is located in Priekuli (57^{o}19'N, 25^{o}20'E) on a sod-podzolic sandy loam soil with the following characteristics in the year of establishment (1958): organic matter content (Tyurin's method) 21 g kg^{-1}, soil pH_{KCl} 5.8 to 6.1, available phosphorus (DL-method) 80–100 mg kg^{-1}, available potassium (DL-method) 100–120 mg kg^{-1}. The mean temperature varied from –6.2 ^{0}C in January to 16.7 ^{0}C in July. The mean annual rainfall was 691 mm.

The experiment included nine different crop rotations:

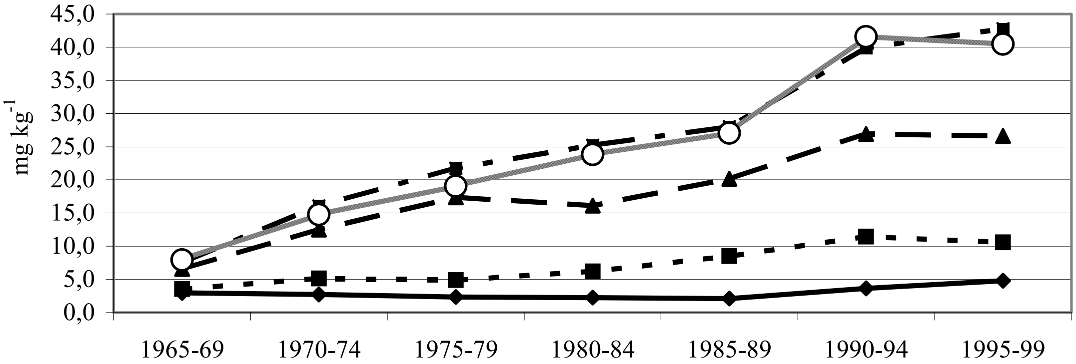
barley – potato – barley or oat;
barley – clover – rye – potato;
barley – clover – barley – rye – barley – potato;
barley – clover – potato;
barley – clover – clover – rye – barley – potato;
black fallow – rye;
barley – rye – oat – rye;
rye – rye – rye – rye – clover – clover- clover- clover;
black fallow – rye – barley – rye.

The clover used in rotations 2–5 was red clover, which was established as an intercrop in barley. The clover used in rotation 8 was white clover. Five different fertiliser treatments were compared with the crop rotations as sub-plots within each fertiliser treatment: 1. Unfertilised. 2. Stable manure: from 1958 to 1980 – 10 t ha $^{-1}$, from 1981 – 20 t ha^{-1}. 3. $N_{66}P_{90}K_{135}$. 4. Stable manure, 10 and 20 t ha^{-1}, respectively, plus $N_{66}P_{90}K_{135}$. 5. $N_{130}P_{180}K_{270}$. Crop rotations 1–6 were only included in the fertiliser treatment $N_{132}P_{180}K_{270}$. The average content of nutrient elements in stable manure was as follows: N-68, P-38, and K-58.

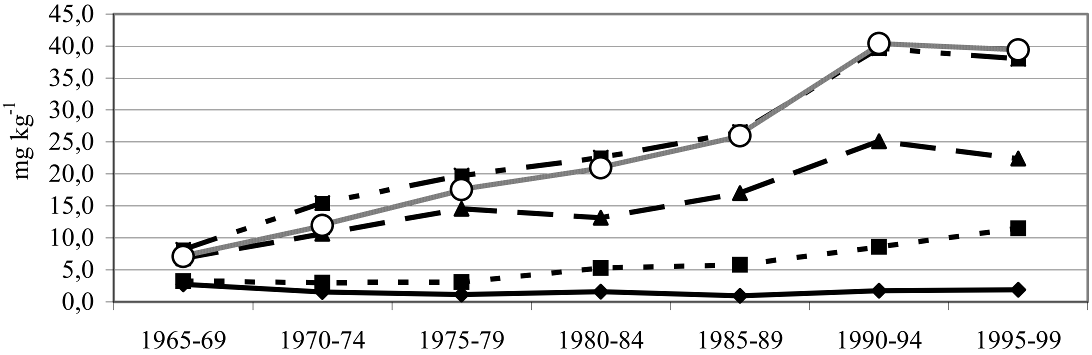
The size of common trial plots was 5900 m^2. In 1959, 22 t ha^{-1} of lime were applied. Measurements of soil nutrient content and crops yield were performed each year. Plant-available P was determined by Egner-Riehm DL method.

Results and Discussion

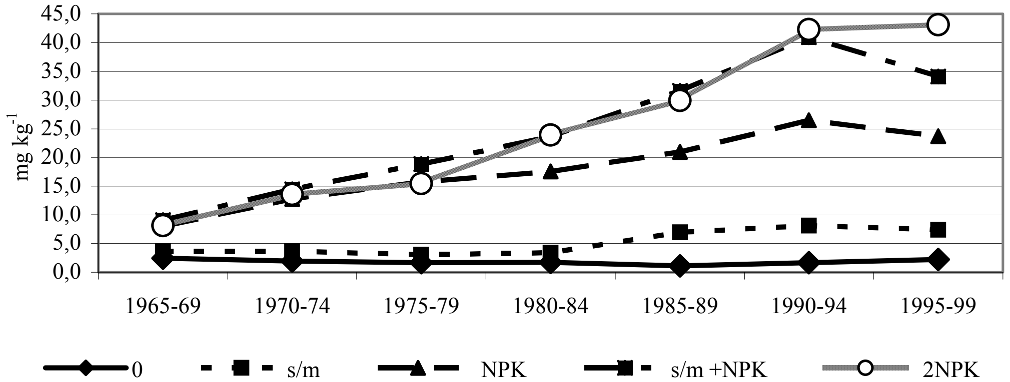
The accumulation of phosphorus was found in all fertilizer application systems in the whole period of investigations. In variants without fertilizing the content of phosphorus decreased significantly, excluding crop rotation barley–potato–barley (Fig. 1). In this crop rotation P_2O_5 content was highest in all fertilizer application systems that pointed on the role of clover included in crop rotation.



a. Crop rotation: barley-potato-barley or oats



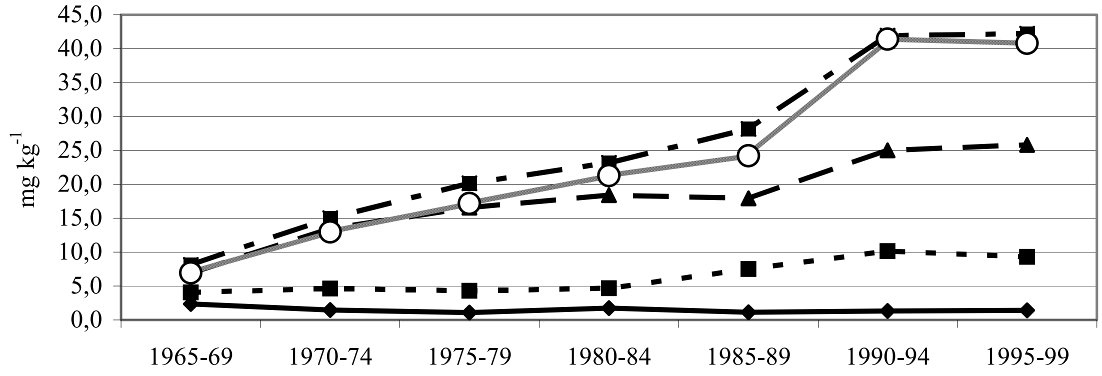
b. Crop rotation: barley-clover-potato



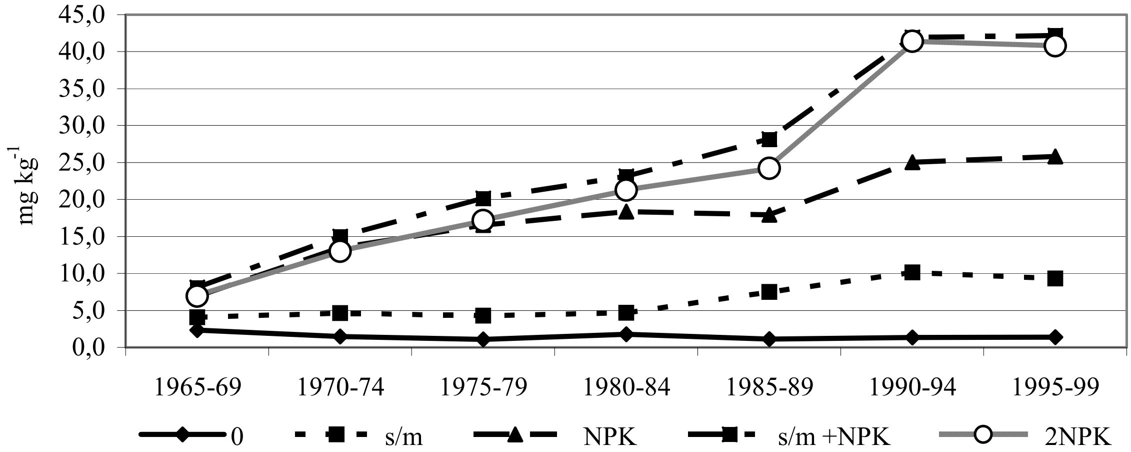
c. Crop rotation: barley-clover-rye-potato

Figure 1. Dynamics of P content in different crop rotation

In fertilizer application system with only stable manure applied, in the first period (1958–1980) P content in all crop rotations decreased a little and changed insignificantly, whereas in the second period (1981–1999) application of increased doses of manure resulted in a little accumulation of P_2O_5 (Fig. 1–3). Data show that application of 20 t ha^{-1} of farmyard manure provided constant phosphorus content in all crop rotations for a long period of time. It shows that phosphorus rate P_{40} could be recommended to provide sustainability in soil phosphorus content.



a. Crop rotation: barley-clover-barley-rye-barley-potato



b. Crop rotation: barley-clover-clover-rye-barley-potato

Figure 2. Dynamics of P content in 6-field crop rotation

Application of P_{90} was beneficial in increasing phosphorus content in soil in 4-field crop rotation (Fig. 3). In other crop rotations the accumulation of phosphorus occurred irregularly and did not exceed the recommended level 250 mg kg^{-1} for sod–podzolic soils as it is reported in the scientific literature (Skromanis and Timbare, 1993) (Fig. 1–3).

Accumulation of P_2O_5 when fertilizing with stable manure plus NPK and 2 NPK occurred periodically, but in these treatments irregularity was observed after a longer period of time than when fertilising with one dose of NPK. If the increasing of P content till 1985–1989 was considered normal, hereafter this accumulation was unacceptable because of discrepancy with sustainability of agricultural management.

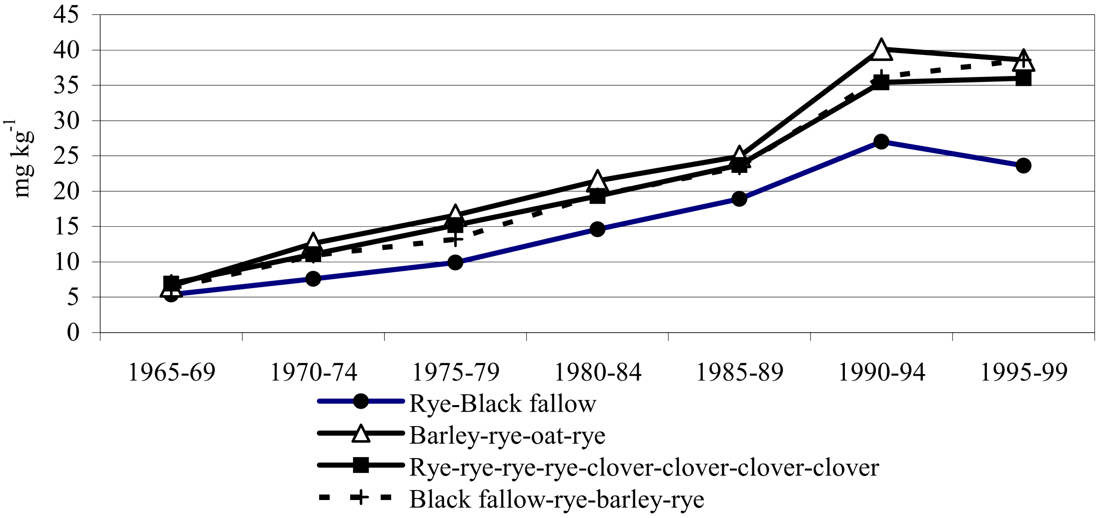


Figure 3. Dynamics of P content in crop rotations 6, 7, 8, and 9

The obtained data show some differences between crop rotations (Fig. 1–3). The content of phosphorus in crop rotation: rye-black fallow was nearly two times lower than that in other crop rotations. It showed that crop rotations with 50% of structure occupied by black fallow were notably uneconomic. Accumulation of phosphorus in crop rotations: rye-rye-rye-rye-clover-clover-clover-clover and: black fallow-rye-barley-rye was comparatively lower compare to other crop rotations with fertilizer treatment 2 NPK, excluding crop rotation: black fallow-rye.

Conclusions

Fertilizing is an important component of soil management. Intensification of agricultural systems has led to phosphorus (P) accumulation in excess of crop needs.

The influence of crop rotation on available phosphorus accumulation on sod-podzolic soils was observed only in some particular cases.

Environmental P concerns and manure management are naturally linked in today's agriculture.

References

1. Ekeberg E., Riley H. (1995) The long-term fertilizer trials at Moystad, S. E. Norway. In: SP report No 29, Research Centre Foulum, 83–105.
2. Fortune S., *et al.* (1999) Optimising phosphorus and potassium management for crop rotations in UK organic farming systems. In: Jorgen E. Olesen *et al.* Designing and testing crop rotations for organic farming, DIAS, 267–275.
3. Johnston A. E. (1995) The significance of long-term experiments to agricultural research. In: SP report No 29, 19–23.
4. Mashauskiene A., Mashauskas V. (1994) The effect of phosphorus and potassium periodical application on the crop rotation productivity and soil fertility. In: Reports of the scientific conference, Fertilizer application systems and soil fertility, Vilnius, 291–292.
5. Mikkelsen G. (1998) Mixed farming, consequence for soil fertility. In: AP Minderhaudhoeve-reeks No 2, Wageningen, 150.
6. Skromanis A., Timbare R. (1993) Ieteikumi zemes kopējiem augsnes racionālai izmantošanai un kultūraugu mēslošanai, Rīga, 67.
7. Stenberg, B., *et al.* (1998) Integrated evalution of variation in biological, chemical and physical soil properties, Ambio 27, 9–15.
8. Барбер С. А. (1988) Биологическая доступность питательных веществ в почве. Агропромиздат, Москва, 36.

Grassland management

PAERFOMANCE OF TEN LUCERNE VARIETIES DEPENDING ON CUTTING REGIME

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Abstract

The aim of the research (carried out in 2000–2004) was to compare the impact of three different cutting regimes and ten varieties on the lucerne (*Medicago* sp.) productivity, forage quality, stand longevity and regrowth intensity in spring and after cuts. Harvest management was as follows: traditional three-cut regime (cutting mainly by stage of plant development, providing stand longevity) – treatment 1; three-cut schedule using fixed time intervals – treatment 2; and four-cut schedule using fixed time intervals – treatment 3. Ten different, according to origin and fall dormancy type, lucerne varieties were used (3 local Baltic and 7 American). Results of the five years of lucerne usage showed that the best average lucerne dry matter (DM) yield was provided using treatment 1 ($p<0.01$). The effect of the used variety on obtained DM yield was more substantial if compared with that of the cutting regime. Treatments 2 and 3 appear more preferable, providing a substantially higher crude protein concentration measured in mg kg^{-1} of dry matter ($t > t_{crit}$). Regrowth intensity in spring and after cuts is connected with characteristics of a specific variety, mainly fall dormancy rating, and individuality of a specific season. Results of the research showed that lucerne stands could be used for up to 5 years even if the four-cut regime was applied, and high yields were obtained in spite of variable stand densities.

Key words: lucerne, variety, cutting regime, DM yield, quality, stand longevity, regrowth intensity

Introduction

Growing of lucerne (*Medicago sp.*) is important for obtaining high and excellent quality yields of hay or silage for cattle without application of nitrogen fertilisers, as well as for increasing crop diversity in crop rotation systems. It is comparatively expensive to establish lucerne stands de novo in Latvia. One of the most asked questions is: how long the stand can be kept. One of the reasons why farmers choose lucerne for forage production, besides high and qualitative yield, is its stand longevity. Cutting of lucerne may be scheduled using stages of plant development, fixed time intervals, crown bud development, or combination of these criteria (Scheaffer *et al.*, 1988). Traditionally, a three-cut schedule is recommended in Latvia, performing the 1^{st} cut in the bud stage, 2^{nd} cut in the stage of first flower (10% flower) and 3^{rd} cut in the bud to first flower stage, but not earlier than 42 days after the 2^{nd} cut. For better wintering and assuring better yield in the next season, October (October 1–10) is a better cutting time if compared with September (after September 20). Our findings in previous years (1994–2000) showed that three-cut schedule (1^{st} cut – bud stage or the 1^{st} ten-day period of June, 2^{nd} cut – early to full bloom stage, generally before 31 July, 3^{rd} cut – after 1 October) is very good for obtaining high yields and stand longevity, however it did not provide a presentable quality of forage in all the cases (Gaile, 2000). Foreign lucerne varieties are mainly used by Latvian farmers and, due to this, variety's winterhardiness (WH) is a trait with critical importance (Gaile, 2003). Traditionally fall dormancy (FD) score was used for predicting WH of a variety, but varieties with lower FD scores in fall are more dormant after cuts, too, and may have the disadvantage of lower yield potential. Nowadays possibility to use modern alfalfa varieties with high regrowth potential in spring and after cuts and sufficient WH provides a chance for choice of a more frequent cutting regime hence obtaining all the necessary characteristics – high yield, excellent quality of forage and long stand persistence.

The aim of the research was to compare impact of three different cutting regimes and ten varieties on the lucerne (*Medicago sp.*) productivity, forage quality, stand longevity and regrowth intensity in spring and after cuts.

Materials and Methods

Field experiments were carried out at the Research and Study farm 'Vecauce' of the Latvia University of Agriculture (LLU) (latitude: N 56° 28′, longitude: E 22° 53′) from 2000 to 2004 (lucerne was sown in 1999). Soil at the site was clay loam altered by cultivation with pH_{KCl} 6.3, containing available for plants P 198 mg kg^{-1}, K 224 mg kg^{-1} and with organic carbon content 15 g kg^{-1} of soil. Before sowing (1999), mineral fertilizers were given: 17.5 kg ha^{-1} of P and 33.2 kg ha^{-1} of K, but before the vegetative period started in the springs of usage years (2000–2004) – 34.9 kg ha^{-1} of P and 99.6 kg ha^{-1} of K. Ten lucerne varieties were used: seven varieties bred in North America (Table 1, Nos. 4–10), three varieties bred in the Baltic states (Skriveru – Latvia, Karlu – Estonia, Birute – Lithuania). The trial was arranged into 3 times replicated randomised blocks, plot size was 5 m^2. Cutting regimes were as follows: traditional three-cut schedule (1st cut – bud stage, June 5 and June 7 in 2004; 2nd cut – early to full bloom stage, July 24–25 depending on a year; 3rd cut – after October 1, October 1–2) – treatment 1; three-cut schedule using fixed time intervals (1st cut – May 25–June 1; 2nd cut – July 10; 3rd cut – August 20) – treatment 2; four-cut schedule using fixed time intervals – with 3 cuts mentioned above for treatment 2, and the 4th cut on October 10 – treatment 3. The yield was measured using direct accounting method: harvesting full plot and recasting per ha. Average yield samples per variety in amount of 0.5 kg were taken after harvest for yield quality analyses carried out in the Scientific Laboratory of Agronomy Research of LLU. Following quality analyses for every hybrid were carried out using standard methods: content of dry matter (DM) g kg^{-1} (Forage analyses met 2.2.1.1.), crude protein g kg^{-1} of DM (ISO 5983), NDF (Forage analyses met 2.2.1.1.) and ADF (Forage analyses met 4.1.), g kg^{-1} of DM, ash (ISO 5984), Ca (ISO 5490/2), P (ISO 6491), g kg^{-1} of DM (data are not presented). In addition, following observations were carried out during the vegetative period: regrowth intensity and dynamics in spring and after cuts, cm per 24 hours, measurements were taken on average after every 10 days; plant height in cm before the cuts; lodging resistance in points 1 to 5 (1 – without any lodging) before the cuts (data are not presented); stand density evaluated every year after the 1st cut visually in percent from that in the fall of establishment year; stand longevity measured by yield in specific years against the yield of first full harvest year. ANOVA procedures, correlation and regression analyses were used for processing the obtained experimental data.

Meteorological conditions were generally similar in all the wintering periods, but different – in vegetation periods. Conditions during vegetative seasons were registered by automatic PC-connected meteorological station Hardi-Metpole placed adjacent to the trial. The year 2000 was cool and wet, suitable for very high yield formation; 2001 – little warmer if compared with the meteorological norm in the region, and rainy; 2002 – atypically hot and very dry in August and September; 2003 – late, cool and dry spring, hot July and first part of August, and with mild temperatures and rainfalls in September; and 2004 – early, dry and cool spring followed by a cool and overly rich with precipitation summer, only August and September were warmer and less wet.

Results and Discussion

Results show that the best lucerne five years' average DM yield per season was obtained using treatment 1, i.e. traditional three-cut regime, where the cutting is organised mainly by stage of plant development ($p<0.01$; Table 1).

Table 1. Average five-year dry matter yield per season depending on variety characteristics and harvest regime, t ha^{-1}, 2000 to 2004

Variety – factor A	Harvest management – factor B			Average for A $\gamma_{0.05A}$ = 1.49	FD (smaller value – marked dormancy)
	Treatment 1	Treatment 2	Treatment 3		
1. Skriveru	14.84	11.72	11.50	12.69	0.5
2. Karlu	15.56	11.82	12.33	13.24	0.5
3. Birute	17.62	16.60	17.08	17.10	1 … 2
4. Vernal	17.78	15.23	15.10	16.04	2
5. ABT – 205	18.53	17.78	17.53	17.94	2
6. WL-324	19.27	17.84	18.58	18.56	3
7. Spreador III	17.73	16.17	15.72	16.54	1
8. Alfagraze	18.25	15.34	15.35	16.31	2
9. DK – 121 HQ	16.32	15.20	16.09	15.87	2
10. Winterstar	18.85	16.76	16.16	17.26	2
Average for B $\gamma_{0.05B}$ = 0.77	17.47	15.45	15.54	x	x

$\gamma_{0.05AB}$ = 2.58.

This is in agreement with the findings of other researchers and our previous findings (Sheaffer *et al.*, 1988; Gaile, 2000). Comparing treatments 2 and 3, the four-cut schedule did not assure a substantial average DM yield increase. The DM yield was influenced substantially by both: the used variety as well as by cutting regime, but variety influence (41.23%) was more important than that of the chosen cutting regime (11.28%).

Two fall dormant varieties – Skriveru and Karlu – never provided a full 4th cut. On October 10, the plant height (PH) of these varieties in the four-cut nursery was 7–24 cm and 7–17 cm, respectively, depending on the year, and was very uneven within the specific year. The plant height of other 8 varieties was 23–44 cm and uniform within a specific year. Interconnection between the DM yield and PH can not be evaluated unambiguously. In some cases, tight positive correlation was found, in some cases – substantial, but week correlation, and in some cases – correlation was not found at all (Table 2). Data found in the literature confirms that PH not always correlated with the DM yield (Marinova *et al.*, 2004).

Table 2. Correlation between plant height (PH) before the cut and dry matter (DM) yield

Treatment	1st cut	2nd cut	3rd cut	4th cut
Treatment 1	0.050	0.223	0.537**	–
Treatment 2	0.904**	0.611**	0.429**	–
Treatment 3	0.887**	0.619**	0.363*	0.792**

** $p<0.01$; * $p<0.05$.

Very important for frequent lucerne cutting is its regrowth intensity in spring and after cuts. If the variety is very dormant, regrowth after cuts started with delay and it was not possible to obtain high DM yields during the short period between cuts as it was using treatments 2 and 3 where between 1st and 2nd cuts as well as between 2nd and 3rd cuts were only ~40 days. Two of Baltic local varieties ('Skrīveru' and 'Karlu') are characterized by very good winterhardiness.

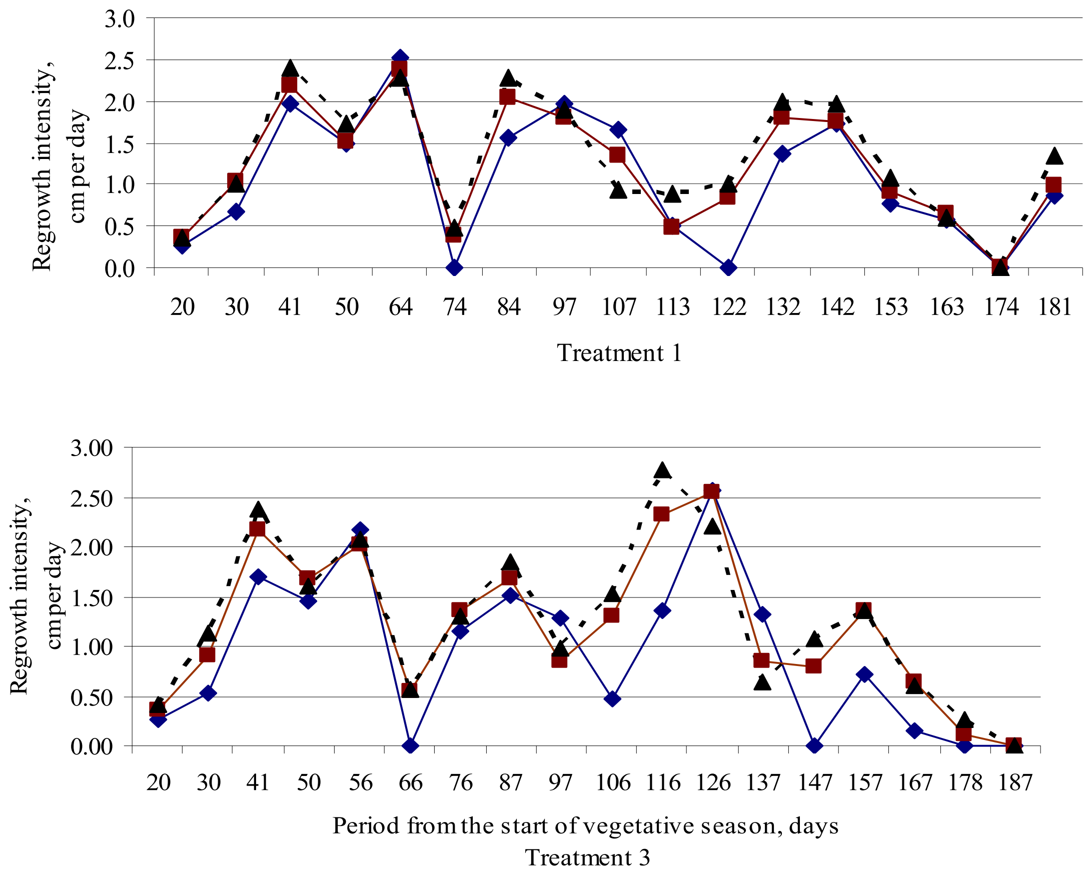

Figure 1. Changes of lucerne regrowth intensity in spring and after cuts per day depending on variety FD score and environmental conditions in 2002

FD= 0.5, on aver. FD =1-2, on aver. WL-324 (FD=3)

For treatment 1: 1st cut at 64th day, 2nd cut at 113th day and 3rd cut at 181st day from the start of vegetative season. For treatment 3: 1st cut at 56th day, 2nd cut at 97th day, 3rd cut at 137th and 4th cut at 187th day from the start of vegetative season.

However, for the mentioned two varieties, this trait is strongly related to low FD rating (Table 1) and, as said already before, these varieties never provided a full 4th cut. Regrowth intensity in spring and after cuts is substantially affected by the used variety ($p<0.05$).

Also a very important consideration is environmental effect on vegetative growth. Our previous findings from other trials showed that regrowth intensity of lucerne correlates with the average air temperature per period (Gaile and Kopmanis, 2001), which was approved by current research during 2000 to 2003 ($r = 0.442>r_{0.05}$). If cutting is done at fixed intervals, higher temperature provides better DM yield (Fick *et al.*, 1988) due to higher regrowth intensity during the period. As the best ocular-proof for the variety and air temperature influence on lucerne regrowth can serve the first 20 days after the cut. Performed measurements showed that sometimes due to low temperatures the regrowth score per first 10 days is zero, for instance, after the 2nd and 3rd cut in 2000 and after the 1st cut in 2001 for all the varieties, but dormant varieties could start to regrow only 10 or more days after the cut even at very good temperature conditions, for instance in 2002 (Fig. 1). Analyses of variance show a substantial effect ($p<0.05$) of both variety and environment on regrowth intensity of lucerne. Figure 1 illustrates both the variety as well as environment effect on regrowth intensity. For instance, two peaks in the middle of regrowth period before the 1st cut shows that regrowth intensity decreased due to the low air temperature. Figure 1 also shows that if the four-cut regime has been chosen for lucerne harvest, dormant varieties are far from suitability: after the 3rd cut regrowth is very weak if any. If we speak about varieties with higher FD ratings and a more intensive regrowth directly after the cut, meteorological conditions of a specific season could be the reason for choice of cutting regime, too.

Our results show that at average cutting frequency, DM yield decreases and forage quality increases, which is in conformity with the results of other scientists (Berardo *et al.*, 1994; Porqueddu *et al.*, 2003). The main interest of lucerne growers in Latvia is related to protein (CP). Treatments 2 and 3 appear more preferable, providing a similar and substantially higher CP concentration measured in g kg^{-1} of dry matter ($p<0.001$; Table 3) if compared with treatment 1.

Table 3. Average crude protein and NDF concentration depending on harvest regime and number of the cut, g kg^{-1}

Number of the cut	Harvest management and nutrition quality of lucerne					
	Crude protein, average from 2000 to 2004			NDF, average from 2000 to 2004		
	Treatment 1	Treatment 2	Treatment 3	Treatment 1	Treatment 2	Treatment 3
1st cut	201.46	220.31	221.51	416.03	382.61	375.86
2nd cut	189.08	202.68	200.05	482.91	435.29	430.67
3rd cut	183.65	202.62	202.52	436.41	443.41	449.35
4th cut	–	–	256.12	–	–	295.31

CP yield per ha per season depends mainly on DM yield per ha (De Falco *et al.*, 2003), and on CP concentration as well. On average during 4 experimental years, treatment 1 (3.379 t ha^{-1}) and treatment 3 (3.373 t ha^{-1}) showed almost the same CP yield, but treatment 2 (3.251 t ha^{-1}) – a substantially lower CP yield per ha ($\gamma_{0.05} = 0.05$). Lucerne DM yield remarkably decreased in the 5th year of usage if compared with the 4th year thus also affecting the CP yield per ha per season. However, the main conclusion remains the same – treatment 3 provided a similar CP yield per ha per season, but treatment 2 – a substantially lower CP yield per ha (Table 4).

The variety affected the average 5-year CP yield per season to a high degree – by 38%, and both, the best DM and CP yield per ha was obtained from WL-324, ABT-205, Birute and Winterstar plots (Tables 1 and 4). Digestibility and dry matter intake of forage is adversely related to ADF (acid detergent fibre) and NDF (neutral detergent fibre) concentration, respectively. NDF concentration was substantially higher ($p<0.05$) using treatment 1 in 1st and 2nd cut, though the difference is not proven statistically for the 3rd cut (Table 3). ADF concentration during the five years could not be evaluated unambiguously: in some years ADF concentration was substantially higher using treatment 1, but on average during the experimental period it was not statistically proven at the 95% confidence level. Responsible for these unexplained differences in lucerne quality could be environmental factors that vary from cut to cut, from season to season.

Table 4. Average five-year crude protein yield per season depending on variety characteristics and harvest regime, t ha^{-1}, 2000 to 2004

Variety – factor A	Harvest management – factor B			Average for A
	Treatment 1	Treatment 2	Treatment 3	$\gamma_{0.05A} = 0.265$
1. Skriveru	3.029	2.637	2.499	2.721
2.Karlu	3.205	2.653	2.708	2.855
3. Birute	3.419	3.422	3.598	3.479
4. Vernal	3.307	3.003	3.085	3.132
5. ABT – 205	3.475	3.584	3.667	3.575
6. WL-324	3.550	3.492	3.794	3.612
7. Spreador III	3.332	3.216	3.195	3.248
8. Alfagraze	3.479	3.139	3.176	3.265
9. DK – 121 HQ	3.145	3.120	3.413	3.226
10. Winterstar	3.568	3.412	3.416	3.465
Average for B; $\gamma_{0.05B} = 0.145$	3.351	3.168	3.255	x

$\gamma_{0.05AB} = 0.459$.

Longevity of lucerne stands could be affected by different aspects: suitability of a variety to specific conditions, soil characteristics, different stress conditions and cutting regime, including cutting height, frequency and critical rest period in the fall (Sheaffer *et al.*, 1988). During four years of usage, high DM yields were obtained and the stand density in 2003 was still above 75%. In the fifth year of usage, 2004, a remarkable stand density decrease was observed (on average by 25%), but it was similar for all three cutting regimes.

Variety effect was substantial ($p<0.01$). The average remainder stand density in 2004 was 53.3, 53.8 and 53.5% for used treatment, respectively. It is well known that severe reduction in plant population is possible before significant yield reduction occurs because decrease of plant population is often compensated for by an increased stem number and DM weight per plant (Sheaffer *et al.*, 1988). In the fifth year of usage (2004) in our experiment, a week correlation between total DM yield per season and stand density was already noted ($p = 0.05$). At the same time, obtained DM yield still was high (10.20 to 16.72 t ha^{-1} on average per variety) and achieved from 70.25 to 84.96% from that in the 1st year of usage (Table 5).

Table 5. Dry matter yield per season in 2004 if compared with that in 2000 depending on variety characteristics and harvest regime, %

Variety – factor A	Harvest management – factor B			Average for A
	Treatment 1	Treatment 2	Treatment 3	$\gamma_{0.05A} = 7.29$
1. Skriveru	64.71	72.53	73.51	70.25
2.Karlu	90.76	83.50	80.63	84.96
3. Birute	60.67	69.88	76.46	69.01
4. Vernal	77.48	67.72	66.16	70.45
5. ABT – 205	86.88	81.32	80.69	82.96
6. WL-324	86.19	76.59	78.64	80.47
7. Spreador III	78.63	69.51	67.55	71.89
8. Alfagraze	82.63	70.68	71.59	74.96
9. DK – 121 HQ	79.74	71.22	69.72	73.56
10. Winterstar	85.83	74.67	75.21	78.57
Average for B $\gamma_{0.05B} = 4.00$	79.35	73.76	74.02	x

$\gamma_{0.05AB} = 12.64$.

Our experiment has shown that in very good lucerne management conditions, including appropriate variety and soil selection as well as nutrition management, stand could be used up to five years even if the four-cut regime is used.

Conclusions

A significantly higher average dry matter yield was obtained using traditional three-cut harvest regime (treatment 1). Though, on the other hand, using treatment 3 for less dormant varieties (WL-324, ABT-205, Birute) it is possible to obtain similar yield if compared with treatment 1, but with better quality. Average effect of cutting regime on stand density decrease during the five years was insignificant. Even in the fifth year of usage, high DM yield per season was obtained using all three cutting regimes, but yield reduction was greater for treatments 2 and 3 if compared with the 1st year yield. Regrowth intensity in spring and after cuts was highly dependent on variety characteristics, and for the four-cut regime less dormant varieties starting to regrow directly after the cut should be used. Consequently, all three cutting regimes could be successfully used under Latvia's conditions with a prerequisite that peculiarities of a specific variety and season are taken into account.

References

1. Berardo, N., Gnocchi, G. *et al* (1994) The role of the cutting regime in the lucerne nutritive value improvement. Fibre and crude protein content. In: Proceedings of EUCARPIA Lucerne Section Meeting "Management and breeding of perennial lucerne for diversified purposes." – National Institute for Agricultural Research (INRA) Forage Plant Breeding Station, Lusignan, France, 135–138.
2. De Falco, E., Landi, G. *et al* (2003) Harvest management effects on Lucerne (*Medicago sativa* L.) forage production and quality in a hilly environment in southern Italy. In: Kirilov, A., Todorov, N., Katerov, I. (Eds.) Grassland science in Europe. Volume 8. Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria, 348–351.
3. Fick, G. W., Holt, D.A. *et al* (1988) Environmental Physiology and Crop Growth. In: Hanson, A. A. (Ed.), Alfalfa and Alfalfa Improvement. ASA, CSSA, SSSA, Madison, Wisconsin, USA, 163–194.
4. Gaile, Z. (2000) Investigations of alfalfa performance and quality at Research and Study farm "Vecauce" (1993–1999). In: Bender, A. (Ed.) Proceedings of International Conference "Collaboration on Plant Breeding in the Baltic Sea Region, Jogeva Plant Breeding Institute, Estonia, 218–225.
5. Gaile, Z., Kopmanis, J. (2001) Performance and regrowth of alfalfa depending on agrometeorological conditions of season. In: Lapins, D. (Executive Ed.) Proceedings in Agronomy, Latvia University of Agriculture, Jelgava, Latvia, 191–195.
6. Gaile, Z. (2003) Evaluation of winterhardiness in lucerne in Latvian conditions using an accelerated test. In: Kirilov, A., Todorov, N., Katerov, I. (Eds.) Grassland science in Europe. Volume 8. Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria, 365–368.
7. Marinova, D., Petkova, D., Yanheva, Ch. (2004) Influence of the multifoliolate trait on quantity and quality of lucerne (*M. sativa* L.) forage. In: Luscher, A. *et al* (Eds.) Grassland science in Europe. Volume 9. Proceedings of the 20th General Meeting of the European Grassland Federation, Lucern, Switzerland, 927–929.
8. Porqueddu, C., Parente, G., Elsaesse, M. Potential of grasslands. In: Kirilov, A., Todorov, N., Katerov, I. (Eds.) Grassland science in Europe. Volume 8. Proceedings of the 12th Symposium of the European Grassland Federation, Pleven, Bulgaria, 11–20.
9. Scheaffer, C. C., Lacefield, G. D., Marble, V. L. (1988) Cutting Schedules and Stands. In: Hanson, A. A. (Ed.), Alfalfa and Alfalfa Improvement. ASA, CSSA, SSSA, Madison, Wisconsin, USA, 411–437.

FESTULOLIUM AND *LOLIUM X BOUCHEANUM* DRY MATTER YIELD FORMATION UNDER CLIMATIC CONDITIONS OF LATVIA

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Abstract

Under conditions of Latvia′s climate, forage grasses are the main fodder source in cattle breeding. The productivity of grasslands and pastures mostly depends on cultivated grass varieties. The aim of the present research was to study photosynthesis activity and crop yield of *Festulolium* and *Lolium × boucheanum* ryegrass foreign varieties under agro-ecological conditions of Latvia. Field trials were established on sod – podzolic soil fertilized with N120 $_{(60+60)}$, N180 $_{(60+60+60)}$, P78 and K90 kg ha^{-1}. Swards were cut three times during the growing season. The productivity of photosynthesis and biomass were dependent on the variety and mineral fertilizer rates. Some parameters were influenced by genetic characteristics of particular cultivars.

Key words: *Festulolium*, *Lolium × boucheanum*, productivity, photosynthesis

Introduction

Agriculture, especially sustainable, is increasingly being considered as one of the most efficient tools for environmental protection, landscape improvement and the management of natural elements still existing in areas affected by human activities (EU Reg. 1578/99). Sustainability is a measure of our ability to produce food with the maximum of efficiency combined with the minimum of damage to the environment. Grasses that persist from year to year under harsh environments will reduce inputs and costs, and improve predictability and stability of production. Persistency is an essential aspect of sustainability of forage production when environmental conditions are limiting (Ghesquière, 2002).

High quality forage *Lolium* has been bred for intensive systems in benign environments, and have proved to be insufficiently robust to meet many of the environmental challenges in more extreme conditions (Humphreys, 2002). Under Baltic climate conditions, it is not widely spread for the reason of unsatisfactory wintering. Sometimes crops considerably suffer even in first winter and decrease productivity (Nekrošas, 2002).

Improvements in yield, quality and persistence of hybrids between *Lolium multiflorum x Lolium perenne* are being made using new genetic resources. The aim of hybrid ryegrass is to combine the best attributes of Italian and perennial ryegrass. It is less winter hardy but higher yielding than perennial ryegrass (Adamovich, 2003; Gutmane, 2004).

Greater sward productivity may be obtained through use of hybrid combinations of contrasting grass species. For the considerable improvement of perennial ryegrass wintering, ryegrass and fescue crosses were started. For a long time breeders have been trying to put together valuable traits of these genera by crossing. Important requirement for *Festulolium* is combining such characters of ryegrass as productivity, growth potential and feeding quality, and from fescues stress resistance in wintering and resistance to drought during the growth period (Domanski, 1999; Kryszak, 2002).

Lolium × Festuca hybrids have better persistence, disease resistance and winter hardiness than ryegrasses, better season-long productivity and higher forage quality than fescues (Sliesaravicius, 1997). *Lolium × Festuca* hybrids have good agronomical potential especially in adverse environments (Nesheim, 2000). *Festulolium* hybrids can show completely novel characters, but mostly traits are expressed intermediately and sometimes the traits of one parental species dominate. Some varieties are more like the ryegrasses and some more like fescues, depending on the breeding effort following the cross (Zwierzykowsky, 1980; Hahn, 1999).

Efficient farming requires better use of grass. Each region needs varieties combining specialized combinations of stress resistance, more appropriate and more productive for local climate conditions. The aim of present research was to study photosynthesis activity and crop yield of *Festulolium* and *Lolium × boucheanum* ryegrass foreign varieties under agro-ecological conditions of Latvia.

Materials and Methods

Field trials were conducted in Latvia on sod-podzolic soils (pH$_{KCl}$ 7.1, P – 253, K –198 mg kg^{-1}, organic matter content 31 g kg^{-1} of soil). Swards were composed of: perennial ryegrass ‘Spidola’ (control), *Festulolium* – ‘Perun’ *(L. multiflorum × F. pratensis),* ‘Punia’ *(L. multiflorum × F. pratensis),* ‘Saikava’

(L. perenne × F. pratensis) 'Lofa' *(L. multiflorum × F. arundinacea),* 'Felina' *(L. multiflorum × F. arundinacea),* 'Hykor' *(L. multiflorum × F. arundinacea),* hybrid ryegrass – 'Tapirus' *(L. multiflorum × L. perenne),* 'Ligunda' *(L. multiflorum × L. perenne)*.

The total seeding rate was 1000 germinating seeds per m^{-2}. The plots were fertilized as follows: N108 $_{(18+90)}$ P78 K90 kg ha^{-1} (at sowing year), P78 and K90 kg ha^{-1} and two N fertilizer treatments N120 $_{(40+40+40)}$ and N180 $_{(60+60+60)}$ kg ha^{-1} (at first and second year of sward use). Swards were cut three times per season. Dynamics of plant leaf area expansion, net photosynthesis productivity (which characterizes the increase of plant DM production per leaf area unit of time, expressed in g m^{-2} day^{-1}) were determined for first cut. Sampling of plants was carried out in 7 to 10 day intervals.

Results and Discussion

In all grasses the basis of growth is photosynthesis. However, the accumulation of DM is not the result of a single process, but represents the net balance among a number of processes (Robson *et al.*, 1989). Development of leaves, age, and photosynthetic capacity influence the grass yield. Leaf area index (LAI) is one of the most significant indices of photosynthesis (Woledge, 1971; Woledge, 1976).

Determination of *Festulolium* and hybrid ryegrass leaf area dynamics showed that the development of the maximum leaf area index was achieved before ear emergence stage. The LAI and net photosynthesis productivity for *Festulolium* and hybrid ryegrass were different.

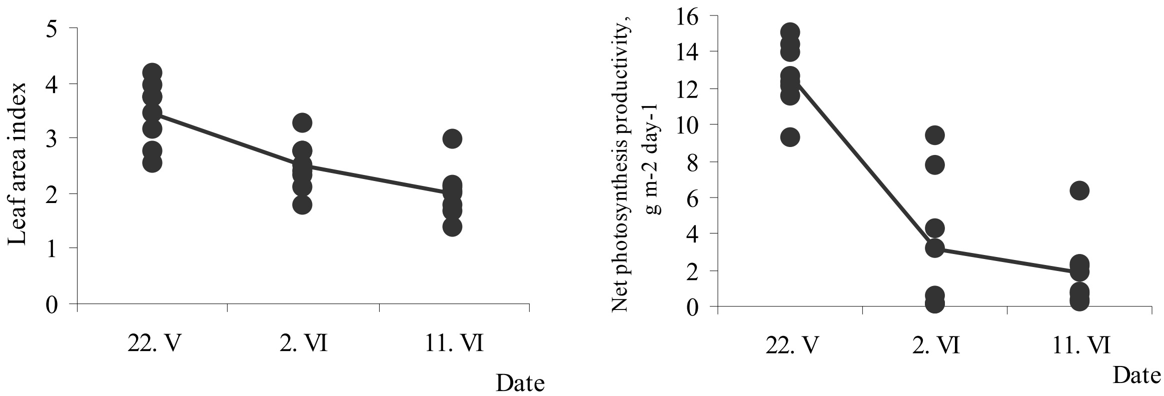


Figure 1. Index of photosynthesis activity for *Festulolium* and hybrid ryegrass swards (2003)

Weather conditions affect development of leaves and their photosynthetic capacity. Dry and hot weather in the beginning of summer 2003 led to faster reaching threshold value of LAI treshold and its reduction afterwards (Fig. 1).

Positive correlation is established between the leaf area and net photosynthesis productivity (r = 0.66) for *Festulolium* and hybrid ryegrass swards in 2003. The maximum average value of LAI – 3.13 was achieved by *Festulolium* cv. Hykor. Small DM yield depending on net photosynthesis productivity was obtained in the year 2003. It is characterized by equation of linear regression, but it has insignificant P-value = 0.0838 > 0.05 (Fig. 2).

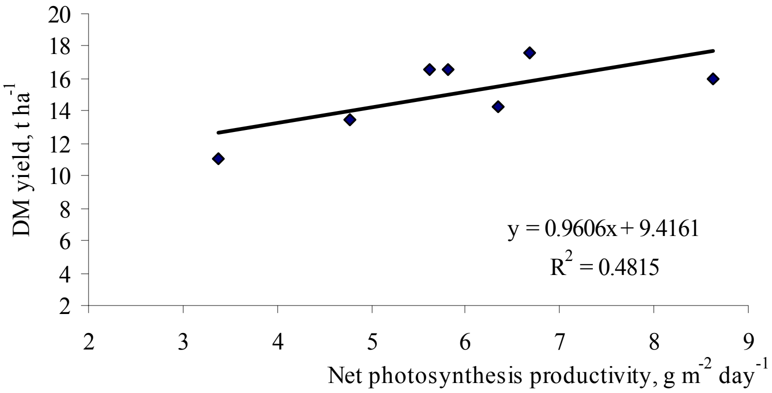
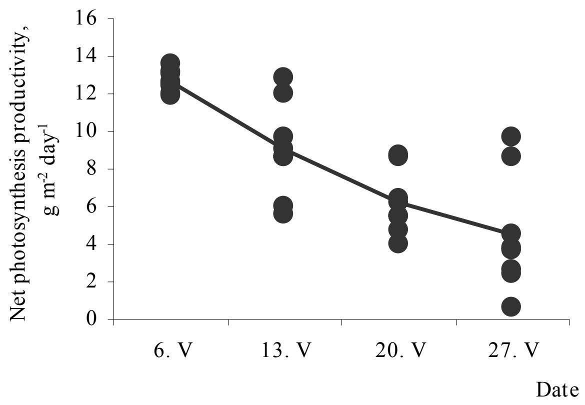


Figure 2. Equation of linear regression between net photosynthesis productivity and plant DM yield (2003)

Late and cool spring in 2004 led to slowed formation of leaf area. Negative correlation is established between the leaf area and net photosynthesis productivity (r = –0.37) for *Festulolium* and hybrid ryegrass swards in 2004. As leaves aged, their photosynthetic capacity declined (Fig. 3). Maximum values of LAI in both trial years were achieved by *Festulolium cv.* Punia accounting for 4.03 to 4.16 and *cv.* Perun accounting for 3.95 to 4.51.



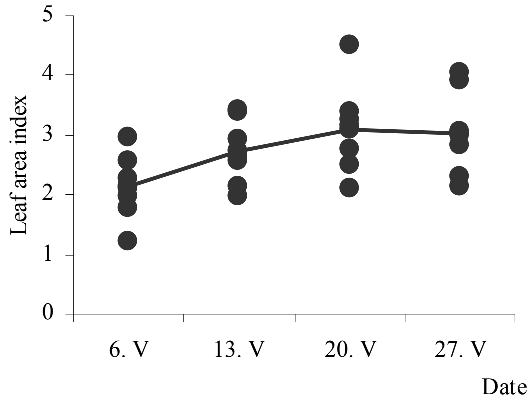


Figure 3. Indices of photosynthesis activity for *Festulolium* and hybrid ryegrass swards (2004)

Significant DM yield depending on leaf area index was obtained in the year 2004. It is characterized by equation of linear regression, with P-value = 0.0121 < 0.05 (Fig. 4).

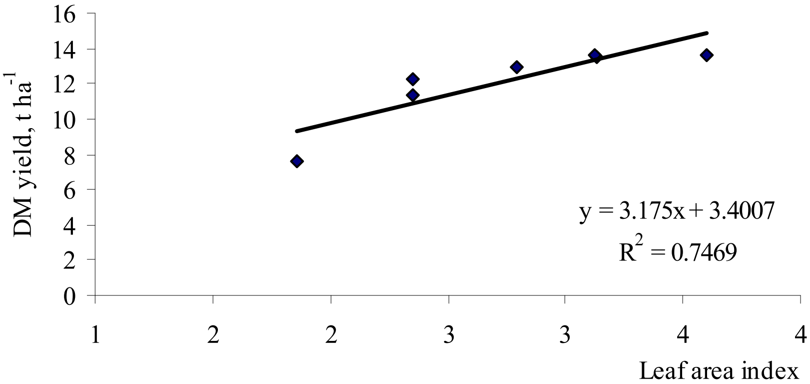


Figure 4. Equation of linear regression between net LAI and plant DM yield, (2004)

The highest average net photosynthesis productivity in both trial years was achieved by *Festulolium cv*. Saikava 8.97 g m^{-2} day^{-1}. All *Festulolium* and hybrid ryegrass cultivars exceeded perennial ryegrass cv. Spidola – 5.5 g m^{-2} day^{-1}. The average net photosynthesis productivity of *Festulolium* cultivars was by 13% higher compared to hybrid ryegrass, and by 38% higher compared to perennial ryegrass.

Unfavorable weather conditions in 2002–2003 didn't cause winterkilling of the studied cultivars except for early heading hybrid ryegrass *cv.* Ligunda. The average DM yield distribution between years showed that the maximum yield was obtained in the 1st year of sward use reaching 44% from total sward DM yield in both N treatments (Table 1).

Table 1. Distribution of DM yield between years, t ha^{-1}, (2002–2004)

Nitrogen rate, kg ha^{-1} (F_A)	Varieties (F_B)	DM yield in sowing year		DM yield in 1st year of sward use		DM yield in 2nd year of sward use	
		t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
N120	Spidola	5.20	100	11.09	100	8.64	100
	Lofa	8.38	161	14.30	129	12.03	139
	Felina	4.60	88	15.96	144	12.64	146
	Hykor	6.64	128	17.55	158	16.13	187
	Perun	8.50	163	16.61	150	12.05	139
	Tapirus	7.84	151	13.43	121	11.15	129
	Punia	7.91	152	16.58	150	12.04	139
N180	Spidola	5.20	100	12.91	100	10.05	100
	Lofa	8.38	161	15.73	122	13.47	134
	Felina	4.60	88	16.86	131	14.88	148
	Hykor	6.64	128	18.88	146	17.38	173
	Perun	8.50	163	18.46	143	14.54	145
	Tapirus	7.84	151	15.07	117	13.80	137
	Punia	7.91	152	18.46	143	14.48	144
$LSD_{0.05}$ for DM yield: F_A				0.32		0.33	
$LSD_{0.05}$ for DM yield: F_B		0.41		0.46		0.62	
$LSD_{0.05}$ for DM yield: F_{AB}				0.61		0.88	

The highest yield of DM 8.5 t ha^{-1} for the sowing year was provided by DLF-Trifolium *Festulolium cv.* Perun. In the 1st and 2nd years of sward use the highest DM yields were provided by DLF-Trifolium *Festulolium cv.* Hykor with N180 kg ha^{-1} applied – 18.9 and 17.4 t ha^{-1}, respectively.

In all production years the average productivity of *Festulolium* accounted for 36.4 t ha^{-1} DM with N120 kg ha^{-1} applied. The N-fertilizer dose increased to 180 kg ha^{-1} contributed to DM yield increase by 3.4 t ha^{-1} or 9 per cent. Total DM yield of hybrid ryegrass accounted for 32.4 t ha^{-1} with N120 kg ha^{-1} added. The N fertilizer dose increased to 180 kg ha^{-1} contributed to DM yield increase by 4.3 t ha^{-1} or 13 per cent. The total DM yield of perennial ryegrass accounted for 24.9 t ha^{-1} with N120 kg ha^{-1} applied. The N fertilizer dose increased to 180 kg ha^{-1} contributed to DM yield increase by 3.2 t ha^{-1} or 13 per cent (Fig. 5).

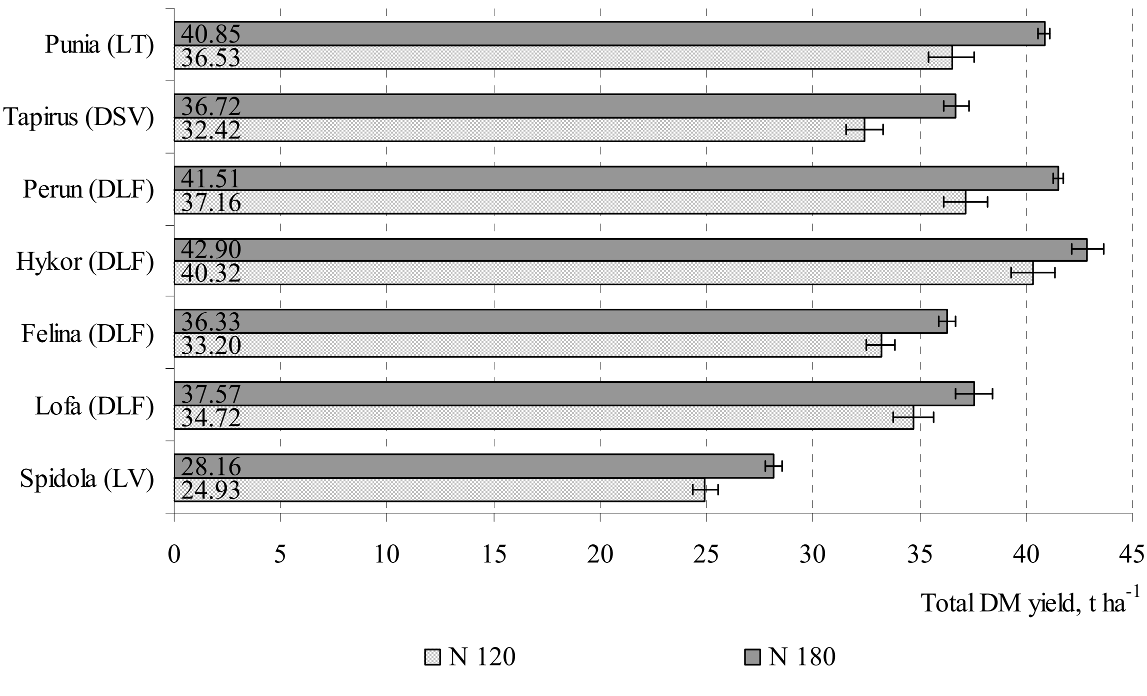


Figure 5. Total DM yield of *Festulolium* and *Lolium × boucheanum*, t ha^{-1}, (2002–2004)

The average DM yields of *Festulolium* cultivars was by 11.6 t ha^{-1} or 44%, but those of hybrid ryegrass by 8.0 t ha^{-1} or 30% higher compared to perennial ryegrass.

Conclusions

Cultivars of *Festulolium* and *Lolium × baucheanum* in Latvia are promising species of fodder grasses. Due to its competitive productivity, *Festulolium* may be equally ranked with the main forage grasses timothy and meadow fescue grown in climatic zone of Latvia.

Early heading hybrid ryegrass cultivars are less appropriate for Baltic climate conditions than the latest ones.

Further research results will show the possibilities of using *Festulolium* and hybrid ryegrass in grassland development.

References

1. Adamovich A. and Adamovicha O. (2003) Productivity and forage quality of *Festulolium/*legume mixed swards in response to cutting frequency. EGF, Grassland Science in Europe, vol. 8, 453–456.
2. Domanski P., Joks W. (1999) *Festulolium* cultivars – biological progress and its effect. Zesz. Nauk. ATR Bydgoszcz 220, 44: 87–94.
3. Ghesquière M., Barre P., Béguier V., Durand J-L., Garnier S., Laurent V. (2002) Interspecific hybridization in the fescue – ryegrass complex for European Grasslands. EGF, Grasland Science in Europe, vol. 7, 298–299.
4. Gutmane I., Adamovich A. (2004) Productivity and yield quality of *Festulolium* and *Lolium x boucheanum* varieties. EGF, Grassland Science in Europe, vol. 9, 428–430.
5. Hahn H., Schōberlein W. (1999) Characterization and identification of *Festulolium* hybrids by electrophoresis of seed proteins. Seed Science and Technology, vol. 27, 525–542.
6. Humphreys J., Tomas H. M., Jones N., Humphreys M. (2002) Sustainable grasslands withstanding environmental stress (SAGES). EGF, Grasland Science in Europe, vol. 7, 310–311.
7. Kryszak, Domanski P. (2002) Use value of *Festulolium brauni* (K. Richter) A. Camus cultivars registered in Poland. EGF, Grassland Science in Europe, vol. 7, 436–437.
8. Nekrošas S., Sliesaravičus A. (2002) Investigation of intergeneric ryegrass-fescue and inerspecific ryegrass hybrids developed in Lithuania. Žemdirbyste: Mokslo darbai. LŽI. Dotnuva-Akademija, t. 78, 158–163.
9. Nesheim L., Bronstad I. (2000) Yield and winter hardiness of *Festulolium* (*Festuca x Lolium*) in Norway. EGF, Grassland Science in Europe, vol. 5, 238–240.
10. Robson M. J., Parsons A. J., Williams T. E. Herbage production. (1989) In: Holmes W. (eds) Grass its production and utilization, Blackwell Scientific Publications LTD, 12–38.
11. Sliesaravičius A. (1997) Methods and results of changing genome composition and number in grasses. Plant Breeding: Theories, achievements and problems. LŽI. Dotnuva-Akademija, 149–152.
12. Woledge J. (1971) The effect of light intensity during growth on the subsequent rate of photosynthesis of leaves of tall fescue (*Festuca arundinacea* Scherb.) Annals of Botany 35, 311–322.
13. Woledge J., Leafe E.L. (1976) Single leaf and canopy photosynthesis in a ryegrass sward. Annals of Botany 40, 773–783.
14. Zwierzykowsky Z. (1980) Hybrids of *Lolium multiflorum* Lam. (2n+14) x *Festuca arundinaceae* Schreb. (2n+42) and its alloploid derivatives. I. Morphology, fertility and chromosome number of F_1 hybrids and C_0 and C_1 alloploid derivates. Genetica Polonica, vol. 21, 259–273.

THE ABOVEABOVEGROUND BIOMASS STRUCTURE OF SEVERAL GRASS SPECIES DEPENDING ON THE SOWING DATE AND SOIL MOISTURE

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Abstract

The aim of the research was to analyse the aboveground biomass structure for varieties for five grass species used in meadow mixtures and to verify the extent at which habitat conditions influence this structure depending on the sowing date. Considering growth and development of grass varieties in Poland, the spring sowing date proved to be better than the late-summer one, due to more advantageous weather conditions, especially in the sowing year. If weather conditions are disadvantageous, and in particular there are moisture shortages, the differences in plant development that occur in the sowing year remain throughout further vegetation. This fact has impact on the aboveground biomass structure; however, it remains characteristic for each grass species, as each of them has a unique morphological structure.

Key words: structure of aboveground biomass, grasses, sowing date, soil moisture

Introduction

Research into grass biology describes among others the phenomena of aboveground and underground biomass development and competitiveness, as well as the role of habitat and anthropogenic factors influencing these processes (Rutkowska *et al.*, 1999). The processes are directly related to the important role that grasses play in agriculture and natural environment. The aboveground biomass structure is specific for each grass species and depends on numerous morphological and biological characteristics, habitat conditions and meadow farming measures (Jewiss, 1972; Kostuch, Twardy, 1975; Rutkowska, 1976; Harkot, 1998; Janicka, 1998).

This research was aimed at a more in-depth description of grass species (varieties) in relation to their aboveground biomass structure and at verifying the extent at which habitat conditions influence this structure considering the sowing date. Particular attention was devoted to the tillering rate and the biomass of tillers, as their concentration constitutes an important element of the structure, determining the variety's productiveness.

Materials and Methods

The research was conducted at the Experimental Station of the Grassland Division of the Warsaw Agricultural University (SGGW) in central Poland, located in the river valley of Pisia Tuczna. The experiment was established on degraded black-earth in two habitats: (1) moderately moist (150 m from the river), and (2) moderately dry (400 m from the river). In the moderately moist habitat the soil was of alluvial character, with the soil textural group of sandy-silty clay, the organic substance content of 4.5%, pH 6.5. In this habitat the level of ground water depended on the precipitation as well as the water level in the nearby river and varied between 50 and 80 cm (Figure 1). In the moderately dry habitat the soil was created from slightly loamy sand on light loam, with the organic substance content of 2.7% and pH 4.8; the ground water level varied more considerably and fell below 150 cm.

The experiment was designed as a randomised complete block in four replications, on plots of land of 2 m^2. The seeds were sown manually in rows on two sowing dates during the same year: in spring (24 April) and late summer (3 September), according to the norms recommended for practice (Grzyb, 1988). The research covered five grass species: *Lolium perenne* (variety – Argona), *Festuca pratensis* (variety – Skra), *Dactylis glomerata* (variety – Baza), *Bromus inermis* (variety – Brudzyńska), and *Arrhenatherum elatius* (variety – Wiwena). Mineral fertilization with the following doses in kg ha^{-1}: 150 N (in three equal doses for each cutting), 40 P (in spring) and 100 K (in two equal doses – in spring and after the first cut) were applied.

In the sowing year, the development rate for each grass species was analysed; four and six weeks after the sowing the number of tillers and their mass were verified. In subsequent years the aboveground biomass structure prior to each of the three cuttings was specified; the first cut was performed during the full inflorescence stage for each variety. Plant samples were collected from a 30 cm long and 12 cm wide stripe of land (the area of 360 cm^2). The height of reproductive tillers that appeared in the first cut, and the heights of vegetative tillers, the number of tillers and their mass were examined. Based on this the number of tillers for 1 m^2 and the weight for 100 tillers were established. All data was statistically analysed by three-factor analysis of variance and verified using F Fisher-Snedecor's test and Tukey's test.

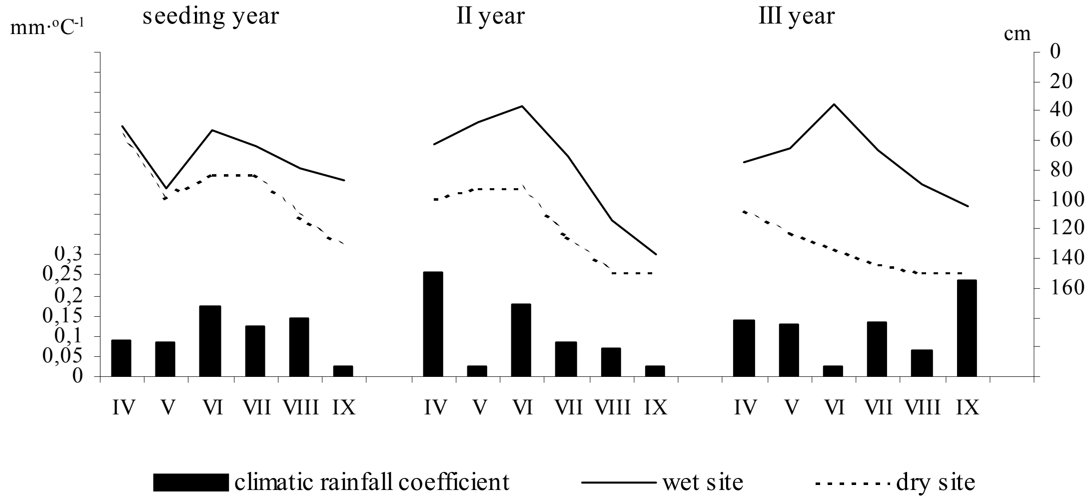

Figure 1. Climatic rainfall coefficients (mm·^{o}C^{-1}) and ground water tables (cm) in wet and dry sites during growing seasons of seeding year, second and third years of vegetation

Results and Discussion

Weather conditions during the research were not advantageous for grass growth and development. There were long periods without rain, and on the basis of the climatic precipitation index they were classified as extra dry and droughty (Fig. 1). Atmospheric conditions in the sowing year were more advantageous in the spring period than in the late summer and autumn one, as September and October that year were droughty. Optimal conditions for grass development (Vinczeffy's index above 0.2; Vinczeffy, 1984) appeared only during short periods after abundant precipitation, i.e. in the sowing year in the first week of June, in April and June of the next year, and in September in the third vegetation year.

Number of tillers. Regardless of the sowing date and soil moisture level in the habitat, *L. perenne* plants developed fastest in the initial period after sowing; during first four weeks after sowing they developed on average more than 3 thousand tillers for each 1 m^2. *A. elatius*, *F. pratensis* and *D. glomerata* developed at a half slower pace. Plants of the *B. inermis* species had the slowest development rate (Table 1).

Table 1. The number of tillers of five grass species per 1 m^2 four weeks after sowing as affected by sowing date and soil moisture

Species	Sowing date		Habitat		Mean for species
	Spring	Late-summer	Wet	Dry	
Lolium perenne	4291	2375	3870	2796	3333 a
Festuca pratensis	1551	1379	1579	1352	1465 b
Dactylis glomerata	1509	1472	1592	1389	1490 b
Bromus inermis	718	652	805	565	685 c
Arrhenatherum elatius	2504	893	1828	1569	1699 b
Mean	2115 A	1354 B	1935 x	1534 y	1734
$LSD_{0.05}$	219.0		173.0		581.3

** Numbers indicated by the same letters are not significantly different.

Out of the analysed species, *B. inermis* was the last to germinate and start tillering, whilst the number of tillers four weeks after sowing was almost five times lower than for *L. perenne*. The order of the species with regard to the development rate was the same four and six weeks after sowing. In the next years, *L. perenne* developed the highest number of tillers both reproductive as well as vegetative, in all around between 5000 and 9000 m^{-2} (in the third year, Table 2, Figure 2). Species with a medium tillering rate (3000–6000 m^{-2}) include *A. elatius*, *F. pratensis* and *D. glomerata*. *B. inermis*, a creeping grass species, had the worst tillering rate (around 2 000 m^{-2}).

The number of tillers largely depended on soil moisture. In the sowing year, the tillering of the analysed species was more intensive in the moderately moist habitat than in the moderately dry habitat (on average around 20–25% more tillers). However, in the third year of vegetation the general number of tillers was similar in both habitats. Nevertheless, it has to be noted that during the first cut in that year in the plots after spring sowing the number of tillers was significantly higher in the moderately moist habitat (on average 3624 tillers per m^{-2} and 3132 tillers per m^{-2}, $NIR_{0.05}$ = 374.9), whilst in the plots after late summer sowing the differences were statistically insignificant. The number of flowering tillers depended on soil moisture to a greater extent than the number of vegetative tillers. In the moderately moist habitat the plants developed a significantly higher number of reproductive tillers than in the moderately dry habitat, whilst the number of vegetative tillers did not differ much between the habitats (Table 2). During subsequent cuttings, the number of tillers in both habitats was similar, most probably due to considerable moisture shortages lasting for long time and similar for both habitats, which is believed to hinder the setting of new tillers (Jewiss, 1972; Rutkowska, 1976; Harkot, 1994).

Table 2. The number of tillers of five grass species per 1 m^2 in every cut (I–III) as affected by sowing date and soil moisture in the third year of vegetation

Species	Sowing date		Habitat		Mean for species
	Spring	Late-summer	Wet	Dry	
	I cut – reproductive tillers				
Lolium perenne	2257	2104	2115	2246	2180 a
Festuca pratensis	1542	792	1292	1042	1167 b
Dactylis glomerata	1184	955	1101	1038	1069 b
Bromus inermis	1049	851	1257	642	950 b
Arrhenatherum elatius	1358	1101	1531	927	1229 b
Mean	1478 A	1160 B	1459 x	1179 y	1319
$LSD_{0.05}$	168.2		119.6		390.9
	I cut – vegetative tillers				
Lolium perenne	3101	2524	2920	2705	2812 a
Festuca pratensis	1726	1212	1667	1271	1469 bc
Dactylis glomerata	2069	1799	1805	2062	1934 b
Bromus inermis	996	1080	802	1274	1038 c
Arrhenatherum elatius	1608	1601	1392	1816	1604 bc
Mean	1900 A	1643 B	1717	1826	1771
$LSD_{0.05}$	254.5		n.s.		623.5
	II cut				
Lolium perenne	7226	5038	6104	6160	6132 a
Festuca pratensis	5187	2889	4055	4021	4038 b
Dactylis glomerata	2896	3024	2976	2944	2960 bc
Bromus inermis	2104	1962	1944	2121	2033 c
Arrhenatherum elatius	4010	3177	3469	3719	3594 bc
Mean	4285 A	3218 B	3710	3793	3751
$LSD_{0.05}$	467.7		n.s.		1612.6
	III cut				
Lolium perenne	9201	8042	9285	7958	8621 a
Festuca pratensis	5271	4066	5264	4073	4668 b
Dactylis glomerata	3537	3135	3295	3377	3336 c
Bromus inermis	2232	2215	2125	2323	2224 d
Arrhenatherum elatius	6410	4878	5691	5597	5644 b
Mean	5330 A	4467 B	5132	4665	4899
$LSD_{0.05}$	450.7		n.s.		1028.2

** Numbers indicated by the same letters are not significantly different.

In the sowing year, all of the species, regardless of soil moisture, developed a considerably higher number of tillers, both vegetative and reproductive, after spring sowing compared to late summer sowing (Table 1). This resulted mainly from disadvantageous moisture conditions (Figure 1; lack of precipitation in October) and less intensive tillering in the sowing year during the autumn period. When considering the two sowing dates, the most significant difference in the number of tillers, four and six weeks after sowing, was observed in the species that developed the fastest – *L. perenne* and *A. elatius* (around 40%). For the majority of the analysed species (except for *F. pratensis*), the impact of the sowing date on the differences in the number of tillers decreased in subsequent years and in the third year of vegetation this difference amounted on average to 15%. For *F. pratensis*, this difference was much more significant throughout the whole research period and varied between 20–45%. This could have resulted from relatively demanding moisture requirements of the species, whilst the disadvantageous weather conditions made it impossible to even out the differences that had occurred during the initial development stage.

The mass of 100 tillers. In the sowing year, regardless of the sowing date and soil moisture, *B. inermis* had the highest mass of 100 tillers, whilst *A. elatius* ranked the second. Six weeks after sowing, tillers with the lowest mass were that of *F. pratensis*. In subsequent years, regardless of the cutting, *B. inermis* developed tillers with the highest mass (as in the sowing year). *A. elatius* had the highest mass of a single tiller in the first cut, whilst *D. glomerata* – in the second and third cuts. *L. perenne* had the lowest mass of 100 tillers in the third vegetation year, which resulted mainly from the differences in the height of tillers (Table 3).

Table 3. Mass (g) of 100 tillers of five grass species in every cut (I–III) as affected by sowing date and soil moisture in the third year of vegetation

Species	Sowing date		Habitat		Mean for species
	Spring	Late-summer	Wet	Dry	
		I cut			
Lolium perenne	10.64	9.12	13.80	5.96	9.88 d
Festuca pratensis	20.30	17.51	22.90	14.91	18.90 c
Dactylis glomerata	21.31	17.39	27.00	11.69	19.35 c
Bromus inermis	48.65	38.11	61.20	25.56	43.38 a
Arrhenatherum elatius	33.31	22.96	34.29	21.99	28.14 b
Mean	26.84 A	21.02 B	31.84 x	16.02 y	23.93
$LSD_{0.05}$	2.33		2.14		4.74
		II cut			
Lolium perenne	4.21	3.34	4.08	3.48	3.78 c
Festuca pratensis	6.29	4.89	6.67	4.51	5.59 c
Dactylis glomerata	13.91	9.05	13.63	9.32	11.48 b
Bromus inermis	21.45	13.21	17.72	16.94	17.33 a
Arrhenatherum elatius	12.70	6.16	11.07	7.79	9.43 b
Mean	11.71 A	7.33 B	10.63x	8.41 y	9.52
$LSD_{0.05}$	1.59		1.45		2.47
		III cut			
Lolium perenne	4.29	3.90	5.00	3.19	4.09 c
Festuca pratensis	7.26	5.05	6.91	5.39	6.15 b
Dactylis glomerata	11.37	11.60	12.37	10.61	11.49 a
Bromus inermis	13.98	10.86	16.62	8.22	12.42 a
Arrhenatherum elatius	5.84	5.12	7.42	3.54	5.48 bc
Mean	8.55 A	7.31 B	9.66 x	6.19 y	7.93
$LSD_{0.05}$	0.47		0.75		1.72

** Numbers indicated by the same letters are not significantly different.

Significant differences in mass, resulting from soil moisture level, did not occur at the initial development stage, especially after the late summer sowing date. Notable statistical differences between the habitats appeared in the sixth week after sowing or later and remained throughout further vegetation stages. In the moderately moist habitat the mass of 100 tillers was on average by 20–50% higher than in the moderately dry habitat; the most significant differences occurred in the first cut.

Considering the sowing dates, the analysed species had a larger mass of tillers at the initial development stage after late summer sowing compared to the spring sowing. However, already six weeks after sowing, tiller mass was larger in the plots sown in spring. A similar dependence occurred also in subsequent cuttings and years (Table 3).

The height of tillers. During the sowing year, regardless of the sowing date and soil moisture, *L. perenne* and *A. elatius* had the fastest elongation rate. Tillers of these species were on average 30% higher than the tillers of *D. glomerata*, which had the slowest growth rate. During further vegetation years, *A. elatius* and *B. inermis* had the highest reproductive tillers in the first cut. In the second and third cuts, high grasses *A. elatius* and *B. inermis* as well as *D. glomerata* had the highest vegetative tillers (on average higher by 40%); the situation was different for *F. pratensis* (Table 4). This could have resulted from low precipitation. The results are supported by previous research on *F. pratensis* that had proved the species to be vulnerable to dry weather (Janicka, Rutkowska, 1992).

Table 4. Height (cm) of tillers of five grass species in every cut (I–III) as affected by sowing date and soil moisture in the third year of vegetation

Species	Sowing date		Habitat		Mean for species
	Spring	Late-summer	Wet	Dry	
I cut – reproductive tillers					
Lolium perenne	55.8	55.0	58.5	52.2	55.4 c
Festuca pratensis	79.2	68.4	78.9	68.7	73.8 b
Dactylis glomerata	87.6	70.4	86.0	72.0	79.0 b
Bromus inermis	102.5	77.0	101.1	78.4	89.7 ab
Arrhenatherum elatius	98.7	104.4	95.8	107.4	101.6 a
Mean	83.7 A	75.0 B	84.1 x	75.7 y	79.6
$LSD_{0.05}$	4.18		4.38		17.37
I cut – vegetative tillers					
Lolium perenne	42.2	40.7	44.3	38.7	41.5 d
Festuca pratensis	54.5	45.6	51.1	49.0	50.1 cd
Dactylis glomerata	59.6	51.1	63.0	47.8	55.4 bc
Bromus inermis	71.5	53.1	70.3	54.4	62.3 ab
Arrhenatherum elatius	77.3	65.5	76.3	66.5	71.4 a
Mean	61.0 A	51.2 B	61.0 x	51.3 y	56.1
$LSD_{0.05}$	2.90		3.21		11.24
II cut					
Lolium perenne	30.0	23.2	29.3	23.8	26.6 b
Festuca pratensis	34.3	22.0	30.5	25.8	28.2 b
Dactylis glomerata	54.5	40.2	49.0	45.7	47.3 a
Bromus inermis	59.0	40.0	52.1	46.9	49.5 a
Arrhenatherum elatius	55.3	41.3	53.4	43.2	48.3 a
Mean	46.6 A	33.3 B	42.9 x	37.1 y	40.0
$LSD_{0.05}$	1.74		1.91		6.57
III cut					
Lolium perenne	21.6	20.6	24.3	17.9	21.1 c
Festuca pratensis	23.6	21.6	27.2	18.1	22.6 c
Dactylis glomerata	37.4	37.1	42.4	32.1	37.3 a
Bromus inermis	30.4	28.3	36.3	22.3	29.3 b
Arrhenatherum elatius	35.4	30.5	40.6	25.3	33.0 ab
Mean	29.7 A	27.6 B	34.2 x	23.1 y	28.7
$LSD_{0.05}$	1.26		1.76		4.86

** Numbers indicated by the same letters are not significantly different.

The height of tillers to a large extent depended on soil moisture. In subsequent years, e.g. in the third vegetation year, flowering tillers in the moderately moist habitat were on average by 20% higher than in the moderately dry habitat (except for *A. elatius*), whilst for vegetative tillers this difference varied from 20% in the first and second cuts to around 50% in the third cut (Table 4). Regardless of the species, tillers of grasses sown in spring, both flowering and vegetative, were significantly higher, most probably due to better development of underground biomass (Janicka, 2004).

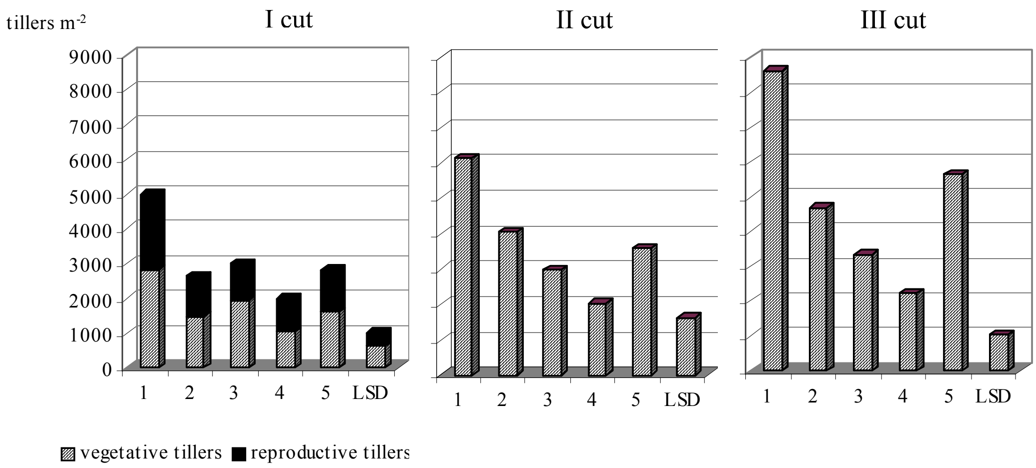

Figure 2. Number of tillers of five grass species per 1 m^2 in every cut (I–III) irrespective of sowing date and soil moisture in the third year of vegetation (1 – *Lolium perenne*, 2 – *Festuca pratensis*, 3 – *Dactylis glomerata*, 4 – *Bromus inermis*, 5 – *Arrhenatherum elatius*)

Conclusions

Soil moisture and sowing date have significant impact on the development of the aboveground structure of grasses.

In the moderately moist habitat, regardless of the sowing date, tillers elongate faster, the number of tillers (especially reproductive ones) is higher, the mass of tillers is higher than in the moderately dry habitat.

The spring sowing date proved to be more advantageous for growth and development of grasses than the late summer date, due to better weather conditions, especially in relation to the sowing year.

Differences in species development created in the sowing year remain throughout further vegetation years.

Grass species (varieties) have different aboveground biomass structure:

– *L. perenne* – short grass, variety: Argona – intensive tillering throughout the whole vegetation period, both during the sowing year and during the next years.

High grasses:

– *B. inermis* – creeping grass, variety: Brudzyńska – with the lowest tillering rate, but has the highest mass;

– *A. elatius,* variety: Wiwena, and *D. glomerata*, variety: Baza – tillering of moderate intensity, high tillers of heavy mass;

– *Festuca pratensis*, variety: Skra – very vulnerable to dry weather, develops relatively short tillers with a low mass, especially when there are shortages of precipitation.

References

1. Grzyb S. (1988) Mieszanki na łąki i pastwiska trwałe. Melioracje Rolne Biuletyn Informacyjny, 2, 1–22.
2. Harkot, W. (1998) Dynamika początkowego wzrostu i rozwoju siewek traw jako kryterium ich przydatności do podsiewu. Łąkarstwo w Polsce (Grassland Science in Poland), 1, 139–146.
3. Janicka M. (1998) The influence of weather conditions and nitrogen fertilization on number and proportion of reproductive shoots of three grass species cultivars. Grassland Science in Europe, 3, 71–76.
4. Janicka M. (2004) Rozmieszczenie biomasy kilku gatunków traw w zależności od terminu siewu i uwilgotnienia siedliska w trzecim roku po zasiewie. Annales UMCS, Sec. E, 59, 4, 1705–1713.
5. Jewiss O. R. (1972) Tillering in grasses – its significance and control. J. Brit. Grassld Soc., 27, 65–82.
6. Kostuch R., Twardy S. (1975) Wpływ czynników meteorologicznych na fazy fenologiczne wybranych roślin łąkowo-pastwiskowych. Wiad. IMUZ t. XII, z 3, 137–145.
7. Rutkowska B. (1976) Krzewienie się *Dactylis glomerata* L. i *Lolium perenne* L. w warunkach intensywnego nawożenia i użytkowania. Rocz. Nauk Rol., F, 79, 2, 23–41.
8. Rutkowska B., Janicka M. (1992) Biomass formation of five grass species in the seeding year. *Annals of Warsaw Agricultural University – SGGW, Agriculture* 24, 45–52.
9. Rutkowska B. *et al.* (1999) Biologia traw łąkowych w polskich pracach badawczych. Łąkarstwo w Polsce (Grassland Science in Poland), 2, 119–128.
10. Vinczeffy J. (1984) The effect of some ecological factors on grass yield. Proc. of the 10th Gen. Meet. of Europ. Grassld. Fed., Ås, Norway, 26–30 June, 76–79.

BENEFITS OF PASTURE LEGUMES TO SEASONAL DYNAMICS OF SWARD YIELD AND FORAGE QUALITY

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Abstract

The best sward composition, stable balance between legumes and grasses in the swards, sustainable forage production within the grazing season and over several years are still relevant objectives in grassland management. Different swards consisting of *Trifolium repens* L., *Medicago sativa* L., *Lolium perenne* L., *Poa pratensis* L., *Festulolium* hybrid were investigated under frequent and less frequent grazing management on a gleyic loamy soil (*Cambisol*). Sward composition and grazing frequency had a significant effect on sward yield and quality. The yield of legumes accounted for nearly half of the total sward yield, and in the swards with lucerne even more than half. Legume yield declined annually in both grazing frequencies until the fourth year of swards use but to a greater extent under frequent grazing. From the fifth year the sward yield started to increase and in the sixth year was nearly the same as in the first year of sward use. Dry matter yield was more stable under the less frequent grazing treatment, but more equal distribution of the yield within the grazing season was observed in the frequent grazing management. The experiment demonstrated a positive effect of legumes on the yield, its quality and distribution of the yield over the whole grazing season.

Key words: grazing frequency, crude protein, forage quality, lucerne, white clover, yield

Introduction

The intensity of grassland production depends on local circumstances and the use of the forage produced, although it might be flexible over time. The farmer managing grazing usually has goals to achieve the best sward composition, stable balance between grasses and legumes in the swards, sustainable forage production under changing conditions and to meet the nutritional requirements of animals. Due to the complexity of interactions between them, the consequences of variation in such factors as competitive abilities, soil fertility, nutrient depositions in urine, and grazing intensity are not easy to predict (Bullock and Marriott, 2000; Hopkins, 2000; Tonkunas and Kadziulis, 1977). Results of investigations show that the N-recovery-rate is rather low for grassland, but could be increased substantially by using legumes (Elsaesser, 2004). Nowadays, there is increased interest in legumes and legume-based swards. Legumes provide the potential for significant N inputs via N_2 fixation and sustain a moderate-high level of productivity in the long-term (Ledgard, 2001). Legume and legume/grass swards could be productive even without the use of nitrogen fertiliser, and could have a better quality than grasses treated with nitrogen (Kadziuliene, 2000; Gutauskas and Petraityte, 2002; Halling *et al.*, 2002). A more even distribution of the yield over grazing season could be achieved by applying nitrogen after each grazing and by proper sward utilisation frequency. Grazing frequency affects the persistence of species, botanical composition and productivity of swards (Gutauskas and Bilevicius, 1989; Hopkins, 2000; 't Mannetje, 2000). However, the best sward composition, stable balance between legumes and grasses in the swards, sustainable forage production within grazing season and over several years are still relevant objectives in grassland management. The large degree of variability within swards and between years has encouraged us to search for a wider diversity of sward combinations incorporating legumes, in order to achieve stability of production and improved forage quality.

The objectives of the research were to determine the effects of frequent and less frequent grazing of legume/grass swards and to compare the productivity, persistence and quality of white clover/grass, white clover/lucerne/grass and lucerne/grass swards, to select more stable and competitive legume/grass swards.

Materials and Methods

In 1998–2004, a bi-factorial field trial of pasture utilization was carried out on a sod gleyic loam soil (*Cambisol*) near Dotnuva, Lithuania (55°24'N, average annual rainfall 555 mm, average annual temperature 6 °C, average length of growing season 194 days). The pastures were re-established in the spring of 1998 with an oat/vetch cover crop for green forage. Soil pH varied between 6.5 to 7.0, humus content was 2.5–3.2%, C content 14,5 g kg^{-1}, available P 50–80 mg and K 100–150 mg kg^{-1}. The treatments of A factor involved 7 different swards consisting of white clover (*Trifolium repens* L.), lucerne (*Medicago sativa* L.), perennial ryegrass (*Lolium perenne* L.), meadow grass (*Poa pratensis* L.), and *Festulolium* hybrid Lithuanian varieties. Legume/grass proportion in the seeding mixtures was 40:60 or 60:40. The composition of mixtures in different treatments (kg ha^{-1}):

1) *Trifolium repens*(4.0) / *Lolium perenne*(9.6);

2) *T. repens*(4.0) / *L. perenne*(4.8) / *Poa pratensis*(3.6);
3) *Medicago sativa*(7.2) / *L. perenne*(3.2) /*P. pratensis*(2.4);
4) *T. repens* (3.0) / *M. sativa*(3.6) / *L. perenne*(6.4);
5) *L. perenne*(16.0) / N_0
6) *L. perenne*(16.0) / N_{240}
7) *T. repens*(4.0) / *Festulolium* hybrid (9.6).

The treatments of B factor involved frequent (F) and less frequent (LF) grazing with 6 and 5 grazings per season, respectively. In 2004 swards in all treatments were used identical – 4 grazings. The grazing season started in the beginning of May and lasted until the middle of October. Pasture swards were grazed by dairy cows. Grazing intensity was 2–2.5 cows ha^{-1} year^{-1}, grazing season duration 150 days. The net plot size was 2.5 × 15.0 meters. P and K were applied according to recommended rates and soil analyses. Before grazing, the dry matter (DM) yield was estimated in four replicates. Crude protein (CP) was calculated according to the nitrogen concentration (determined by Kjeldahl method), and multiplying it by 6.25. The yield data were statistically processed using analysis of variance.

Results and Discussion

The sward composition and grazing frequency had a substantial effect on DM yield and quality. In the first year of sward use total DM yield varied between 2.62 and 6.51 t ha^{-1} among the treatments with different swards under frequent grazing. When the same swards were used under less frequent grazing, DM yield varied between 3.23 and 7.55 t ha^{-1} (Table 1).

Table 1. Total annual DM yield of different swards under frequent (F) and less frequent (LF) grazing

Swards	Dry matter, t ha^{-1}											
	1999		2000		2001		2002		2003		2004*	
	F	LF	F	LF	F	LF	F	LF	F	LF	F*	LF*
Trifolium repens/ Lolium perenne	5.61	6.12	3.47	5.49	3.05	5.02	1.42	2.58	1.98	2.69	5.53	5.26
T. repens/L. perenne/ Poa pratensis	5.62	6.56	3.39	5.36	3.21	5.16	1.08	2.47	1.64	2.20	5.22	4.73
Medicago sativa/ L.perenne/P.pratensis	6.51	7.55	6.32	8.87	4.44	7.19	2.30	3.04	3.97	5.59	7,21	8.63
T. repens/M. sativa/ L. perenne	5.96	6.96	4.91	8.11	3.99	6.56	1.62	3.02	3.14	4.76	6.66	7.04
L. perenne/N_0	2.62	3.23	2.68	4.45	3.14	4.73	0.89	3.12	1.77	2.31	4.86	4.38
L. perenne/N_{240}	5.74	7.54	4.39	7.10	3.18	4.51	1.53	3.04	4.04	4.20	7.64	7.72
T. repens/Festulolium hybrid	6.16	6.74	4.23	6.21	3.46	5.36	1.41	2.60	1.96	2.53	5.43	4.97
$LSD_{0.05}$ (A / Bfactor)	0.303/0.124		0.300/0.122		0.243/0.099		0.320/0.130		0.257/0.105		0.327/0.133	

* In the year 2004, 4 grazings were used for both treatments of B factor.

Frequent grazing caused significant annual DM losses from the first to the fourth year of use. DM yield in the fourth year accounted for only 19–35% of the first year DM yield level, depending on sward composition. DM yield decreased from the first to the fourth year under less frequent grazing, too. However, the yield of legume/grass swards in the fourth year in less frequent grazing declined more slowly than in frequent grazing and accounted for 37–54% of the first year yield. Nevertheless, from the fifth year the sward yield started to increase and in the sixth year it was nearly the same as in the first year of sward use. The *M. sativa/L. perenne/Poa pratensis* and *T. repens*/*M. sativa/L. perenne* swards gave the best yield under both grazing frequencies in all four years of use, and in five years under less frequent grazing. High and stable yields in the 3–4 grazings season^{-1} regime have been obtained in Dotnuva in lucerne variety trials (Gutauskas and Petraityte, 2002). The previous research revealed a marked reduction of lucerne under more intensive utilisation (Putvinskis, 1992).

In the current experiment, in the *T. repens*/*M. sativa/L. perenne* swards lucerne persisted well in all years even under frequent grazing, and white clover did not have any influence on DM yield of those swards as we had expected. However, all legume-based swards in terms of the yield were similar to the grass swards applied with mineral nitrogen, and lucerne-based swards significantly outyielded the grass swards with nitrogen. The presented results are in line with findings of Elsaesser (2004) suggesting that the use of legumes resulted in a great increase of productivity because of the much higher N efficiency, but there exist significant differences between white clover and lucerne.

The share of legumes varied between sward type and grazing frequency (Table 2). A higher legume share was observed for the swards of *M. sativa/L. perenne/P. pratensis* and *T. repens/M. sativa/L. perenne.* Even under frequent grazing the share of legumes in these swards was higher than in swards of *T. repens/L. perenne* or *T. repens/L. perenne/P. pratensis.* The greatest share of legumes was obtained in the first year of sward use. However, by the second year the yield of legumes had decreased, except for the *M. sativa/L. perenne/P. pratensis* sward. The content of legumes in this sward was higher than that in the first year. Thus, in the third year the content of legumes under both grazing frequencies was higher than in the second year, again with the exception of the *M. sativa/L. perenne/P. pratensis* sward. The content of white clover decreased more rapidly than the content of lucerne. The less frequent grazing treatment had a negative effect on white clover, but positive on lucerne content in the swards. We expected that white clover would substitute for the declining share of lucerne in the *T. repens/M. sativa/L. perenne* sward by the third year of use. This assumption did not prove to be valid, as white clover competed poorly in that sward. It is interesting to note that in the fourth year of sward use lucerne competed well even under frequent grazing. This can be explained by the dry climatic conditions, which were adverse to white clover. Some researchers remarked that complex forage mixtures were more productive than simple grass-legume mixtures during drought and also reduced weed pressure. An increasing plant species diversity on pastures may be a simple way to increase forage productivity, stability, and reduce weed competition (Sanderson *et al.*, 2004).

Table 2. Annual share of legumes in the DM yield of swards under frequent (F) and less frequent (LF) grazing

Swards	Legume, %									
	1999		2000		2001		2002		2003	
	F	LF	F	LF	F	LF	F	LF	F	LF
Trifolium repens/ Lolium perenne	52.8	43.1	20.6	15.5	31.7	22.8	26.0	22.5	13.7	6.9
T. repens/L. perenne/ Poa pratensis	55.2	48.8	19.4	20.6	31.2	24.0	26.6	29.6	17.4	8.2
M. sativa/ L.perenne/P.pratensis	68.5	69.8	72.7	68.2	39.3	52.7	57.2	52.2	68.1	72.5
T. repens/M. sativa/ L. perenne	61.2	58.1	47.3	34.6	36.6	35.5	49.7	53.9	55.4	66.8
L. perenne/N_0	8.3	4.1	23.5	11.2	27.8	22.2	8.5	4.3	9.7	3.7
L. perenne/N_{240}	1.4	0.6	0.9	0.4	2.4	0.7	8.5	5.6	4.1	2.4
T. repens/Festulolium hybrid	43.2	35.6	23.2	13.4	25.5	21.0	25.0	19.1	17.3	6.9

The share of legumes in botanical composition was the greatest in second half of the season, therefore legumes had a positive impact on the yield distribution over the season. Distribution of the annual DM yield over grazing season on average was more even in the swards containing *Medicago sativa* or/and *Trifolium repens*, less equal in *Lolium perenne* swards without N fertilisers (Table 3). In this aspect, frequent grazing was noticeably superior over the less frequent. The climatic conditions of a season had affected considerably the distribution of annual yield over the whole grazing period (Table 4). The least dispersion of sward DM yield over season was in 1999, 2000 and 2003, the worse in the very dry 2002 year. The superiority of swards with *M. sativa* in such worse season was especially significant.

The effect of sward composition and grazing frequency on crude protein (CP) content reflected their effect on DM yield and legume share. CP showed a fairly consistent seasonal pattern, however in all swards and under both grazing frequencies met animal requirements. In spring (first grazing), CP values ranged from 179 to 238 mg kg^{-1} DM in frequent grazing and from 155 to 219 mg kg^{-1} in less frequent grazing.

Table 3. Distribution of annual yield of sward over the grazing season, avarage data, 1999–2003

Swards	Grazing frequency*	Annual DM yield share in grazings, %						Yield dispersion, s^2
		1st	2nd	3rd	4th	5th	6th	
Trifolium repens/ Lolium perenne	F	26	21	19	13	13	8	43
	LF	32	26	17	16	9	–	82
T. repens/L. perenne/ Poa pratensis	F	26	19	18	13	15	9	34
	LF	36	25	16	17	11	–	70
M. sativa/ L.perenne/P.pratensis	F	26	14	17	24	13	6	55
	LF	27	22	24	20	7	–	56
T. repens/M. sativa/ L. perenne	F	24	16	18	20	14	8	30
	LF	26	24	23	20	7	–	58
L. perenne/N_0	F	28	23	17	10	15	7	62
	LF	37	28	12	17	6	–	140
L. perenne/N_{240}	F	28	18	18	12	15	9	43
	LF	31	27	16	18	8	–	84
T. repens/Festulolium hybrid	F	26	19	19	15	13	8	40
	LF	32	24	17	18	9	–	74

* F – frequent grazing, LF – less frequent grazing.

Table 4. Dispersion of distribution of annual DM yield over different grazing seasons

Swards	Grazing frequency*	Annual yield dispersion in different grazing seasons, s^2				
		1999	2000	2001	2002	2003
Trifolium repens/ Lolium perenne	F	26	62	139	293	99
	LF	41	141	170	1161	313
T.repens/L.perenne/ Poa pratensis	F	24	50	151	230	147
	LF	52	156	176	1077	417
Medicago sativa/ L.perenne/ P. pratensis	F	13	141	110	188	57
	LF	30	123	196	376	153
T. repens/M. sativa/ L. perenne	F	11	61	132	157	33
	LF	29	148	177	446	169
L. perenne/N_0	F	132	26	119	256	203
	LF	103	176	178	1489	1070
L. perenne/N_{240}	F	45	33	114	349	33
	LF	69	84	170	1117	250
T.repens/Festulolium hybrid	F	31	80	107	262	119
	LF	33	163	167	1212	465

* F – frequent grazing, LF — less frequent grazing.

In the second and the third grazings, CP values declined a little, but in the fourth-sixth grazings they recovered to values around or higher than the first grazing (Table 5). Crude protein content had been generally lower between June and August (Schils *et al.*, 1999) and CP values showed a sharp increase toward the end of the growing season. Legumes usually produce a higher content of crude protein than grasses (Halling *et al.*, 2002), however, too high amounts of CP increase the risk of undesired N losses in the rumen (Bertilsson *et al.*, 2002).

Table 5. Crude protein concentration in different swards, g kg^{-1} DM, average data 1999–2003

Swards	Grazing						Annual
	1st	2nd	3rd	4th	5th	6th	
	Frequent grazing						
Trifolium repens/Lolium perenne	209	172	184	214	255	227	181
T. repens/L. perenne/Poa pratensis	213	170	188	212	261	226	205
M. sativa/L. perenne/P. pratensis	236	210	225	229	277	244	233
T. repens/M. sativa/L. perenne	234	188	210	227	255	225	222
L. perenne/N_0	179	138	164	191	234	201	173
L. perenne/N_{240}	238	172	211	290	264	221	223
T. repens/Festulolium hybrid	201	177	168	257	248	222	195
	Less frequent grazing						
Trifolium repens/Lolium perenne	181	149	189	214	255		172
T. repens/L. perenne/Poa pratensis	191	141	191	212	215		180
M. sativa/L. perenne/P. pratensis	205	195	212	232	233		207
T. repens/M. sativa/L. perenne	206	180	209	233	219		200
L. perenne/N_0	155	117	187	189	194		152
L. perenne/N_{240}	219	154	258	220	214		200
T. repens/Festulolium hybrid	184	145	219	199	197		176

Conclusions

The experiment demonstrated a positive effect of legumes on the distribution of the yield over the whole grazing season. Swards containing lucerne exhibited the highest sustainability over five years under both grazing frequencies. Frequent grazing was more suitable for a more even distribution of the yield over the season, however, higher and more stable annual DM yields were obtained under less frequent grazing.

References

1. Bertilsson J. *et al.* (2002) Effects of legume silages on feed intake, milk production and nitrogen efficiency. Landbauforschung Völkenrode*,* 234, 39–45.
2. Bullock J. M., Marriott C. A. (2000) Plant responses to grazing and opportunities for manipulation. In: Rook A. J. and Penning P. D. (eds.), Grazing management*.* No. 34, British Grassland Society, 17–26.
3. Gutauskas J., Bilevicius V. (1989). Ankstyvuju varpiniu ir velyvuju ankstiniu-varpiniu ganykliniu zolynu naudojimo daznumas. LZI moksliniu straipsniu rinkinys, 64, 68–76.
4. Gutauskas J., Petraityte E. (2002) Yield and quality of lucerne cultivars in the cut or grazed swards. Grassland Science in Europe, 7, 420–421.
5. Elsaesser M. (2004) Optimum management intensity of legume- and grass-based grassland swards. Grassland Science in Europe, 9, 510–512.
6. Halling M. *et al.* (2002) Forage legumes – productivity and composition.Landbauforschung Völkenrode, 234, 5–15.
7. Hopkins A. (eds.) (2000) Grass. Its Production and Utilization, Blackwell Science, 440.
8. Kadziuliene Z. (2000) White clover/grass mixtures for sustainable low input pastures. Grassland Science in Europe, 5, 344–346.
9. Ledgard S. F. (2001) Nitrogen cycling in low input legume-based agriculture, with emphasis on legume/grass pastures. Plant and Soil, 228, 43–59.
10. Mannetje L.'t (2000) The importance of grazing in temperate grasslands. In: Rook, A. J. and Penning, P. D. (eds.), Grazing management. Occasional Symposium No.34*,* British Grassland Society, 3–13.
11. Putvinskis V. (1992) Kulturiniu ganyklu zolynu technologiju palyginimas. LZI trumpi pranesimai, 25, 102–106.
12. Tonkunas J., Kadziulis L. (1977). Pievos ir Ganyklos. Vilnius, Mokslas, 304.
13. Sanderson M. A. *et al.* (2004) Plant species diversity influences on forage production and performance of dairy cattle on pasture. Grassland Science in Europe, 9, 632–634.
14. Schils R. L. M. *et al.* (1999) Dry-matter yield and herbage quality of perennial ryegrass/white clover sward in a rotational grazing and cutting system. Grass and Forage Science, 54, 19–29.

INFLUENCE OF STILITES ON GERMINATION AND DEVELOPMENT OF LAWN GRASS SEEDS

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Abstract

The investigations were carried out in the Laboratory of Genetics and Biotechnology and at the Experimental Station of the Lithuanian University of Agriculture in the period of 2002–2003. The research was focused on growth regulators – stilites, which had been synthesized at the Department of Organic Chemistry, Kaunas University of Technology, and on their influence on germination and development of gramineous grasses – perennial ryegrass (*Lolium perenne* L.), red fescue (*Festuca rubra* L.), and common-meadow-grass (*Poa protensis* L.). Growth dynamics of the investigated gramineous grasses was determined by means of measurements. Stilites were established to have positive influence on the germination of common-meadow-grass seeds. Having moistened the seeds of common-meadow-grass with 90 mgl^{-1} concentration solutions of the tested stilites, the seedlings after 10-day period were by 0.1–0.2 cm bigger than those in the control, where seeds had been moistened with distilled water. Stilites enhanced growth of cultivated seeds. By moistening the seeds with 90 mgl^{-1} concentration solutions of stilit-85 and stilit-123, the length of roots of perennial ryegrass and red fescue increased by 0.1–0.2 cm and roots of common-meadow-grass – by 0.4 cm compared to those in the control. Having sown seeds of gramineous grasses, moistened with solutions of stilites, the tested growth regulators were established to stimulate the growth of grasses. Under the influence of stilites, perennial ryegrass grew by 1–1.6 cm higher than the plants in the control variant. Under the influence of stilit-85 and stilit-123, common-meadow-grass grew by 0.5–1.5 cm higher compared to the control.

Key words: growth regulators – stilites, *Lolium perenne*, *Festuca rubra*, *Poa pratensis*, germination, dynamics of growth

Introduction

Nice lawns have to be arranged and tended with patience. Arrangement of parterre decorative lawn aims at formation of thick and solid turf. Decorativeness and solidity of the turf are determined by the level of overground part of grasses and root system development. Rapid and uniform germination of seeds, intensive growth and rooting of seedlings condition rapid development of the lawn [1].

Arrangement of sown sward is always related to risk caused by unfavourable meteorological conditions – drought, delayed sowing, different time of germination, weed infestation, etc. Mistakes made in the arrangement of the lawn shorten its longevity, worsen qualitative indices and make maintenance works more difficult. Even good care does not help to correct an improperly arranged lawn [2].

The most important preconditions of good lawn formation are as follows: good quality clean seeds of grasses, favourable sowing time, proper sowing and care in the period of seed germination and primary growth. Application of growth regulators should also be numbered among these preconditions [3].

Natural growth regulators (phytohormones) and their synthetical analogues is an effective measure to regulate processes of plant ontogenesis, therefore they are widely used in biotechnology and plant growing. Conditions of growth regulators' application, their concentration and physiological state of plant stimulate formation of roots, intensity of tillering, growth of stem, time of blossom, and maturity of plant [4, 5]. Having got into the plant, exogenous growth regulators stimulate activity of natural (endogenous) phytohormones and in this way change the intensity of natural physiological processes and make plant metabolism more active. Active metabolism stimulates the physiological processes that naturally occur in the plant during application of regulators [6]. Having been moistened with growth regulators, plant seeds germinate quicker and strike root. Due to spraying with growth regulators, seedlings grow and develop more intensively, the concentration of chlorophylls in leaves increases, photosynthesis is more productive, and bigger and better quality yield is harvested [7, 8].

For many years, the Experimental Station of the Lithuanian University of Agriculture has been involved in the research on the physiological activity of exogenous growth regulators – stilites and their influence on growth and development of field plants. Growth regulators – stilites are synthesized at the Department of Organic Chemistry, Kaunas University of Technology. These compounds belong to the group of heteroauxins and contain acryl, alanin and pyrrolidinon. Such derivatives are applied in many fields. Their fragments are found in the structure of pharmaceutical preparations, plant growth regulators, and thermostable polymers. Exogenous growth regulators are used in the form of water-soluble salt [9]. Field experiments at the Experimental Station of the Lithuanian University of Agriculture have established that application of very low concentrations of these compounds (10 g of regulator per 100 l H_2O) induces more intensive growth of the plants and quicker formation of maximum assimilating leaf area. Photosynthesis processes are more intensive, transportation of photosynthates from leaves to the rootcrop is quicker, which finally result in a bigger and better quality yield [10, 11, 12].

In the case of arrangement of sown decorative lawn or laying ready-made roller turf for lawns, their overground part should be made of thick sward formed from grass leaves and vegetative shoots, while the underground part – from dense roots, rootcrops, and stolons in the top soil layer [13]. Uniform germination of seeds, quick rooting of seedlings, intensive tillering and early formattion of thick turf are important for proper formation of decorative lawn [14]. Application of growth regulators could stimulate these processes.

The aim of the investigations: to determine the influence of growth regulators stilites on germination of seeds of gramineous grasses for lawns and growth of their seedlings, to select optimal solution concentrations of these compounds.

Material and Methods

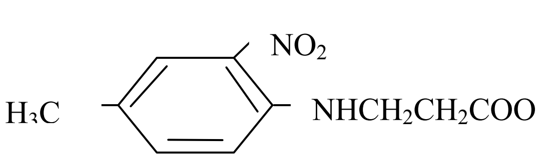
The investigations were carried out in the Laboratory of Genetics and Biotechnology and in the Experimental Station of the Lithuanian University of Agriculture in the period of 2002–2003. Soil – Idg8 – k (LVg-p-w-cc) – Calc(ar)I – Epihypogleyic Luvisols. Growth regulators stilit-85 (acrylic acid sodium salt) and stilit-123 (alanin acid sodium salt), synthesized at the department of Organic Chemistry, Kaunas University of Technology were investigated [Table 1]. Physiological activity of these growth regulators was checked by laboratory screening method. Seeds of gramineous grasses – perennial ryegrass (*Lolium perene* L.), red fescue (*Festuca rubra* L.) and common-meadow-grass (*Poa pratensis* L.) – were moistened with 10 ml of 0.009% concentration solutions of the tested growth regulators and grown in Petri dishes. Germination of seeds was observed after 7 days (perennial ryegrass and red fescue) and after 10 days (common-meadow-grass). Germinability of seeds was calculated, length of roots and seedlings was measured and the seedlings were weighted.

The field trial was arranged at the Experimental Station of the Lithuanian University of Agriculture in 2002. Before sowing the seeds of tested gramineous grasses were moistened with 60, 90 and 125 mg l^{-1} concentration solutions of growth regulators stilit-85 and stilit-123.

The area of the registered experimental plots was 1 m^2. The following seed norms were used: perennial ryegrass 'Sodre' – 1.8 g m^{-2}, red fescue 'Stilis' – 1.4 g m^{-2}, and common-meadow-grass 'Gausa' – 1.3 g m^{-2}.

At the beginning of vegetation, the height of the tested gramineous grasses was measured to determine the dynamics of growth.

Table 1. The analyzed growth regulators

Structural formula	Growth regulator
	Stilitas – 123
CH=CHCOONa	Stilitas – 85

Results and Discussion

Growing of seeds of gramineous grasses, moistened with 0.009% concentration solutions of stilit-85 and stilit-123, revealed the positive influence of growth regulators on growing only in the variant with common-meadow-grass. In these variants, after 10 days of growing, seedlings of common-meadow-grass grew bigger by 0.2 cm under the influence of stilit-123 and by 0.1 cm under the influence of stilit-85, compared to those in the control variant where seeds had been grown in distilled water. The tested growth regulators had no important influence on the growth of red fescue seedlings. In the case of growing perennial ryegrass seeds, moistened with 0.009% concentration solutions of the tested stilites, the seedlings grew smaller than those in the control (Fig. 1).

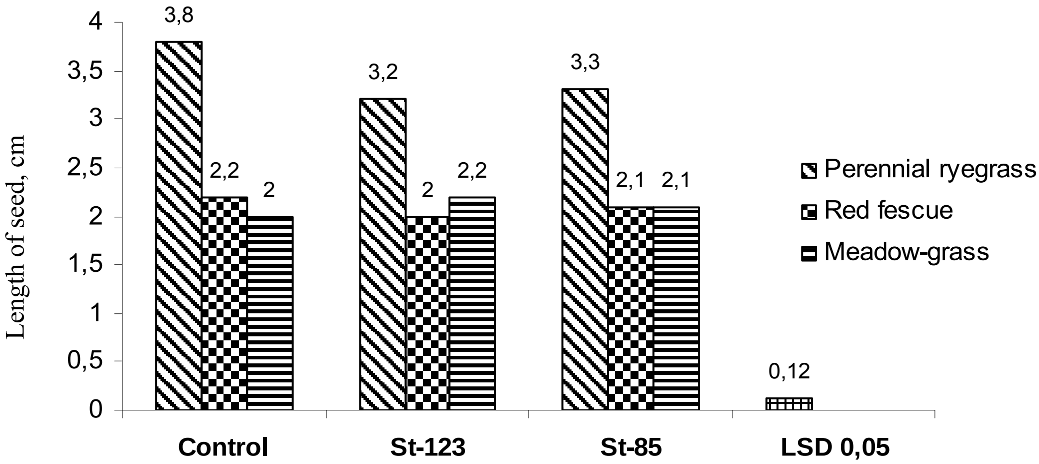


Figure 1. The nfluence of stilites on the length of seedlings of gramineous grasses

The tested growth regulators had a stronger influence on root growth. Under the influence of stilit-123, roots of perennial ryegrass and red fescue grew by 0.1–0.2 cm longer than those in the control. Growth of common-meadow-grass roots was more intensive under the influence of stilit-85. In this variant the roots grew by 0.4 cm longer than those in the control (Fig. 2).

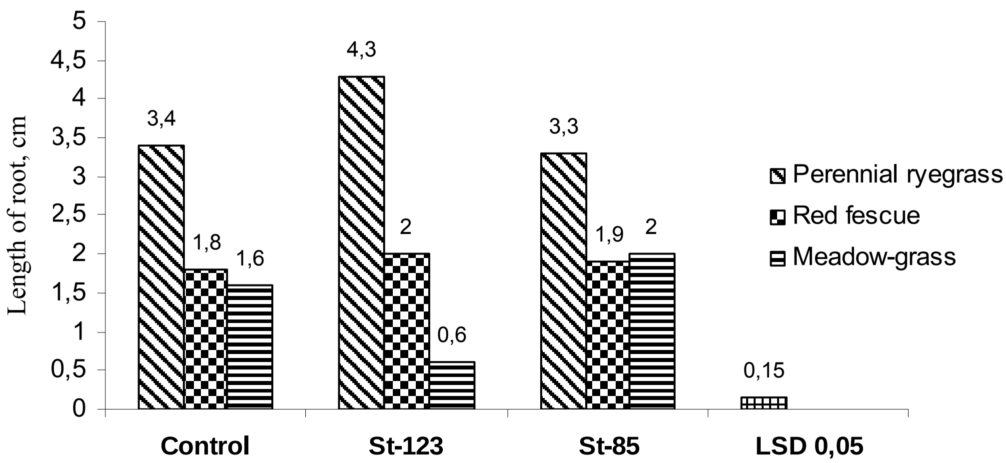


Figure 2. The influence of stilites on the length of roots of gramineous grasses

In other variants the tested growth regulators had no significant influence on the growth of roots. In the variant where seeds of common-meadow-grass had been moistened with 0.009% concentration solution of stilit-123, the growth of roots was inhibited and they grew by 1 cm shorter in comparison with the control.

In the arrangement of exact field trials before sowing the seeds were moistened with different concentration solutions of stilites. The experiment aimed to investigate the influence of growth regulators on the growth dynamics of gramineous grasses. The measurements determined that growth of perennial ryegrass was more intensive under the influence of stilit-123 (Fig. 3). In the variant where before sowing the seeds had been moistened with 125 mgl^{-1} concentration solution of stilit-123, the seedlings grew by 1.6 cm higher than those in the control. Other concentrations of this growth regulator that had been tested in this experiment also stimulated growth of grasses. Under the influence of 60 mgl^{-1} concentration solution of stilit-123, perennial ryegrass grew by 1.1 cm higher and under the influence of 90 mgl^{-1} concentration – by 0.8 cm higher than plants in the control variant.

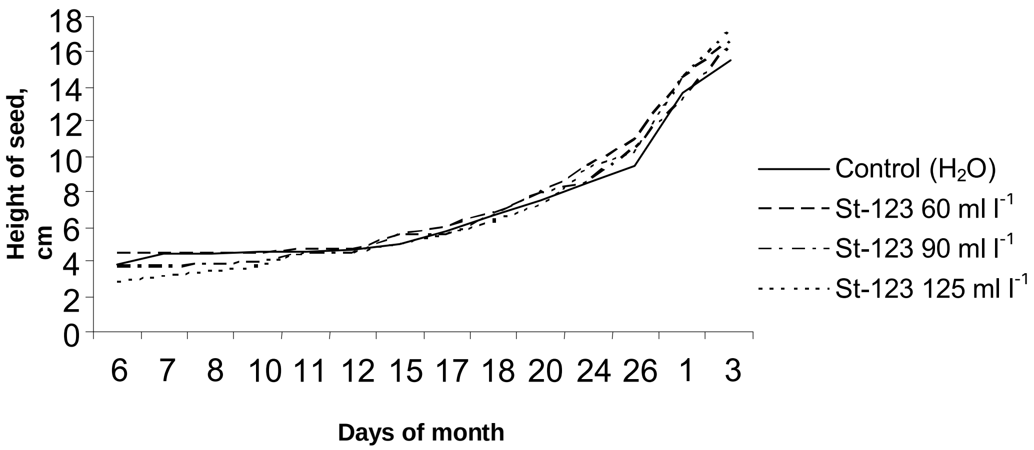


Figure 3. The influence of stilit-123 concentrations on growth dynamics of perennial ryegrass

Stilit-85 also stimulated growth of perennial ryegrass (Fig. 4). Having moistened the seeds with 90 mgl^{-1} concentration solution of this growth regulator before sowing, the plants grew by 0.3 cm higher and under the influence of 125 mgl^{-1} concentration – by 0.7 cm higher than those in the control.

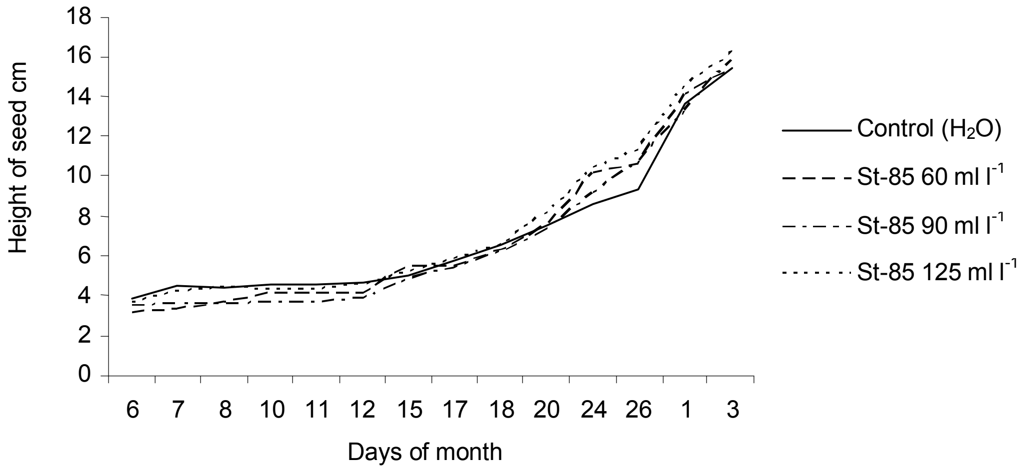


Figure 4. The influence of stilit-85 concentrations on growth dynamics of perennial ryegrass

In the period of measurements no influence of the tested growth regulators on the growth of red fescue was determined (Fig. 5, 6). In comparison with the control, all the tested concentrations slightly inhibited growth of plants. The average height of plants was by 0.2–0.7 cm lower than that in the control variant.

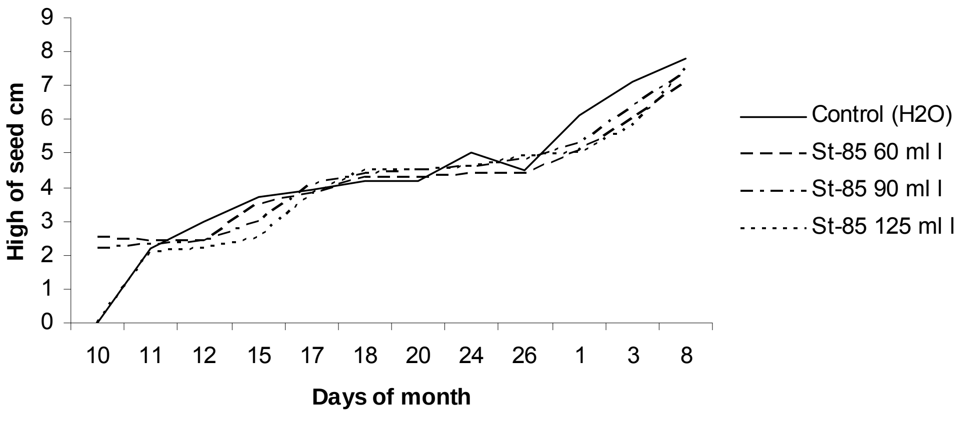


Figure 5. The influence of stilit-85 concentrations on growth dynamics of red fescue

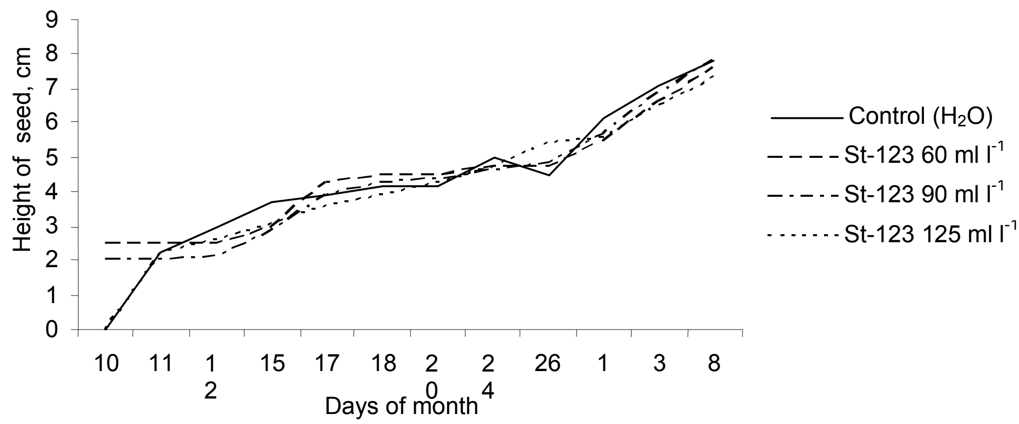


Figure 6. The influence of stilit-123 concentrations on growth dynamics of red fescue

Growth of common-meadow-grass was stronger stimulated by stilit-85 (Fig. 7). Having moistened the seeds with 90 mgl^{-1} and 125 mgl^{-1} concentration solutions of this growth regulator before sowing, the plants grew by 1.5 and 0.7 cm higher, respectively, than those in the control variant. No significant influence of 60 mgl^{-1} concentration solution of stilit-85 on the growth of common-meadow-grass was observed.

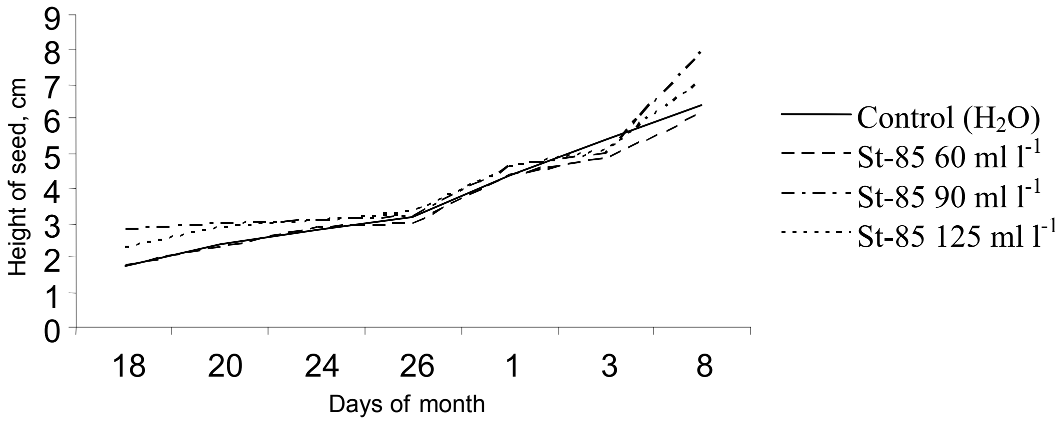


Figure 7. The influence of stilit-85 concentrations on growth dynamics of common-meadow-grass

Growth regulator stilit-123 stimulated the growth of common-meadow-grass only in the variant where seeds had been moistened with 125 mgl^{-1} concentration solution before sowing. In this variant the plants grew by 0.5 cm higher in comparison with the control (Fig. 8). In other experimental variants in the period of measuring the average height of plants was 0.1–0.4 cm lower than that of plants in the control variant.

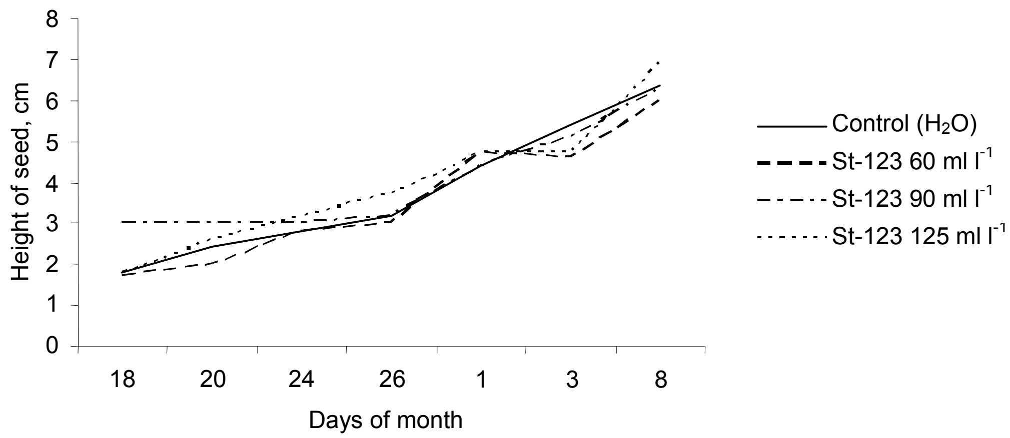


Figure 8. The influence of stilit-123 concentrations on growth dynamics of common-meadow-grass

Conclusions

The tested growth regulators stilit-85 and stilit-123 did not influence growth of red fescue seeds. Moistening of seeds of perennial ryegrass with 90 mg l^{-1} concentration solutions of these regulators inhibited their growth. After 7 days of growing, the seedlings were by 0.5 cm higher than those in the control variant.

Growth regulators were established to have a positive influence on growth of common-meadow-grass seeds. Having moistened the seeds with 90 mg l^{-1} concentration solutions, after 10 days the seedlings were by 0.1 cm bigger, and under the influence of stilit-123 – by 0.2 cm bigger than those in the control.

The tested growth regulators had the strongest influence on growth of roots of gramineous grasses. When growing seeds of perennial ryegrass and red fescue, moistened with 90 mg l^{-1} concentration solutions of stilit-85 and stilit-123, the roots were by 0.1–0.2 cm longer than those in the control variant. Under the influence of stilit-85, after 10 days the roots of common-meadow-grass were by 0.4 cm longer than those in the control.

Field experiments established that moistening of seeds of gramineous grasses with solutions of the tested stilites had the strongest influence on the intensity of perennial ryegrass growth. Under the influence of stilit-123, average height of plants was by 1–1.6 cm higher than that in the control variant.

No influence of the tested growth regulators on growth of red fescue was established.

Higher intensity of common-meadow-grass growth was established in the variants where before sowing the seeds had been moistened with 90 mg l^{-1} and 125 mg l^{-1} concentration solutions of stilit-85 and with 125 mg l^{-1} concentration solution of stilit-123. In these variants, the average height of plants was by 0.5–1.5 cm higher than that in the control.

References

1. Jakienė E., Beresnevičius Z., Venskutonis V., (2001) Growth regulators in Sugar Beet growing technology. Conference on Sustainable Agriculture in Baltic States. Tartu, June 28–30, 39–43.
2. Jakienė E., Malinauskaitė R. (2002) Augimo reguliatorių – stilitų įtaka žieminių rapsų produktyvumui. Žemės ūkio mokslai. Nr.2, Vilnius, 29–34.
3. Jakienė E., Venskutonis V., Mickevičius V., (2004) The Impact of Different Concentrations of Growth Regulators – Stilits on Sugar Beet Productivity. Vagos. Mokslo darbai 64 (17), Akademija, 26–31.
4. Merkys A., Miliuvienė L., Novickienė L. (1993) Nauji augimo reguliatoriai ir jų fiziologinio aktyvumo įvertinimas. Biologija, Nr. 4, 45–53.
5. Mockaitis J. (1999) Vejų įrengimas ir priežiūra. UAB “Dotnuvos projektai”, 7–85
6. Novickienė L. (1994) Augalų augimą, vystymąsi ir produktyvumą reguliuojančių fitohormonų ir retardantų analogų kūrimo fiziologiniai pagrindai. Vilnius, 71–80.
7. Sapijanskaitė B. Mickevičius V. *et al.* (2001) 1–(9–Alkil–3–karbazolil)–4-karboksi-2-pirolidinono darinių sintezė. Organinė chemija: konferencijos pranešimų medžiaga. Kaunas, 22–24.
8. Stašauskaitė S. (1995) Augalų vystymosi fiziologija. Vilnius, 62–74.
9. Лаптев А. А. (1983) Газоны. Наукова думка, Киев, 176.
10. Матвеев И. Т., Похитон С.В. (1974) Применение регуляторов роста при уходе за газонами. Киев, 37.
11. Прилипко Л. И., Сигалов То. Я., Абесадзе Г. Ф. и др. (1977) Газоны. Москва, Наука, 238.
12. Серебрякова Т. И. (1971) Морфогенез побегов и эволюция жизненных форм злаков. Москва, Наука, 358.
13. Третьяков Н. Н., Лосева А. С., Макрушин Н.М. (1998) Физиология и биохимия сельскохозяйственных растений. Москва, 357–380.
14. Шевелуха В. С., Калашникова Е.А. и др. (1998) Сельскохозяйственная биотехнология. Москва, “Высшая школа”, 3–321.

THE YIELDS OF LEGUME – CEREAL MIXES IN YEARS WITH HIGHT – PRECIPITATION VEGETATION PERIODS

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Abstract

A research where common vetch (*Vicia sativa*) and pea (*Pisum sativum*) were grown together with either spring wheat (*Triticum aestivum*) or oats (*Avena sativa*) was conducted in experimental fields of the Department of Field Crop Husbandry of the Estonian Agricultural University in 2003 and 2004. The summer with high precipitation caused an intense vegetative growth of legumes and, therefore, cereals grown together with legumes remained in the lower front. Starting from a legume sowing rate of 60 germinating seeds per m^{-2}, downpour in July caused heavy lodging of legume-grain mixed crops in both experimental years. The average data of the two years show that, to ensure maximum yield, the amount of vetch added in mixed crops of grain should be considerably small in years of high precipitation. The optimum sowing rate of vetch mixed with wheat and oats was 30–50 germinating seeds per m^{-2} in the area, which ensured yields bigger by 800 kg ha^{-1} in the same conditions as grain pure crops. The optimum sowing rate of pea was 70–90 germinating seeds per m^{-2} when mixed with wheat and 60–80 germinating seeds per m^2 when mixed with oats. The mixed crops of vetch and oats gave higher yields than vetch-wheat mixed crops. The yields of pea-oats mixed crops reached a maximum of 3500 kg ha^{-1}, which is by 700 kg ha^{-1} more than the yield of pea-wheat mixed crops.

Key words: common vetch, pea, spring wheat, oats, yield, legume-cereal mixed crop

Introduction

Studies have shown that vetch-wheat mixes need practically no nitrogen fertilisation as the efficacy of a nitrogen fertiliser in a mixed crop is modest, particularly with regard to protein yield. Nitrogen fertilisation decreases the share of vetch in the yield of the mixed crop since the effect of a nitrogen fertiliser on the seed-producing capability of the vetch component is negative (Lauk *et al.*, 2003; Lauk *et al.*, 2004a).

Although we have engaged ourselves in studies of legume-cereal mixes for many years and the results of the research have been published in several articles (Lauk *et al.*, 1997; Lauk *et al.*, 1999; Lauk *et al.*, 2001), we still continue the studies of legume-cereal mixed crops as a number of issues are yet to be resolved. In our studies we assume that legume-cereal mixes produce a relatively high and protein-rich yield even under no use of mineral nitrogen fertilisers. We try to find out the best combinations for different circumstances and the optimal seed densities for different combinations. On the theoretical plane, we are interested in inter-species (legume-cereal-weed) and intra-species competition for plant growth factors in mixed crops.

In the present article, the results from the 2003 and 2004 mixed crop trials are considered in more detail. In the said years the level of precipitation during the growth period of the mixed crops was higher than usual; as a result, some new regularities were observed.

Materials and Methods

The study, in which spring vetch and pea were grown in a mix with either spring wheat or oats, was performed in accordance with the methods worked out at the Department of Field Crop Husbandry of the Estonian Agricultural University (Lauk *et al.*, 2004b). The field trials involved a total of five series: common vetch + spring wheat; vetch + wheat under nitrogen fertilisation (N_{50}); vetch + oats; pea + wheat and pea + oats. Pursuant to the methodology, the seed density of the cereals was identical in all the variants of the trial series: 250 germinating seeds per m^{-2}. The seed densities of vetch and pea varied in all the trial series from 0 to 120 germinating seeds per m^{-2} (a total of 11 different variants of legume seed density in each trial series). The interval between the different variants was 12 germinating legume seeds per m^{-2}. The variants were places at random in the trial series, with the area of a trial plot being 10 square metres. The mixed crops of vetch-cereal and pea-cereal were placed in two different blocks in a trial, with soil fertility differing from one block to the other. For this reason the yields of vetch-cereal and pea-cereal mixes are treated separately in the article.

The trials were performed on the trial fields of the Estonian Agricultural University at Eerika, outside Tartu, Estonia, on pseudopodzolic soil, which in the international WRB classification are called Albeluvisols (Kõlli *et al.*, 1999). The soil properties were as follows: pH_{KCl} of the ploughed layer was 5.05–5.39, organic matter content was 2.16–2.48%, and the available phosphorus and potassium contents (determined using the AL method) were 74.3–112.9 mg kg^{-1} and 83.6–143.8 mg kg^{-1}, respectively. No phosphorus or potassium fertilisers were applied to the mixed crops. The crop preceding the mixed crops was wheat.

Both 2003 and 2004 were characterised by high precipitation in summer. The precipitation rates during the mixed crop growth periods totalled 360 mm in 2003 and 420 mm in 2004. The usual precipitation rate, calculated from a long-time average, is 250 mm. The year 2004 was different in that the spring was relatively dry until early June. In both years the air temperature was relatively low in June.

The rainfalls in July (the precipitation rate exceeding 100 mm in both years) led to heavy lodging of legume-cereal mixes having legume seed densities of 60 germinating seeds per square metre or higher at the end of the second decade of the month in both trial years. No lodging until the harvest was observed in cereal monocultures and in the mixed crop variants where legume seed was included in cereal seed at the rate of 12 germinating seeds per m^{-2}. Relatively low lodging was observed in variants where the legume seed density was 24, 36 and 48 germinating seeds per square metre. Fertilisation with a relatively modest amount of nitrogen (N_{50}) led to a minor reduction in the intensity of mixed crop lodging.

After harvest, the yields were recorded both by their separate components and as total yields. The yields were calculated at a 14% water content. Additionally, the 1000 seed weight was determined for each variant.

The yield data obtained after the implementation of the trial were processed using regression analysis according to the following generalising equation:

$$y = a + bx + cx^2,$$

where: y – the argument function (yield of legume-cereal mix, kg ha^{-1}; 1000 seed weight, g);
a – the absolute term (constant) of the regression;
b and c – regression coefficients;
x – the argument (legume seed density, germinating seeds per m^{-2}).

The correlations between the legume seed density and the mixed crop yield as well as the 1000 seed weight were very strong in all the trial series as demonstrated by the numerical values of the correlation coefficients (R), and had a 99% reliability. All the data presented in the tables were calculated from equations derived from regression analysis. To evaluate the reliability of the differences between the trial series the least significant differences were calculated in accordance with the methodology (Lauk *et al.*, 2004b) at a 95% reliability level.

Results and Discussion

The maximum yields of wheat and oats were obtained from the monocultures of the cereals (Table 1). The inclusion of vetch seed in cereal seed and the increasing of vetch seed density very strongly reduced the yield of cereals in the high-precipitation years. The correlations between the vetch seed densities and the cereal yields were very strong (R = 0.990–0.994). As the crops experienced heavy lodging at higher vetch seed densities (over 50 vetch seeds per m^{-2}) and the conditions were unfavourable during the time of grain formation and filling in cereals, the yields of the cereals were several times smaller. The application of a nitrogen fertiliser lead to an increase in wheat productivity in both a monoculture and a mix with vetch. Oats as a less pretentious crop exceeded wheat by productivity in both a monoculture and a mix. The difference in the yields at vetch densities of up to 60 germinating seeds per square metre constituted slightly over 1100 kg ha^{-1} in favour of oats.

Vetch productivity was high starting already from low vetch seed densities. At the vetch seed density of 20 germinating seeds per m^{-2}, vetch yielded 1420–1770 kg ha^{-1}, depending on the trial series. Compared to the control series, fertilisation with nitrogen and mixing with oats led to a reduction in vetch yield at the said vetch seed density. The greatest vetch yields were obtained under no nitrogen fertilisation in a mixed crop with wheat or oats at vetch seed densities of 50–70 seeds per m^{-2}. Further increases in vetch seed density led to considerable reductions in vetch productivity. Nitrogen fertilisation led to decreased vetch yields at lower seed densities compared to the control series but increased the yields at high vetch seed densities, with the maximum yield of vetch being obtained at the maximum vetch seed density.

Table 1. Yield formation in cereal monocultures and in vetch-cereal mixes at different vetch seed densities and a comparison of different trial series (two-year averages, kg ha^{-1})

Seeding rate of vetch, seeds per m^{-2}	Vetch + wheat, yield (check)	Vetch + wheat + N_{50}		Vetch + oats	
		yield	difference	yield	difference
	yield of cereals				
0	1938	2400	463	3053	1115
20	1375	1884	508	2555	1180
30	1136	1658	522	2323	1186
40	926	1454	528	2102	1176
50	744	1271	528	1892	1148
60	590	1110	521	1693	1104
70	464	971	507	1506	1042
100	256	681	425	1010	754
120	258	596	338	736	477
		$LSD_{95\%}$	105		115
	yield of vetch				
20	1772	1635	–137	1421	-351
30	1930	1747	–183	1621	-309
40	2046	1850	–197	1778	-268
50	2120	1941	–179	1892	-228
60	2152	2022	–130	1964	-188
70	2143	2093	–50	1994	-148
100	1861	2241	380	1828	-33
120	1463	2287	824	1505	42
		$LSD_{95\%}$	111		104
	total yield of vetch-cereals mixes				
20	2711	3066	355	3682	972
30	2817	3148	331	3776	959
40	2874	3204	330	3814	940
50	2882	3234	352	3797	916
60	2840	3238	397	3725	885
70	2749	3214	465	3597	848
100	2181	2988	807	2880	699
120	1555	2704	1,149	2125	570
		$LSD_{95\%}$	260		238

The maximum yields of the mixed crops (2840–2880 kg ha^{-1}) were obtained from the control series (vetch + wheat) at vetch seed densities of 40–60 germinating seeds per m^{-2}. At its maximum, the per-hectare yield of the vetch-wheat mix was approximately 950 kg greater than that of wheat monoculture. Under nitrogen fertilisation the vetch-wheat mix produced the maximum yields (slightly over 3200 kg ha^{-1}) at vetch seed densities of 50–70 seeds per m^{-2}, and the per-hectare yield of the mix exceeded that of monocultural wheat by 800 kg.

The yields of vetch-oats mixes were considerably greater than those of vetch-wheat mixes, with the margin attributable to the oats component. The maximum yields in the said crops (approximately 3800 kg ha^{-1}) were obtained at vetch seed densities of 30–50 germinating seeds per m^{-2}. The mixes produced per-hectare yields that exceeded those of monocultural oats by up to 800 kg.

The results of the research suggest that in a high-precipitation year vetch-cereal mixes should be set up by including relatively small amounts of vetch seed in cereal seed. As the weather conditions are unpredictable in spring, the results of the research may be generalised for wetter growth sites. On wetter growth sites, accordingly, vetch-cereal (oats, wheat) mixed crops should be set up by including relatively small amounts of vetch seed in cereal seed, for under wetter circumstances the vegetative growth of vetch is very intensive and its competitiveness with cereals is high. On a wetter growth site, vetch seed should be added to oats and wheat seed at the rate of 30 germinating seeds per m^{-2}; higher vetch seed densities, while potentially conducive to even greater yields, raise the risk of crop lodging.

As regards the pea-wheat and pea-oats mixes, the cereals also produced their maximum yields in a monocultural form, and the inclusion of pea seed in the cereal seed and the increasing of pea seed density led to considerable reduction in the cereal yields (R = 0.988–0.993). At the maximum pea seed density, wheat yielded 3.8 times less and oats 2.2 times less than in their monocultural form. It was observed that pea tends to be less competitive with cereals than vetch, for the yield decreases were smaller than those of the cereals grown in a mix with vetch. Oats produced higher yields than wheat in both a monoculture and a mix.

Table 2. Yield formation in cereal monocultures and in pea-cereal mixes at different pea seed densities and a comparison of different trial series (two-year averages, kg ha^{-1})

Seeding rate of pea, seeds per m^{-2}	Pea + wheat, yield (check)	Pea + oats	
		yield	difference
	yield of cereals		
0	2172	2813	641
20	1832	2670	838
40	1522	2484	962
60	1240	2254	1014
70	1109	2123	1014
80	986	1980	994
90	870	1827	957
100	761	1662	901
120	564	1301	737
	$LSD_{95\%}$		95
	yield of pea		
20	860	714	-146
40	1373	1106	-267
60	1777	1442	-335
70	1938	1590	-348
80	2072	1723	-349
90	2178	1843	-335
100	2258	1949	-309
120	2334	2119	-215
	$LSD_{95\%}$		61
	total yield of pea-cereals mixes		
20	2443	3103	660
40	2671	3348	677
60	2811	3479	668
70	2847	3501	654
80	2862	3495	633
90	2853	3461	608
100	2824	3398	574
120	2698	3185	487
	$LSD_{95\%}$		78

The productivity of pea in a mix with cereals was high already at smaller pea seed densities (Table 2). At the pea seed density of 20 germinating seeds per m^{-2}, pea yielded between 710–860 kg ha^{-1}; nevertheless, this is approximately 2 times smaller than the yield of vetch at the same seed density. This shows that at smaller legume seed densities the competitiveness of cereals is greater with pea than with vetch. At greater pea seed densities the competitiveness of cereals with pea decreases. In a mix with cereals, pea produced the maximum yield (2120–2330 kg ha^{-1}) at the maximum seed density (120 germinating seeds per m^{-2}). In a mix with oats, the yield of pea was reliably smaller than in a mix with wheat.

The maximum yields of the pea-wheat mixes (2550–2560 kg ha^{-1}) were obtained at pea seed densities of 70–90 germinating seeds per m^{-2}, and the yields of the pea-oats mixes were at their maximum (3480–3500 kg ha^{-1}) at the pea seed densities of 60–80 germinating seeds per m^{-2}.

Generalising the data for wetter growth sites, the recommended pea seed density in pea-cereal (wheat or oats) mixes might be 60–70 germinating seeds per square metre.

One of the reasons for the reduction in cereal yields might be the reduction in the 1000 seed weight of wheat and oats due to the inclusion of legumes in crops and to the increasing of legume seed densities (Table 3).

Table 3. Cereal 1000 seed weights in different combinations depending on legume seed densities (two-year averages, g)

Seeding rate of legumes, seeds per m^{-2}	Vetch + wheat	Vetch + wheat + N_{50}	Vetch + oats	Pea + wheat	Pea + oats
0	28.8	27.8	37.6	32.4	33.9
20	23.8	23.1	34.9	31.9	33.6
30	21.9	21.4	33.7	31.7	33.4
40	20.3	20.1	32.5	31.4	33.2
50	19.1	19.2	31.3	31.2	32.9
60	18.4	18.8	30.2	30.9	32.6
70	18.0	18.7	29.2	30.6	32.2
100	19.0	21.1	26.5	29.8	30.9
120	21.6	24.8	24.9	29.2	29.8

When wheat was mixed with vetch, which in the high-precipitation years occupied the upper storey, the wheat 1000 seed weight reduced even by more than 10 grams, and the correlations between vetch seed densities and cereal 1000 seed weights were very strong (R = 0.958–0.966). When the cereals were mixed with pea, which has a shorter stem and therefore proves less competitive with cereals, the 1000 seed weights of the cereals experienced smaller reductions: wheat by 3.2 g at the maximum and oats by 4.1 kg at the maximum. Yet even in pea-cereal mixes the correlations between the pea seed densities and the cereal 1000 seed weights were very strong and reliable (R = 0.871–0.923).

Conclusions

In a high-precipitation year, the yields of legumes grown in a mix with wheat or oats were high already at low seed densities. At the legume seed density of 20 germinating seeds per m^{-2}, the seed harvest of vetch was between 1420–1770 kg ha^{-1} and that of pea between 710–860 kg ha^{-1}. This also means that at lower seed densities the competitiveness of cereals was greater with pea than with vetch.

The inclusion of legumes in the crops and the increasing of legume seed density led to substantial reductions in the cereal yields. One of the reasons for the reductions in the yields was the formation of smaller grains in cereals, which was particularly evident in the vetch-cereal mixes.

Under no fertilisation the per-hectare yields of the vetch-wheat and vetch-oats mixes were greater than those of the cereal monocultures by 950 kg and 800 kg, respectively. The maximum yields in the wheat-vetch (2880 kg ha^{-1}) and oats-vetch (3800 kg ha^{-1}) mixes were obtained at the vetch seed densities of 40–60 and 30–50 germinating seeds per square metre, respectively. As well, the yields of the cereal-pea mixes were considerably higher than those of the monocultures of either species; however, the maximum yields of the cereal-pea mixes were approximately 300 kg ha^{-1} smaller than those of the cereal-vetch mixes.

Generalising the results of the research for wetter growth sites, mixed crops should be set up on wetter growth sites by including vetch seed in the wheat or oats seed at the rate of 30 germinating seeds per m^{-2} and pea seed in the same at the rate of 60–70 germinating seeds per m^{-2}. On a wetter growth site the vegetative growth of legumes, particularly vetch, is very intensive and their competitiveness with cereals is great.

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References

1. Kõlli, R., Lemetti, I. (1999) Eesti muldade lühiiseloomustus I. Normaalsed mineraalmullad. Tartu, 122 lk.
2. Lauk, E. *et al.* (1999). Some results of the research on growing cereals and leguminous crops in mixtures. – Agroecological optimization of husbandry technologies. Proceeding of International Scientific Conference of Baltic States, 45–56.
3. Lauk, E., Lauk, R. (2004a) On the effect of nitrogen fertilizer on mixed seedings of common vetch (*Vicia Sativa* L.) and wheat (*Triticum aestivum* L.). – VAGOS, Research papers 64 (17), 38–43.
4. Lauk, E. *et al.* (2004b) Experimental planning and methods in regression analysis. – IAMFE/RUSSIA 2004. Proceeding of the 12th International Conference and Exhibition on Mechanization of Field Experiments. Saint-Petersburg, Pushkin, Russia, CD-ROM, 51–56.
5. Lauk, E., Leis, J. (1997). Mixed Crops of Spring Wheat and Common Vetch. Productivity and Protein Content. – Problems of Field Crop Husbandry and Soil Management in Baltic States. Collection of scientific articles. Agronomy. Kaunas, 44–49.
6. Lauk, R., Lauk, E. (2001) Yields in Pea-Grain Mixed Crops. – Conference on Suistainable Agriculture in Baltic States. Proceeding of the International Conference, Tartu, 94–98.
7. Lauk, R., Lauk, E. (2003). Lämmastikväetise mõjust viki-nisu segukülvides. – Agraarteadus, XIV * **5,** 260–268 ek.

CHANGES OF BOTANICAL COMPOSITION OF GRASSLAND DUE TO THE USE INTENSITY

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Abstract

The aim of the study was to estimate changes in botanical composition and yielding of meadow due to cutting frequency and nitrogen fertilisation in moderate dry and moderate wet sites. The field experiment was conducted from 2000 to 2002 on permanent grassland. Two field trials were established on the black-earth soil on the moderate dry and moderate wet sites. Three levels of nitrogen fertilisation were applied (90, 120 and 180 kg N ha^{-1}) depending on cutting frequency (3, 4 and 6 cut per year respectively). In 2000 meadow sward was dominated by *Festuca rubra* (31,5 %), *Poa pratensis* (29%) and *Dactylis glomerata* (13%) in dry site and *Poa pratensis* (30,4%) and *Alopecurus pratensis* (17,8%) in wet site. Different fertilisation and cutting frequency caused clear changes in botanical composition and yielding of meadow sward. The most intensive management (180 kg N ha^{-1}, 6 cuts per year) caused a decrease of the percentage of tall grass species in comparison to low species. *Festuca rubra* seems to be the most tolerant species for cutting frequency and nitrogen fertilisation in dry site whilst in wet site – *Poa pratensis*. In both sites the reduction of herbs and legumes as a result of nitrogen fertilisation has been observed but percentage of legumes on wet site was better than on a dry one.

Key words: botanical composition, cutting frequency, nitrogen fertilisation, soil moisture

Introduction

Botanical composition of grass communities depends on many factors (moisture, soil type, fertilisation, frequency and kind of utilisation). Among the factors, nitrogen undoubtedly plays a major role (Tallowin *at al.*1994). High doses of nitrogen increase the yield but reduce the number of species. Some fast-growing species like *Dactylis glomerata, Lolium perenne* exclude the others. Intensification of grassland is the main reason of simplification of botanical composition but on the other hand extensification not always improves the biodiversity (Fisher and Rahmann 1997)

The influence of nitrogen fertilisation is related to the nitrogen status in the soil and site conditions. Effect of N and cutting frequency on botanical composition is still an interesting subject of grassland studies. The aim of the present paper was to study the directions of floristic composition changes and yielding of permanent grassland caused by different use intensity.

Materials and Methods

The field experiment was conducted from 2000 to 2002 on permanent grassland in the Pisia Tuczna valley about 40 km south-west of Warsaw. It was conducted on the black-earth soil (Typic haplaqiolss acc. to FAO) in two sites differing moisture: moderate wet (water table about 35 cm) and moderate dry (water table about 120 cm). The measurements of ground water table levels were made once a week. Climatic conditions and ground water table have been recorded in studies period within 2000-2002. Mean values of meteorological data of vegetation period have been shown in Table 1.

Table 1. Mean temperatures (^{o}C), sum of precipitation (mm), level of ground water (cm) and Vinczeffy index in vegetation period within 2000–2002

	2000	2001	2002	Mean
Mean temperature (^{o}C)	13.9	12.7	14.6	13.7
Sum of precipitation (mm)	311.3	413.0	383.2	369.2
Index of Vinczeffy	0.10	0.18	0.15	0.14
Mean level of ground water table in moderate dry site (cm)	–128	–112	–112	117.3
Mean level of ground water table in moderate wet site (cm)	–30	–28	–50	–36

The soil test made at the beginning of study in1999 showed the following contents of different elements in the top soil layer (up to 20 cm): 0.75 g N kg^{-1} of the soil, 29.5 g P kg^{-1} of the soil, 29.3 g K kg^{-1} of the soil in moderate dry site and 0.94 g N kg^{-1} of the soil, 189.6 g P kg^{-1} of the soil, 33.3 g K kg^{-1} of the soil, in moderate wet site. The content of organic C was 25 g kg^{-1} of the soil with pH 4.8 in dry condition and 37.6 g kg^{-1} of the soil with pH 6.2 in wet condition.

Three levels of management intensity have been used: intensive management (6 cuts per year and 180 kg N ha^{-1}), moderate (4 cuts per year and 120 kg N ha^{-1}) and extensive management (2–3 cuts per year and 90 kg N ha^{-1}). Phosphorus fertilisation was applied using a dose 30 kg P ha^{-1} per year whereas potassium – 100 kg K $ha^{-1}y^{-1}$. The experimental design was a randomised complete block design with eight replications. Plot size was 12 m^{-2} (2 × 6 m). The experimental data were calculated by analysis of variance.

Botanical composition of meadow sward was determined by visual observation and by botanical-weight method. Samples were divided into the group of plants: grasses, legumes and other herbs and weeds. Grasses have been separated into main species. Yield of dry matter (DM) was measured by cutting biomass from all plots in each regrowths.

Results and Discussion

At the beginning of the experiment the meadow sward was dominated by grasses in both sites (83.5% in dry site and 76.9% in wet one) (figure 1). Percentage share of legumes was about 2% in moderate dry and 10% in wet conditions. Herbs and weeds constituted 14.7% in dry and 13.2% in wet site. Date of botanical composition of grassland after three years of utilisation indicated the botanical transformation of sward.

a)

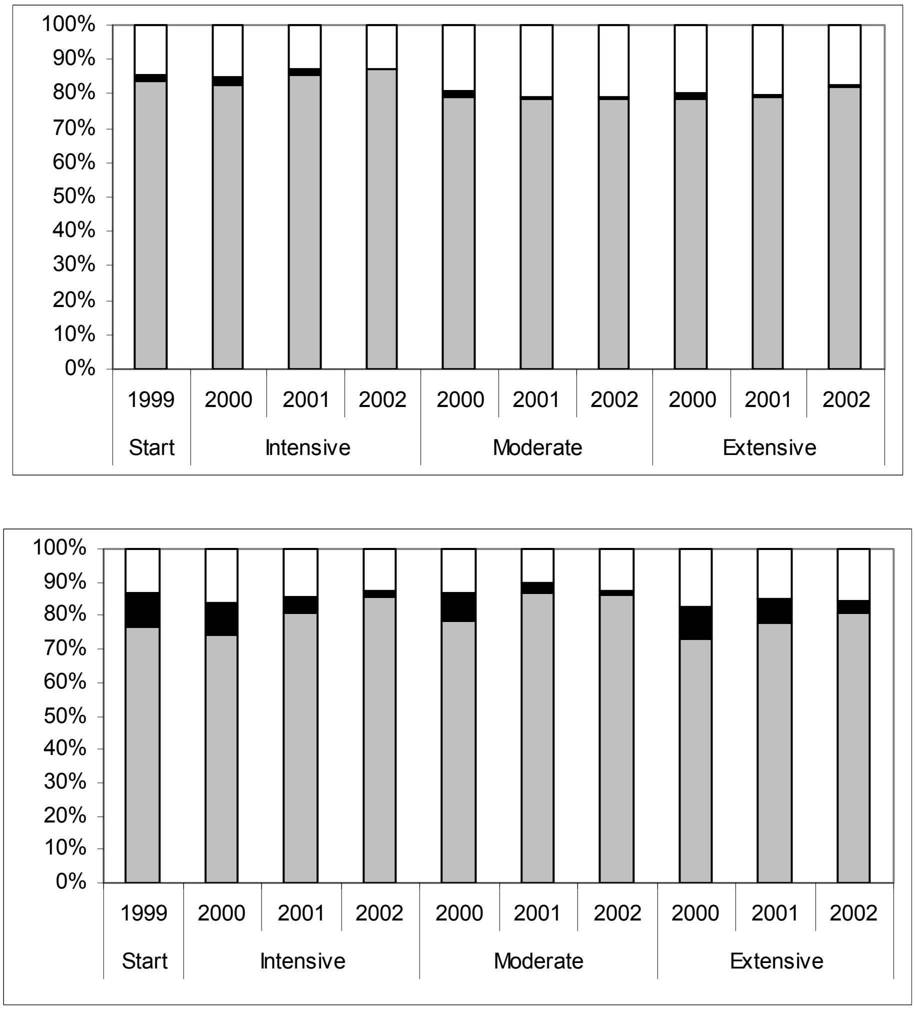

Figure 1. Percentage share of plant groups: grasses (grey), legumes (black) and herbs/weeds (white) in botanical composition of meadow sward due to management intensity and soil moisture (%); a) dry site, b) wet site

Decrease of content of legumes was observed as a result of intensive management witch had been shown in the previous studies (Sawicki and Gajda 1996). The low nitrogen fertilisation and cutting frequency caused slight increase of the share of weeds in both sites (especially participation of *Rumex crispus*).

The main components of meadow old sward in 1999 were (before study) *Festuca rubra* (31.5%), *Poa pratensis* (29%) and *Dactylis glomerata* (13%) in moderate dry site and *Poa pratensis* (30.4%) and *Alopecurus pratensis* (17.8%) in moderate wet site. Different management intensity caused changes in floristic composition of the plant communities in both sites (table 2). The percentage of tall grasses increased in the sward due to less intensive management and it should be stressed that *Dactylis glomerata* dominated in dry site and *Alopecurus pratensis* in wet one.

Table 2. The participation of grass in the sward within 2000–2002 and in moderate dry and moderate wet site due to use intensity (%)

Species	Moderate dry site			Moderate wet site		
	2000	2001	2002	2000	2001	2002
Intensive management						
Short species						
Poa pratensis L.	22.1	25.7	16.5	24.3	21.9	36.2
Festuca rubra L.	32.5	31.2	27.1	9.7	10.0	7.6
Lolium perenne L.	4.3	2.9	4.0	13.4	25.9	27.9
Holcus lanatus L.	2.1	0.5	3.2		2.8	0.7
Tall species						
Alopecurus pratensis	3.4	1.3	0.2	13.0	14.6	6.3
Dactylis glomerata L.	16.0	18.8	20.1	3.3	1.6	1.8
Phalaris arundinacea L.				7.4	1.9	0.6
Festuca arundinacea Schreb				6.5	4.1	4.6
Festuca pratensis Huds.	2.6	3.5	11.5			
Arrhenatherum elatius L.						0.6
Moderate						
Short species						
Poa pratensis L.	20.2	17.4	11.4	23.6	14.1	14.0
Festuca rubra L.	30.6	26.7	21.0	10.2	3.0	1.4
Lolium perenne L.	2.4	8.4	4.2	9.5	14.9	10.1
Holcus lanatus L.	3.1		2.5		0.5	0.6
Tall species						
Alopecurus pratensis	0.4	1.7	0.6	22.6	34.1	34.1
Dactylis glomerata L.	21.4	21.7	36.6	1.2	1.5	4.2
Phalaris arundinacea L.				4.9	7.7	7.7
Festuca arundinacea Schreb				6.3	10.6	8.2
Festuca pratensis Huds.	2.7	3.4	10.8		2.1	3.1
Arrhenatherum elatius L.						2.9
Phleum pratense L.			0.8			
Extensive management						
Short species						
Poa pratensis L.	23.4	15.5	13.0	24.3	10.8	13.2
Festuca rubra L.	27.1	11.5	14.0	8.2	5.3	5.7
Lolium perenne L.	3.6	4.8	4.5	11.9	14.3	5.9
Holcus lanatus L.	3.1	2.3	8.1			
Tall species						
Alopecurus pratensis	1.8	1.2	2.4	18.9	30.8	30.4
Dactylis glomerata L.	20.6	35.1	34.3	1.8	2.5	3.9
Phalaris arundinacea L.				4.6	6.9	10.8
Festuca arundinacea Schreb				3.6	4.3	7.9
Festuca pratensis Huds.	3.0	9.6	9.2		2.9	1.6
Arrhenatherum elatius L.						2.0
Phleum pratense L.					3.6	1.2

Higher cutting frequency (6 cuts per year) and nitrogen fertilisation (180 kg N ha^{-1}) caused an inconsiderable decrease of percentage of *Festuca rubra* and *Poa pratensis* and increase of *Dactylis glomerata* but only on the dry site. Moderate cutting frequency (3–4 cuts per year) and dose of nitrogen (120–90 kg N ha^{-1}) caused almost double increase of *Dactylis glomerata* in comparison to 1999. There was also an increase of *Festuca pratensis* in dry site. The data enclosed in the table 2 suggest, that *Alopecurus pratesis* and *Poa pratensis* were the most dominated species in moderate wet conditions. The intensive management caused an increase of *Poa pratensis* and *Lolium perenne* but share of *Alopecurus pratensis* was higher on the most extensive management.

Dactylis glomerata was not such aggressive and competitive at intensive use management as it could be concluded on the base of the previous studies (Rutkowska 1973). The percentage share of *Dactylis glomerata* was rather low especially in wet soil condition (Table 2).

Dry matter yield was affected by cutting frequencies and nitrogen fertilisation. Moreover larger number of species was found in moderate wet site than dry one, as noted also by Nielsen *at al*. (1998) and Wilkins *at al*. (1989).

The total DM yield in the year 2001 (8.57 t ha^{-1}) was higher than in 2000 or 2002 (6.37 t ha^{-1} and 6.01 t ha^{-1} respectively) due to more favourable weather conditions – higher average temperatures and longer growing period with enough rainfall (tab. 3). The highest DM yield (7.43 t ha^{-1}) in both sites was obtained on intensive use treatment (6 cuts annually and 180 kg N ha^{-1}) and the lowest (6.64 t ha^{-1}) at 3 cuts and 90 kg N ha^{-1}. It was found, that the average yield obtained in moderate wet site was significantly higher than in dry one (12.2%).

Table 3. Average yearly dry matter yield (t ha^{-1}) regarding intensity of management and soil moisture (DM t ha^{-1})

	Moderate dry site				Moderate wet site			
Management	2000	2001	2002	Mean	2000	2001	2002	Mean
Intensive	5.51	8.95	6.45	6.97	7.10	9.96	6.59	7.88
Moderate	6.07	8.09	5.62	6.59	6.66	9.10	5.79	7.18
Extensive	6.29	6.70	5.07	6.02	6.61	8.59	6.55	7.25
$LSD_{0,05}$	0.65	1.36	0.66	0.35	1.01	0.95	0.64	0.45

After three years of cutting regimes and nitrogen fertilisation the density of plants increased in the sward in all treatments of experiments. The highest plant cover was related to the higher contribution of short grasses, mainly *Festuca rubra*, *Poa pratensis* and *Lolium perenne.* Sward density depended on site moisture. It was proved that plant cover was significantly better in moderate wet conditions than dry ones.

Conclusions

The most intensive management caused the decrease of percentage of tall grass species in comparison to low species.

Festuca rubra seems to be the most tolerant grass to intensive use in dry site whilst in wet site those are *Poa pratensis* and *Lolium perenne*.

The intensive management did not increase percentage of *Dactylis glomerata.* It was not such aggressive grass as others and its share was about 20% in dry site and only 2% in wet one. It was probably caused by low tolerance for cutting frequency.

References

1. Fisher G. E. J. and Rahmann G. (1997) Extensification – benefits and disadvantages to grassland biodiversity. In Management for grassland biodiversity. Proceedings of the International Occasional Symposium of the European Grassland Federation, Warszawa – Łomża, Poland, 15–123.
2. Nielsen A. L., Debosz K. and Schierup H. H. (1998) Extensive grassland systems: N-mineralisation, productivity and biodiversity. In Nagy G and Petö K. (eds) Ecological Aspects of Grassland Management. Proceedings of the 17th General Meeting of the European Grassland Federation, Debrecen, Hungary, 315–318.
3. Rutkowska B. (1973) Badania rozwoju kupkówki pospolitej (*Dactylis glomerata*) w warunkach różnego nawożenia i użytkowania. Zeszyty Naukowe SGGW – AR, Rozprawy Naukowe 34, 99.
4. Sawicki J. and Gajda J. (1996) Wpływ zmiennej częstotliwości użytkowania i nawożenia azotem na plon białka i skład gatunkowy łąk kośnych na glebach torfowo-murszowych. Fragmenta Agronomica, 1(49), 80–95.
5. Tallowin J. R. B, Mountford J. O., Kirkham F. W., Smith R. And Lakhani K. H. (1994) The effect of inorganic fertiliser on a species-rich grassland, implications for nature conservation. In L. 't Mannetje and J. Frame (eds) Grassland and Society. Proceedings of the 15th General Meeting of the European Grassland Federation, Wageningen, 332–337.
6. Wilkins R. J., Hopkins A., Kirkham F. W., Sargent C., Mountford O., Dibb C. and Gilbey J. (1989) Effect of changes in fertilizer use on the composition and productivity of permanent grassland in relation to agricultural production and floristic diversity. Proceedings of the 16th International Grassland Congress Vol. 1, 101–102.

THE CARBON AND NITROGEN BALANCE ON GRASSLAND DUE TO MANAGEMENT INTENSITY

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Abstract

The goal of studies, which were carried out in the years 2000–2002, was to check if grasslands are able to reduce the glasshouse effect by CO_2 accumulation. Two field trials were established on black-earth soil on two sites (moderate dry and moderate wet). Three levels of management were used: intensive management (180 kg N ha^{-1} per year, 6 cuts), moderate (120 kg N, 4 cuts per year), and extensive (90 kg N, 3 cuts per year). A special attention was paid on the C and N content in plants (in different organs) and soil. The C content was measured by spectrophotometer. Plants used nitrogen very effectively (about 90%) and without clear differences between sites and fertilisations. The nitrogen content decreased in the soil, but almost the same quantity of N was found in grass roots; the total balance between N input and output was almost zero. Carbon content increased in the soil (particularly in the dry site) for about one ton per ha per year. Carbon accumulation in plant biomass was higher in the treatment of 180 N compared to extensive use (4.5 t C ha^{-1} and 3.6 t C ha^{-1}, respectively). A lot of carbon was accumulated in grass roots (5–6.4 t C ha^{-1} (especially in less intensive grassland management). It was concluded that less intensive grassland use is a method for increasing carbon accumulation in plant and soil. It is also a good method to reduce nitrogen losses.

Key words: carbon accumulation, fertilisation, grassland management, nitrogen balance

Introduction

The grasslands could play an important role in CO_2 sequestration and in reduction of the negative consequences of greenhouse effect (Lal, 2000). The grasslands of the world store ca. 15% of all global organic carbon and majority of its carbon is stored in the soil and roots. More than two thirds of annual grassland biomass is allocated below ground surface (Körner, 2002). On the other hand, higher CO_2 assimilation by plants could change the N contents in aboveground biomass and C/N ratio, which means some negative consequences for consumers. The intensive grassland management increases the dry matter yield but it could be a reason of the depletion of grass root biomass and could cause higher nitrogen losses.

Losses of soil carbon and nitrogen as a consequence of cultivation are known and well documented (Davidson and Ackerman, 1993; Lampe *et al.*, 2004). These losses were partly due to erosion, inadequate fertilisation, removal of crop residues and intensive management. For agricultural systems, a decrease in NO_x emissions together with an increase in soil carbon stock (CO_2 sequestration) could help reduce the greenhouse effect. It could be achieved, for instance, through conversion of arable land to permanent grassland and by reduction of management intensity. It seems to be important to carry out some complex studies on grassland management systems and intensity in comparison to carbon and nitrogen balance.

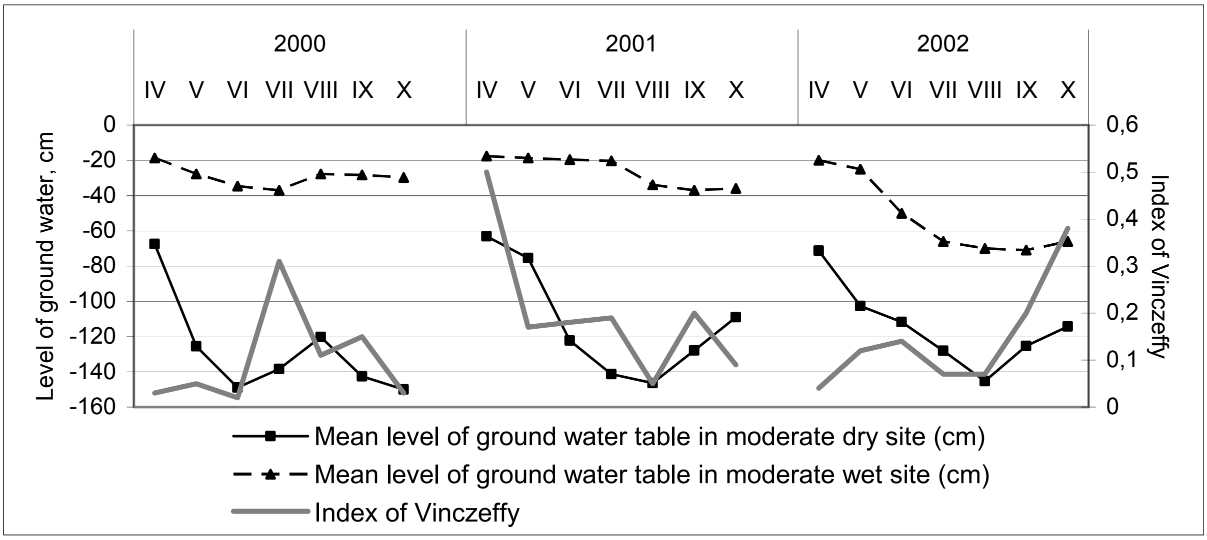
The purpose of this research was to check if grasslands are able to reduce the greenhouse effect by CO_2 accumulation and to quantify C and N partitioning in the plant-soil system on permanent grassland.

Materials and Methods

The study was carried out at the Experimental Station of SGGW at Jaktorów, in the years 2000–2002. The experiment was situated on a mineral soil (Typic haplaqiolss acc. to FAO) on two sites differing in moisture: moderate wet (water table about 35 cm) and moderate dry (water table about 120 cm). The measurements of ground water table levels were made every ten days. Climatic conditions and ground water table were recorded in the study period during 2000–2002. Mean values of Vinczeffy's index and level of ground water table of the vegetation period are shown in Figure 1.

At the beginning of the study (autumn 1999) the soil was poor in potassium, phosphorus and magnesium concentration with pH 4.8 on the moderate dry site. The soil on moderate wet site was poor in potassium concentration and rich in phosphorus and magnesium concentration with pH 6.2. The content of organic C was 25 g kg^{-1} of soil in dry conditions and 37.6 g kg^{-1} of soil in wet conditions. The nitrogen content in the soil was: 0.75 g kg^{-1} of soil on moderate dry site and 0.94 g kg^{-1} of soil on moderate wet site.

Figure 1. Mean monthly level of ground water (cm) and Vinczeffy index in the vegetation period during 2000–2002



The experiment was carried out on a permanent meadow which had been extensively managed and fertilised before 1999. The experiment was designed as a randomised complete block with eight replications. Each plot was 12 m^{-2} in area.

Three levels of management intensity were used: intensive management (6 cuts per year and 180 kg N ha^{-1}), moderate (4 cuts per year and 120 kg N ha^{-1}), and extensive management (2–3 cuts per year and 90 kg N ha^{-1}). Carbon content was measured by direct method by using spectrophotometer-analyser C MAT 55 00. The content of nitrogen in the plant and in the soil was determined using the Kjeldahl method. Chemical analyses of plant material were done for each regrowth separately for leaves, stems, inflorescences and roots for each treatments. On the basis of N and C contents in plants' organs and dry matter, biomass uptake of those components were evaluated. The experimental data were calculated by analysis of variance.

Results and Discussion

The nitrogen content in different organs was significantly affected by management intensity. On the basis of the results presented in Table 1 it can be concluded that on both sites the nitrogen content in leaves, stems and inflorescences at intensive management treatment was higher than in the extensive treatment. It was very clear in aboveground biomass but in roots the differences were rather small.

Table 1. The mean nitrogen content in different organs of grasses regarding management intensity and soil moisture (g N kg^{-1} DM)

	Inflorescences	Leaves	Stems	Roots	Aboveground mass
Moderate dry site					
Intensive	20.7a	25.1a	15.1a	5.8a	20.3
Moderate	16.0b	19.1b	10.3b	5.3b	15.1
Extensive	13.3c	15.4c	8.6c	5.2b	12.4
Mean	16.7b	19.8a	11.3c	5.5d	16.0
Moderate wet site					
Intensive	18.9a	20.9a	12.3a	5.6a	17.3
Moderate	16.9c	17.6b	10.1b	5.4b	14.9
Extensive	19.1b	16.0c	6.9c	4.9c	14.0
Mean	18.3a	18.2a	9.7b	5.3c	15.4

Also nitrogen content was generally higher in plants growing in moderate dry conditions compared to those on the moderate wet site. It could have been expected on the basis of previous studies (Stypiński and Moraczewski, 1984), though, it should be stressed that intensive nitrogen fertilisation mostly increased the content of N in aboveground biomass.

Values followed by the same letters did not differ significantly at the probability level of 0,05 according to Newman-Keuls q test.

There is a lot of information about the effect of nitrogen fertilisation on N content in grass but very little data about the influence of nitrogen fertilisation and cutting frequency on the content of organic carbon. Our results show that carbon in grassland plants in stems and leaves did not depend on the level of intensification. Also site humidity had a rather small effect on carbon content (Table 2).

Table 2. The mean carbon content in different organs of grasses regarding management intensity and soil moisture (g C kg^{-1} DM)

	Inflorescences	Leaves	Stems	Roots	Aboveground mass
Moderate dry site					
Intensive	515.2a	551.4a	555.9a	397.4a	540.8
Moderate	557.1b	550.5a	557.5a	401.3b	555.0
Extensive	557.7b	551.9a	557.2a	404.7b	555.6
Mean	543.3a	551.2b	556.9c	401.1d	550.5
Moderate wet site					
Intensive	554.2a	544.8a	553.2a	396.2a	550.7
Moderate	554.8a	545.6a	557.1b	421.5b	552.5
Extensive	555.2a	544.9a	556.8b	435.0c	552.3
Mean	554.7a	545.1b	555.7a	417.5c	551.9

Values followed by the same letters did not differ significantly at the probability level of 0,05 according to Newman-Keuls q test.

On the basis of biomass productivity (yield of dry matter aboveground mass and root yield) and content of C and N, total uptake of carbon and nitrogen was calculated (Table 3). On both sites, total nitrogen uptake in aboveground plant biomass depended on the intensity level. Higher doses of nitrogen together with most frequent cutting (180 kg N ha^{-1}, six cuts per year) caused a much higher uptake of nitrogen, compared to less extensive management (90 kg N, 3 cuts per year).

Table 3. Carbon and nitrogen accumulation and uptake in grasses according to management intensity and soil moisture (t C $ha^{-1}y^{-1}$; kg N $ha^{-1}y^{-1}$)

	Inflorescences		Leaves		Stems		Roots		Aboveground mass	
	N	C	N	C	N	C	N	C	N	C
Moderate dry site										
Intensive	2.5	0.08	139.2	3.18	24.6	0.98	76.0	5.21	166.4	1.41
Moderate	8.5	0.32	88.4	2.51	17.2	0.96	75.4	5.79	114.0	1.26
Extensive	6.9	0.31	63.3	2.09	12.4	0.86	80.4	6.37	82.5	1.09
Mean	6.0	0.24	97.0	2.59	18.0	0.93	77.3	5.79	121.0	1.25
Moderate wet site										
Intensive	3.8	0.16	120.6	3.25	22.9	1.19	71.6	5.01	147.3	1.53
Moderate	5.2	0.21	84.2	2.77	18.8	1.11	69.1	5.37	108.2	1.36
Extensive	7.0	0.25	74.9	2.58	15.2	1.32	70.9	6.12	97.1	1.39
Mean	5.4	0.21	93.2	2.87	19.0	1.20	70.6	5.50	117.5	1.43

The differences between intensive and extensive management on wet and dry habitats were 84 and 51 kg of N per 1 ha per year, respectively. Nitrogen efficiency (calculated as a ratio of N uptake to N applied in fertilisation) was rather good on both sites and varied between 81% (intensive use in wet conditions) to

95 per cent (moderate intensity, dry conditions). At extensive management treatment, in wet soil conditions, plants took more nitrogen than had been applied as fertilisation. The content of nitrogen in soil decreased during the three years of experiments (especially in dry conditions), though it does not mean that nitrogen leaching was observed (Table 4). It should be stressed that a lot of nitrogen was found in root biomass, thus the total balance between nitrogen input and output was almost zero. The nitrogen transfer between soil and root (mineralisation versus immobilisation) is probably the main reason why in long-term experiments nitrogen content in soil is rather stable, especially in less extensive management systems, which has also been shown by other authors (Körner, 2002).

Table 4. The mean organic C and N content (g kg^{-1}) in the soil before and after study in dry and wet conditions and the total average uptake (t ha^{-1}) of carbon nitrogen due to soil humidity

	C				N			
	Dry site		Wet site		Dry site		Wet site	
	Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake
1999	25.0	75.0	37.6	112.8	0.75	2.25	0.94	2.82
2002	26.0	78.0	37.8	113.4	0.69	2.07	0.50	2.85
Balance	+1	+3	+0.2	+0.6	–0.06	–0.18	–0.44	–0.03

Carbon sequestration in grass roots was three times higher than carbon accumulation in aboveground biomass as shown in Table 3. It is connected with root mass productivity and it should be stressed that about 5–6 tons per ha per year of pure carbon was found in root mass (up to 20 cm, but mostly in the layer of 0–10 cm) compared to maximum 1.5 tons in aboveground mass. It was also proved that extensive management caused the highest carbon accumulation in the grass root system (on both sites the differences were similar – about 1 ton of C per ha per year). Also the content of organic carbon in soil increased during the three years of the experiment, but it could be only a short- term effect (Table 4). In some long term trials, increasing of carbon content was not observed or results were different due to weather and soil conditions (Körner, 2002; Lal, 2000).

It could be concluded that not such intensive grassland management (2–3 cuts per year, no more than 120 kg of nitrogen) is a simple method to increase carbon sequestration in soil, roots and aboveground biomass. Probably it is also a way to reduce carbon emission to the atmosphere from pastures and meadows but it is very difficult to estimate the total emission from Polish agriculture (Sapek, 2000). We can only suppose that carbon emission from peat lands might be very high (Czaplak and Dębek, 2000), and proper grassland management is one of the solutions to reduce harmful greenhouse effect.

Conclusions

Nitrogen content depends on plant organs, management intensity, and site humidity. The leaves, inflorescences and stems contained much more nitrogen than grass roots.

Nitrogen content in plant aboveground mass on dry soil was higher than in plants on moderate wet site.

The intensive grassland management caused a significant increase in N content in plants on both sites (the differences between intensive and extensive management were about 1% of dry matter – the average from a three years' study).

Nitrogen efficiency was rather good (on average about 90%) and slightly depended on soil site and management intensity.

The differences in carbon content were not so clear as in the case of nitrogen but more carbon was found in roots at less intensive management, compared to intensive one.

The total nitrogen accumulation and uptake was higher in aboveground biomass than in roots. In case of carbon, the situation was just opposite – three times more carbon was accumulated in roots than in leaves and stems.

Less intensive use caused higher carbon accumulation (mostly in grass root system), thus it could be concluded that extensive grassland management is a way to reduce the harmful greenhouse effect.

The carbon and nitrogen cycle and balance is a very complicated process and some interdisciplinary studies and complex research are needed to find some good solutions both for practical use and scientific opinion.

Acknowledgements

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References

1. Aeschlimann U., Blum H. *et al.* (2004) Nitogen supply strongly altered the net ecosystem carbon uptake in managed grassland exposed to nine years of free air CO_2 enrichment in In:
2. Lüscher A., Jeangros B. *et al.* (eds) Land Use Systems in Grassland Dominated Regions. Proceedings of the 20th General Meeting of Grassland Federation, Luzern, Switzerland,Grassland Science in Europe vol. 9, 145–146.
3. Czaplak I. and Dębek W. (2000) Torfowiska Polski jako źródło emisji dwutlenku węgla. Zeszyty Edukacyjne 6, 61–71.
4. Davidson E.A. and Ackerman I.L. (1993) Changes in soil carbon inventories following cultivation of previously untilled soils. Biogeochemistry, 20, 161–164.
5. Körner C. (2002) Grassland in CO_2 – enriched world. In Durand J.L *et al* eds Multifunction grasslands Proceedings of the 19th General Grassland Federation, La Rochelle,, Grassland Science in Europe vol. 7, 611–632.
6. Lal R. (2000) Węgiel glebowy i nasilenie efektu cieplarnianego. Zeszyty Edukacyjne 6, 22–36.
7. Lampe C., Dittert K. *et al.* (2004) Nitrous oxide fluxes from grassland soils with different fertiliser regimes. In: Lüscher A., Jeangros B., Kessler W., Huguenin O., Lobsiger M., Millar N. and Suter D. (eds) Land Use Systems in Grassland Dominated Regions. Proceedings of the 20th General Meeting of Grassland Federation, Luzern, Switzerland,Grassland Science in Europe vol. 9, 334–336.
8. Sapek A. (2000) Emisja gazów cieplarnianych z rolnictwa do atmosfery. Zeszyty Edukacyjne 6, 9–21.
9. Stypiński P. and Moraczewski R. (1984) The influence of soil moisture and cutting frequency on chemical compositions on some species of grass in conditions of intensive production. In: Riley H. and Skjelvag A., O. (eds) The impact of climate on grass production and quality. Proceedings of the 10th General Meeting of Grassland Federation, Ås, Norway, 412–416.

THE IMPACT OF LEGUME NITROGEN ON THE FORMATION OF WINTER WHEAT YIELD

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Abstract

For efficient functioning of various cropping systems, the most essential nutrient element is nitrogen. Introducing of suitable legumes in cropping systems is important due to their ability to fix nitrogen. The possibilities of intercropping legumes and winter wheat were investigated in the experiment conducted at the Lithuanian Institute of Agriculture in 2003–2004. The pre-crops for winter wheat were peas, white clover, red clover, barley, and perennial ryegrass. In the autumn of 2003, wheat was directly drilled into clover crop and peas, or was conventionally drilled after the afore-mentioned pre-crops. Inorganic soil nitrogen as indicator of nutrient source was studied in the autumn and wheat vegetative growth period at main growth stages the following year. The concentration of inorganic soil nitrogen in the autumn and spring varied depending on the pre-crop and sowing method. The amount of inorganic soil nitrogen decreased in spring compared with autumn. A positive correlation was found between inorganic soil nitrogen and wheat grain yield. The wheat grain yield was significantly higher after peas, white and red clover pre-crops than after barley or perennial ryegrass.

Key words: legumes, peas, clovers, winter wheat, nitrogen, intercropping

Introduction

It has been known for over a decade that intensive systems of animal production reliant on large inputs of inorganic fertiliser nitrogen are inefficient in nitrogen use and can give rise to large emissions to the environment (Jarvis and Aarts, 2000; Jarvis, Menzi, 2004; Scholefield *et al.*, 2002). The total loss of nitrate was highly dependent on the specific species composition of the communities, plots with legumes lost significantly more NO_3^- than plots without them (Scherer-Lorenzen, 2004) and through nitrogen mineralisation complementary uptake of nitrate by grasses and herbs (Scherer-Lorenzen *et al.*, 2003). Without additional nitrogen input through legumes, plant diversity had no influence on available mineral nitrogen pools of the soil and net nitrogen (Scherer-Lorenzen*,* 1999). A failure to maintain a vast biodiversity and growing of only grass/legume mixtures can be hazardous to ground water, since the biomass does not completely utilise the N_2 content abundantly fixed by legumes, which results in inevitable leaching of nitrates (Scherer-Lorenzen, 2004). The experiment carried out in the United Kingdom clearly demonstrated that when cereals and clover were grown together, the cereals utilised a greater proportion of all the mineral nitrogen made available from the soil, only 3 to 14 percent of the applied nitrogen was recovered in the clover (Akhonzada *et al.*, 2001). The aim of our experiment was to ascertain how to accelerate utilisation of biological nitrogen potential accumulated by legumes for winter wheat already from the first year of their inclusion in the crop rotation.

Materials and Methods

Field studies were conducted on loamy *Endocalcari-Epihypogleyic Cambisol* in Dotnuva (55^o 24' N). Soil pH_{KCl} varied between 6.5 to 7.0, humus content was 2.5–4.0 per cent, available P 50–80 mg kg^{-1} and K 100–150 mg kg^{-1}. The pre-crops for winter wheat (*Triticum aestivum* L.) were peas (*Pisum sativum* L.), white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.), barley (*Hordeum vulgare* L.), and perennial ryegrass (*Lolium perenne* L.). In the autumn 2003, wheat was direct drilled (DD) into clover crop, peas and perennial ryegrass, or was conventionally drilled (CD) after the afore-mentioned pre-crops. Inorganic soil nitrogen as indicator of nutrient source was studied in the autumn and wheat vegetative period at main growth stages. Soil samples for analysis were taken from the depths of 0–30 and 30–60 cm. The amount of inorganic nitrogen was determined by summing up NO_3^- and NH_4^+ amounts. Ammonium (NH_4^+) was extracted from the soil by shaking 30 g of fresh soil with 75 ml 1 M KCl (pH 5.6-6.0) and the extract was analysed colorimetrically. Nitrate (NO_3^-) was extracted from the soil by shaking 20 g of fresh soil with 50 ml of potassium aluminium sulfate (1 per cent) and measured using ionometer 85 JONANALYSER with nitrate selective electrode. The experiments had a randomised block design with four replicates. The net plot size was 2.5×13 m, P and K were applied according to the plant need based on soil status.

The yield of swards was taken at the flowering stage of legumes. Peas were cut at wax stage for silage, barley for grain – at complete ripeness stage. Winter wheat was grown without nitrogen fertilisation in order to estimate different effects of nitrogen. Winter wheat yield was corrected to 15 per cent of moisture. The data were statistically processed using analysis of variance and exponential regression.

Results and Discussion

The amount of inorganic soil nitrogen depended on different pre-crops and growing conditions. The higher amount of inorganic soil nitrogen in the soil at the depth of 0–60 cm was identified in all the cases when winter wheat was sown after plough-in of pre-crops (Table 1). By direct drilling into stubble or sward of pre-crops (peas or clover) the amount of inorganic nitrogen was lower after peas or clovers probably due to weaker mineralisation of organic matter.

Table 1. The amount of inorganic nitrogen in the soil at the depth of up to 60 cm and the winter wheat grain yield

Wheat pre-crops*) + sowing method*)	Soil N min pool, mg kg^{-1}										Wheat grain yield, kg ha^{-1}
	Autumn		Spring		Booting		Heading		Ripeness		
	0–30	30–60	0–30	30–60	0–30	30–60	0–30	30–60	0–30	30–60	
B – CD	6.88	8.21	5.10	6.44	1.50	1.50	6.40	7.08	3.18	3.46	2680
P – CD	7.22	8.12	4.40	6.10	1.66	1.66	5.20	5.41	3.00	3.30	3698
P – DD	4.79	5.47	4.84	6.97	1.64	1.64	6.10	6.46	2.84	3.13	3215
Wcl – CD	7.41	8.54	4.44	6.16	1.70	1.70	5.30	5.61	3.31	3.68	3773
Wcl – DD	4.30	5.15	4.39	6.32	1.50	1.50	6.70	7.37	3.64	4.28	1019
Rcl – CD	6.69	7.96	4.80	6.69	1.49	1.49	6.30	6.66	3.28	3.49	3798
Rcl – DD	4.94	6.09	3.93	5.36	1.88	1.88	6.10	6.60	3.29	3.88	479
Pr – CD	5.96	6.47	4.16	5.83	1.65	1.65	5.30	5.68	3.33	3.76	2912
$LSD_{0.05}$	3.00	3.66	0.73	1.26	0.32	0.32	1.04	1.62	0.80	1.21	305.9

* Pre-crops: B – barley, P – peas, Wcl – white clover, Rcl – red clover , Pr – perennial ryegrass.
* Wheat sowing method: CD – conventional drilling, DD – direct drilling.

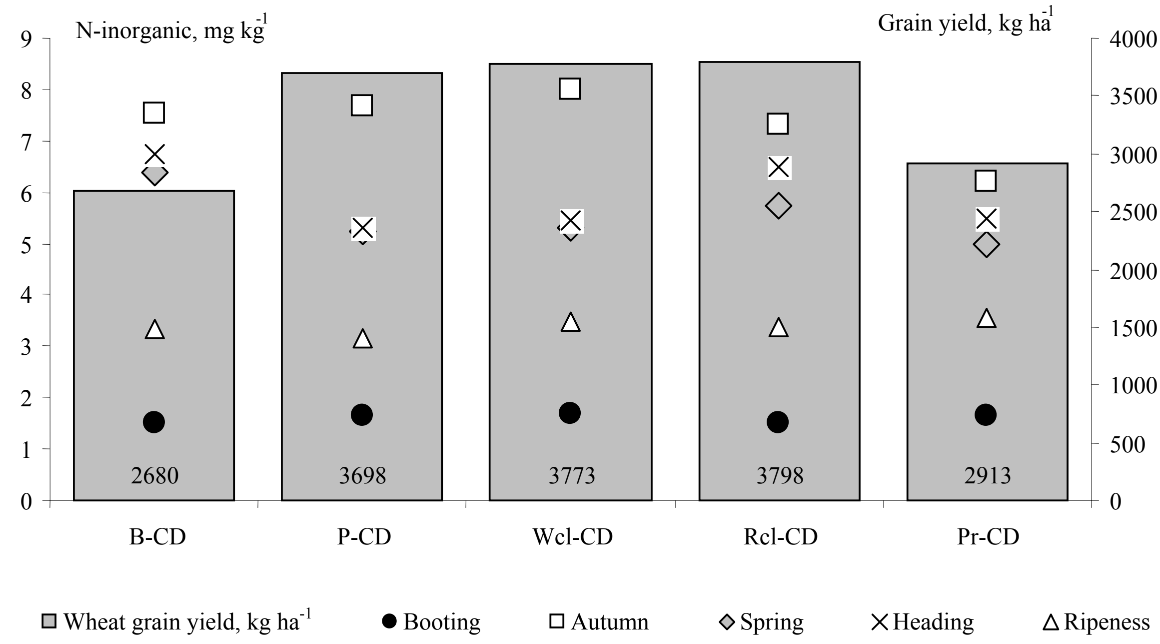
The amount of inorganic nitrogen in spring (April) at wheat tillering was lower than in autumn in all treatments, while the lowest content was identified in the soil of direct drilled wheat into clovers or perennial ryegrass swards. Compared with autumn, the amount of inorganic nitrogen decreased more significantly at the depth of 0–30 cm when the amount of nitrogen at lower depth almost did not change. Depending on microbiological processes and structure of organic matter, different amounts of NO_3^- and NH_4^+ appear in the soil. In our experiment, more NO_3^- appeared. Since this form of nitrogen is more mobile than NH_4^+, a slight reduction in inorganic nitrogen in spring and more essential reduction at wheat booting stage (early June) might occur. Decreasing of inorganic nitrogen might be influenced by more intensive infiltration of precipitation (43.0 mm in March). Taking into account the fact that the amount of inorganic nitrogen was also low at the 0–30 cm soil depth we can presume that it was most intensively used at wheat booting (intensive growth) stage.

In midsummer 2004, the conditions for mineralisation of organic matter were favourable. Therefore the amount of inorganic nitrogen at wheat heading stage increased again and reached the level similar to that in the depth 0–60 cm in autumn 2003. At ripeness stage, the average amount of inorganic nitrogen was found and it only slightly differed in separate treatments.

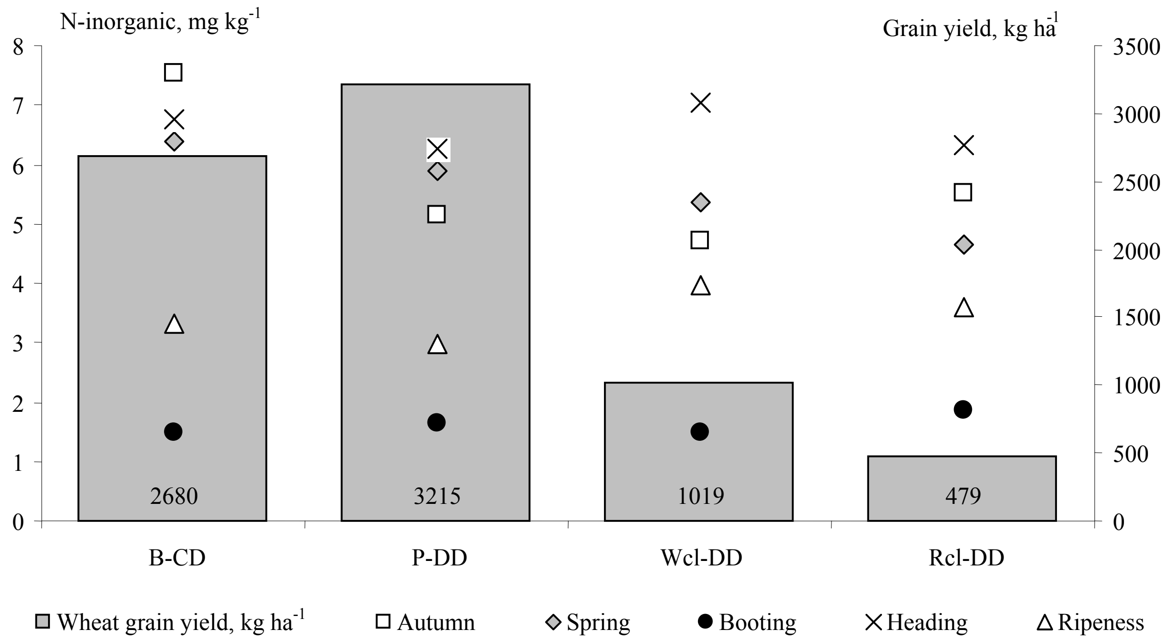
The wheat grain yield was determined by different growth conditions: sowing methods, amounts of biological nitrogen accumulated by different pre-crops, and climatic conditions in spring and summer. In April and May, the temperature was sufficient or some less (7.6 and 11.2 ^{0}C), but the amount of precipitation was insufficient (11.1 and 27.8 mm) compared with long-term means – 5.7 and 12.2 ^{0}C and 37.8 and 52.0 mm, respectively. In June and July, the air temperature was close to long-term mean, but in August it was by 1.5 ^{0}C higher than normal. In midsummer, the moisture was abundant: the amount of rainfall in July (81.6 mm) and August (94.5 mm) exceeded the long-term mean by 7.8 and 21.1 mm.

The highest wheat grain yield was achieved on the ploughed-in legumes plots after using conventional sowing method. Active microbiological processes in autumn influenced the mineralisation of organic matter, and large amount of inorganic nitrogen appeared up to start of wheat growing. As a result, the wheat grain yield the following year was by 28–42 per cent higher compared with barley or perennial ryegrass pre-crops.

Data of the experiment illustrated influence of drilling type on the grain yield and changes of inorganic soil nitrogen during the overall wheat growing season (Fig. 1). Winter wheat yield depended on conventional drilling more positively. Grain yield after ploughed-down peas and conventional drilling was 15 per cent higher compared to direct drilling after pre-crop peas. Grain yields with application of conventional drilling after white clover and after red clover were respectively 3.7 and 7.9 times higher compared to direct drilling application after the same pre-crop.

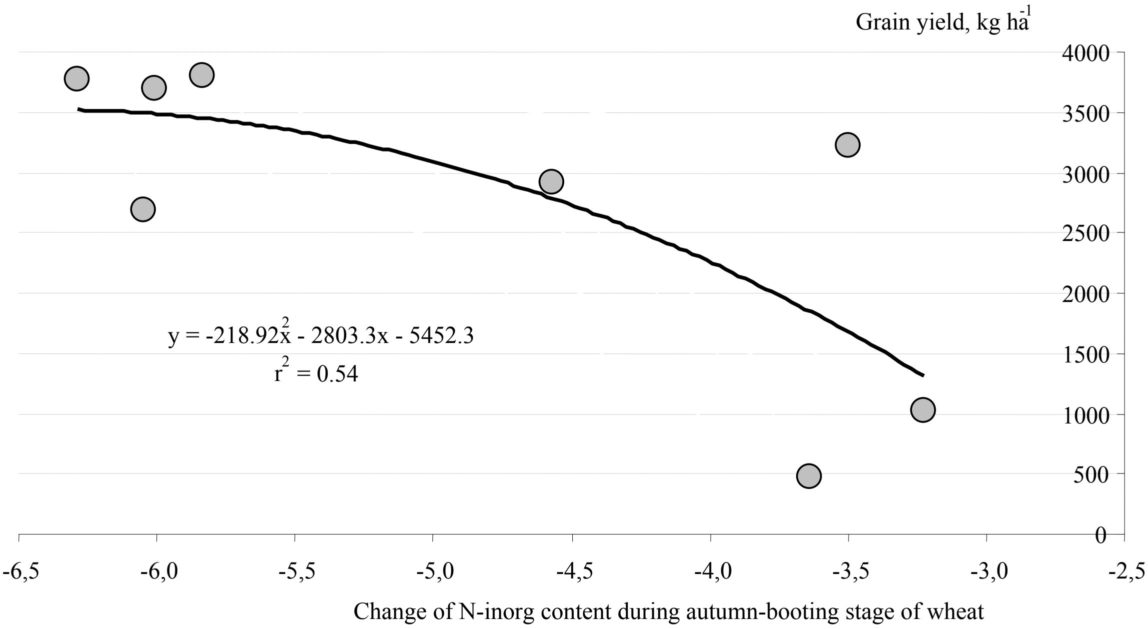


Conventional drilling

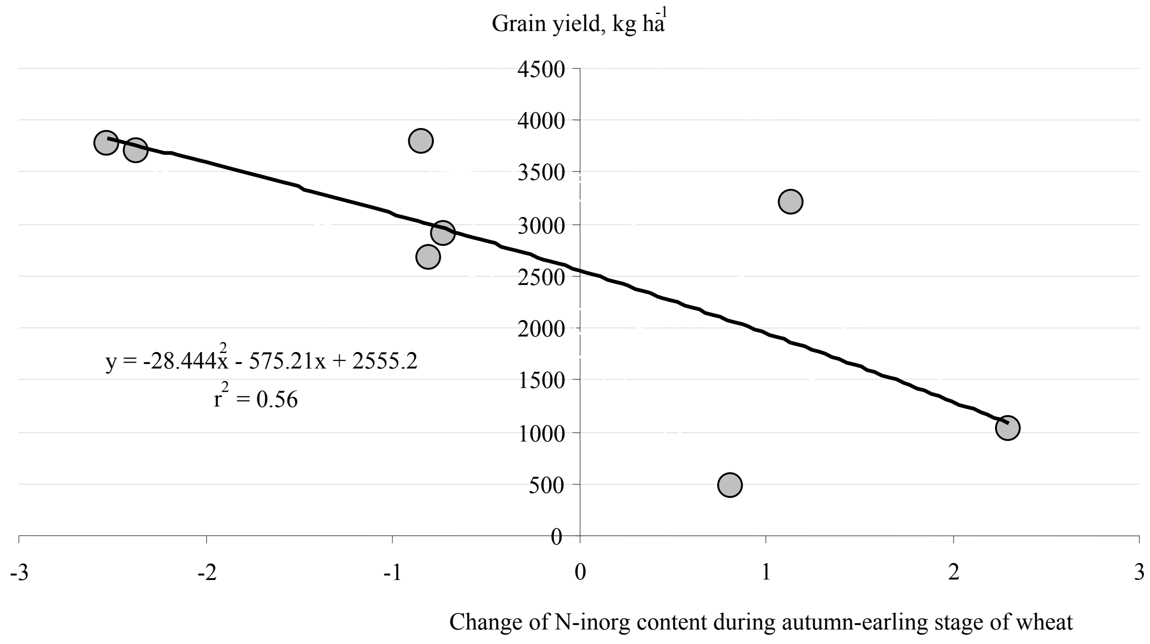


Direct drilling

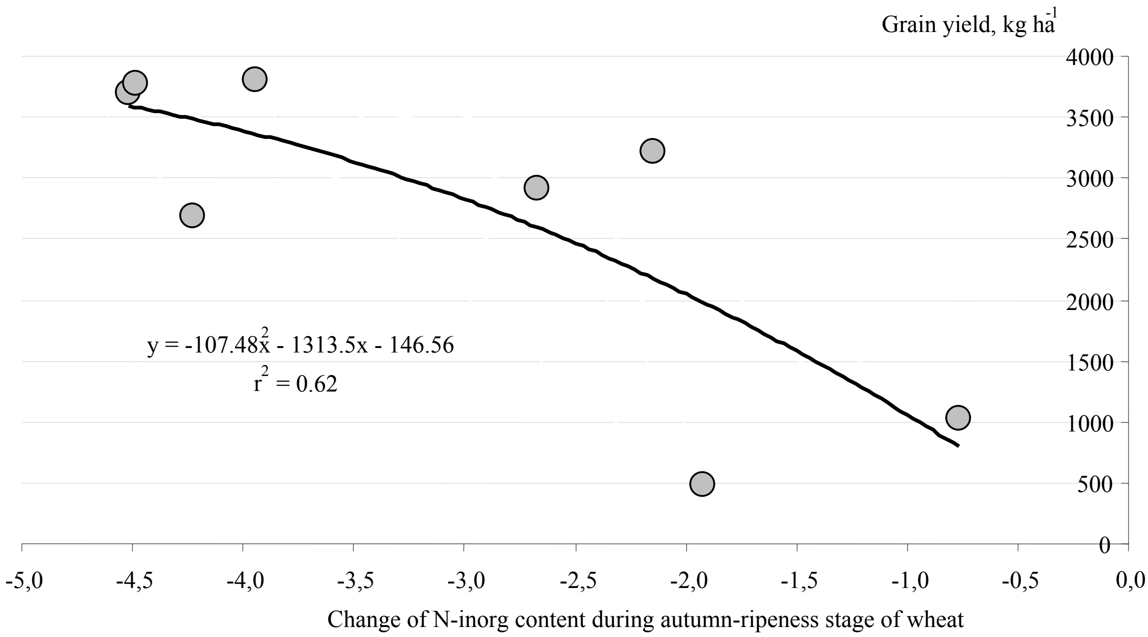
Figure 1. Dynamics of inorganic soil nitrogen at different wheat growth stages (Pre-crops: B – barley, P – peas, Wcl – white clover, Rcl – red clover , Pr – perennial ryegrass; CD – conventional drilling, DD – direct drilling)


Grain yield, kg ha-1
4000
3500
3000
2500
2000
1500
1000
500
0
y = -218.92x2 - 2803.3x - 5452.3
r2 = 0.54
-6,5
-6,0
-5,5
-5,0
-4,5
-4,0
-3,5
-3,0
-2,5
Change of N-inorg content during autumn-booting stage of wheat

A


Grain yield, kg ha-1
4500
4000
3500
3000
2500
2000
1500
1000
500
0
y = -28.444x2 - 575.21x + 2555.2
r2 = 0.56
-3
-2
-1
0
1
2
3
Change of N-inorg content during autumn-earling stage of wheat

B



C

Figure 2. Correlation between winter wheat grain yield and inorganic soil nitrogen (mg kg^{-1}) at different wheat growth stages (A, B, C)

Yield data correlations with inorganic soil nitrogen amount at different terms of investigation were not strong. Whilst, the relations of grain yield with nitrogen changes rate during different terms of soil sampling were very clear and statistically significant (Figure 2). The higher differences of inorganic soil nitrogen were registered during autumn and certain cereal vegetation stages, the greater winter wheat grain yield was obtained.

Conclusions

Legumes as wheat pre-crops were more valuable in terms of inorganic soil nitrogen content.

The winter wheat yield depended on the amount of inorganic nitrogen after different pre-crops and on wheat sowing method: it was the highest after ploughed-in red or white clover and peas, and the lowest when direct drilled into growing white or red clover.

The winter wheat grain yield was mostly determined by the amount of inorganic soil nitrogen in autumn and spring. The highest amount of inorganic nitrogen in the soil was found in autumn after ploughing-in of white clover (7.98 mg kg^{-1}) or peas (7.67 mg kg^{-1}). In spring it was by 22–36 per cent lower than in autumn at conventional wheat sowing, but after direct drilling of wheat the amount of inorganic nitrogen was similar to that in autumn or a little higher.

References

1. Akhonzada N. A. *et al.* (2001) Fate of ^{15}N-labelled fertiliser when applied to cereal and legume grown together and separately. Grassland Science in Europe, 6, 79–81.
2. Jarvis S. C., Aarts H.F.M. (2000) Nutrient management from a farming systems perspective. Grassland Science in Europe, 5, 363–373.
3. Jarvis S. C., Menzi H. (2004) Optimizing best practice for N management in livestock systems: meeting production and environmental targets. Grassland Science in Europe, 9, 361–372.
4. Scherer-Lorenzen M. (1999) Effects of plant diversity on ecosystem processes in experimental grassland communities. Bayreuther Forum Okologie, 75, 1–195.
5. Scherer-Lorenzen M. (2004) Plant diversity and nitrogen dynamics in experimental grassland systems. Grassland Science in Europe, 9, 180–182.
6. Scherer-Lorenzen M. *et al.* (2003) The role of plant diversity and composition for nitrate leaching in grasslands. Ecology, 86(4), 1539–1552.
7. Scholefield D. *et al.* (2002) Assessment of nitrate leaching from beneath forage. Landbauforschung Völkenrode, SH 234, 17–25.

Horticulture

BIOLOGICAL ACTIVITIY ASSESMENT OF FERTILISER *AGROVIT-KOR*

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Abstract

Experiments are carried out to investigate biological activity of fertiliser *Agrovit-kor.* Plant biotests, pot and small-scale field experiments were conducted at the Department of Plant Biology and Protection, Latvia University of Agriculture. Maize and wheat coleoptiles were used for determination of preparation auxin activity. The effect of preparation on vegetable seed germination was tested. Vegetable growth as well as soil biological activity was studied in the pot culture. Tests with coleoptiles showed that *Agrovit-kor* hadn't auxin activity. Germination of seeds depended on preparation's concentration and seeds weight. Large seeds were less sensitive to preparation. 100 g L^{-1} and 5 g L^{-1} solutions of *Agrovit-kor* inhibited seed germination. Positive correlation is found between preparation's concentration and soil biological activity. The pot experiments with different vegetables showed that the recommended doses of preparation were lower than plants needs for their growth. The decrease of plant length, weight and number of leaves was observed in comparison with variants where mineral fertilisers were used. Small-scale field experiments did not prove the advantage of *Agrovit-kor* in comparison with mineral fertiliser.

Key words: *Agrovit-kor*, biotests, seed germination, vegetables, soil biological activity

Introduction

The use of organic fertilizers to improve soil is very old. Theophrastus (372–287 B.C.) pointed out the importance of legumes and grasses used as mulches. Other common organic fertilizers included dung of birds and bats (guano), fish fertilizer, dry blood, and dry meat. All these organic compounds help improve the soil by increasing water retention capacity, thus impeding nutrient loss by leaching, by decreasing erosion and surface drainage, and by helping control weeds and other pests (J. A. Caamal-Maldonado *et al.*, 2001).

Lot of different organic fertilisers are recommended for farmers today. Producers advertise their products stimulating plant growth, increasing yield, improving plant quality and resistance to environmental stresses and diseases.

The aim of the work was to test biological activity of the organic fertiliser *Agrovit-kor*.

Materials and Methods

Experiments were carried out in 2002 and 2003 at the Department of Plant Biology and Protection, Latvia University of Agriculture for investigation of effect of the preparation *Agrovit-kor,* AVK, on cultures. It is produced in Russia as an organic fertilizer prescribed for improvement of soil structure and increase of yields in organic farming. It is made from soil, poultry manure, and peat and contains: organic matter 68–74%, N – 1.35%, P – 1.45%, K – 1.07%, Ca – 0.64%, Mg – 0.96%, microelements Fe, Mn, Zn, Cu and bio active compounds according to the specifications (declaration) of the producer. Biotests, vegetation (pot) and small-scale field experiments were designed for determination of the effect of AVK.

Activity of auxins was determined with the growth of wheat and maize coleoptiles. Seeds of the grains were germinated in a thermostat, at 25 ºC. When the coleoptiles were approximately 2 cm long, the middle part, precisely 1.0 cm, was cut with 2 parallel blades fixed in a cork. The pieces of the coleoptiles were put in a 100 ml weighing glasses with 20 ml of 100, 50, 10, 5, 1, 0.5 or 0.1 g L^{-1} solution of AVK, and incubated for 24 hours in a thermostat at 25 ºC. Simultaneously, pieces of coleoptiles were incubated in water and in solutions of indolylacetic acid, IAA, 1, 0.1 and 0.01 mg L^{-1}. After the incubation the increase of the length of each piece of coleoptile was determined. Five coleoptile pieces were put in each weighing glass. Experiments were done in three replications (Гродзинский А. М. *et al.*, 1973).

A seed germination test was designed for investigation of the biological activity of AVK. Ten seeds of different vegetables were placed in Petri dishes with filter papers moistened with 10 ml of: 100, 50, 10, 5, 1, 0.5 or 0.1 g L^{-1} AVK, and placed in the thermostat. The control was germinated with water only. Vegetables, their varieties, temperature and time of incubation are presented in Table 1. After the incubation time, the length of the primary roots was determined. Experiments were done in 3 replications (Гродзинский А.М. *et al.,* 1973).

Vegetation experiments were placed in pots with neutralized peat in 4 replications. Three variants and 2 controls were chosen:

Control 1 (c1) – neutralised peat;
Variant 1 (v1) – 1 g of AVK per 1L of peat;

Variant 2 (v2) – 2 g of AVK per 1L of peat;
Variant 3 (v3) – 3 g of AVK per 1L of peat;
Control 2 (c2) – 1 g of KEMIRA 10:10:20 per 1L of peat.

Table 1. Vegetables, varieties, temperatures and time of incubation for germination of seeds

Vegetable	Variety	Temperature of incubation, ºC	Time of incubation, days
Cucumber	'Grīva'	25	8
Cabbage	'Amager red'	20	10
Carrots	'Amsterdam'	20	14
Radish	'Žara'	20	10
Lettuce	Novogodnij'	20	7
Maize		25	7

The volume of pots varied depending on culture and number of plants. 10 radishes were grown in 6 L pots, 4 lettuces in 400 mL pots, and single cabbage and cucumbers in 400 mL pots, all placed in a greenhouse. The weight, the length, the number of leaves, and dry matter content were determined after one month of vegetation. The pH and the biological activity of the soil were determined at the harvest time. The activity of catalase in the soil was used as a measure of the biological activity in the soil. The activity was determined as follows: 10 g of soil and 30 mL distilled water were put in a Bunsen flask and mixed. A small beaker with 1.0 ml of 3% hydrogen peroxide was then carefully put in the flask and the flask was closed with a stopper. The side tubing was connected with rubber tubing to a gas burette. After three minutes the temperature and pressure were equalised and the hydrogen peroxide was poured out and mixed with the soil slurry. Readings of the volume of evolved oxygen were taken after 1, 3 and 5 minutes (Klāsens *et al.*, 1987).

Field experiments were conducted on a loamy sand soil with the following parameters: pH_{KCl}-7.4, P – 270 mg L^{-1}, K – 273 mg L^{-1}, Ca – 19625 mg L^{-1}, Mg – 3075 mg L^{-1}, Fe – 1455 mg L^{-1} in four replications. The vegetation experiments showed that the recommended doses of AVK were too small, therefore doses for field experiments were calculated using the recommendations given by V. Nollendorfs (V. Nollendorfs, 1998) and the nitrogen content in AVK. Three different fertiliser programmes were used:

1) Mineral fertilising with KEMIRA 10:10:20 with microelements, 50 g m^{-2} and twice dressed with 25 g of fertiliser, i.e. 50+25+25 g m^{-2}.
2) Fertilising with *Agrovit-kor*, AVK – 370+185+185 g m^{-2}.
3) Mixed fertilising – half mineral, half AVK.

The experiments were carried out with the cucumber variety *Pioneer* and cabbage *Amager Red*. Four cabbage or three cucumber plants were grown per square meter.

Results and Discussion

The experiments with the wheat and the maize coleoptiles showed different sensitivity of the cultures to AVK. The highest concentration of AVK (100 g L^{-1}) inhibited the growth in length of the pieces of wheat coleoptiles. Lower concentrations did not significantly affect the length. There was no significant effect of AVK on the maize coleoptiles. All used concentrations of IAA showed stimulating effect (Fig. 1).

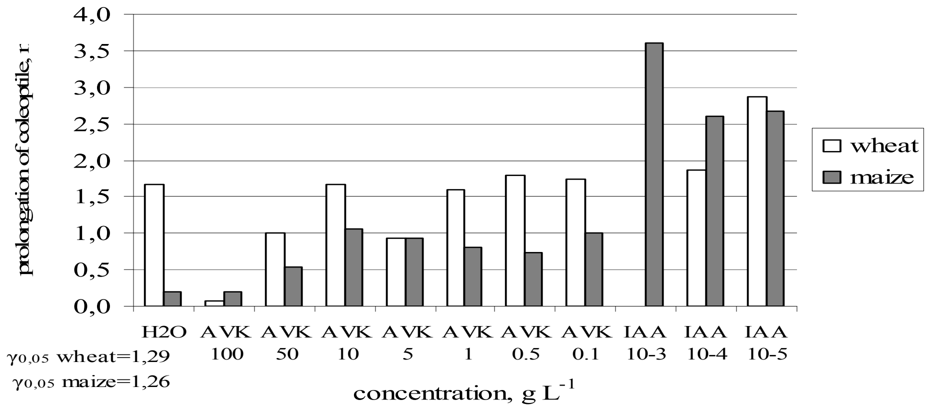

Figure 1. Effect of AVK on coleoptiles growth given as increase in length in mm

The germination experiments showed that seeds of different cultures had different germination ability and sensitivity to AVK, as shown in Table 2. Cabbage and lettuce seeds had the lowest germination. Radish, maize and cucumbers germinated well. The effect of AVK on the seeds was related to the seed weight. There wasn't observed effect on large seeds as on those of maize.

Table 2. The effect of AVK on vegetable seed germination as % of germinated seeds

Culture	Concentration of preparation, g L^{-1}							
	H_2O	100	50	10	5	1	0.5	0.1
Cucumber	87.5	62.5*	75.0	75.0	87.5	87.5	100.0#	75.0
Radish	100.0	30.0*	95.0	100.0	100.0	95.0	100.0	95.0
Lettuce	10.0	0.0	0.0	30.0#	40.0#	50.0#	45.0#	40.0#
Maize	90.0	95.0	85.0	95.0	90.0	100.0	100.0	95.0
Cabbage	10.0	0.0	5.0	20.0	35.0#	15.0	40.0#	45.0#
Carrot	60.0	0.0*	10.0*	55.0	65.0	50.0	65.0	65.0

γ0.05 between concentrations 10.4;
γ0.05 between varieties 14.7;
*Result is significantly lower than control (H_2O);
#Result is significantly higher than control (H_2O);
Concentration 100 g L^{-1} was too high for germination of cucumber and radish seeds.

Lettuce, carrot and cabbage seeds were significantly inhibited by concentrations higher than 50 g L^{-1}. Lower concentrations stimulated the germination. The largest effect was observed on seeds of low germination ability (cabbage and lettuce). The experiments showed that for seed treatment, concentrations of AVK of more than 10 g L^{-1} were not acceptable. The stimulating effect was found in the concentration range 0.1–10 g L^{-1}.

At concentrations 100 and 50 g L^{-1} of AVK a decrease of the length of the primary roots was observed, but at 1–10 g L^{-1} a significant increase was observed (Table 3).

Table 3. The effect of preparation *Agrovit-kor* on the length of primary root, cm

Culture	Concentration of AVK, g L^{-1}							
	H_2O	100	50	10	5	1	0.5	0.1
Radish	1.2	0.2*	0.7	2.3#	2.4#	1.5	0.9	1.3
Maize	3.0	0.6*	7.0#	7.0#	6.9#	4.0#	2.7	3.3
Cucumber	4.9	0.2*	1.4*	4.6#	5.5#	4.7#	3.7#	4.1#
Lettuce	0.6	0.0	0.0	1.7#	1.7#	1.4#	1.3#	0.8
Carrot	2.1	0.0*	1.2*	2.3	2.6	3.2#	1.6	2.4
Cabbage	4.6	0.0	0.0	6.2#	4.0	6.5#	3.8*	3.6*
Mean	2.7	0.5*	2.1*	3.7#	3.9#	3.5#	2.6	2.5

$\gamma_{0.05}$ between concentrations 0.6;
$\gamma_{0.05}$ between varieties 0.6;
* Result is significantly lower than control (H_2O);
#Result is significantly higher than control (H_2O).

Table 4. The effect of preparation AVK on the parameters of radish

Variants	Weight of leaves, g	Weight of radish, g	Length of leaves, cm	Dry matter content in leaves, %	Dry matter content in radish, %
Control 1	0.5	1.0	5.5	8.45	11.70
Variant 1	1.4	4.5	9.8	8.04	10.72
Variant 2	1.3	4.6	9.8	10.73	10.68
Variant 3	2.7	7,6	12.9	6.65	8.78
Control 2	7.7	17.9	19.3	5.00	5.71
$\gamma_{0.05}$	2.4	5.6	3.4	1.95	3.28

Pot experiments showed that AVK significantly influenced the growth of radish (Fig. 2). The recommended doses were too small in relation to the requirement of the plants. Therefore the best results were obtained with mineral fertilisers (control 2). As it is shown in Table 4 the roots of the fertilized variant were 2.4 times, but leaves 2.9 times heavier than in the best variant of AVK. The average length of leaves increased with the dose of fertiliser. The dry matter content in radishes significantly decreased with the dose of fertiliser (coefficient of correlation is –0.98). It shows that the recommended doses could not meet the plant requirements for nutrients.

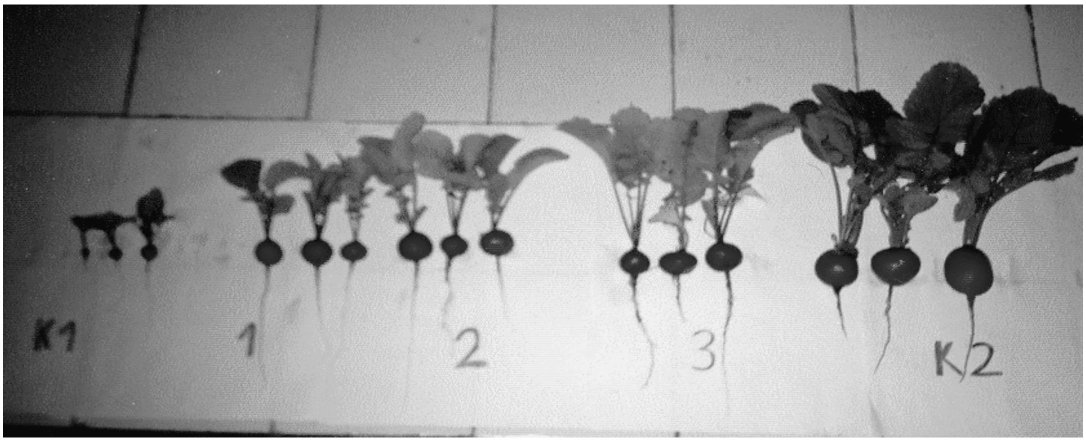

Figure 2. Effect of AVK on the growth of the radish in pot experiments
K1 – control 1, 1, 2 and 3 – variants 1, 2 and 3 respectively, and K2 – control 2

Similar results were obtained with cabbage and cucumber seedlings as shown in Table 5. Plants with mineral fertilizers were approximately 2 times larger; they had more leaves, the weight of a leaf increased according to the used dose of fertiliser. The plants fed with mineral fertilizer had less dry matter in comparison with those fed with AVK.

Table 5. The effect of AVK on the cabbage and cucumbers

Variants	Cabbage				Cucumbers			
	length of leaves, cm	number of leaves	dry matter content, %	weight of a leaf, g	length of leaves, cm	number of leaves	dry matter content, %	weight of a leaf, g
Control 1	9.7	2,2	16.1	0.097	8.1	3.8	16.2	0.21
Variant 1	11.2	2.0	18.2	0.126	8.0	4.0	18.2	0.23
Variant 2	10.7	2.3	18.5	0.125	8.5	4.0	18.5	0.24
Variant 3	13.5	3.8	18.5	0.210	10.2	4.0	18.5	0.30
Control 2	15.1	4.5	9.1	0.303	17.5	5.6	6.1	0.51
$\gamma_{0.05}$	4.4	1.0	3.4	0.035	3.5	0.2	3.4	0.15

As presented by Table 5, AVK at recommended doses could not meet the plant requirements for nutrients at early stages of growth.
At the end of experiments the soil acidity and biological activity was measured. Non-significant effect of the used fertilizer on the soil pH was observed.

Table 6. The effect of AVK on the soil parameters

	pH_{KCl}			Soil activity, cm^{-3} O_2 min^{-1} (100g dry soil)$^{-1}$		
	radish	cabbage	cucumbers	radish	cabbage	cucumbers
Control 1	6.5	6.5	6.6	35.5	29.5	39.3
Variant 1	6.6	6.2	6.4	27.5	35.6	31.0
Variant 2	6.5	6.2	6.4	45.3	33.8	30.8
Variant 3	6.5	6.2	6.5	33.3	39.1	32.7
Control 2	6.6	6.4	6.6	24.0	36.2	48.8
	$\gamma_{0.05}$= 0.3			$\gamma_{0.05}$= 9.8		

Soil biological activity was significantly influenced by the grown culture, type and the dose of fertilizer used. The highest activity was observed in cucumber soil fertilized with Kemira 48.8 cm^3 O_2 100g of air-dry soil, but the lowest (24.0 cm^3 O_2 per 100g of soil) was observed in the same variant, but on soil sown to radish. The lowest average soil activity was observed in the 1st variant using 1g of *Agrovit-kor* per 1L of soil.

Field experiments showed that cabbage fertilised with AVK were 5% taller, but the diameter of the canopy decreased by 9.6%, the average number of leaves by 4.7%, and the weight of cabbage-heads by 10.1%. The visual differences were observed as well. The cabbage grown with AVK had steeper foliage. Results of mathematical data processing do not show significant differences between fertilisers.

Table 7. The effect of AVK on the parameters of cabbage in field experiments

Variants	Weight of cabbage heads, kg	Plant height, cm	Diameter of canopy, cm	Number of leaves per plant
Agrovit-kor	3.21	29.2	82.6	14.3
Mineral fertiliser	3.57	27.8	91.4	15.0
$\gamma_{0,05}$	1.07	3.3	8.9	0.9

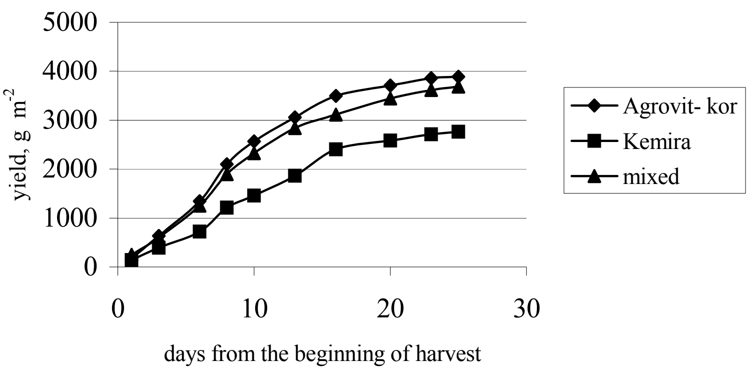

Figure 3. The effect of fertiliser on the cucumber yield formation

The activity of AVK was tested also on cucumbers (Fig. 3). The best results were obtained with AVK on average 3.89 kg per square meter, with mixed fertilisers 3.69 kg, with mineral fertilizer – 2.76 kg, i.e., the cucumber yield with organic fertiliser was 1.5 times higher, but great differences between replications were observed as well, therefore statistically significant differences were not observed.

Conclusions

Preparation *Agrovit-kor* did not show auxin activity.

The effect of preparation on the germination of vegetable seeds depended on culture and concentration of *Agrovit-kor*. The stimulating effect could be expected if the doses of preparation were 0.1–10 g L^{-1}.

The recommended doses (1–3 g per L of peat) for the growth of vegetables and their seedlings were too low.

The advantage of mineral fertiliser or *Agrovit-kor* was not verified in field trials with cabbage and cucumbers.

References

1. Caamal-Maldonado J. A., Jiménez-Osornio J. J., Torres-Barragán A., Anaya A. L. (2001).The Use of Allelopathic Legume Cover and Mulch Species for Weed Control in Cropping Systems//Agronomy Journal 93:27–36
2. Nollendorfs V. Gurķu mēslošana ziemas un vasaras siltumnīcās un atklātā laukā ar "Hydro Agri" minerālmēsliem Latvijas apstākļos Ražība, 1998., Nr. 9 (117), 6.–9.
3. Klāsens V., Mārka B., Strokša I. Augu fizioloģija (Fotosintēze. Elpošana) // Metodiskie norādījumi un uzdevumi laboratorijas darbiem Agronomijas un Mežsaimniecības un mežtehnikas fakultātes studentiem, – Jelgava, LLA, 1987, 20
4. Гродзинский А. М., Гродзинский Д. М. Краткий справочник по физиологии растений, Киев, Наукова Думка, 1973, 591.

LILIES (*LILIUM* L.) IN LATVIA – GENETIC RESOURCES

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Abstract

The aim of the research was the evaluation of the genetic sources of lilies (*Lilium* L.) in Latvia. Lilies – among the most popular bulb flowers in Latvia – have been cultivated there for two centuries. Everywhere lily breeders are very interested in finding bulbs in the wild, collect and use them in the production of new plants. *Lilium martagon* L. (*L. martagon)* is the only wild-growing species in Latvia. From 1993 to 1998, to evaluate the survival of martagonlilies (*L. martagon*), habitats of this species were inspected in the regions of Aizkraukle, Ventspils, Kuldiga and Tukums. Considering the morphological traits, Latvian wild-growing *L. martagon* genotypes vary according to the various locations of their distribution. For the purpose of the maintenance of the genetic source, cultivars originated in Latvia have been evaluated. V. Orekhov, one of the most prominent lily breeders in the world, was one of the first pioneers in Latvia and J.Vasarietis was the first Latvian breeder who established contacts with breeders in the West. The goal of research was to estimate genetic sources of lilies in Latvia and to evaluate the diversity of wild-growing *L.martagon*.

Key words: *Lilium, L. martagon*, genetic sources, wild-growing

Introduction

Used worldwide as an ornamental flower the lily (*Lilium* L.) is a perennial bulb plant. The genus is scattered all over the Northern Hemisphere (North America, Europe and Asia). More than half of the approximately 100 species originated in Asia. Cultivation of lily bulbs for ornamental purposes started at the end of the 19th century in Europe, Japan and the United States of America (Straathoff, 1994). Across the Euro-Asian continent, *L. martagon* holds a vast growing range and as far as endurance is exceeding most other species (Fox, 1991).

All the species of lilies grown in Latvia have been introduced there from other countries. *L. martagon* is the only natural wild species in Latvia. It is a rare species and the north-western border of its distribution area is in Latvia. One of the oldest sources of information on cultivation of lilies in Latvia is the catalogues of Tsigra's Horticultural Society. In 1805 five species of lilies were mentioned there e.g. *L. bulbiferum* L.*, L. candidum* L.*, L. chalcedonicum* L.*, L. martagon* and *L. superbum* L. In the catalogues of Shokh's Horticultural Society 31 species were listed (1850–1878). *L. regale* Wils. has been introduced to Latvia in 1925 and by 1932 Kotser's nursery had produced 6000 bulbs of the species which has retained a permanent place in the gardens (Nesaule and Orehovs, 1970). The Botanical Garden of the University of Latvia became interested in lilies in the 1920s and by 1936 seven species were grown there *L. monadelphum* Bieb.*, L. henryi* Bak.*, L. sargentiae* Wils.*, L. formosanum* Wallace*, L. tigrinum* Ker-Gawler*, L. martagon* and *L. regale* (Zorgevics and Balode, 1989). Lily specialist, P.Upitis, from 1950 to 1960 introduced species found in the Caucasus e.g. *L. kesselringianum* Miscz.*, L. monadelphum* and *L. szovitsianum* Fish.et Avé-Lall – all with bright yellow bell-shaped flowers.

V.Orekhov was one of the most prominent lily breeders in the former Soviet Union and a pioneer of lily culture in Latvia. According to literature, from 1941–1974, Orekhov was the supervisor of a nursery in Jekabpils where he developed one of the largest lily collections in Latvia and, indeed, also in the former Soviet Union (Zobova and Vasarietis, 1988). Jekabpils is a town flanking both sides of the River Daugava in southeastern Latvia. In 1967, there were 30 000 lily bulbs from 280 different species and varieties there. Orekhov's book on lilies, written jointly with Nesaule, was published in 1970. In the International Lily Register (ILR) there are in total 338 lily varieties from Latvia, including 159 bred by Orekhov (Leslie, 1982). The ILR is the only source of information on the data of lily hybrids and varieties.

Contrary to the cut-flower industry in the Netherlands, for example, Latvian lily breeders are aiming at breeding suitable varieties under local ecological conditions – so these varieties are resistant to most widely spread diseases (*Botrytis* Micheli ex Fr., *Fusarium* Link ex Fries.); chemical protection is unnecessary or reduced to a minimum and their cultivation is economically sound and ecologically friendly. Lilies are widely used as garden and cutting flowers and, in their natural setting, pollinated by bees, bumble-bees, night-moth, ants and various other insects. According to the latest research, many of the cultivars originated in Latvia are in a limited supply and rather endangered; therefore, work is planned to be done on the maintenance and sustainable use of these plants.

Materials and Methods

The initial dates of the location of wild-growing *L.martagon* in Latvia were obtained in the Laboratory of Botany of the Institute of Biology of the University of Latvia. From 1993 to 1998, to evaluate the survival of *L.martagon* in Latvia, habitats of this only wild-growing lily species in Latvia were inspected in the regions of Aizkraukle, Ventspils, Kuldiga and Tukums. Between 1996 and 1998, phenological observations were carried out on *L.martagon* that had been collected from different sites – Vigante Park, Staburags, Klintaine, Riva, Padure, Plani and Kuksu Parks, and then the ten bulbs of each wild-growing species were cultivated under standardised conditions in the garden without fungicides. Between 2001 and 2003 sources of literature was studied and observation of lilies originated in Latvia were made.

Results and Discussion

L. martagon found in Latvia.

It was found that *L. martagon* is widespread in the regions of Aizkraukle, Ventspils, Kuldiga and Tukums. Considering morphological traits of *L. martagon* cultivated under garden conditions between 1996 and 1998, they were classified into three groups:

Wild-growing *L. martagon* found on the left bank of the River Daugava near Vigante Park and Staburags (areas which belong to the region of Aizkraukle), must be regarded as species belonging to the same site. Significant differences between this martagonlily and those found on other sites are their colour – their flowers are pale greyish-pink with small dots; and their late start of growth – from late April to early May – with flowering late in June. The height of the plant is up to 105–111 cm. Variability in some morphological traits could be explained with interaction between genotype and the environment.

Wild-growing *L. martagon* found in the regions of Ventspils, Kuldiga and Tukums are similar by phenotypes and are characterized by bright violet-pink flowers. The height of the plant is up to 114–130 cm. The growth period begins from late April; the flowering takes place in early June.

Wild-growing *L. martagon* occurring in the region of Aizkraukle on the right bank of the River Daugava, at the site near Klintaine, is having more distinct parameters when compared with other specimens of martagonlilies; also, flowers are of paler violet-pink with exceedingly fine and scattered dots; stems are up to 90 cm, and blossoms are greater in size. They are late starters – with growth period from early May and blossoming in early July.

Under garden conditions, persistence of genetic variability among the populations was evident. The individuals of each biotope were characterized by stable inherited traits: colour, form and flower diameter, plant height and bulb colour. The plant height of the estimated martagonlilies is presented in Figure 2.

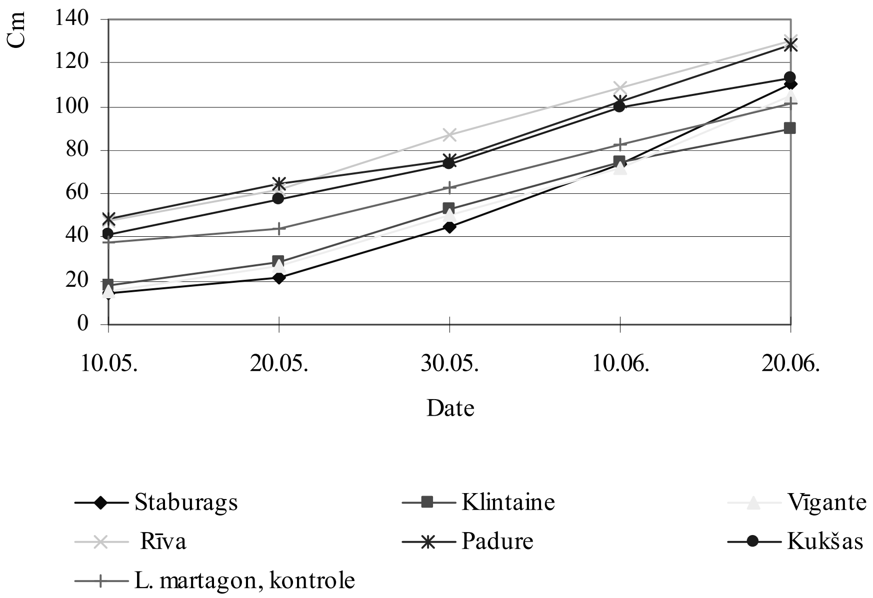

Figure 1. Dynamics of growing *Lilium martagon* L., (1996–1998)

More intensive growth of plants was observed after May 1 – and more rapid development was observed in plants obtained from Riva (in the region of Ventspils), Padure (in the region of Kuldiga), Plani and Kuksas (in the region of Tukums). With initiation of the flowering stage, the plants had reached their maximum height.

The breeding work with martagonlilies was done by V. Orekhov. In spite that there are few hybridizers in Latvia who have produced the *L. martagon* hybrids, J. Wadekamper from Minnesota, USA, when he visited lily show in Latvia said: "I have never seen more spectacular martagonlilies shown anywhere. There were 51 stems among which was a four foot stem of *L.martagon* var. *album* West. with 39 flowers and buds in perfect condition" (Wadekamper, 1993). He had the opportunity to visit the upper River Daugava in search of a martagonlily called *L. martagon* var *daugava* Lacis and he found hundreds of plants, no longer in bloom, but with fat seed pods.

By using *L. hansonii* Leichtl.ex D.T.Moore and *L. martagon,* Orekhov has produced the variety 'Marta', yellow violet with dark spots. He has also hybridized *L.martagon* hybrids and *L. candidum* hybrids, including interspecific crosses between *L. candidum, L. monadelphum* and *L. szovitsianum* – wild species of the Caucasus. They are 'Lone' – creamy white without spotting, 'Lelde' (*L. monadelphum* x *L. candidum*), yellowish white (Balode, 1994). To his credit is also a wide range of commercially profitable early-flowering Asiatic hybrids in yellow, orange and red flowers e.g. 'Banga' – light yellow, early-flowering. He has an especially important strain of Asiatic lilies – 'Vasaras Prieks' (Div. I (b)), of which there are over 20 named clones. It was derived from hybrids of *L. amabile* Palibin and 'Fialkovaja' (*L. szovitsianum* x *L.x maculatum* Baker*)* – itself one of the oldest hybrid lilies raised in Russia in 1914. As initial material for his breeding work, Orekhov used varieties raised in Russia by breeders I.Mitchurin and Z.Cvetajeva. One of his successful hybrids was 'Wiltigrinum Orehovii', crossing *L. davidii* var. *wilmottiae* Raffil with *L. tigrinum* producing flowers of the shape of *L. davidii* Duchartre but the colour and size of *L. tigrinum.*

Very popular outside Latvia was the variety 'Saule' (1987) with outward-facing flowers of very bright dark-yellow with golden-orange spots in the center. It is also a triploid – a cross between Asiatic varieties 'Connecticut Lemonglow' and 'Amalija'. One of the Orekhov's most prominent achievements was the Asiatic hybrid 'Nakts Tango' from the 'Tango' group which contains varieties of colors with dense spotting in the flower center. These lilies have two contrasting colors, the center being dark cherry with either cream or yellow tips. The first lily of this group bloomed in the summer of 1985. His 'Tango' varieties have become very popular in Latvia and beyond e.g. 'Nakts Tango'- blackish violet red with creamy margins and a pale star in the centre, 'Argentīnas Tango' – light orange with brown marbling and spotting; 'Cha-Cha-Cha' – orange with maroon marbling. Now many breeders all over the world successfully continue to develop hybrids of this group, unfortunately, too often forgetting to note the originator of the 'Tango' group – i.e. Orekhov. One of the breeders who obtained the initial material (bulbs and pollen) of this group was P.Schenk from the Netherlands and one of the first varieties he named 'Latvia' – yellow with brown dense spotting in the flower center.

As well as a wide range of the commercially useful Asiatic hybrids in yellow, orange and red, Orekhov also pioneered in breeding violet and pink-flowered hybrids which were relatively scarce in the former Soviet Union e.g. 'Amalija' – a hybrid from *L. cernuum* Komarov with violet flowers, 'Lausks' – smoky violet pink, 'Lucija Baumane' – light pink with dark pink spots.

Orekhov also hybridized Trumpet lilies. In the 1960's he crossed *L. henryi* with *L. x aurealianense* and created a strain which he named after the part of Latvia where he lived, called Latgale – and this group is well-known as 'Latgale'. Majority of these lilies have graceful, star-shaped flowers of *L. henryi* – 'Brunava' is white and orange with brown markings, 'Aglona' is white with green eye and discreet brown markings, 'Rušons' – orange with a red-violet blush. One of his most famous is 'Pārgalvīgā' – a large wide petalled orange flower with a lighter reverse (Wadekamper, 1994). Other hybrids of the 'Latgale' group have trumpet-shaped flowers reminding of *L. x aurealianense* presence in the crosses: 'Eksotika' and 'Suvenīrs' with greenish yellow flowers.

Generally, Orekhov gave in floriculture substantial contribution. He raised lilies all his life in both public and private gardens. Although access to information was limited in the former Soviet Union, Orekhov's lilies reached countries in Europe, the United States, Asia and Australia. In the ILR totally there are 338 lily varieties from Latvia, including 159 bred by Orekhov's (Šķimele, 2000). Varieties developed by Orekhov's carry off the name of Latvia all over the whole world. He worked with lilies in the home garden till the last summer of his life. He died in February, 1998. Orekhov, in 1998, received the prestigious E.H.Wilson Award. The research revealed that many cultivars originated by Orekhov have not been grown. Trumpet lilies are very susceptible to viruses and, under ordinary circumstances; the intensity of propagation is low.

J. Vasarietis was the first Latvian breeder who established close contacts with breeders in the West; namely, the North American Lily Society (NALS), so as to obtain seeds of hybrids for breeding in Latvia. Vasarietis is working with Asiatic hybrids. The ILR has registered more than 50 of his varieties (Šķimele, 2000). One of the earliest of his blooming varieties is his 'Saules Meita' – dark yellow without spots, flowering outdoors in mid June. It has been found that varieties originated by Vasarietis are very popular in gardens and in lily shows.

The Botanical Garden of the Latvia University in the former Soviet Union was one of the largest growing centres of lilies in Latvia. The director, A. Zorgevics together with biologist A. Balode has created many varieties of Asiatic and Trumpet hybrids. Eight of the varieties are recorded in the ILR: Asiatic hybrids 'Dzintars'-yellow, 'Rotaļa' – bright orange, 'Teika' – light orange-brown with small black spots, 'Nākotne' – yellow with an orange brush mark, 'Saulstarīte' – yellow, 'Veltījums' – orange red: Trumpet hybrids 'Atblāzma' – apricot yellow, 'Atvasara' – pinkish-yellow, 'Dzelme' – dark apricot, 'Zemgale' – white with dark brown reverse. The book 'Lilies' by Zorgevics and Balode, published in 1989, is of great help to lily growers. At present the Botanical Garden of the University of Latvia of the lilies were showed off in an excellent garden design.

A notable contribution to lily hybridizing in Latvia has been made by K. Zeltans. The Oriental lilies grown by him were very popular in Latvia in previous years. Zeltan's Orientals lilies are characterized by a vigorous stem system, hardiness in the Baltic climate and are highly decorative. The most popular are: 'Liesma' – carmine-pink with white margins, 'Paija' – light pink with white margins, 'Mara' – pure white, 'Sarmite' – intensive pink with white margins (Balode, 1989). After Zeltans death the work with Oriental lilies was continued by E. Ievina and T. Gertsons, but they both are also gone now. At present there has been no noteworthy successor to continue the work with Oriental lilies in Latvia, but the genetic material is very good.

The latest sensation in lily breeding in Latvia is A. Krumins (Mynett, 1996). He is continuing to work with Orekhov's 'Tango' hybrids. His hybrids are basically cream, yellow, salmon or pinkish with contrasting mahogany marbling in the centre – large, cup-shaped flowers, brighter in colour than those in Orekhov's Tango group. Krumins breeding work is promising. Every year he produced many perspectives of hybrids from Asiatic, Trumpet and Orienpet groups. Nowadays his hybrids has become very popular in the Latvian gardens.

The research showed that promising hybridizers of Trumpet lilies are I. Zilgalvis and D. Hercbergs, both of Vecumnieki. Zilgalvis has a collection of Trumpets and 'Latgale' hybrids developed by Orekhov e.g. 'Eksotika'. By using local variety and 'Louise', 'White Henryi', bred in USA, he produced many excellent Trumpet hybrids with white reverse colouring – with the orange varying from light to very deep. Most of them are erect and about 2 m tall with twelve to fifteen blooms. One, called '70th Anniversary' is white with a very deep orange face. Others have brown markings and papillae. Trumpet hybrids originated by Zilgalvis bloom before *L. henryi* and are earlier than 'Latgale' that are intermediate in blooming period, flower form and height. Most of them probably have *L. regale* as the Trumpet parent since it is commonly found throughout Latvia (Wadekamper, 1994). Zilgalvis is a very productive breeder and has hundreds of seedlings with a wide colour range. In form, they vary from typical trumpet shape to ruffle.

Hercbergs has a large collection of Asiatics, Martagons and Trumpets. He has many seedlings with a wide range of colours and forms. His main line is the polyploidy hybrids.

Conclusions

As a result of this research it has been found that Trumpet lilies are very popular in Latvia. The research points out the importance of the local Trumpet varieties as most resistant to late frosts. *L.regale* and their hybrids are generally quite susceptible to spring frosts. The obtained results lead to the conclusion that the desired characteristics for *Lilium* for both gardens and landscapes under agroecological conditions of Latvia are the following: 1) Cultivars are needed that will readily perennialize under wide ranges of temperatures and wet weather conditions. Winters may be plagued by frequent thaws followed by deep freezes – critical for planted bulbs. 2) Disease resistance is significant in all cultivars. 3) A wide range of flower colors, plant height and flower types relevant to the growing goal, visual attractiveness is desired, and the average flowering time should be no less than one week. 4) More than three blooms should be produced from a 3–4 cm bulb. 5) Plants must have excellent stem strength. To achieve that, Latvian breeders work with Asiatic division hybrids developed by Orehovs and Russian breeders, crossing those with the strongest varieties imported from the Netherlands and the USA. Chinese trumpet lilies (Division 6) and Orienpet (OT) lilies are two other varieties extensively hybridized in Latvia today.

References

1. Balode A. (1996) Lilu breeding and introduction in moderate climates. Acta Horticulturae. 414, 55–58.
2. Balode A. (1989) Selective Hybridizing of Lilies in Latvia. The Lily Yearbook of the North American Lily Society, 42, 68–69.
3. Fox D. (1991) Lilies of Lake Baikal. The Lily Yearbook of the North American Lily Society, 44, 15–18.
4. Leslie, A. C. (1982) The International Lily Register, including 19 supplements (1982–1999). The Royal Horticultural Society, London, 377.
5. Mynett K. (1996) Research, production and breeding of lilies in Easter European countries. Acta Horticulturae, 414, 47–54.
6. Nesaule V., Orehovs V. (1970) Lilijas, Liesma, Rīga, 134.
7. Straathof Th. P. (1994) Studies on the *Fusarium* – lily interaction: a breeding approach. Doctoral dissertation, Wageningen, 129.
8. Šķimele D. (2000) Latvijas selekcionāru izveidoto liliju šķirņu reģistrs. Liliju audzētāju asociācija "Lilium Balticum", Rīga, 47.
9. Wadekamper J. (1993) Lily Shows in Riga, Latvia. The Lily Yearbook of the North American Lily Society, 46, 7–9.
10. Wadekamper J. (1994) The Trumpet Lilies of Latvia. The Lily Yearbook of the North American Lily Society, 47, 73–75.
11. Zobova A., Vasarietis J. (1988) The Latvian Lily Breeder Victor Orekhov. The Lily Yearbook of the North American Lily Society, 41, 95–96.
12. Zorgevics Ā., Balode A. (1989) Lilijas. Rīga: Avots, 154.

HARVEST MATURITY AND STORAGE LIFE INVESTIGATIONS ON LATVIAN APPLE CULTIVARS

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Abstract

Investigations on storability of the most important Latvian apple cultivars in the Pure Horticultural Research Station are in the process. The main tasks of investigations are to find optimal harvest maturity grade and the most suitable testing methods for each cultivar, to elaborate harvest and storage recommendations for local advisory service. Cultivars `Auksis`, `Antey`, `Belorusskoe Malinovoe`, `Beforest`, `Bogatir`, `Forele`, `Iedzenu`, `Ilga`, `Kovalenkovskoe`, `Lobo`, `Noris`, `Rubin` (Kazakhstan cultivar), `Sinap Orlovskii`, `Saltanat`, `Stars`, `Spartan`, `Talvenauding`, `Tiina`, `Wealthy` and `Zarya Alatau` were tested. The dynamics of fruit ripening and storability in conventional atmosphere were evaluated during 1989–2004. The first trials under controlled atmosphere conditions were carried out during 2002–2004.

Cultivars `Kovalenkovskoye` and `Saltanat` are not recommended for long storage in conventional atmosphere due to tendency of early losses of fruit taste and flesh softening. Cultivar `Rubin`, depending on season, showed unacceptable fluctuations of skin browning presence. Therefore at this moment this cultivar cannot be suggested for safe storage at all and needs further investigations. `Sinap Orlovskii`, `Belorusskoe Malinovoe` and `Zarya Alatau` were the most suitable for long storage till June under conventional atmosphere conditions. Fruits of `Saltanat`, `Kovalenkovskoe` and `Orlik` were significantly damaged under controlled atmosphere conditions. Cultivars `Auksis`, `Antey`, `Sinap Orlovskii` and `Lobo` showed the best storage results. It can be assumed that apple storage in conventional atmosphere is preferable to reach the optimal level of acids, flesh firmness and aroma during consumption for apple cultivars with high acidity. The fruit harvest maturity influenced the storability and fruits quality. It was possible to decelerate further fruit ripening processes by using combination of conventional atmosphere with following controlled atmosphere storage or by using only controlled atmosphere storage for some apple cultivars. The optimum harvest maturity parameters differed for the conventional cold storage and controlled atmosphere storage conditions.

Key words: *Malus,* storage, conventional atmosphere, controlled atmosphere, fruit quality, weight losses

Introduction

The rapid expansion of commercial plantations with winter ripening time apple cultivars makes storability questions actual in Latvia. Harvest maturity is generally recognised as one of the main factors determining duration of storability and *ex store* quality of fruits (De Jager and Roelofs, 1995).

Most of apple cultivars of Latvian or East European origin have improved biosynthesis of organic acids, relatively high content of vitamins, excellent aroma and more intensive skin colour development in comparison to apple cultivars grown in several Western regions. Fruits are of very high biochemical quality, however, they need special storage conditions to reach optimal taste and aroma at the moment of consumption. In such climatic conditions the acid content for part of local cultivars sometimes is too high even during the period of consumption maturity. Sensory evaluation of taste is in close correlation to acid content. This factor determines the necessity to decrease the level of acids during storage for apple cultivars with genetically determined high content of acids. Apple storage in controlled atmosphere may cause unacceptable high acid level and flesh firmness grade during consumption for cultivars with genetically determined slow biodegradation of acids – such as `Iedzenu`, `Belorusskoe Malinovoe`, `Forele`, `Talvenauding`, `Sinap Orlovskii` (Drudze, 2003). The main task is to avoid such storage conditions, when process of maturing, especially the process of biodegradation and transformation of organic acid complex, is significantly depressed. Conventional atmosphere storage is preferable to reach optimal levels of acids and aroma at the moment of consumption for apple fruits grown under Latvia′s conditions.

Recommendations for fruit harvest maturity and conventional storage made for the West European region cannot be used in Latvia due to significant influence of the growing area climate conditions on the fruit maturity terms. Therefore it is necessary to find optimum harvest maturity parameters for conventional cold storage, suitable for specific features of Latvia′s climate. The main task of trials was to find the optimal harvest maturity grade ensuring good taste quality and appearance, to minimise the fruit weight losses in conventional atmosphere cold storage without any after-harvesting chemical treatment. Potential storability of a cultivar for 5–6 months in conventional atmosphere was preferable, but not the limiting trait. On the other hand, conventional storage usually increases different microbiological weight losses, significantly reduces possible marketing period of apple fruits. Apples lose their flesh firmness, crispness, juiciness and good shelf life too early to be marketable during all season. A way to expand the marketing period for cultivars usually consumed only till February – March under conventional atmosphere storage conditions, is also needed. The possible solution could be deceleration of further ripening by switching to CA or ULO conditions, when the acidity level of fruits in conventional atmosphere becomes acceptable for consumption. Because of lack of previous trials conducted under CA and ULO conditions for cultivars grown in Latvia′s climate, we have no knowledge about the possible reaction of each cultivar. Besides, the cultivar reaction to modified atmosphere could be related to fruit maturity stage. The aim of the investigation in controlled atmosphere was to find preliminary storage conditions for significant decelerating of further fruit ripening till June. Most important was to determine the tolerance level for each tested cultivar in different maturity stages (including advanced maturity) to O_2 and CO_2 concentrations.

Materials and Methods

In 1989–1993, a storability trial of seven cultivars on two rootstocks was conducted as the first stage of investigations. \`Beforest\`, \`Belorusskoe Malinovoe\`, \`Iedzenu\`, \`Talvenauding\`, \`Wealthy\`, \`Stars\` and \`Forele\` were budded according to the following scheme: B 490 and M1 + crown of \`Antonovka\` + cultivar top-grafting. Other trials were conducted in 1997–2000. Cultivars \`Sinap Orlovskii\`, \`Ilga\`, \`Lobo\`, \`Tiina\`, \`Noris\` were budded on MM106 and M1+crown of \`Antonovka\` + cultivar top-grafting; \`Orlik\` was budded on MM106, B9 and M1+crown of \`Antonovka\` +cultivar top-grafting, \`Belorusskoe Malinovoe\` was budded on dwarfing rootstocks B 9 and Pure 1, \`Spartan\`- on dwarfing rootstocks B 9 and Pure 1. During 2001–2004 fruit samples from cultivars \`Antey\` on MM 106, B9, \`Auksis\` on B9, \`Belorusskoe Malinovoe\` on Pure 1 and B9, \`Kovalenkovskoe\` on MM 106, B9, \`Lobo\` on \`Antonovka\` seedlings, \`Orlik\` on MM 106, \`Rubin\` (Kazakhstan cultivar) on B9, \`Saltanat\` on MM106, \`Sinap Orlovskii\` on MM106, \`Zarya Alatau\` on \`Antonovka\` seedlings and MM 106 were tested. Fruit samples were placed in the conventional atmosphere cold storage room with cooling temperature +2±1 ^{o}C, relative humidity 90±5% and active ventilation. No chemical treatment was applied on fruit surface after harvesting.

The first preliminary trial under controlled atmosphere was started in 2002, when fruits of 24 different apple cultivars were placed in two gas compositions – 1.5% O_2, 3% CO_2, 95.5% N_2 and 1.5% O_2, 5% CO_2, 93.5% N_2. A combined two-step storage trial was conducted to evaluate the possibility to expand the marketing period for the cultivars usually sold till February – May if stored in normal atmosphere. In the 1st step of combined storage the fruits were stored under normal atmosphere conditions until they reached the stage of consumption maturity, decreased undesirable acidity, and developed full aroma. At the 2nd step the fruits were removed into ULO – type atmospheres. The most promising cultivars for future testing were found out in the result of this preliminary trial.

Since 2003, more detailed trials are in progress, using only most promising cultivars for commercial apple market in Latvia. Fruits were placed in different modified atmospheres immediately after fruit harvesting. The cultivars \`Auksis\`, \`Antey\`, \`Belorusskoe Malinovoe\`, \`Kovalenkovskoe\`, \`Lobo\`, \`Orlik\`, \`Rubin\` (Kazakhstan cultivar), \`Saltanat\`, \`Sinap Orlovskii\`, \`Spartan\`, \`Zarya Alatau\` were tested under the following gas compositions: 1.5% O_2, 3% CO_2, 95.5% N_2; 1.5% O_2, 5% CO_2, 93.5% N_2; 3% O_2, 3% CO_2, 94.0% N_2 and 3% O_2, 1.5% CO_2, 95.5% N_2. No antioxidants or another kind of chemical treatments were applied on the fruits after harvesting, to ascertain possible scald development and natural reactions of cultivars on different levels of atmospheric components.

The pre-harvest maturity of fruit samples was tested periodically every seven days in the orchard and at the day of harvesting. Approximately 3 kg large samples of medium sized fruits were used. Iodine – starch index test, flesh firmness measurements and seed colour test were chosen as suitable to express testing of maturity degree. Iodine – starch index test was scored by 10-point scale (samples were scored by 1, if hydrolysis of starch had not started yet, till 10 points, if starch was completely hydrolysed into sugars). Measurements of flesh firmness were made for peeled fruits in two places (on the sun side and shade side) by a hand Effegi type penetrometer. Seed colour was scored visually by 5 point scale, where 1 point – all the seeds were white, 2 points – tips of some seeds became light brown, 3 points – approximately 2/3 of the seeds were light brown or all the seeds were white with light brown coloured tips, 4 points – all the seeds were light brown, 5 points – all the seeds were brown. Since 2003, the measurement of soluble solids by a portative hand refractometer was added to the complex of methods to express maturity testing. For the characterisation of complex maturity level for each fruit sample, the Streif – Index (*id.* maturity index MI) was used (Streif, 1995). That index was calculated as: MI = flesh firmness degree / (soluble solids Brix % * iodine – starch test degree).

Transpiration, physiological and microbiological losses of weight and the spectrum of damages, fruit quality (flavour, appearance, subjective evaluation of ripeness, flesh firmness and soluble solids) were registered monthly. The flavour and appearance were evaluated sensorily. The complex visual evaluation of fruit size, gradation and nuance of skin colour, shape and damages of the fruit were taken into account. The maturity score showed the subjective impression of a person during tasting. Gradation scale: 2 points – slightly unripe, 3 points – ripeness seems optimal, 4 points – too ripe, 5 points – unacceptable grade of ripening. Intermediate gradations taking decimals were permitted.

For trials under modified atmosphere conditions the same complex of weight losses and fruit quality measurements as for conventional atmosphere were used in the beginning, middle and end the of storage period. Modified atmosphere conditions were ensured by gas flow through the plastic containers. There was no necessity for ethylene elimination because of constant gas flow, substituting with fresh gas mix every 15 minutes. The correct gas compositions were established preliminarily by rotametric control using separate compressed gases as a source.

The coefficient of variation was used for the evaluation of suitability of one or another maturity testing method for different cultivars. It gave a possibility to rate and to compare the levels of annual measurement fluctuations inside the tested fruit samples.

Results and Discussion

Not all of the investigated cultivars showed marketable quality and acceptable features for storability in conventional cold storage. Cultivar `Stars` had too serious problems for commercial growing due to irregular fruit shape, unattractive skin colour, high tendency to water-core and early fruit dropping. Cultivars `Beforest`, `Ilga`, `Tiina` and `Wealthy` had unacceptable appearance for market, despite their nice taste. During the storage period significant influence of rootstock on the transpiration rate and microbiological losses of weight was observed for cultivars `Belorusskoe Malinovoe`, `Iedzenu`, `Spartan`, `Orlik`. The dwarf rootstock Pure 1 slowed down the fruit maturing in the garden approximately for 5 to 7 days, decreased physiological and microbiological damages, but transpiration losses from 4^{th}–5^{th} month of storage were increased in comparison with the rootstock B 9 (Drudze, 2000). In generally fruits grown on Pure-1 had relatively higher flesh firmness grade at the harvesting and consumption maturity stage. The rootstock Pure 1 is evaluated as a promising for increasing the fruit storability for cultivars `Belorusskoe Malinovoe` and `Spartan`. Cultivar `Rubin` showed unacceptable fluctuations of skin browning development, depending on season. Therefore this cultivar cannot be recommended for safe storage at all at this moment and needs further investigations of the browning genesis mechanism. The most appropriate cultivars for conventional cold storage and market seem to be `Antey`, `Auksis`, `Saltanat`, `Iedzenu`, `Forele`, `Spartan`, `Orlik`, `Belorusskoe Malinovoe`, `Sinap Orlovskii`, `Zarya Alatau`, but only the three last mentioned cultivars were suitable for long storage till June under conventional atmosphere conditions. Harvest maturity parameters for most important Latvia′s commercial apple cultivars on rootstocks tested up to now are given in Table 1. Under conventional cold storage conditions fruit maximum storage period is till April–May, except `Belorusskoe Malinovoe`, `Sinap Orlovskii` and `Zarya Alatau`. If a longer marketing period is needed, conventional storage could not be a solution.

The first results of the two-stage combined atmosphere trial show that it is possible to decelerate fruit ripening processes during storage for some cultivars, so that fruits in advanced maturity stage could keep good market quality for a prolonged time. The best preliminary results during combined storage were obtained with cultivars `Ilga`, `Bogatir`, `Merrigold`, `Sinap Orlovskii`, `Auksis`, `Orlik`, `Belorusskoe Malinovoe`, `Spartan`, `Lobo`, `Pervinka`, `Kovalenkovskoe`, `Lawfam`, `Tellissaare`.

In more detailed trials with commercial cultivars the best results in modified atmosphere storage until now have been achieved with `Auksis`, `Antey`, `Sinap Orlovskii` and `Lobo`. Trials must be continued to find the optimal harvest maturity and secure gas compositions for each cultivar.

A correctly chosen harvest maturity stage of apple fruits is one of the most important factors having significant influence on the following fruit life processes during storage. Not only marketable taste quality, but also potential decreasing of physiological and microbiological weight losses during storage, less or more successful prediction of the best marketing intervals or possibly latest marketing periods for each cultivar are in close correlation with the harvest maturity.

Table 1. Harvest maturity parameters for most important Latvia′s commercial apple cultivars

Cultivar / rootstock combination	Flesh firmness, kg*cm^{-2}	Seed colour, 1–5 points	Iodine – starch test, 1–10 points	Soluble solids, Brix %	Maturity index	Latest possible months of marketing
Antey / B 9	6.4–6.6	4.0–5.0	1.5–2.0	12.0–13.0	0.5–0.3	III–IV
Antey / MM 106	6.4–6.6	4.5–5.0	3.0–4.0	11.0–13.0	0.2–0.1	III–IV
Auksis / B 9	6.0–5.9	3.0–4.0	5.0–6.0	13.0–14.0	0.1	I–II
Auksis / B 9	7.5–6.7	2.0–4.0	3.0–4.0	13.0–14.0	0.2–0.1	III–V
Auksis / MM 106	6.0–6.1	3.0–4.0	5.0	12.0	0.1	I–II
Belorusskoe Malinovoe / B 9, Pure 1	7.0–7.5	5.0	4.0–6.0	11.4	0.2–0.1	VI
Belorusskoe Malinovoe / MM 106	7.0–7.2	3.0–5.0	4.0	10.0	0.2	VII–VIII
Belorusskoe Malinovoe / MM 106	6.0–7.0	3.0–5.0	4.6	11.0	0.1	III
Belorusskoe Malinovoe /B 9, Pure 1	6.4–6.7	5.0	6.0–9.0	11.0–11.5	0.1	II–III
Kovalenkovskoe / B 9	6.8–7.1	1.0–2.0	4.0–5.0	12.0–13.0	0.1	XII
Kovalenkovskoe / B 9	5.3–5.4	2.0–3.0	7.0–8.0	12.0–13.0	0.2	IX
Kovalenkovskoe / MM 106	6.0–6.1	2.0–3.0	5.0–6.0	12.0–13.0	0.1	XII
Lobo / MM 106	7.8–7.2	2.0–3.0	1.5–3.0	12.0	0.4–0.2	II
Lobo / MM B 9	6.0–6.2	4.0	3.0–4.0	12.0	0.2–0.1	II
Orlik / MM 106	6.1–7.9	2.0–3.0	3.0–4.0	11.0–11.2	0.2	V
Orlik / MM 106	5.7–5.9	3.0–4.0	5.5–6.0	11.2–11.4	0.1	IV
Orlik / MM B 9	5.7–7.0	2.0–4.0	2.0–4.0	11.0	0.2–0.1	II–III
Rubin / MM 106	6.7–6.8	3.0	4.0–5.0	10.0–11.0	0.2	V
Saltanat / B 9	7.8–8.1	3.0	2.0	10.0–11.0	0.4	I–II
Saltanat / B 9	6.8–7.6	3.0–4.0	3.0–4.0	11.0–12.0	0.2	XII
Saltanat / MM 106	7.5–8.0	3.0–4.0	2.5–3.5	10.0–11.0	0.3–0.2	XII
Sinap Orlovskiii / MM 106	5.7–7.5	3.0	2.0–5.0	11.0–13.0	0.1	VI
Sinap Orlovskii / MM 106	7.0–7.5	3.0–4.0	1.0–3.0	11.0–12.0	0.3–0.2	V

In practical horticulture an optimal choice of harvest maturity testing methods is of great importance as they must be as mobile, fast and cost effective as possible. The stability of measurements for different maturity testing methods differs among cultivars. In addition, seasonal fluctuations have influence on the interpretation of testing results (Tables 2, 3, 4). Therefore the level of validity for one or another testing method is different for each cultivar. Proper conclusions about the actual fruit sample maturity level could be made only by using the complex of 3–4 methods together and by calculating maturity index. As follows from J. Streif's investigations, exactly the maturity index, based on three parameters – firmness, soluble solid content and starch index, gives the best correlation with judgements of storability. This index is highly cultivar specific but rather independent from orchard or different annual climatic conditions (Streif, 1995). Calculated maturity indexes for tested cultivars are given in Table 1 and show the general impression about fruit maturity degree.

The flesh firmness test was one of the best to express testing of maturity grade for all evaluated cultivars and showed good annual stability (Table 2). The flesh firmness degree at the harvesting time had influence on the flesh firmness during further storage. Fruits with higher flesh firmness at the harvest moment had higher flesh firmness during the storage, and besides apples were crisper, with optimal ripening grade in consumption period, which is a desirable factor for maintaining the market quality (Drudze, 2000). Such relation was especially noticed for cultivars `Ilga`, `Tiina`, `Orlik`, and `Noris`. It was found that the place of penetration had significant influence on the results of testing firmness. High differences were observed between the flesh firmness, measured on the sun and shade sides of the fruits for some of tested cultivars, especially at unripe stages.

The flesh firmness was significantly higher at the sun side for cultivars `Belorusskoe Malinovoe` and `Spartan`. Probably the reason was some kind of cultivar-specific reactions, resulting in more active biosynthesis level and therefore relatively faster accumulation of carbohydrates at the harvesting maturity stage on the sun side of the fruits in comparison to the shade side (Drudze, 2000). The difference was not significant anymore at the consumption maturity due to progressing of protopectin hydrolysis processes. Probably not only the average value of flesh firmness, but also the magnitude of this difference could be used as one of additional characterisation to detect the present fruit maturity level at the harvesting moment for both the mentioned above.

Table 2. Stability of flesh firmness test

Cultivar	Coefficient of variation ± standard error of coefficient of variation, %			
	year 2001	year 2002	year 2003	year 2004
Antey	0.33±0.08	0.15±0.05 *a*	0.34±0.11 *b*	0.30±0.07 *b*
Auksis	0.15±0.03	0.28±0.08 a	0.53±0.16 *ab*	0.18±0.04 *c*
Belorusskoe Malinovoe		0.47±0.12	0.39±0.12	0.16±0.04 *ab*
Iedzenu		0.42±0.15		0.33±0.07
Kovalenkovskoe	0.22±0.04	0.36±0.09 *a*	0.20±0.06 *b*	0.18±0.04 *b*
Lobo	0.50±0.10	0.25±0.07 *a*	0.58±0.19 *b*	
Orlik		0.38±0.11	0.43±0.14	0.16±0.04 *ab*
Rubin	0.38±0.08	0.56±0.19	0.49±0.15	0.23±0.05 *abc*
Saltanat	0.23±0.06	0.28±0.08		0.35±0.08
Sinap Orlovskii		0.71±0.21	0.62±0.20	0.40±0.16
Spartan		0.24±0.08		0.21±0.05
Zarya Alatau	0.32±0.06	0.45±0.12	0.34±0.11	0.45±0.10

In Tables 2, 3, and 4 genotypes marked with different letters have significant annual difference considering the standard error.

The seed colour test showed high annual stability, but the use of this parameter was problematic for some of the tested cultivars because of very slow colour changes during the harvesting season (Table 3). Early development of seed browning with following stagnation for 2–3 weeks was typical for most of the tested cultivars. Therefore seed colour test, despite of its high stability, in praxis had low importance for the determination of the actual maturity level of fruit samples.

Table 3. Stability of seed colour test

Cultivar	Coefficient of variation ± standard error of coefficient of variation, %			
	year 2001	year 2002	year 2003	year 2004
Antey	0.20±0.05	0.27±0.09	0.38±0.13 *a*	0.49±0.15 *a*
Auksis	0.71±0.13	0.27±0.08 *a*	0.34±0.09 *a*	0.88±0.19 *bc*
Belorusskoe Malinovoe		0.18±0.04	0.05±0.02 *a*	0.05±0.01 *a*
Iedzenu		0.79±0.32		0.47±0.11 *a*
Kovalenkovskoe	0.00±0.00	0.51±0.14 *a*	0.33±0.10 *ab*	0.39±0.09 *ab*
Lobo	0.27±0.06	0.40±0.11	0.29±0.09 *b*	
Orlik		0.60±0.19	0.67±0.21	0.49±0.11
Rubin	0.75±0.15	0.80±0.28	0.73±0.22	0.29±0.06 *abc*
Saltanat	0.62±0.17	0.20±0.06 *a*		0.33±0.09 *a*
Sinap Orlovskii		1.26±0.40	0.00±0.00 a	0.30±0.10 ab
Spartan		0.27±0.08		0.25±0.06
Zarya Alatau	0.44±0.09	0.56±0.21	0.38±0.12	0.18±0.04 *abc*

The iodine-starch test showed one of the greatest annual variations inside the tested samples for all cultivars. Nevertheless, it was one of the most informative in praxis for the major part of tested cultivars (Table 4). A sufficient size of fruit sample and test performing time (immediately after sample picking) were the most important factors for measurement precision in this testing method. It was noted that application of the iodine-starch index test for cultivars \`Antey\`, \`Rubin\`, \`Belorusskoe Malinovoe\` and \`Forele\` was problematic due to unacceptable variation amplitude inside samples. Besides, for cultivar \`Forele\` it was typical that the starch hydrolysis process often started not near the core, but diffused into all of the fruit flesh. Therefore the standard iodine-test images could not be correctly used for comparison with the colouring ornament of tested apple slices for 'Forele'.

Table 4. Stability of iodine – starch test

Cultivar	Coefficient of variation ± standard error of coefficient of variation, %			
	year 2001	year 2002	year 2003	year 2004
Antey	2.41±0.60	0.83±0.26 ^{a}	1.06±0.34 ^{a}	12.84±3.50 ^{abc}
Auksis	0.27±0.05	1.03±0.30 ^{a}	0.65±0.19 ^{a}	6.55±1.46 ^{abc}
Belorusskoe Malinovoe		7.90±2.12	4.85±1.53	1.74±0.38 ^{ac}
Iedzenu		0.33±0.12		1.50±0.34 ^{a}
Kovalenkovskoe	0.64±0.13	1.09±0.30 ^{a}	0.42±0.11 ^{b}	0.23±0.05 ^{abc}
Lobo	0.24±0.05	0.64±0.17 ^{a}	0.25±0.08 ^{b}	
Orlik		2.24±0.65	1.51±0.47	0.31±0.07 ^{ab}
Lubin	0.52±0.11	5.50±1.94 ^{a}	8.80±2.72 ^{a}	0.31±0.07 ^{abc}
Saltanat	0.24±0.06	3.81±1.19 ^{a}		0.23±0.05 ^{b}
Sinap Orlovskii		0.39±0.12	0.20±0.06 ^{a}	0.28±0.06
Spartan		0.10±0.02		0.30±0.07 ^{a}
Zarya Alatau	2.13±0.44	0.32±0.14 ^{a}	0.97±0.31 ^{ab}	0.50±0.11 ^{ac}

Conclusions

It could be assumed that apple storage in conventional atmosphere was preferable to reach the optimal level of acids, flesh firmness and aroma during consumption for apple cultivars with high acidity.

The fruit harvest maturity had high influence on the storability and fruit quality.

The first results of the trial show that it was possible to decelerate further fruit ripening processes by using the combination of conventional atmosphere with following controlled atmosphere storage or by using only controlled atmosphere storage for some apple cultivars, so that fruits could keep good market quality for prolonged period of time.

The optimum harvest maturity parameters differed for the conventional cold storage and controlled atmosphere storage conditions.

References

1. De Jager A. and Roelofs F. P. M. M. (1995) Prediction of optimum harvest date of Jonagold. In: The postharvest treatment of fruit and vegetables. European Commission, Louxemburg: 21–31.
2. Drudze I. (2000) The influence of apple rootstock Pure 1 on storage quality of fruits. In: Proc. of the international conference Fruit Production and Fruit Breeding, Tartu, Vol. 207: 32–37.
3. Drudze I (2003) Investigations of harvest maturity and suitability for storage of some apple cultivars in Latvia. In: Proc. of the international conference Postharvest Unlimited, Acta Hort. N 599: 631–635.
4. Streif J. (1995) Optimum harvest date for different apple cultivars in the `Bodensee` area. In: The postharvest treatment of fruit and vegetables. European Commission, Louxemburg: 15–20.

ADAPTING TECHNOLOGY FOR LOCAL RHUBARB (*RHEUM RHAPONTICUM* L.) CLONES PROPAGATION *IN VITRO*

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Abstract

Rhubarb (*Rheum rhaponticum*) is a wide spread vegetable in the North part of Europe, USA and Canada, as well as in Latvia. Easy cultivation and low inputs are the main reasons for profitable commercial growing of rhubarbs. The problem is a lack of planting material. Propagation by generative method does not ensure homogenous offspring because rhubarb is an open-pollinated plant. Traditional, vegetative propagation method by mother plant division has low rate of propagation. An alternative is *in vitro* micropropagation. It is a way to produce rather high amount of rhubarb planting material identical to mother plant. The aim of the investigation was to find the most appropriate *in vitro* micropropagation technology for local genotypes of rhubarbs and the best method of bud disinfection. Buds with a small segment of root without stem base, approximately 0.25 cm^2 of size had the lowest rate of infection in the initiating medium. Different genotypes had different attitude to media nutrient composition. Basal medium consisting of MS mineral salts and vitamins, 1 mg L^{-1} of 6-BAP (benzylaminopurine) and 1 mg L^{-1} IBA (indolebutyric acid) with 20 g L^{-1} sucrose and 8 g L^{-1} phytoagar, with pH adjusted to 5.5 was appropriate for one clone, but for other clones this media composition was not acceptable. It means that media composition should be adapted to each genotype.

Key words: rhubarb, propagation, *in vitro*

Introduction

Rhubarb was used as medical plant in China almost for 5000 years. In Europe it has been grown as vegetable since 18th century when it was introduced into England. Nowadays cultivars are acquired by hybridisation of two species *Rheum rhaponiticum* and *Rheum undulatum*. Rhubarb is an open pollinated perennial. High winter hardiness is characteristic for rhubarbs. Therefore it is a wide spread vegetable in the North part of Europe, USA and Canada (Roggemans and Boxus, 1988). Rhubarbs are used as one of the first vegetables in spring, and it is quite rich in vitamins, organic acids and minerals. Rhubarb is indiscriminate for soil conditions, but the best results are obtained in well cultivated and drained, fertile loam soils. Easy cultivation and low inputs are the main reasons for profitable commercial growing of rhubarbs. The problem for establishing plantations is a lack of planting material. Rhubarb is an open pollinated plant and is divided in different genotypes by using the generative propagation. Therefore it is difficult to ensure supply with homogenous planting material at an appropriate rate by using this method.

Vegetative rhubarb propagation by mother plant division is an alternative for the generative propagation. There is low propagation rate in this case (Baumane, 1960; Roggemans and Claes, 1979). Advantage of this method is that these plants are cloned, therefore completely similar to the mother plant.

Another way of rhubarb propagation is *in vitro* culture. This way was found to be interesting to investigate for rapid propagation of homogenous material of local genotypes. As it is known, somaclonal variation is observed for some species during plants propagation *in vitro,* but it is not reported on rhubarbs (Lassus and Voipo, 1994; Skirvin *et al.*, 1994). Nevertheless in some cases increased number of growing points on micropropagated plants in the first season of field growth is observed (Zhao *et al.*, 2003). Therefore rhubarb is interesting and promising vegetable for *in vitro* propagation.

The aim of the investigation was to find the most appropriate *in vitro* micropropagation technology for local genotypes of rhubarbs. The first stage of the investigation was to find the best dormant bud segment disinfection technology. The next step was to study out a suitability of the nutrient media composition (Roggemans and Claes, 1979) for local rhubarb clones initiation and propagation *in vitro*. These were the main objectives of the study.

Materials and Methods

Six most promising rhubarb clones from the field collection of local rhubarb genetic resources in the Pure Horticultural Research Station were selected for propagation *in vitro*: 2 II, 3 II, 3.2, 12, 32.2 and 33.2 as well as two varieties of Latvian origin 'Tukuma' and 'Ogres'. Eight genotypes in total were included in the experiment. Four genotypes (3.2, 12, 32.2 and 33.2) were investigated for finding the best and the most handy size of the mother plant root segment with dormant bud for disinfection. Two types of root segment with bud were cut: 1) dormant bud with root segment of 0.5 cm^2 size and short (0.5 cm) stem; 2) dormant bud with root segment of 0.25 cm^2 size without stem base were cut for disinfection.

Excised root segments with buds were disinfected for one minute in 400 ml L^{-1} alcohol and the following six minutes in 100 ml L^{-1} solution of Ace (trade mark) bleaching liquid, finally washed four times in sterile distilled water.

As explants were used meristematic tissue of dormant buds. The size of excised meristems varied between 0.2 and 0.5 mm.

One composition of basal media according to Roggemans and Boxus (1988) was used in the experiment for all eight investigated genotypes. Basal medium consisted of MS (Murashige and Skoog) mineral salts and vitamins, 1 mg L^{-1} of 6-BAP (benzylaminopurine) and 1 mg L^{-1} IBA (indolebutyric acid) with 20 g L^{-1} sucrose and 8 g L^{-1} phytoagar, with pH adjusted to 5.5.

Plants were grown in 2–3 ml of nutrient media in glass tubes (0.2 × 0.21 m) for the first two subcultures. Following subcultures were grown in 170 ml glass jars (covered with one layer of foil) consisting 15 ml of nutrient media and were cultivated at 22 to 25 ºC and 16 h photoperiod. Microplants were divided and transplanted monthly. Eight genotypes in four subcultures were analysed to study the suitability of the media composition. Propagation rate was calculated monthly as ratio between numbers of the obtained plantlets and number of the divided plantlets of previous subculture. Analysis of variance for propagation rates of each subculture was accomplished, confidence intervals were calculated for average rate of propagation, coefficient of variation and its standard error were calculated to evaluate stability of the propagation rate in all analysed subcultures.

Results and Discussion

The best disinfection results were obtained when dormant bud with root segment of 0.25 cm^2 was cut for disinfection (2nd variant). Average proportion of infected explants in the initiation media for four investigated genotypes in the 2nd variant was observed at 27.5 % level (Table 1).

Table 1. Proportion of infected explants, %

Genotype	Explant size	
	0.5 cm^2 with stem base	0.25 cm^2 without stem base
33.2.	66.6	25.0
32.2.	40.0	27.4
12.1.	60.0	–
3.2.	–	30.0
Average	55.5	27.5

Compare to other plant species it is quite high level of infection (Упадышев и Височкий, 1991), but it should be taken into account that explants were taken from the underground part of the plant, where soil microflora is well developed. Also perfect mechanical and chemical cleaning of the cut root segment is cumbersome without injuring the bud. It is impossible to remove completely microscopic scraps of soil and necrotic tissue of plant. Moreover internal structure of the bud bothers removing of the meristematic tissues. It is sticky and slimy and infection can be transmitted easy. Disinfection solutions were similar to be used in other investigations (Rodgemans and Boxus, 1988). Taking into account all these circumstances, infection level of 27.5% was tolerable. The next important item was to clarify whether the media used in the investigation is suitable for propagation of all investigated genotypes. In four investigated subcultures it was noted that used composition of mineral salts, vitamins and hormones was not suitable for reaching high rate of proliferation for all investigated genotypes (Table 2). The variety 'Ogres' and clone 33.2 had the lowest proliferation rate in the 1st subculture. Transplanting of these genotypes was continued till the 2nd subculture. Therefore plants of the variety 'Ogres' and clone 33.2 collapsed. Following propagation was impossible. Low suitability of media composition for these genotypes was proved also statistically (Table 2). These two genotypes had the lowest rate of proliferation, moreover at the confidence level 0.05 it could drop under 0 (Fig. 1).

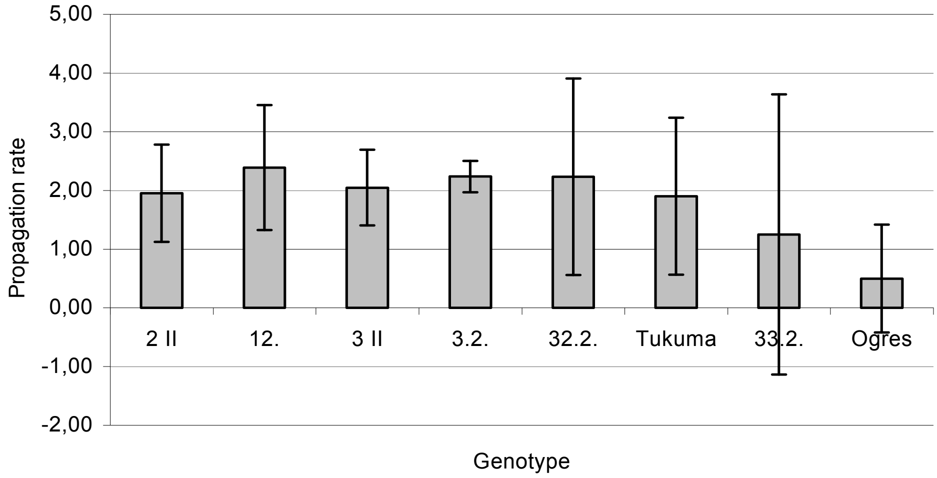

Figure 1. Comparison of rhubarb clones by average propagation rate in four subcultures and its confidence interval (*α = 0.05*)

Coefficients of variation for these two genotypes do not illustrate real stability of propagation rate in every subculture because for the last two subcultures the proliferation rate was 0, and it was included in the calculation of the results (Table 2).

Investigated variety 'Ogres' is selected from the variety 'Viktoria'. Lassus and Voipo (1994) reported that for the variety 'Viktoria' there was observed lower propagation rate in comparison to other genotypes in the same media composition. There is high possibility that such low propagation rate and finally decease of the variety 'Ogres' in this media was genotypically determined.

Plants of other six investigated genotypes showed better results, but statistically significant difference between them was not stated according to propagation rate. In several publications it is mentioned, that different genotypes react different in the same composition of media (Lassus and Voipo, 1994). It was proved also in this experiment. The highest average rate of propagation in four subcultures had clone No. 12, but it did not differ significantly from the other five genotypes according to variance analysis. From the viewpoint of commercial production, the lowest value of confidence interval of propagation rate should be considered, to escape a risk of unforeseen low propagation rate.

Table 2. Statistical description of proliferation rates for all investigated genotypes

Genotype	Average rate of propagation in four subcultures	Coefficient of variation, %
2 II	1.95 [a]*	27±9 [bc]**
12.	2.39 [a]	28±10 [bc]
3 II	2.05 [a]	20±7 [b]
3.2.	2.24 [a]	8±3 [a]
32.2.	2.23 [a]	47±17 [c]
33.2.	1.25 [b]	120±42 [d]
Tukuma	1.90 [a]	44±16 [c]
Ogres	0.50 [b]	115±41 [d]

* genotypes marked with different letters have significant difference (*LSD 1.05, α = 0.05*);
** genotypes marked with different letters have significant difference by taking into account the standard error.

The lowest possible proliferation coefficient of the clone No.12 is 1.33 (*α* = 0.05). From this viewpoint, only clone No. 3.2 significantly differed from the all investigated. Also propagation stability was high for this clone in all four analysed subcultures. The significantly lowest coefficient of variation (8±3) confirms it. The next genotype with high propagation rate (2.05±0.65) was 3 II. Also stability of proliferation rate for this genotype was satisfactory: coefficient of variation is quite low (20±7). Nevertheless the lowest possible proliferation rate for 3 II was 1.4 at confidence level 0.05. It is not sufficient for commercial propagation of rhubarbs. Used media composition was not suitable also for commercial propagation of clone

2 II (the lowest possible propagation rate was 1.13) as for clone 32.2 and variety 'Tukuma' (the lowest possible rate for both genotypes was 0.56). In this case, if the lowest possible propagation rate drops under 1, used media composition is completely unacceptable for propagation of these genotypes.

In literature findings different propagation rates for rhubarb *in vitro* have been reported by different authors: 3.2–2.1 per month (Lassus and Voipo, 1994) up to 5 per month (Roggeman and Claes, 1979). Comparatively low propagation rates in the experiment were stated. It follows that different nutrient media composition should be developed for successful propagation of the local genotypes of rhubarb.

Cnclusions

In conclusion, media composition has significant impact on the propagation rate of different rhubarb genotypes therefore media composition should be adapted to each genotype. The rhubarb clone No. 3.2 was the most suitable for micropropagation from eight investigated genotypes in the used media. Dormant buds with possibly smaller root segment (until 0.25 cm^2) should be disinfected before cutting of meristems.

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References

1. Baumane M. (1960) Rabarberi, LVI, Rīga, 46.
2. Lassus C. and Voipo I. (1994) Micropropagation of rhubarb with special reference to weaning stage and subsequent growth. Agricultural Science in Finland, 3, 189–194.
3. Roggemans J. and Boxus P. (1988) Rhubarb (*Rheum rhaponticum* L.). In: Bajaj Y. P. S. (ed) Biotechnology in Agriculture and Forestry, Vol. 6, Crops II, Springer-Verlag, Berlin Heidelberg, 339–350.
4. Roggemans J. and Claes M. C. (1979) Rapid clonal propagation of rhubarb by *in vitro* culture of shoot – tips. Scientia Horticulturae, 11, 241–146.
5. Skirvin R. M. *et al.* (1994) Sources and frequency of somaclonal variation. HortScience, 29(11), 1232–1237.
6. Zhao Y. *et al.* (2003) Inadvertent selection for unwanted morphological forms during micropropagation adversely affects field performance of european rhubarb (*Rheum rhaponticum*). Acta Horticulturae, 616; 301–305.
7. Упадышев М. Т. и Высоцкий В. А. (1991) Размножение ежевики и малины черной методом культуры тканей. Садоводство и виноградство, 6, 24–27.

NUTRIENT STATUS OF THE AMERICAN CRANBERRIES *VACCINIUM MACROCARPON* AIT IN LATVIA

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Abstract

The industrial cultivation of the American cranberry (*Vaccinium macrocarpon* Ait.) in Latvia was started during last decade. These cultivated berries have been noted as a good source of antioxidants, bacterial inhibitors, dietary fibber and vitamin C. A substantial economic value of cranberry production in Latvia could be associated with appropriate cultivation conditions – vast high bog territories, mild climate and unfulfilled market. To realize the full potential of modern high yielding crop, balanced plant nutrition is vitally important. Investigations were done to find out the actual mineral nutrition status of American cranberries in Latvia. About 100 (peat and plant) samples were collected from different cranberry producing sites in Latvia (2001 to 2004). A complex diagnostic method, i.e. plant tissue analysis and soil testing were used to evaluate the cranberry supply with all of the biogenous elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B). The results obtained were compared to a set of standards for nutrient elements developed by Dr. Nollendorfs (Latvia). In general, optimal plant supply with N, K, Ca, Mg, S, Zn and B, insufficient level of P, Fe, Cu, Mo, and increased concentration of Mn were stated in the vast majority of plant samples. Although broad range of element concentrations in peat samples was observed, rather good relationship between soil and plant nutrient levels was found. Based on the present work, it can be concluded that disbalance of plant mineral nutrition could be one of the factors limiting cranberry productivity in Latvia.

Key words: cranberry, mineral nutrition, plant analysis, soil testing

Introduction

The commercial cultivation of American cranberry *Vaccinium macrocarpon* Ait fruit indigenous to North America, began in the early 1800s, when Henry Hall (Massachusetts) noticed that wild cranberries covered by a layer of windblown sand produced more abundantly than usual. Today the cranberry's commercial success is impressive for the fruit that was not even cultivated until 1816. Yearly production of cranberries in 2003 in the United States was 290.000 t with average yield more than 20 t ha^{-1} (http://www.umb.edu./). The U.S. produces approximately 85% of the world's cranberry supply; Canada produces 15% (http://www.mindfuleating.org/).

A first not very successful attempt of cranberry cultivation in Latvia was made in 1970s (Ripa, 1996). The industrial cultivation of the American cranberry was started only during last decade and today there are more than 30 ha of production plantations in Latvia.

Cranberry fruits, juice, and other products have become increasingly popular due to its fresh taste and healthy components. A growing body of research suggests that cranberry is a relatively unique fruit in that it may provide two different pathways for health: through microbial anti-adhesion and broader benefits that may be related to antioxidant activities (Kuzminski, 1996; Leahy *et al.*, 2002).

A substantial economical value of cranberry cultivation in Latvia could be associated with the geographical situation and climate of Latvia which provide all of the major growing conditions for cranberries: 1) vast high bog territories, 2) sufficient freshwater, 3) a moderate, moist summer climate, as well as unfulfilled market.

Many factors are important in producing a high cranberry yield including soil type, water ability, temperature, sunlight, and management practices (Roper and Combs, 1992). To realize the full potential of modern high yielding crop, balanced plant nutrition is vitally important to ensure adequate vegetative growth and fruit production. There are three main ways to evaluate plant nutrient status: visual diagnostics, tissue analysis, and soil testing. Plant tissue and soil analysis used together are powerful tools to prevent mineral nutrient deficiencies or toxicities as well as to access current fertilization management practices in specific acid environment (DeMoranville, 1998; Roper, 2001; Nollendorfs, 1998).

The main aim of this study was to find out the actual mineral nutrition status of American cranberries in Latvia. A complex diagnostics method, i.e. plant and soil analysis were used to evaluate the cranberry supply with all of the biogenous elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B).

Materials and Methods

Cranberry plants and soil samples were taken from different cranberry production sites in Latvia (Aluksne, Liepaja, Madona, and Talsi districts) over the period of four years (2001 to 2004). The soil (peat) samples were taken with a soil probe to a depth of 10–15 cm. For each sample, five to eight subsamples were taken and thoroughly mixed to form one reference sample. To determine the plant available amounts of 12 biogenous elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) the soil samples were extracted with 1 *M* HCl (soil/extractant ratio 1:5) (Ринькис и др., 1987).

For each plant sample about 200 current season upright tips were collected from locations representative of the planting. The plant material was dried at 60 ^oC and ground. Then the plant samples were dry-ashed with HNO_3 vapours and re-dissolved in HCl (3:100) (Ринькис и др., 1987).

Concentrations of 12 biogenous elements (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, B) were determined in all soil and leaf samples. The levels of Ca, Mg, Fe, Cu, Zn, and Mn were estimated by atomic absorption spectrophotometer (Perkin Elmer 403, acetylene-air flame), those of N, P, Mo, B by colorimetry, S by turbidimetry, and K by flame photometer. The pH of the soil was potentiometrically measured in a suspension of a 1:2.5 soil: 1 *M* KCl mixture (Anonymous, 1982, Ринькис и др., 1987). The results (in mg l^{-1} for soils, macroelements in % and microelements in mg kg^{-1} for plants) are the means of at least three independent replications.

Results

Between 2001 and 2004 in the Laboratory of mineral nutrition of plants at the Institute of Biology University of Latvia about 100 (American cranberry plant and soil) samples were analysed. Although this was not a great number of samples it may be representative of the cranberry bogs in the country as a whole.

To characterize the mineral nutrition status of American cranberry, the levels of 12 biogenous elements were estimated in cranberry plant samples. Mean macro- and microelement concentrations, concentration range as well as tissue standards in Latvia developed by Dr. biol. Nollendorfs (1998) and North American cranberry tissue nutrient guidelines (DeMoranville, 1997; Roper, 2001) are shown in Table 1. In general, mean macronutrient concentrations, with exception of phosphorous, could be characterized as optimal. The main tendencies in microelement supply were stated – deficiency of Fe, Cu, and Mo, optimal level of Zn and B, and increased concentrations of Mn in plant tissue.

Table 1. Nutrient concentrations in cranberry plant samples (2001 to 2004)

Element	Unit	Concentrations un dried tissue			Optimal concentrations	
		min	max	mean	Latvia *	The U.S.**
Nitrogen (N)	%	0.55	2.20	1.02	1.00–1.50	0.90–1.10
Phosphorous (P)	%	0.07	0.30	0.15	0.20–0.30	0.10–0.20
Potassium (K)	%	0.32	1.96	0.61	0.40–0.70	0.40–0.75
Calcium (Ca)	%	0.34	1.46	0.75	0.60–0.80	0.30–0.80
Magnesium (Mg)	%	0.15	0.32	0.23	0.20–0.30	0.15–0.25
Sulphur (S)	%	0.05	0.58	0.14	0.15–0.25	0.08–0.25
Iron (Fe)	mg kg^{-1}	30.0	142.0	62.9	80–150	>20
Manganese (Mn)	mg kg-1	17.0	380.0	126.0	40–100	>10
Zinc (Zn)	mg kg^{-1}	17.0	56.0	30.7	30–80	15–30
Copper (Cu)	mg kg^{-1}	2.0	18.6	6.5	8–12	4–10
Molybdenum (Mo)	mg kg^{-1}	0.1	0.9	0.4	1–5	–
Boron (B)	mg kg^{-1}	1.0	105.0	30.1	30–60	15–60

* Tissue standards developed by Nollendorfs (1998);
** Cranberry tissue nutrient guidelines (DeMoranville, 1997; Roper, 2001).

The count of cranberry samples in different nutrient supply levels for N, S, Fe, Mn, Cu, and B are shown in Figures 1–3.

Although the mean level of N and S in cranberry samples, in general, were optimal for plant growth and development, rather broad range of element concentrations were found. Over the past several years, only 43% of the samples were sufficient (above 1.00%) in N (Fig. 1). Similar results were obtained on the other major element of interest – S (Fig. 1). The concentrations of S in 75% of the samples were in the insufficient range (below 0.15%).

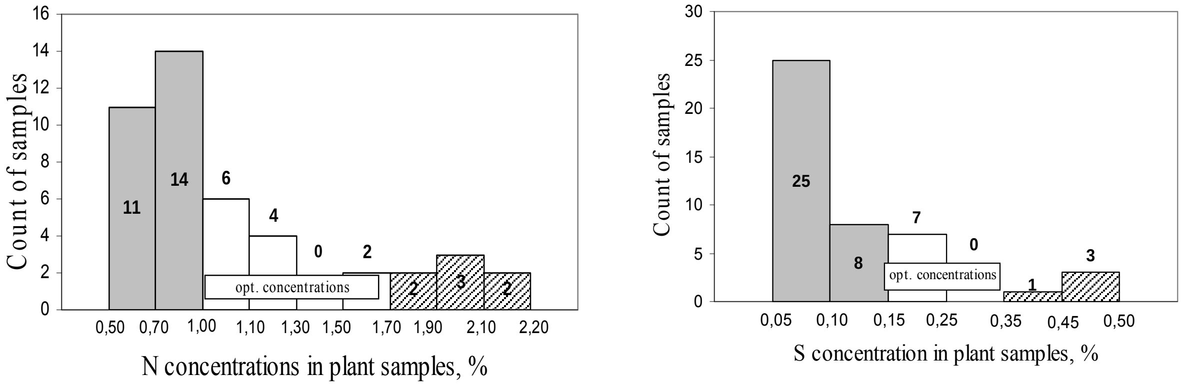

Figure 1. Nitrogen and sulphur levels in cranberry plant samples in Latvia (2001 to 2004)

– decreased nutrient level;
– optimal nutrient level;
– increased nutrient level.

The results obtained on the levels of micronutrients in plant tissue are of particular interest. With the exception of Zn and B, serious disbalance in plant supply with microelements was stated. Only 20% of the samples had tissue Fe at or above the critical level of 80 mg kg^{-1} (Fig. 2). The vast majority of samples tested (80%) were sufficient for Mn (above 40 mg kg^{-1}). Moreover, about 40% of them were in the high or abundant range (above 100 mg kg^{-1}) (Fig. 2).

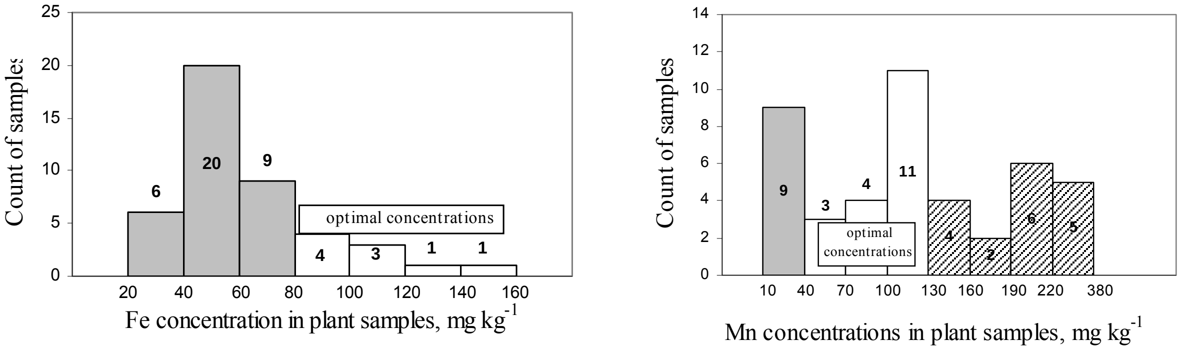

Figure 2. Iron and manganese levels in cranberry plant samples in Latvia (2001 to 2004)

– decreased nutrient level
– optimal nutrient level
– increased nutrient level

One of the main problems for cranberry cultivation in specific acid growing environment could be associated with deficiency of Cu (Fig. 3). About 75% of the samples had tissue Cu levels below the critical 8 mg kg^{-1} and did not correspond to the optimal supply of plants.

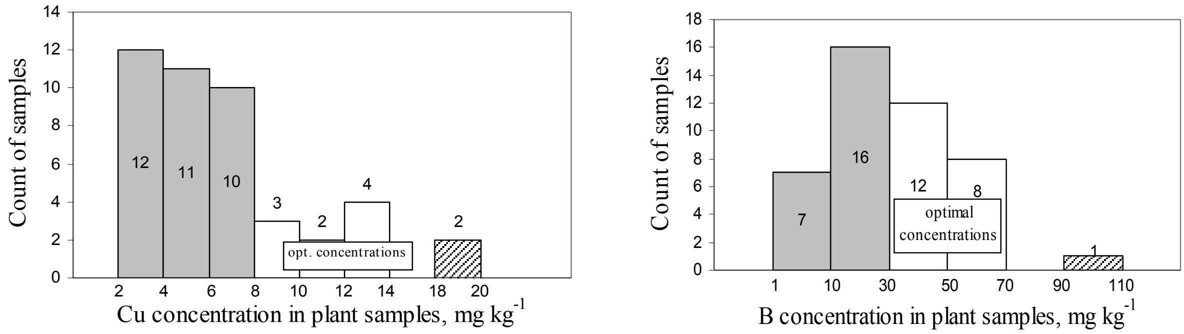

Figure 3. Copper and boron levels in cranberry plant samples in Latvia (2001 to 2004)

– decreased nutrient level;
– optimal nutrient level;
– increased nutrient level.

Similar to N and S, adequate mean B concentration in cranberry plant tissue was stated. But such optimal supply with B was provided only for 48% of samples (Fig. 3). More than half of cranberry plant samples were in deficient range (below 30 mg kg^{-1}).

Information obtained on plant available essential mineral nutrient concentrations in peat samples as well as pH and available soil standards are shown in Table 2.

The results obtained on macroelement concentrations showed serious N deficit in all of the peat samples (from 12 to 53 mg l^{-1}) and insufficient level of S in most of them. Slightly decreased mean concentration of P was stated in samples analysed. The mean content of K, Ca, and Mg could be characterized as sufficient, but not always optimal for plant growth and development in separate samples.

Although a broad range of peat microelement concentrations were stated, in general, deficiency of Cu, Zn, Mo, and B, optimal concentrations of Fe and slightly increased level of Mn were observed in samples analyzed.

High bog territories are mostly used for American cranberry cultivation in Latvia. Therefore decreased values of pH for the bulk of the peat samples tested did not correspond to optimal (pH 4.0 to 5.0) for cranberry growth (Table 2).

Table 2. Nutrient concentrations (mg l^{-1}) in peat samples (2001 to 2004)

Element	Concentrations in 1 *M* HCl extraction			Optimal concentrations *
	min	max	mean	
Nitrogen (N)	12	53	24.2	80–120
Phosphorous (P)	1	283	51.0	60–100
Potassium (K)	23	350	91.0	60–100
Calcium (Ca)	210	3850	763	500–1000
Magnesium (Mg)	5	2750	278	120–200
Sulphur (S)	3	110	21	60–80
Iron (Fe)	24	720	144	100–200
Manganese (Mn)	0.3	69.0	8.6	4.0–8.0
Zinc (Zn)	0.5	4.0	2.2	4.0–8.0
Copper (Cu)	0.15	8.20	1.90	6.0–10.0
Molybdenum (Mo)	<0.01	0.26	0.05	0.10–0.25
Boron (B)	<0.1	1.6	0.3	1.0–1.5
$pH/_{KCl}$	2.76	5.84	3.38	4.0–5.0

* Soil standards in 1 *M* HCl developed by Nollendorfs (1998).

Discussion

American cranberry cultivation is a new branch of agriculture in Latvia with high potential in the country's economics and ecology. Balanced mineral nutrition is very essential in the production of high and qualitative yield.

While nutrient status of cranberries in the United States and Canada (the main cranberry production countries in the world) has been studied in considerable detail (Greidanus and Dana, 1972; Roper and Combs, 1992; Davenport and Provost, 1994), mineral nutrition problems of cranberry crop in Latvia have not been elucidated sufficiently. Moreover there is practically no information available about actual mineral nutrition status of American cranberries in Latvia. In the northern part of United States cranberries are grown in irrigated beds of sandy soil placed on top of high-organic-matter or clay subgrade (DeMoranville, 1998). These growing conditions are very different from those in Latvia where cranberry plantings are mostly developed in high bog territories. Therefore, direct application of nutrition recommendations, fertilizer and management practices, and other information are limited.

The results obtained on nutrition status of American cranberry revealed the main problems in plant supply with essential mineral elements in Latvia. Serious disbalance was stated in the system of plant mineral nutrition. Insufficient level of P, Fe, Cu, and Mo as well as increased concentration of Mn was stated in the vast majority of plant samples. Several investigations have shown that tissue analysis provide picture of the nutrient status of a crop at a particular point in time resulting from all factors affecting plant growth (Nollendorfs, 1998; Roper, 2001). But this diagnostic method cannot detect character of the nutrient deficiencies or toxicities and soil content of nutrients. Therefore soil test is very important in determining the ability of the soil to supply nutrients needed for optimum plant growth. Although broad range of element concentrations in peat samples was found, soil or peat tests revealed even more serious disbalance in cranberry providing with biogenous elements – deficiency of N P, S, Cu, Zn, Mo, and B, optimal concentrations of Fe and slightly increased level of Mn were stated in samples analysed.

The results presented here differ from those of Roper and Combs (1992) for nutrient status of Wisconsin cranberries where, with the exception of Zn, almost all cranberry-production beds had adequate conditions of mineral nutrition. Our results suggest that only about 20% of cranberry production plantings in Latvia were optimal provided with all of the biogenous elements. It is not surprising because cranberry plantings in Latvia are developed on high bogs and sphagnum peat could be characterized as nutrient-poor environment with low cation holding capacity and high element leaching. Very acid growing environment in high bogs (mean $pH/_{KCl}$ 3.38) may create problems in plant root supply with Ca and accumulation of increased Mn concentrations in plant tissue (Nollendorfs, 2004). In combination with deficiency of Cu and B often stated, it could seriously limit cranberry yield in Latvia.

In general, our study suggests amazingly good relationship between substrate and plant nutrient level. As a rule, no correlation is found for nutrient levels in plant tissue and corresponding soil nutrient contents (Roper and Combs, 1992; Roper, 2001). The only confusion in the relationship between soil and plant N concentrations, in general, optimal in plants and decreased in substrate, could be explained by release of N from soil organic matter during summer season (DeMoranville, 1998).

Conclusions

In general, optimal cranberry supply with N, K, Ca, Mg, S, Zn and B, insufficient level of P, Fe, Cu, Mo, and increased concentration of Mn were stated in the vast majority of plant samples.

Decreased values of pH for the bulk of the peat samples tested revealed problems with substrate pH adjustment and could affect availability of nutrients.

A complex diagnostic method – plant tissue and soil analysis is the most reliable method to determine cranberry nutrient deficiencies or toxicities as well as to assess current fertility management practices.

A disbalance of plant mineral nutrition could be one of the factors limiting cranberry productivity in Latvia.

References

1. Anonymous (1982) Methods of soil analysis. Part 2. Chemical and microbiological properties, Wisconsin, 1159.
2. Davenport J. R. and Provost J. (1994) Cranberry tissue nutrient levels as impacted by three levels of nitrogen fertilizer and the relationship to fruit yield and quality. Journal of Plant Nutrition, 17 (10), 1625–1634.
3. DeMoranville C. J. (1997) Cranberry nutrition and fertilizers. In: Sandler H. A. (ed) Cranberry production: a guide for Massachusetts, Univ. of MA Extensions, 81–85.
4. DeMoranville C. J. (1998) Mineral nutrition: What are the guiding principles? htpp://www.library.wisc.edu/guides/agnic/cranberry/proceedings/1998/mindem.pdf [05.12.2004].
5. Greidanus T. and Dana M. N. (1972) Cranberry growth related to tissue concentration and soil test phosphorus. Journal of American Soc. Horticulture Science, 97, 326–328.
6. Kuzminski L. N. (1996) Cranberry juice and urinary tract infections: Is there a beneficial relationship? Nutrition Review, 54, 87–90.
7. Leahy M., at al (2002) Latest development in cranberry health research. Pharmaceutical Biology, 40, 50–54.
8. Ripa A. (1996) Amerikas lielogu dzērvene [American cranberry]. Latvijas Zinību biedrība, Rīga, 75.
9. Roper T. (1992) Cranberry soil and tissue analysis: Diagnostic tools. The Wisconsin Cranberry IPM Newsletter, 6 (7), 1–2.
10. Roper T. R. and Combs S. M. (1992) Nutrient status of Wisconsin cranberries. Cranberries: The National Cranberry Magazine, 15 (2), 11–15.
11. Roper T. R. (2001) Taking and interpreting soil and tissue samples. htpp://www.hort.wisc.edu/cran/Publication/2001%20Proceedings/min_nutr.pdf [05.12.2003].
12. Nollendorfs V. (1998) Augu barošanās līmeņa noteikšana lielogu dzērvenēm [Plant nutrition levels for American cranberries]. Grām.: Dzērveņaudzētāju gadagrāmata, Latvijas dzērveņu audzētāju asociācija, 53–5 (in Latvian).
13. Nollendorfs V. (2004) Augsto krūmmelleņu prasības pēc mēslojuma [High bush blueberry nutrition demands]. Ražība, Nr. 6, 8–10. (in Latvian).
14. Ринькис Г. Я., и др. (1987) Методы анализа почв и растений [Methods of Soil and Plant Analysis]. Рига, Зинатне. 174. (in Russian).
15. htpp://www.mindfuleating.org/cranberry.htm 2003 [09.01.2004].
16. htpp://www.umb.edu/conne/marsha/cranintro.html [23.12.2004].

EARLINESS AND YIELD DYNAMICS OF RHUBARB (*RHEUM RHAPONTICUM* L.) UNDER CONDITIONS OF LUBELSZCZYZNA REGION

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Abstract

The research on the yielding of rhubarb 'Wczesny Hosera' was carried out in the years 1995–2003 in the Experimental Station of Agricultural Academy in Lublin. The aim of studies undertaken in this work was evaluation of earliness and yield dynamics of rhubarb during successive 9 years of running the plantation. Effect of weather conditions in the winter-spring period on the yield earliness of rhubarb was proven. Depending on years, the first harvest of leaves was recorded on 10 April (in the year 2001), the last on 5 May (in the year 1997). In the period of 9 years of running the rhubarb plantation significant differences in the number of petioles picked from one plant were observed between years. Significantly lower petioles yield was harvested in the year 1995 (average 11.0 per plant), the highest yield was obtained in the year 2003 (average 87.5 per plant). The highest marketable yield of rhubarb 'Wczesny Hosera' petioles was obtained in the 6^{th} to 8^{th} year of running the plantation – in the years 2000-2002 (average 6.4–8.4 kg plant^{-1}).

Key words: rhubarb, yielding, weather conditions

Introduction

Rhubarb (*Rheum rhaponticum* L.) is a perennial plant over-wintering of which in our climate conditions is very good. It is cultivated without crop rotation usually for 10–12 years in the same place (Shoemaker, 1953).

Rhubarb is a plant of temperate and cool climate. It has small temperature requirements. Weather conditions in the spring-summer period (light intensity, day length, temperatures and rainfall) have great effect on growth and development of rhubarb plants (Loughton, 1965; Wiebe, 1997).

Recently growing rhubarb is of economic significance in Poland. This vegetable is gaining popularity owing to relatively small costs of cultivation and high yield. At present, rhubarb is used in the processing industry as a natural preservative. An addition of rhubarb to juice or concentrates is resulting in increased product's acidity (Sałata *et al.*, 2001).

The aim of studies was evaluation of earliness and yield dynamics of rhubarb during successive 9 years of running the plantation.

Materials and Methods

The research was carried out in the years 1995–2003 in the Experimental Station of Agricultural Academy in Lublin. Before planting crowns in the autumn of 1993, dung 50 t ha^{-1} and mineral fertilizers: P – 40, K – 150 kg ha^{-1} were applied. Each year after harvests plants once received fertilizer: N – 50, P – 30, K – 100 kg ha^{-1}.

Plants of rhubarb 'Wczesny Hosera' were cultivated in spacing of 2.0×1.5 m. 10 plants were chosen randomly and each year the same plants were studied. Leaves with petioles longer than 20 cm and wider than 2.0 cm in the half of the length were harvested. A few leaves were picked from one plant at the time. Leaves were harvested four times each year of the study, while in the year 2001 deficiency of rainfall in the spring period was the cause for picking them only twice. The early term of harvest were petioles from the two first dates of harvest and in the year 2001 the early yield was the one obtained only in the first date.

The analysis of temperatures in the years 1995–2003 was done. Data were obtained from the Agrometeorological Observatory in Felin, which belongs to the Department of Agrometeorology of Agricultural Academy in Lublin.

Rhubar leaves were picked separately from each plant and yield parameters were defined for a single rhubarb plant. Characteristics of rhubarb yield in the years 1995–2003 were presented on the ground of the chosen parameter values of yielding: total yield of leaves (kg·plant^{-1}) and commercial yield of petioles (kg·plant^{-1}), number of petioles in the yield and average weight of a petiole (g).

The yield parameters of rhubarb were statistically analysed using the variance analysis method. Differences were analysed by Tukey's Multiple Range Test at 5% level of significance.

Results and Discussion

In the climate conditions of Lubelszczyzna region rhubarb plants start vegetation in early spring immediately after ground surface thawing at the end of March and beginning of April. Progress in weather conditions in early spring in the years 1995–2003 had significant effect on yield earliness of this vegetable (Table 1 and Figure 1).

Table 1. Monthly temperatures and precipitation from January to July, 1995–2003

Month	Long-term monthly averages (1951–2000), °C	Years								
		1995	1996	1997	1998	1999	2000	2001	2002	2003
		average monthly temperatures, °C								
January	–3.6	–2.3	–6.9	–6.1	–0.4	–1.9	–3.4	–0.9	–1.6	–6.9
February	–2.8	2.3	–6.8	0.2	2.1	–3.2	0.1	–1.0	3.5	–6.2
March	1.0	2.3	–3.0	1.8	0.3	2.8	2.6	2.2	4.7	0.5
April	7.5	7.4	7.3	3.9	9.5	8.8	11.1	8.5	8.6	6.5
May	13.0	12.2	15.5	13.9	13.8	11.6	14.5	13.9	17.3	16.2
June	16.5	17.1	16.5	16.8	17.5	18.5	17.0	15.3	17.8	17.4
Average January-June	5.3	6.5	3.8	5.1	7.1	6.1	7.0	6.3	8.4	4.6
	Total precipitation, long-term averages (1951–2000), mm	monthly sum of rainfall (mm)								
January	21.7	10.0	10.4	1.6	19.6	16.2	26.9	29.2	35.6	26.6
February	24.8	27.2	26.9	12.5	23.3	41.8	32.7	18.4	45.2	25.0
March	25.8	43.7	23.6	16.2	22.5	17.0	64.9	33.8	33.2	6.6
April	40.6	40.0	15.4	40.8	63.9	81.6	69.8	64.9	18.3	40.7
May	58.3	32.8	115.5	83.1	49.6	45.9	50.7	19.9	28.6	71.4
June	65.8	70.3	28.0	36.2	61.5	160.9	36.4	47.6	116.8	39.6
Total January-June	237.0	224.0	219.8	190.4	240.4	363.4	281.4	213.8	227.7	209.9

Depending on weather conditions, first leaves were harvested in different terms. The earliest harvest was recorded in the year 2001 (10 April), when the average monthly temperatures in the period from January to May were higher than long-term averages. In May 2001 there was a deficiency of rainfall, which in combination with the early start of vegetation was the cause for harvesting leaves only twice, while in the other years leaves were picked four times. In the period of January–March 1998 and 2002 mean monthly temperatures were higher or similar to long-term averages. Such temperatures were favorable for the early vegetation start of rhubarb plants. First leaves were harvested on 18–19 April, 8 days earlier than in the years 1999 and 2000. Favorable temperatures in January–March appeared also in the year 1995 when leaves for the first time were harvested on 20 April. In February and March 1996 average monthly temperatures were by 4 °C lower than long-term averages. In the year 1996 weather conditions did not favor early vegetation, so first leaves were harvested on 8 May. Temperatures and moisture conditions were also less favorable in the beginning of rhubarb vegetation in the years 1997 and 2003. April 1997 was exceptionally cool, mean monthly temperature was by 3.6 °C lower than long-term averages (7.5 °C), and in the year 2003 mean April temperature was by 1 °C lower. Less stable temperatures in early spring of 1997 and 2003 were the cause of the first leaves harvest on 5 May (1997) and on 6 May (2003). Taking as a basis results of this investigation as well as results obtained by other researchers (Buczkowska and Sałata, 1999; Wróblewska, 1965) it can be stated that the yield earliness of rhubarb is dependent on weather conditions in winter-spring period prior to renewal of vegetation.

A large differentiation in petioles yield values obtained in the successive rhubarb harvests was proved (Fig. 1). In the first term during all years a similar marketable yield was obtained from one plant. Significantly high yield was obtained in the first term of harvest in the year 2001. During the next terms of leaves harvest differentiation between years of study was larger. On the basis of average rhubarb petioles yield obtained in the years 1995–2003 in successive terms of harvest the influence of weather in winter-spring period on dynamics of rhubarb yielding cannot be proven.

The progress in rhubarb 'Wczesny Hosera' yield obtained in the successive years of cultivation is shown in Table 2. Significant differences between years of cultivation in relation to early leaves and petioles yield, number of leaves and average mass of a petiole were observed. In the years 1995–2003 the average yields of leaves and petioles were 8.5 and 5.5 kg·plant^{-1}, respectively. During 9-years of running the plantation the highest average early yield of leaves and petioles was obtained from rhubarb plants in the year 2002 – 12.5 and 8.4 kg plant^{-1}, respectively and in 2001 – 12.0 and 7.7 kg·plant^{-1}, respectively in the 7th and 8th years of use. Significantly lower leaves and petioles yields were obtained from plants in 1995 – the first year of running the plantation. Obtained results show that age of plants had a significant effect on the value of early yield in 1995–2003 (Buczkowska and Sałata, 1999; 2001; Sałata, 2001; 2002b).

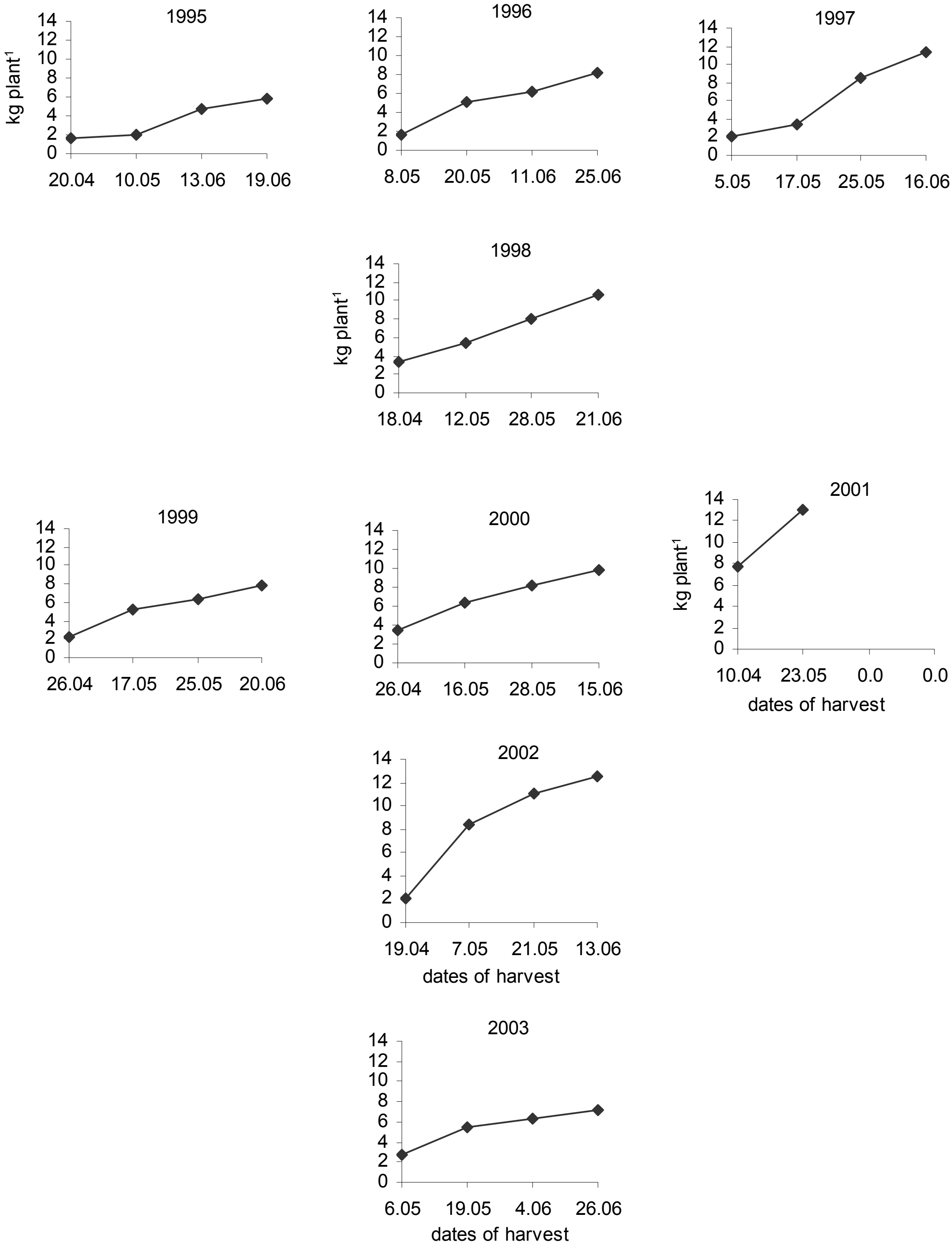

Figure 1. Harvest earliness and yield dynamics of marketable yield of rhubarb petioles in 1995–2003

Difference in the average number of leaves in the early yield obtained from a rhubarb plant was observed in 1995–2003. The most leaves from one plant (average 87.5) but with the least average petiole mass (63.8 g) were obtained in 2003 in the 10th year of running the plantation. Whereas leaves with petioles of the largest average mass (164.4 g) were obtained in 2001. The least amount of leaves from one plant was obtained in the first years of running the plantation. It was observed that the older the plants the more leaves were obtained from one plant. It shows that age of plantation should also be considered. Results of this research are in agreement with those obtained earlier (Sałata, 2001; 2002a).

Table 2. Early yield structure of rhubarb, 1995–2003

Years	Total yield of leaves, kg plant^{-1}	Marketable yield of petioles, kg plant^{-1}	Average number of petioles, per plant	Average mass of petioles, g
1995	4.0	2.0	11.0	160.8
1996	9.1	5.1	46.0	117.0
1997	5.5	3.5	31.8	111.6
1998	8.8	5.5	52.3	105.6
1999	8.6	5.2	52.3	100.0
2000	8.3	6.4	41.5	153.0
2001	12.0	7.7	45.5	164.4
2002	12.5	8.4	67.5	123.1
2003	8.0	5.5	87.5	63.8
Average	8.5	5.5	48.4	122.1
$LSD_{0.05}$ Years (a)	3.25	2.32	16.72	51.50

Conclusions

Effect of weather conditions in the winter-spring period on the yield earliness of rhubarb 'Wczesny Hosera' was proven. Depending on weather between years, the earliest harvest of the first leaves was recorded on 10 April (in 2001), the last on 5 May (in 1997). The highest early yield was obtained in 2002 (leaves 12.5 kg plant^{-1} and petioles 8.4 kg plant^{-1}).

During 9 years of running the rhubarb 'Wczesny Hosera' plantation significant differences in petioles numbers picked from one plant was observed between years. Significantly lower petiole yield was harvested in 1995 (average 11.0 per plant), highest yield was obtained in 2003 (average 87.5 per plant).

The highest marketable yield of rhubarb 'Wczesny Hosera' petioles was obtained in the 6th to 8th year of running the plantation – in the years 2000-2002 (average 6.4–8.4 kg plant^{-1}).

References

1. Buczkowska H. and Sałata A. (1999) The effect of weather conditions on the yielding of rhubarb (*Rheum rhaponticum* L.). Zeszyty Problemowe Postępów Nauk Rolniczych, 466, 249–257.
2. Buczkowska H. and Sałata A. (2001) Evaluation of yielding of several rhubarb cultivars in the first years of utilization of a plantation. Electronic Journal of Polish Agricultural Universities, Series Horticulture, 4, Issue 2.
3. Loughton A. (1965) Effects of environment on bud growth of rhubarb, with particular reference to low temperature. Journal Horticultural Science 40, 325–339.
4. Sałata A. (2001) Yielding of several rhubarb cultivars (*Rheum rhaponticum* L.) depending on age of plantation. Folia Horticultural, 13, 399–403.
5. Sałata A. (2002a) Relation between the yielding and some morphological features of five rhubarb cultivars (*Rheum rhaponticum* L.). Annales Universitatis Mariae Curie-Skłodowska, Sectio EEE, 11: 37-42.
6. Sałata A. (2002b) Evaluation of yielding of several cultivars in years 1996–2001. Electronic Journal of Polish Agricultural Universities, Series Horticulture, 5, Issue 2.
7. Sałata A., Najda A. and Kuzyk K. (2001) Effect of weather conditions and leaf age on total acidity in leaf stalks of some rhubarb cultivars. Vegetable Crops Research Bulletin, 55, 109–113.
8. Shoemaker J. S. (1953) Rhubarb. In: Vegetable growing (eds) New York, John Wiley and sons, London, Chapman and Hall, 75–84.
9. Wiebe J. (1967) Physiodormancy requirements of forcing rhubarb. Proceeding American Society Horticultural Science, 90, 283–289.
10. Wróblewska Z. (1965) Results experiment with four rhubarb cultivars in the years 1952–1960. Biuletyn Warzywniczy, 8, 87–96.

Organic agriculture

PROTECTION OF THE BALTIC SEA ENVIRONMENT BY ECOLOGICALLY SOUND LAND USE ON THE UNDULATING LANDSCAPE OF LITHUANIA

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Abstract

The presented research data were obtained on the undulating landscape of the Žemaičiai upland (Western Lithuania) where loamy sand and clay loam Eutric, Dystric and Gleyc Albeluvisols prevail. The thickness of the lost soil layer differed due to effects of water, wind and tillage erosion and varied from 0.12 to 1.07 m according to the slope gradient and degree of soil erosion. The fertility of soil decreased by 21.7–22.1%, 38.9–39.7% and 62.4%, on slopes of 2–5^o, 5–10^o and 10–14^o, respectively. The mean water erosion rates under the field crop rotation varied from 6.43 m^3 ha^{-1} yr^{-1} to 20.5 m^3 ha^{-1} yr^{-1} on the slopes of 2–5^o, 5-10^o and 10-14^o according to average results of 18 years of investigations. The mean annual erosion rates decreased by 74.7–79.5% under erosion-preventive grass-grain crop rotations compared with the field crop rotation, and they decreased by 22.7–24.2% under the grain-grass crop rotation. The losses of N, P and K nutrients were in close correlation with soil losses. The resourceful selection of optimum erosion-preventive phytocenoses assists the erosion control, cleaning water and ecological stability of the landscape. All investigated land management systems were ecologically sound and environment friendly, according to crop quality records.

Key words: water erosion, Albenuvisols, Western Lithuania, highland-lowland-marine interactions

Introduction

The terrestrial landscape is the result of systematic and intense interactions between natural environment and human activities. The soil is the essential component interfacing these relationships, and it has been deeply affected. Therefore, it is important to define the consequences of the undulating landscape areas (the Žemaičiai upland in Western Lithuania) as well as lowland environment (the Maritime Lowland) to Marine systems of the Baltic Sea (highland-lowland-marine interactions).

Lithuania is a lowland country. However, there is the island-like Žemaičiai upland in the western part of the Republic and the edge of the Baltic uplands in the Eastern and Southern parts of it. About 52% of terrain in Lithuania are on the undulating landscape (slopes' inclination over 2^o). The glacial clay loam and loamy sand moraine of the Uplands is erodible (Jankauskas, Švedas, 2001). The erosivity of soils depends on the erodible glacial parent rock, on the undulating relief, on abundance and intensity of precipitation, and on the state of cover plants. Runoff waters from all terrain of Lithuania streams to rivers and flows to the Baltic Sea. The natural vegetation (grasses, shrubs and trees) is able to preserve soils against erosion processes. The farmers create the favourable conditions for soil erosion using the soil tillage equipment on the arable land areas, especially on the arable slopes. Therefore, the tillage erosion is the primary course for water and wind erosion (Kiburys, 1989; Jankauskas and Jankauskiene, 2003[a]). The average 40 years' research data of the Dūkštas Research Station of the Lithuanian Institute of Agriculture showed that the losses of clay loam soil due to water erosion on the slope of 5–7^o of Eastern Lithuania (Baltic uplands) ranged from 4.5 t ha^{-1} under cereal grain crops to 46.6 t ha^{-1} under black follow. There was only 0.05 t ha^{-1} loss of soil under the perennial grass field and no losses under the waste (Bundinienė, Paukštė, 2002).

The main problems for ecologization of crop agriculture on the hilly and undulating relief are minimization of soil erosion rates and growing of high quality crop production by optimisation of plant nutrition and plant protection. Improving of the Baltic Sea environment is closely dependent on minimization of erosion rates. Therefore, the main purposes of this paper are to show how: i) to minimize soil erosion rates from hilly-undulating areas of agricultural land, ii) to minimize pollution into inland waters (channels, rivers, lakes, ground water) and Baltic Sea, iii) to satisfy consumers' needs for high quality of agricultural products.

Materials and Methods

The research data of the landscape transect investigations were obtained on the hilly-to-rolling relief of the Žemaičiai upland (Western Lithuania) by description of 23 landscape transects profiles, 87 individual soil profiles and 69 bore-holes of soil and by analysing of 647 soil samples. Loamy sand and clay loam Dystric, Eutric and Gleyc Albeluvisols prevailed on the investigated areas. The degree of soil erosion on investigated undulating landscape was determined by comparison of the thickness of lost soil layer, slope gradient and different thickness of genetic soil horizon.

The long-term field experiments comparing erosion-preventive ago-phytocenoses on slopes of various inclinations have been carried out on the undulating relief of the KRS of LIA since 1982. Four six-course crop rotations of the following structure were compared:

I. The field crop rotation: 1. Winter rye (*Secale cereale* L.); 2. Potato (*Solanum tuberosum* L.); 3.–4. Spring barley (*Hordeum vulgare* L.); 5.–6. Mixture of clover-timothy (CT) (*Trifolium pratense* L. – *Phelum pratense* L.);

II. The grain-grass crop rotation: 1. Winter rye; 2.–4. Spring barley; 5.–6. CT;

III. The grass-grain I crop rotation: 1. Winter rye; 2. Spring barley; 3.–6. CT;

IV. The grass-grain II crop rotation: 1. Winter rye; 2. Spring barley; 3.–6. Mixture of orchard grass-fescue red (OF) (*Dactylis glomerata* L. – *Festuca rubra* L.).

The field experiments were carried out on slopes of 2–5^o, 5–10^o, and 10–14^o. The perennial grasses of multiple compositions for long-term use (sod-forming perennial grasses) were grown on a slope of 10–14^o instead of field crop rotation. This grass mixture included timothy common, fescue red, clover white (*Trifolium repens* L.), bluegrass Kentucky (*Poa pratensis* L.), and trefoil birdsfoot (*Lotus corniculatus* L.) (20% of each). The soil was an eroded sandy loam Eutric Albeluvisol. Optimum ground and fertiliser treatments were used according to the soil properties. The yields of different crops were evaluated by the amount of metabolizable energy, digestible protein and feed units according to the data of chemical analysis of each crop production. The annual precipitation during the period of study was from 635 to 1075 mm.

Water erosion rates were assessed by measuring the length and cross-sectional area of rills, to calculate the soil loss volume (Zaslavskij, 1983; Watson and Evans, 1991; Chambers *et al.*, 2000). The statistical evaluation of results investigated (losses of soil, crop productivity, quality values of crop production) was done using computer programs ANOVA, STAT, SPLIT-PLOT from the package SELKCIJA and IRRISTAT (Tarakanovas and Raudonius, 2002).

Results

The thickness of the lost soil layer differed due to common effects of water, wind and tillage erosion and varied from 0.12 to 1.07 m according to the slope gradient and degree of soil erosion. The thickness of soil layer deposited on the foot-slopes varied from 0.31 to 1.62 m. Among 155 investigated soil profiles or borecoles even 116 eroded plots were established (74.8%). Very severely and severely eroded soils were on 49 plots (31.6%), 29 plots (18.7%) were moderately eroded, 18 plots (11.6%) were slightly eroded, and 20 plots (12.9%) contained eroded-alluvial soil. The spring barley grain and straw grass yield on growing stages of soft or hard dough development were harvested on the plain tops of hills (conditionally non-eroded soil), on slopes of 2–5^o (slightly eroded), 5–10^o (moderately eroded), 10–14^o (severely eroded), and on the alluvial foot-slopes. The natural fertility of soil on slopes of 2–5^o, 5–10^o and 10–14^o decreased by 21.7–22.1%, 38.9–39.7% and 62.4%, respectively. The soil on the mentioned slopes was slightly, moderately and severely eroded.

The dependence of slope steepness and plant cover on water erosion rates from long-term field experiments is presented in Table 1.

Table 1. The influence of plant cover and slope steepness on water erosion rates (mean, 1983–2000)

Slope steepness	Soil loss (m^3 ha^{-1}) when growing:			
	Perennial grasses	Winter rye	Spring barley	Potato
2–5^o	0	3.17±0.259	9.01±1.036	24.20±5.590
5–10^o	0	6.70±0.853	19.11±1.668	62.22±10.323
10–14^o	0.04±0.001	8.60±1.521	27.09±4.112	* 87.12± 12.485

* On the 10–14^o slope, potatoes were not grown. The data were calculated by the method of group comparison.

The erosion-preventive capability of different crops determined erosion-resisting capability of different crop rotations (Table 2).

Table 2. The influence of plant cover and slope steepness on water erosion rates (mean, 1983–2000)

Slope steepness	Soil loss (m^3 ha^{-1} y^{-1}) under the crop rotatios: field *	grain-grass	grass-grain I	grass-grain II	LSD_{05}
2–5°	6.43	4.88	1.61	1.63	0.57
5–10°	14.53	11.16	3.03	2.93	1.18
10–14°	20.50 *	15.88	4.61	4.69	0.92

* The sod-forming perennial grasses were grown instead of the field crop rotation on the slope of 10–14°. Therefore, water erosion rate for field crop rotation was calculated by the method of data group comparison.

The losses of N, P and K nutrients were in close correlation with soil losses (Table 3). It is evident from the results of the lost total and available NPK nutrients due to soil erosion from the slopes of different gradient. Considering the losses of total nutrition's less than 5 kg ha^{-1} of phosphorus, 10 kg ha^{-1} of nitrogen and 150 kg ha^{-1} of potassium and 10 times lesser contents of available nutrition's are tolerable, the grass-grain crop rotations on all investigated slopes and additionally grain-grass crop rotation on the slopes up to 5° can be evaluated as environmentally friendly (shaded parts of Table 3).

Table 3. The influence of crop rotations to losses of NPK nutrients due to water erosion

Crop rotations	Loss of total nutrition from the slopes of different gradient, kg ha^{-1} y^{-1}: 2-5° N	2-5° P	2-5° K	5-10° N	5-10° P	5-10° K	10-14° N	10-14° P	10-14° K
Total NPK									
Field	11.9	6.5	164.3	28.1	15.3	388.3	38.6*	21.1*	534.4*
Grain-grass	9.0	4.9	124.8	21.6	11.8	298.3	29.9	16.4	413.8
Grass-grain I	3.0	1.6	41.2	5.9	3.2	81.0	8.7	4.8	120.2
Grass-grain II	3.0	1.7	41.7	5.7	3.1	78.4	8.8	4.8	122.2
LSD_{05}	1.06	0.58	14.61	2.28	1.25	31.52	1.73	0.94	23.90
Available NPK									
Field	1.02	0.62	1.48	1.94	0.86	3.44	2.50*	1.45*	4.53*
Grain-grass	0.78	0.47	1.13	1.49	0.66	2.64	1.93	1.12	3.51
Grass-grain I	0.26	0.16	0.37	0.40	0.18	0.72	0.56	0.33	1.02
Grass-grain II	0.26	0.16	0.38	0.39	0.17	0.69	0.57	0.33	1.04
LSD_{05}	0.091	0.055	0.132	0.157	0.070	0.279	0.112	0.065	0.203

*The perennial grasses of long-term use were grown instead of the field crop rotation on the slope of 10–14°. Therefore, water erosion rate for field crop rotation was calculated by the method of data group comparison. Shaded values are considered as environment friendly.

According to average annual data of 18 years of field experiments, the highest content of metabolisable energy accumulated (67.0–70.9 GJ ha^{-1}) was on the slope of 2–5°, and alterations due to land use systems were not significant among the three from four crop rotations. The significantly higher energy accumulated was only from the erosion-preventive grass-grain II crop rotation (Table 4).

Table 4. The amount of metabolisable energy accumulated by different crop rotations (mean, 1983–2000)

Slope steepness	Metabolisable energy accumulated by crop rotations (GJ ha^{-1}): field *	grain-grass	grass-grain I	grass-grain II	LSD_{05}
2–5°	67.9	68.2	67.0	70.9	1.08
5–10°	64.2	65.1	67.3	69.3	1.58
10–14°	66.1 *	61.1	65.0	70.2	0.99

* The sod-forming perennial grasses were grown instead of the field crop rotation on the slope of 10–14°.

The quality of crop production by nutrients' concentration is presented in Table 5. The hay of clover-timothy and spring barley are represented by highest amount (n = 129 and 109) of analysed samples. Representation of sod-forming perennial grasses and potato is much less (n = 33 and 12, respectively).

Table 5. Quality of plant production by nutrients' concentration (g kg^{-1} of dry matter)

Crop production	Nutrient (n)	Mean value	Standard error	SD	Min. value	Max. value
Spring barley, grain	N (n=109)	18.05	0.213	2.22	13.30	23.80
	P (n=109)	2.39	0.064	0.67	1.31	3.67
	K (n=109)	4.63	0.070	0.73	3.15	7.64
Winter rye, grain	N (n=55)	15.61	0.239	1.77	12.20	20.40
	P (n=55)	2.45	0.099	0.73	1.18	3.50
	K (n=55)	4.25	0.075	0.56	3.40	5.49
Clover-timothy, hay	N (n=129)	16.77	0.383	4.35	7.50	25.80
	P (n=129)	1.75	0.050	0.56	0.76	2.97
	K (n=129)	20.09	0.260	2.95	13.30	27.30
Orchard grass-fescue red, hay	N (n=69)	18.41	0.346	2.88	12.40	28.70
	P (n=69)	2.34	0.091	0.76	0.89	3.80
	K (n=69)	24.51	0.496	4.12	15.70	33.70
Sod-forming perennial grasses, hay	N (n=33)	18.29	0.73	4.21	11.80	30.90
	P (n=33)	2.22	0.11	0.66	0.96	3.33
	K (n=33)	19.05	0.64	3.65	13.10	30.40
Potato	N (n=12)	14.94	0.612	2.12	12.00	18.60
	P (n=12)	1.50	0.118	0.41	0.93	1.96
	K (n=12)	18.48	0.554	1.92	15.70	21.80

Shaded values exceed tolerable level.

Discussion

The erosion-protective capability of different crops varied in a broad range. Mean soil losses under winter rye were 3.2, 6.7 and 8.6 m^3 ha^{-1} yr^{-1} and under spring barley – 9.0, 19.1 and 27.1 m^3 ha^{-1} yr^{-1} from slopes of 2–5°, 5–10° and 10–14°, respectively according to average results of investigations during 1983–2000. Perennial grasses prevented erosion almost completely, with only a small soil loss from the grass-grain I crop rotation due to poor red clover cover in 1992. Potatoes had the least erosion-preventive capability, with soil losses from slopes of 2–5° and 5–10° being 8.7 times higher than under winter rye and 3.1 times higher than under spring barley (Table 1). Rates of erosion largely depended on rainfall intensity when cultivated soil was not covered by plant cover. Some authors (Chambers and Garwood, 2000) indicated that approximately 80% of the erosion events in England and Wales were on land cropped to winter cereals, the others (Fullen, 2003) recommend „of 'set-aside' on erodible soils, grass strips on arable slopes and bufer strips in riparian zones".

The erosion-protection capabilities of different crops and crop rotations varied widely. According to the data of 18 years of field experiments, the mean annual erosion rates under erosion-preventive grass-grain crop rotations decreased by 74.7–79.5% compared with the field crop rotation. Under the grain-grass crop rotation the rate decreased by 22.7–24.2% (Table 2). Lowest losses were under the grass-grain crop rotation, and they increased from 1.62 m^3 ha^{-1} yr^{-1} on the slope of 2–5° to 4.65 m^3 ha^{-1} yr^{-1} on the slope of 10–14°. However, the mentioned losses as well as losses from the grain-grass crop rotation on the slope of 2–5° could be considered as environment friendly, because they could be minimized to tolerable level by additional measures as minimisation of soil tillage operations and by cultivation of catch crops (Feiza, Feiziene and Ryley, 2003; Kinderienė, 2004). Therefore it was recommended that slopes >10° should be grassed, and erosion-protective crop rotations, erosion-protective tillage and fertiliser-liming treatments should be used on 2–10° slopes (Jankauskas and Jankauskiene, 2003).

The mean water erosion rate under the field crop rotation was 11.16 m^3 ha^{-1} yr^{-1} on the slope of 5–10° of the long-term monitoring sites. The rates had increased (to 15.88 m^3 ha^{-1} yr^{-1} on the slope of 10–14°) with an increasing slope inclination and had been lower (4.88 m^3 ha^{-1} yr^{-1}) on the 2–5° slope (Table 2). Eroded soil on the slopes becomes poor when deposited soil on the lower parts of slopes becomes heterogeneous, containing buried humic horizon, and their properties depended on thickness and quality of deposits.

The lowest productivity on the slope of 5–10° was under the field crop rotation and it has increased gradually under the grain-grass, grass-grain I and grass-grain II crop rotations. The lowest productivity on the slope of 10–14° was under the grain-grass crop rotation and increased significantly under the both grass grain crop rotations and under the long-term use of perennial grasses. Productivity of grass-grain II crop rotation was significantly higher also in comparison with grass-grain I and stand of long-term perennial grasses (Table 4). It indicates different possibilities of agri-phytocenoses for erosion-resisting and productivity levels. The scientists from Belgium estimated that land cover factor can be used as a criterion to select an appropriate rotation system to reduce erosion risk on site (Gabriels *et al.*, 2003).

Results presented in Table 5 demonstrate the high quality of all investigated crop production, becase the mean values of all main nutrients' (N, P and K) concentration did not exceed the standard records, and there were only 3 samples of orchard grass-fescue red hay among the 69 analysed samples and 1 sample of multiple perennial grass hay among the 33 analysed samples, where maximal K concentration slightly exceeded tolerable 3% or 30 g kg^{-1} level (shaded in Table 5). It means that we are able to evaluate all our land management systems as ecologically sound and environment friendly systems, according to crop quality records.

Conclusions

According to soil erosion investigations on the undulating landscape of Western Lithuania:

From the historical point of view the soil of hilly-undulating relief in Lithuania had been strongly affected by erosion processes: the thickness of lost soil layer varied from 0.12 m on the slightly eroded slopes to 1.07 m on the very severely eroded slopes for the common action of tillage, water and wind erosion; the thickness of alluvial soil deposits varied from 0.31 to 1.62 m on the foot-slopes. Its means that these processes lead to differentiation of conditions for agricultural practice, lovelization of landscape, and influence the highland-lowland-marine interaction processes.

The mean water erosion rate under the field crop rotation varied from 6.43 m^3 ha^{-1} yr^{-1} to 20.5 m^3 ha^{-1} yr^{-1} on the slope of 2–5°, 5–10° and 10–14° according to average results of 18 years of investigations. Lowest losses were under the grass-grain crop rotation, and they increased from 1.62 m^3 ha^{-1} yr^{-1} on the slope of 2–5° to 4.65 m^3 ha^{-1} yr^{-1} on the slope of 10–14°. The mentioned losses as well as losses from the grain-grass crop rotation on slope of 2–5° (4.88 m^3 ha^{-1} yr^{-1}) could be considered as environment friendly. They could be minimizing by additional measures as minimisation of soil tillage operations and cultivation of catch crops. Therefore, selection of optimum erosion-preventive phytocenoses (sod-forming perennial grasses or erosion-preventive crop rotations) assists the erosion control, cleaning water (rivers, lakes, and the Baltic Sea) and the ecological stability of the landscape.

The significantly lower crop production measured by metabolizable energy accumulated was under field and grain-grass crop rotations on the slopes of 5–14° and under grass-grain I crop rotation on the slopes over 10°. However, all investigated land management systems were ecologically sound and environment friendly, according to crop quality records.

References

1. Bundinienė O., Paukštė V. (2002), Lietuvos žemdirbystės instituto bandymų stoties veikla 1960–2000 m. Žemės ūkio mokslai, 4, 45–53.
2. Chambers B. J. and Garwood, T. W. D. (2000), Monitoring of water erosion on arable farms in England and Wales. 1990–94. Soil Use and Management, 16, 93–99.
3. Chambers B. J., Garwood T. W. D., and Unwin R.J. (2000), Controlling soil water erosion and phosphorus losses from arable land in England and Wales. Journal of Environmental Quality, 29, 1, 145–150.
4. Feiza V., Feizienė D., Riley H. (2003), Soil available P and P offtake responses to different tillage and fertilisation systems in the hilly landscape of Western Lithuania. Soil and Tillage Research, 74, 1, 3–14.
5. Fullen M. A. (2003), Soil erosion and conservation in north Europe. Progress in Physical Geography, 27, 3, 331–358.
6. Gabriels D., Ghekiere G. Schiettecatte W. and Rottiers I. (2003), Assessment of USLE cover-management C-factors for 40 crop rotation systems on arable farms in the Kemmelbeek watershed, Belgium. Soil and Tillage Research, 74, 1, 47–53.
7. Jankauskas B., and Jankauskiene G. (2003), Erosion-preventive crop rotations for landscape ecological stability in upland regions of Lithuania. Agriculture, Ecosystems and Environment, 95, 129–142.
8. Jankauskas B., and Jankauskiene G. (2003[a]), Tillage erosion as a predictor of runoff erosion on cultivated slopes. Soil management for sustainability. Proceedings of ISTRO 16th conference. Brisbane, Australia, 589–595.
9. Jankauskas B., Švedas A. (2001), Vandeninė dirvožemio erozija. In Eidukevičienė M. and Vasiliauskienė (Eds.)
10. Lietuvos dirvožemiai, Lietuvos mokslas, 32 knyga, Vilnius, 719–728.
11. Kiburys, B. (1989), Mechaninė dirvožemio erozija. Mokslas, Vilnius, 174.
12. Kinderienė I. (2004), Rudeninio žemės dirbimo būdų, šiaudų ir tarpinių augalų įtaka eroduojamo dirvožemio struktūringumui. Žemės ūkio mokslai, 2, 22–29.
13. Tarakanovas P., Raudonius S. (2003), Agronominių tyrimų duomenų statistinė analizė taikant kompiuterines programas ANOVA, STAT, SPLIT-PLOT iš paketo SELKCIJA ir IRRISTAT. LŽŪU leidybos centras, Akademija, 57.
14. Watson A., and Evans R. (1991), A comparison of estimates of soil erosion made in the field and from photographs. Soil and Tillage Research, 19, 17–27.
15. Заславский М.Н. (1983) Эрозиоведение. Высшая школа, Москва, 320.

SOIL TILLAGE DEPTH OPTIMIZATION IN ORGANIC FARMING

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Abstract

It is scientifically proven that the use of efficient herbicides in conventional farming allows minimizing soil tillage depth significantly, however, there is no sufficient data on optimum soil tillage depth in organic farming. Our stationary field experiments were conducted on the background of both conventional and organic farming systems. Four years (2000–2003), in autumn, the soil of the treatment plots was tilled, after previous crops – spring barley (*Hordeum sativym* L.) in 2000 and maize (*Zea mays* L.) in 2001; and after the crops under investigation – soybeans (*Glycine max* L.) in 2002 and sugar-beet (*Beta vulgaris* L., *var. saccharifera*) in 2003, at three depths of 0 cm., 10–12 cm. and 20–25 cm. The area of each test plot was 134 m^{-2}; the experiment was carried out in five replications. The influence of tillage depth on crops yield, weed infestation, soil physical properties, earthworm abundance and energy input and output were investigated during the field trial. Efficiency of soil tillage depth in organic farming depended on weed mass, which varied significantly in the case of each crop. In 2002, when weed infestation was high – 65.0 g m^{-2} (measured in air, dry weight), the highest soybeans corn yield was obtained ploughing at the depth of 20 cm, and the yield negatively correlated with weed mass. Similarly, in 2003, sugar-beet yield negatively correlated with weed mass, obtaining the highest yield in a shallow ploughing treatment (at the depth of 10 cm). The smallest weed mass (8.9 g m^{-2}) was observed in the case of spring barley in 2004; therefore, significant negative correlation was not detected.

Key words: ploughing depth in organic farming, weeds, earthworms

Introduction

The progress in conventional intensive farming, new technologies, using of glyphosate and other herbicides allowed farmers to practice the direct drilling technology (Allen, 1985) and minimize ploughing at all. In organic farming, there is steel debate about the best depth of ploughing. N. Lampkin (1999) recommends ploughing at the depth at of about 10–14 cm, at the same time this author does not eliminate theoretic possibility of direct drilling in organic farming. For green manure, annual weed seeds and crops residues incorporation it is necessary to plough not less than at the depth of 12 cm (Kurstjen and Perdok, 2000).

Materials and Mmethods

A stationary field experiment was carried out in 2000 on the fields of the Experimental Station of Lithuanian University of Agriculture.

The soil of the site – Drined Calc(ar)i- Epigleyic Luvisol – LVg-p-w-cc(sc) (FAO) silty loam, soil pH – 7.0–7.2 (determination by potentiometer), humus content – 2.36–2.54% (apparatus Heraeus).

Three autumn ploughing depths were investigated in three treatments: 1) ploughing at the depth of 20 cm; 2) ploughing at the depth of 10 cm; and 3) no-plough, shallow loosening in spring at the sowing depth of about 5 cm. The trials were carried out in five replications. The experiment was established according to randomized block design. The area measured was 50.0 m^{-2} for each plot. The rotation was as follows: in 2002 – soybeans, in 2003 – sugarbeets, and in 2004 – spring barley.

The weed infestation level in crops was determined in the $2^{nd-}3^{rd}$ decades of July by pulling out all the weeds inside the frame 0.25 m ^{2} in size in ten places of each plot (50 points for each treatment). The weeds were dried out and analysed.

The samples for water content determination in the soil were taken from 13 places of each plot at the depths of 0–10 cm and 10–20 cm by a sound 10 mm in diameter after t sowing and in the active growth period of crops.

Earthworms were collected at three points of each plot. Holes 0.5 × 0.5 m in size were dug out at the depth of 0.3 m.

Obtained data were statistically evaluated by analysis of variance (ANOVA), using *LSD* test.

Results

With the reduction of soil tillage depth, the soybean yield (2002) decreased significantly (P<0.01; Table 1). In 2003, the obtained yield of sugar beet roots was similar in both ploughing treatments performed 20 cm and 10 cm deep (53.6 and 54.2 t ha $^{-1}$ respectively), being lower only in the no-plough treatment

(47.4 t ha $^{-1}$), however this difference was not significant. In 2004, barley yields fluctuated fractionally and did not depend on the tillage depth significantly.

Table 1. Influence of ploughing depth on crop yield

Ploughing depth, cm	Crops					
	soybeans, 2002		sugar beets, 2003		barley, 2004	
	yield, t ha $^{-1}$	difference	yield, t ha $^{-1}$	difference	yield, t ha $^{-1}$	difference
Ploughing 20 cm deep	1.07	0	53.3	0	3.71	0
Ploughing 10 cm deep	0.84**	–0.23	54.22	+0.62	3.65	–0.06
Shallow loosening at the depth of 5 cm	0.67**	–0,4	47.4	–0.62	3.73	+0.02
$LSD_{0.05}$		0,147		7.505		0.314
$LSD_{0.01}$		0.201		10.237		0.428

* Significant difference (P<0.05), compare to plough at the depth of 20 cm;
** Significant difference (P<0.01), compare to plough at the depth of 20 cm.

During 3-experimental years a tendency of weed volume increase with reduced tillage depth was observed. In 2002, the highest weed infestation level was noted in soybean stand, but weed mass was significantly greater in no-ploughed treatment – 98.2 g m $^{-2}$ (air-dry mass) compare to 37.4 g m $^{-2}$ in treatment with ploughing depth 20 cm and 59.3 g m $^{-2}$ in treatment with ploughing depth 10 cm (Table 2). In the case of sugar beets and barley, significant weed mass differences among tillage treatments were not established.

Table 2. Influence of ploughing depth on crop weed infestation level

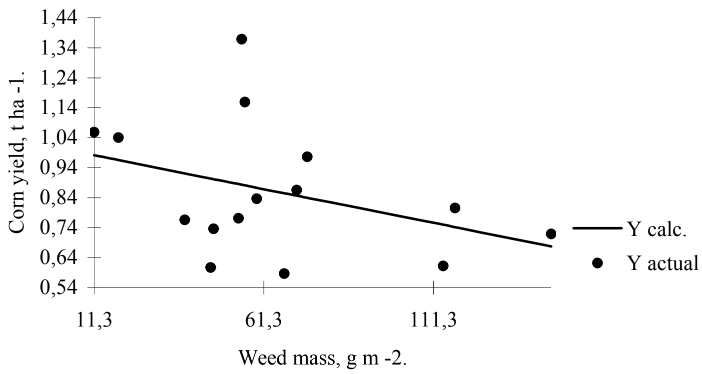
Ploughing depth, cm	Crop weed infestation level, g m $^{-2}$		
	soybeans, 2002	sugar beets, 2003	barley, 2004
Ploughing 20 cm deep	37.4	9.92	6.67
Ploughing 10 cm deep	59.3	11.7	6.82
Shallow loosening at the depth of 5 cm	98.2**	16.44	13.12

1)** Significant difference (P<0.01), compare to ploughing at the depth of 20 cm.
2) Data are not compared.
3) Not transformed values of means are shown in this table, but weeds mass initial data for analysis of variance was transformed by using equation Y=SQRT (X+1).

In 2002, in the crop stand of soybeans, the greatest number of weeds was noted in the shallow tillage treatment – 231 per 1 square meter, after ploughing at the depths of 10 and 20 cm, there were recorded 107 and 70 weeds, respectively. In 2003, in sugar beets, the amount of weeds was growing when the tillage depth was decreasing, however, significant differences were not noticed. There was no clear tendency of weed infestation in the crop stand of barley in 2004; likewise substantial differences were not observed

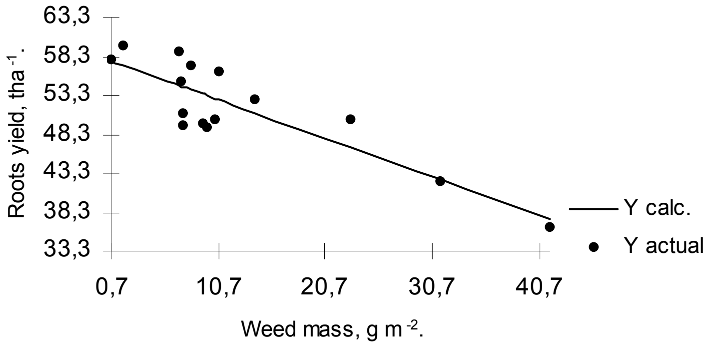
Correlation analysis is used to find out dependence of agricultural plants yield on weed infestation level of the crop stand. A strong negative correlation between sugar beet root yield and weed mass ($r = –0.865$**) is established only in 2003, when the average weed infestation of a crop stand was 12.7 g m $^{-2}$ (air-dry mass) (Fig. 1 B).

In soybeans with highest weed infestation level, negative correlation of the average size ($r = –0.371$) is observed (Fig. 1 A). In barley with low weed infestation level (8.9 g m $^{-2}$) correlation is weak. However, both in soybeans and barley correlation is not significant.



Y=1.007-0.002X; R2=0.138; t=0.501;

A



Y=58.01-0.492X; R^2=0.748; t=4.059;

B

Figure 1. Dependence of soybean yield (A) and sugar beet yield (B) – Y on weed mass in the crop – X
Notes: R^2 – determination coefficient.

Soil moisture content was higher in the top tillage depth 0–10 cm (Table 3) of unploughed plots after sowing of sugar beet and barley and somewhat lower in plots ploughed at the depth of 10 cm compare to plots ploughed at the depth of 20 cm.

Table 3. Influence of ploughing depth on soil moisture content

No	Time of assessment	Layer, cm	Crop	Moisture content, %		
				ploughing at the depth of 20 cm	ploughing at the depth of 10 cm	shallow loosening at the depth above 5 cm
1	After sowing	0–10	Sugar-beets	17.6	16.9	19.2**
			Barley	16.9	16.4	17.3
		10–20	Sugar-beets	20.1	19.0**	19.4*
			Barley	21.0	19.6**	19.0**
2	Active growing period	0–10	Soybeans	18.1	18.4	18.5
			Sugar-beets	15.9	14.9	15.9
			Barley	22.1	21.9	21.7
		10–20	Soybeans	19.9	17.6**	18.9
			Sugar-beets	18.4	17.0**	16.9**
			Barley	20.1	18.6**	18.8**

* Significant difference (P<0.05), in comparison to ploughed treatment at the depth of 20 cm.
** Significant difference (P<0.01), in comparison to ploughed treatment at the depth of 20 cm.

The soil bulk density values were similar during all the years of the research and varied slightly only in treatments with different depths. Only in 2002, in the top tillage depth 0–10 cm the bulk density was significantly ($P<0.01$) higher in unploughed treatment (1.45 t ha^{-1} compare to 1.35 t ha^{-1} at the depth of 20 cm in the second treatment) and in plots under sugar beets (1.45 and 1.39 t ha^{-1} respectively). There were no significant differences of bulk density noticed when ploughing at the depth of 20 and 10 cm.
In barley, there were no significant differences observed in the bulk mass between treatments of different ploughing depth.

At the depth of 10–20 cm, shallow (10 cm) tillage and no-till treatment compare to ploughing at the depth of 20 cm, the bulk density was significantly higher only in 2002 – the year of soybean growing. In sugar beets and barley, there were no significant differences noticed among the treatments.

In soybeans, there was significantly greater number and mass of earthworms found in the no-till treatment than in the treatment with the tillage depth of 20 cm ($P<0.01$). The differences among treatments with the tillage depths 20 and 10 cm were insignificant.

In barley, the tendency of the increase in the amount of earthworms was noticed when reducing the tillage depth, however significant difference was noticed only in the no-till treatment ($P<0.01$).

Amount of earthworms in barley was not dependent on tillage depth.

Discussion

According to soil tillage researchers′ opinion, reduction of ploughing depth in traditional farming system has no significant effect on the crop yield. However, Kouwenhoven *et al.* (2002) has noted that under organic farming conditions on loamy soils, when weeds are controlled, the influence of ploughing depth on the yield is generally small. According to Hakansson *et al.* (1998), on lighter soils the crop yield is raised by an increase in ploughing depth. The impact of ploughing depth on the yield is also dependent on the type of a crop. Kouwenhoven *et al* (2002) reported that after reduction of ploughing depth the yield of sugar beet has decreased by about 17–9 per cent compare to ploughing to the depth of 20–25 cm.; however, cereals are not so demanding for deep ploughing. In the majority of cases in our experiment, the decrease of ploughing depth had no significant influence on the yield.

Conclusions

The reduction of ploughing depth consistently increased the weed infestation of crops.

The influence of ploughing depth on the crop yield was dependent on weed infestation of crops: when weed infestation of crops was high, the reduction of ploughing depth had a negative impact on the yield; however, when weed infestation was low, the depth of ploughing had no significant influence on crop yield.

After the reduction of ploughing depth, statistically significant difference of moisture content in treatments in 0–10 cm topsoil layer was not detected.

In 10–20 cm soil layer the reduction of ploughing depth significantly reduced the moisture content in the soil almost in all the cases of the investigation.

In the majority of cases, the reduction of ploughing depth had no significant effect on soil bulk density.

The amount of earthworms and biomass increased significantly in no-till treatment.

References

1. Allen H. P. (1985) Direct drilling and reduced cultivation. Agropromizdat, M, 208.
2. Germanas L. (2000) Razienines sejos energetiniai tyrimai. LZUI Instituto ir LZUU mokslo darbai, 32(1), 17–26.
3. Hakansson I., *at al* (1998) Long-term experiments with different depths of mouldboard ploughing in Sweden. Soil Till. Res., 46, 209–223.
4. Kurstjens D. A. G., Perdok U.D. (2000) The selective covering mechanism of weed harrows on sandy soil. Soil Till. Res., 55, 193–206.
5. Kouwernhoven J.K., *at al* (2002) Soil management by shallow mouldboard ploughing in The Netherlands. Soil Till. Res., 65, 125–139.
6. Lampkin N. (1999) Organic farming. Farming Press, UK, 701.
7. Szymona J. (1993) Uprawa roli. In: Rolnictwo ekologiczne. Ekoland. Warszawa, 131–137.

PERFORMANCE OF LATVIAN SPRING BARLEY (*HORDEUM VULGARE* L.) VARIETIES IN CONDITIONS OF ORGANIC FARMING

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Abstract

In order to recommend the most appropriate spring barley varieties for organic farming, trials in certified organic fields were carried out in four Latvian research institutions. The article summarises the data about grain yield, quality, plant height, the length of vegetation and infection with diseases of six registered barley varieties, which were tested in 2003 (2 test sites) and 2004 (4 test sites). The mean grain yield of varieties 'Ruja', 'Malva' and 'Rasa' was significantly higher if compared to the check variety 'Abava' (P = 95%). The influence of genotype and test site on grain yield was significant (p-value = 0.004 and <0.0001, respectively). The highest mean TGW (thousand grain weight) was estimated for varieties 'Idumeja' (47.0 g) and 'Ruja' (46.7 g). None of the varieties exceeded the mean grain volume weight of standard variety 'Abava' (679 g l^{-1}). The influence of genotype on the content of crude protein and starch in grain was not significant. The duration of vegetation of variety 'Idumeja' was on average 8 days shorter than that of check 'Abava'. The mean plant height of check variety 'Abava' significantly surpassed the rest of tested varieties. None of the varieties showed complete resistance to loose smut (*Ustilago nuda*); the lowest infection level was detected for varieties 'Malva' and 'Idumeja', which can be recommended for organic farming from this point of view.

Key words: spring barley, organic farming, yield, grain quality, loose smut

Introduction

Organic farming is a comparatively new and growing direction of agriculture in Latvia. There are plans to expand the area of agricultural land, which is certified for organic farming from 1% to more than 3% in the year 2010 (Programme for development…, 2003). Special varieties for growing in organic agriculture are not registered in Latvia yet and the choice of appropriate varieties is essential for farmers.

The modern European varieties are created mostly for high input growing conditions where high amounts of mineral fertilizers and pesticides are used. It is not proved yet, if the differences between organic and conventional farming systems are large enough to motivate breeding and testing of varieties in both environments. Large-scale comparison of 120 barley varieties and variety mixtures in organic and conventional conditions is carried out in Denmark. Plant height was found to be one of the traits, which correlates with grain yield differently in organic and conventional conditions (Ostergaard, Jensen, 2004). Some of the Latvian barley varieties are bread for different growing conditions, compared to most European countries. Due to economical reasons, varieties were often selected on fields with comparatively low application of fertilisers and pesticides. The plant height of most Latvian barley varieties exceeds the European ones.

It is essential for organic farming (particularly for seed production) to put more focus on the control of seed borne diseases. The choice of resistant varieties is an important component of preventative strategy. Loose smut of barley (*Ustilago nuda*) can be mainly controlled by choosing resistant varieties (Borgen, 2004). Since only organically grown seed will be allowed for organic farming in the future and the number of infected plants with loose smut is restricted by Latvian seed legislation, it is essential to choose varieties resistant to this disease.

The aim of the study was to summarise the results obtained from testing six registered Latvian barley varieties in organic farming conditions in various environments in four Latvian agricultural research institutions.

Materials and Methods

The trials were carried out in certified organic fields. Six registered spring barley varieties, which were recommended by the breeders as most suitable for organic farming ('Abava', 'Idumeja', 'Sencis', 'Malva', 'Rasa', and 'Ruja'), were included in the study. The testing was arranged in geographically distinctive locations: in 2003 in Priekuli (NE Latvia) and Stende (NW Latvia) and in 2004 in Priekuli, Stende, Vecauce (SW Latvia) and Skriveri (SE Latvia). Abava, the oldest currently grown barley variety in Latvia with good adaptation ability to poor growing conditions, was used as check. The soil characteristics and growing conditions in all locations are shown in Table 1. The number of replications was four; random plot layout or systematic layout in blocks using simple repetition method (in Skriveri) was used. The weed control was done by harrowing. Emergence was calculated as the percentage of emerged seedlings from the sown seeds able to germinate in 0.5 m^2. Lodging was assessed at the maturity stage (1 – compleately lodged, 9 – no signs of lodging). Infected spikes with loose smut (*Ustilago nuda* (Jens.) Rostr.) were counted in each plot. Infection with powdery mildew (*Blumeria graminis* f.sp. *hordei*) and net blotch (*Drechslera teres* (Sacc.) Shoem) was assessed in points 0–4 (0 – no infection, 4 – very strong infection) in Priekuli and in Stende. Crude protein content was determined by Kjeldahl and starch content by Evers method or by express method (for Priekuli in 2004).

Table 1. Characteristics of soil and growing conditions

Indices	2003		2004			
	Priekuli	Stende	Priekuli	Stende	Vecauce	Skriveri
Soil type	sod-podzolic sandy loam	sod-podzolic loamy sand	sod-podzolic sandy loam	sod-podzolic loamy sand	sod-gleysolic sandy loam	sod-podzolic sandy loam
pH_{KCl}	6.4	6.3	5.8	6.3	6.8	6.4
Organic matter, g kg^{-1}	21	21	21	23	32	36
P, mg kg^{-1}	64.2	92.1	123.9	111.3	39.7	64.6
K, mg kg^{-1}	148.6	124.5	190.9	110.4	65.6	123.7
Previous crop	rape (green manure)	buckwheat (green manure)	perennial grass	buckwheat (green manure)	potatoes	winter rye
Seed rate, seeds able to germinate per m^2	400	500	400	500	430	500
Sowing date	12.05.	26.04.	21.04.	13.04.	15.04.	30.04.
Plot size, m^2	23.1	20.6	23.1	20.6	21.8	30.0

The beginning of growing season in 2003 (April in both sites and also May in Priekuli) was wet (Fig. 1); the monthly amount of rainfall was by 38–42% higher than the long-term average.

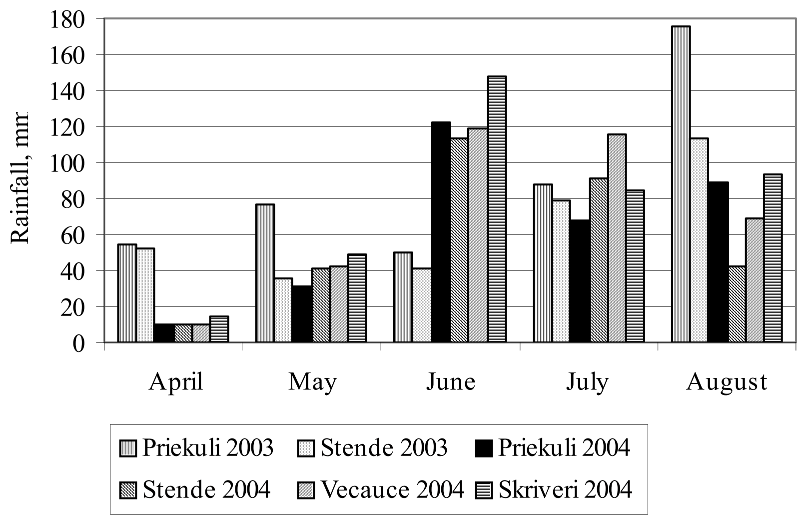

Figure 1. The amount of rainfall during the vegetation

It ensured sufficient moisture for germination and establishment of plants. Very dry conditions were observed in the beginning of June (9 and 1.6% of the long-term average amount of rainfall in Priekuli and Stende, respectively), middle of July in Priekuli (24% of long-term average) and 1st decade of August (52 and 13%). The mean air temperature in the middle of June was by 2.1–2.3 ºC lower, but in July by 3 ºC higher than in long-term period. High amount of precipitation in the 2nd and 3rd decade of August (270 and 186% of long-term average in Priekuli and Stende, respectively) interfered harvesting and caused lodging and sprouting. In 2004, the dry conditions in April and May hindered plant emergence. In the 2nd and 3rd decade of May, considerable frosts (–5 to –7 ºC) partially damaged the seedlings, nevertheless most of the plants were able to continue the growth. Low temperatures in May promoted tillering, and resulted in sufficient amount of productive tillers. High amount of rainfall was registered at the end of June (245, 366, 232 and 355% of the long-term data in Priekuli, Stende, Vecauce and Skriveri, respectively) and in the middle of August (particularly in Priekuli). The mean air temperature in May, June and July was below the long-term data.

ANOVA (two factor with or without replication) was used for data analysis. The data was analysed as if it was from 6 test sites; the influence of the year was calculated for Stende and Priekuli.

Results and Discussion

The mean grain yield of varieties 'Ruja', 'Malva' and 'Rasa' was significantly higher if compared to the check 'Abava' (P = 95%, Table 2).

Table 2. Grain yield and quality

Variety	Grain yield, t ha^{-1}	TGW, g	Volume weight, g l^{-1}	Crude protein*, %	Starch**, %
Abava	3.71	45.2	678.8	12.8	60.9
Idumeja	3.88	47.0	635.1	12.4	60.5
Sencis	3.70	41.4	678.5	12.7	61.2
Malva	3.95	40.0	666.6	12.6	61.5
Rasa	3.93	40.9	659.7	12.6	61.6
Ruja	4.08	46.7	675.1	12.0	61.9
$LSD_{0.05}$	0.213	1.21	20.51	0.59	1.06
p-value (genotype)	0.004	< 0.0001	0.003	0.14	0.2
p-value (site)	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

* Priekuli, Stende, Vecauce;
** Priekuli, Vecauce.

The mean yield of 'Idumeja' and 'Sencis' did not differ significantly from that of 'Abava'. Variety 'Ruja' was significantly higher yielding than 'Abava' in 3 sites (Stende, 2003; Priekuli and Vecauce, 2004)); only in Skriveri, 2004) it had the lowest yield (difference not significant). None of the varieties had a significantly lower yield than the check except 'Rasa' in Priekuli in 2003 (this was the only case when 'Abava' had the highest yield among the tested varieties, Fig. 2).

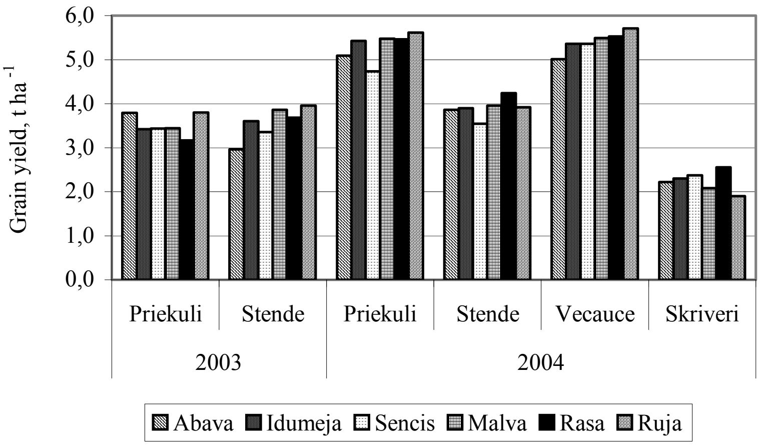

Figure 2. Grain yield of barley varieties

The influence of the genotype on grain yield was significant if data from all test sites was analysed together (p-value = 0.004); it was significant also in all test sites separately (p-value<0.03) except in Vecauce (p-value = 0.17). Test site influenced the yield significantly (p-value<0.0001). The highest yield level was achieved in Vecauce and in Priekuli in 2004 (mean yield – 5.41 and 5.30 t ha^{-1}, respectively), but the lowest yields were in Skriveri (mean – 2.24 t ha^{-1}), which could be caused by very high amount of rainfall in June as well as by lower amount of nitrogen in soil after the previous crop – winter rye. The influence of agrometeorological conditions of the growing year was not significant in Stende (p-value=0.3), but it was highly significant in Priekuli mainly because of the differences in soil characteristics (p-value<0.0001). The reasons for various yield performance of varieties in organic farming may be explained by differences in ability to uptake nitrogen and other fertilizing elements from soil. Variation of the competitive ability with weeds among barley varieties has been stated (Doll, 1997).

The highest mean TGW was estimated for varieties 'Idumeja' (range 40.3–50.2 g) and 'Ruja' (38.7–53.0 g), which significantly surpassed that of 'Abava' (Table 2). None of the varieties exceeded the mean grain volume weight of the check variety 'Abava' (range 612–713 g l^{-1}), but the volume weight of 'Idumeja' (579–679 g l^{-1}) was significantly lower than that. No significant influence of the genotype on the content of crude protein and starch in grain was observed. The mean crude protein content of 'Ruja' was significantly lower than that of 'Abava'. The highest mean starch content was stated for 'Ruja'.

The highest mean seedling emergence was registered for variety 'Sencis' and it was lower for 'Idumeja', but the differences between the varieties were not significant (Table 3). Low emergence (50–64%) was registered in Priekuli in 2004 due to insufficient soil moisture in spring. Emergence can be essential to ensure optimal plant density, which results in the ability of plants to compete with weeds. H. Doll (1997) reported that normal plant density of barley was more important for the competitiveness with weeds than it was for obtaining high grain yield.

Table 3. Some plant growth characteristics and resistance to lodging and diseases

Variety	Field emergence, %*	Plant height, cm	Lodging, 1-9*	Length of vegetation, days*	Loose smut, spikes per m^2	Powdery mildew, 0–4*	Net blotch, 0–4**
Abava	73.8	95	8.3	103	0.204	2.6	2.3
Idumeja	71.4	84	8.6	95	0.093	2.2	2.2
Sencis	81.0	87	7.6	98	2.180	1.2	2.5
Malva	75.5	85	8.2	100	0.076	1.9	2.4
Rasa	79.1	88	8.4	100	0.128	1.8	2.4
Ruja	73.0	90	8.7	103	1.119	3.0	1.8
$LSD_{0.05}$	11.19	4.5	0.69	1.8	1.35	1.00	0.77

* Priekuli, Vecauce, Skriveri;
** Priekuli, Stende.

The duration of vegetation of variety 'Idumeja' was on average 8 days shorter than that of check variety 'Abava', which had the longest growing period together with variety 'Ruja'. Earliness can be a useful trait for organic farming because of rapid development of plants, which can be related to better ability to compete with weeds and use the nutrients from soil, as well as a possibility to harvest the grain earlier and have a longer growing period for following crop (e.g. green manure).

The mean plant height of check variety 'Abava' (range 78–108 cm) significantly surpassed the rest of tested varieties. Shortest plants were registered in Skriveri (mean of all varieties – 69 cm), but the highest plants were in Priekuli (mean – 98 cm). H. Ostergaard and J. W. Jensen (2004) stated that plant height is one of the important characteristics of spring barley for organic farming and it is related to competition ability with weeds. In our study the variety with the highest plants did not prove to be the best yielding one. Lowest mean lodging resistance was observed for variety 'Sencis', the assessments of other varieties did not differ significantly. There were no signs of lodging registered in Skriveri. Lodging is usually not considered a problem in organic farming due to the relatively low amount of nitrogen in soil.

The main seed-borne disease observed in the trials was loose smut. None of the varieties showed complete resistance to loose smut; the lowest infection level was detected for 'Malva' and 'Idumeja' (Fig. 3, Table 3). The most infected variety was 'Sencis', which had infected spikes in all test sites. Considerably high infection was stated also for 'Ruja'. Infection with loose smut for 'Abava' and 'Rasa' was registered only once (Priekuli, 2004). Barley leaf stripe (*Drechslera graminea* Ito) was observed only in Priekuli for varieties 'Malva', 'Abava', and 'Sencis'. Most susceptible was the variety 'Malva' with 1.5 (2003) and 8 (2004) infected plants per plot.

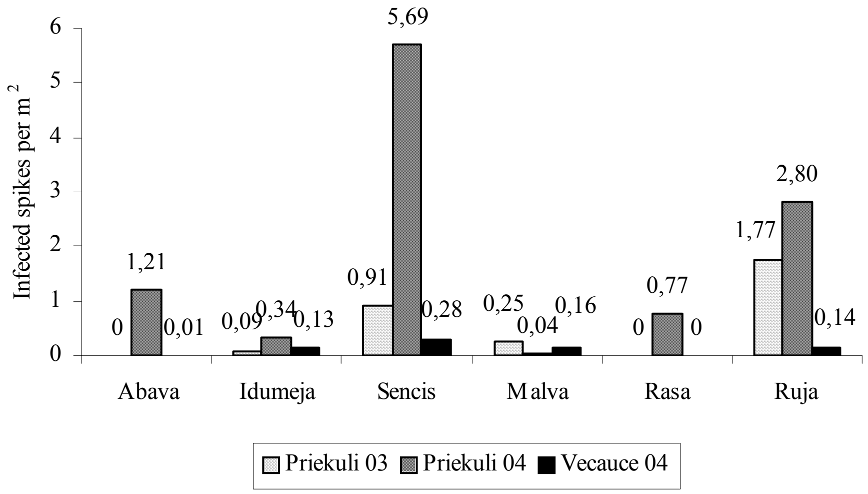

Figure 3. Infection of barley varieties with loose smut in Priekuli and Vecauce

There are no Latvian barley varieties with known resistance genes against loose smut registered, but some of them (e.g. 'Abava' and 'Idumeja') flower with closed flowers, and the infection level is usually low. Variety 'Ofir', which is resistant to loose smut, is included in the pedigree of 'Malva' (Belicka, 2001). Since 'Idumeja' flowers comparatively early, it is possible that there are less sources of infection available at that time and it is a reason for better resistance. In the case 'Ruja' is chosen for growing in organic farming (due to its good yield potential), it is necessary for seed production to treat the seed against loose smut. Seed pre-treatment with warm water followed by hot water treatment was reported to have 98–99% efficiency in loose smut control (Nielsen *et al.*, 2000), but this method might be not economical. Other possibility to reduce loose smut infection is by seed separation and use of only largest fraction for sowing (Borgen, 2004).

The highest mean infection level with powdery mildew was recorded for 'Ruja' (range 2–3.6 points). Significantly lower infection was found for 'Sencis'. The infection with net blotch was medium high and did not significantly differ in between the varieties.

Conclusions

No one of the tested varieties was ideally suited for organic farming, but several of them can be recommended to organic farmers as most appropriate for growing in organic conditions.

The positive traits of 'Idumeja' were earliness, low infection with loose smut and high TGW, but the yield level was medium and volume weight low. 'Malva' was comparatively resistant to loose smut and good yielding, but infection with leaf stripe was registered. The best yielding variety was 'Ruja', but seed treatment against loose smut in seed production is required. 'Rasa' is good yielding, but infection with loose smut is possible. 'Abava' had the highest plants, but the yield was comparatively low. 'Sencis' can not be recommended for organic farming due to high infection with loose smut and low yield.

Acknowledgements

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References

1. Borgen A. (2004) Strategies for regulation of seed borne diseases in organic farming. Seed Testing International, 127, 19–21.
2. Belicka I. (2001) Origin and characteristics of spring barley 'Malva'. Proceedings in Agronomy, 3, 209–214 (In Latvian, abstract in English).
3. Doll H. (1997) The ability of barley to compete with weeds. Biological Agriculture and Horticulture, 14, 43–51
4. Nielsen B. J., Borgens A., Kristensen L. (2000) Control of seed borne diseases in production of organic cereals. In: Pest and Diseases. Proceedings of The Brighton Conference 2000, 171–176.
5. Ostergaard H., Jensen J.W. (2004) Characteristics of spring barley varieties for organic farming. In: Vollmann J., Grausgruber H., Ruckenbauer P. (eds.) Genetic variation for plant breeding. Proceedings of the 17th EUCARPIA General Congress, BOKU, Vienna, Austria, 483.
6. Programme for development of organic farming in Latvia. 2003–2006 (2003). (in Latvian) Ministry of Agriculture of Republic of Latvia. Riga, Latvia, 25.

THE LONG TERM IFLUENCE OF ORGANIC FARMING ON SOIL AGROCHEMICAL CHARACTERISTICS AND NPK BALANCE

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Abstract

In the period of 1997–2001, the long-term influence of organic farming on NPK balance was investigated in two different crop rotations on an organic farm of the Agroecological centre of the Lithuanian University of Agriculture. The predominating soil was *Endohypogleyi-Eutric Planosols – Ple-gnl-w* medium clay loam. The investigations were carried out in phosphorus, potassium and humus rich soils that were close to neutral or neutral. The following two crop rotations were applied on Kazliskiai farm of organic production: crop rotation I – winter wheat, spring crops + under crop, perennial grasses of the first year, perennial grasses of the second year (fertilised with manure); crop rotation II – winter wheat, spring cereals, leguminous cereals for seed and for green manure, spring crops + under crop, perennial grasses of the first year, perennial grasses of the second year (no manure). Under the long term influence of organic farming, the amounts of humus and organic carbon, mobile phosphorus and potassium decreased in both crop rotations, but organic farming did not influence the soil pH. Calculation of NPK balances in the fields of crop rotations I and II on Kazliskiai organic farm in the period of 1997–2001 established negative NPK balances. A comparatively large amount of nitrogen was removed together with plant production in the field of crop rotation I fertilised with manure. Large amounts of phosphorus and potassium was removed from the soil in the field of crop rotation II where leguminous plants had been grown and no manure had been introduced.

Key words: nitrogen, phosphorus, potassium, balances, organic farming

Introduction

Large amounts of nutrients are removed from the field with the yield, and the lack of nutrients has to be compensated to protect the soil from exhaustion. Otherwise, the amount of main nutrients in the soil decreases. The maintaining of soil productivity and positive balance of humus on organic farms are the key elements of farming. The humus level decreases due to insufficient amount of organic and mineral fertilizers, growing of small amount of perennial grasses, and resowing of cereals year after year in the same plot. Application of a proper amount of fertilisers and growing perennial grasses increase the amount of humus and improves its composition. Crop rotation in organic farms has to be designed to support soil productivity, to maintain positive balance of plant nutrients, to decrease the number of weeds, spread of pests and diseases, and to prevent erosion. Legumes have to be included into the crop rotation. Positive balance of phosphorus and potassium as well as optimal soil reaction has to be assured. The applied farming systems impact the plant supply with nutrients (Bagdonienė, 1997; Granstedt, 1995; Janušienė, 1995; Mažvila, *et al.*, 1992).

The specialists of the Lithuanian Institute of Agriculture have estimated that on average 3.2% of humus is decomposed annually. Data of investigations shows that balance of humus is negative when humus amount in soil is larger than 3%, as the amount of demineralised humus exceeds that produced from plant residues. The increase of humus quality very much depends on rational use of organic and mineral fertilisers. It is supposed that a proper use of organic fertilisers stipulates sufficient amount of organic matter in the soil, increasing the amount of humus and enrichment of its composition (Niggli *et al.*, 1995; Niggli *et al.*, 1999).

Investigations, conducted in England, Holland, the USA and Switzerland, show that on mixed organic farms losses of nitrogen because of leaching decrease in 50–80%, in comparison with that on conventional farms. Meanwhile, the yield on conventional farms is by 50% bigger. The losses of nitrogen in conventional farming system are from 2.2–2.7 to 104 kg ha^{-1}. The medium data from 12 years investigations, carried out in Sweden, shows that the losses of nitrogen in organic farming system reach the level of 5.5 kg ha^{-1} (Oberson *et al.*, 1993; Pekarskas *et al.*, 1999).

The results of the investigations, conducted in Switzerland, show that in the case when organic farming system is applied, the amounts of mobile phosphorus and potassium are smaller (due to smaller input of phosphorus and potassium) than in conventional farming system, but the amounts of calcium and magnesium are bigger. Meanwhile, the most significant continual change between organic matter and solution of soil is observed in biodynamic farming system. The negative balance of potassium and phosphorus in the organic farming system also is estimated in the investigations in Norway. The reliable decrease of phosphorus and potassium balance has been estimated in the period of transition from conventional to organic farming (Janušienė, 1995; Reisinger, 1998; Švedas, 1992).

Materials and Methods

In the period of 1997–2001, the long-term influence of organic farming on NPK balance was investigated in two different crop rotations on the organic farm of the Agroecological centre of the Lithuanian University of Agriculture. The predominating soil was *Endohypogleyi-Eutric Planosols – Ple-gnl-w* medium clay loam. The investigations were carried out in phosphorus, potassium and humus rich soils that were close to neutral or neutral. Two crop rotations were applied on the organic production farm: crop rotation I (12.28 ha) – 1) winter wheat, 2) spring crops + under crop, 3) perennial grasses of the first year, 4) perennial grasses of the second year (fertilised with manure); crop rotation II (12.72) – 1) winter wheat, 2) spring cereals, 3) leguminous cereals for seed and for green manure, 4) spring crops + under crop, 5) perennial grasses of the first year, 6) perennial grasses of the second year (no manure).

Seven stable grounds of 100 (10×10) m^2, divided into 25 m^2 plots, were arranged for investigations of the impact of organic farming system on the soil characteristics. The soil samples were taken from a 20 cm depth from all four 25 m^2 grounds after the vegetation of plants at the beginning of September.

The amount of mobile phosphorus, potassium, calcium and magnesium were estimated by the method of Egnerio-Rimo-Domingo (A-L), organic carbon-dry burning according to the amount of CO_2 gas – by the Cherey apparatus, soil pH – in 1 N KCl extract. In crop rotation I, plants were fertilised with 40 t ha^{-1} litter manure. In crop rotation II, plants did not receive any fertilisers. No other mineral and organic fertilisers or pesticides were applied.

Results

The field of crop rotation I produced 5.6-8.8 t ha^{-1} of perennial grasses, 4.6 t ha^{-1} of winter wheat grain and 4.01 t ha^{-1} of straw, 2.8 t ha^{-1} of spring barley grain and 2.2 t ha^{-1} of straw. The field of crop rotation II produced 4.06 t ha^{-1} of perennial grasses hey, 3.06–3.45 t ha^{-1} of spring barley grain and 2.7–3.0 t ha^{-1} of straw, 1.83 t ha^{-1} of vetch and oat mixture grain and 1.2 t ha^{-1} of straw, 3.9 t ha^{-1} of oats grain and 3.3 t ha^{-1} of straw. The lowest yield was in 1999 due to unfavourable weather conditions in the beginning of plant vegetation.

Table 1. Crops and their yields on Kazliskiai organic farm

Year	Crop rotation I (fertilized with manure)	Crop rotation II (fertilized with legume crops)
1997	Perennial grasses, 3rd year of use, yield – 5.6 t ha^{-1} of hay	Spring oats, yield – 3.9 t ha^{-1} of grain and 3.3 t ha^{-1} of straw
1998	Winter wheat, yield – 4.6 t ha^{-1} of grain and 4.0 t ha^{-1} of straw	Spring barley, yield – 3.45 t ha^{-1} of grain and 3.0 t ha^{-1} of straw
1999	Spring barley, yield – 2.8 t ha^{-1} of grain and 2.2 t ha^{-1} of straw	Vetch + oat mixture for grain, yield – 1.83 t ha^{-1} of grain and 1.20 t ha^{-1} of straw
2000	Perennial grasses, 1st year of use, 4.4 t ha^{-1} of hay, 3.5 t ha^{-1} of after crop	Spring barley, yield – 3. 06 t ha^{-1} of grain and 2.70 t ha^{-1} of straw
2001	Perennial grasses, 2nd year of use, 6.4 t ha^{-1} of hay	Perennial grasses, 1st year of use, yield – 4.06 t ha^{-1} of hay

In the field of crop rotation I, 159.98 kg ha^{-1} of nitrogen, 39.99 kg ha^{-1} of phosphorus and 192.04 kg ha^{-1} of potassium were introduced with organic fertilisers. In crop rotation II, legumes fixated 70.0 kg ha^{-1} of nitrogen. In the period of 1997–2001, in crop rotation I, plants with the yield took 563.78 kg ha^{-1} of nitrogen, 71.59 kg ha^{-1} of phosphorus, and 466.64 kg ha^{-1} of potassium. In crop rotation II, plants removed the following amounts of nutrients: 441.0 kg ha^{-1} of nitrogen, 65.32 kg ha^{-1} of phosphorus and 340.24 kg ha^{-1} of potassium. The largest amount of nutrients was removed from the field of crop rotation I, where organic fertilisers had been applied. The plants grown, as well as higher fertility of the field soils and bigger yields, influenced by application of manure, had impact on the nutrient output. The NPK balance was negative in both crop rotations. A marked negative balance of nitrogen was estimated in the field of crop rotation I, that of phosphorus and potassium – in the field of crop rotation II. Single application of 40 t ha^{-1} of litter manure did not ensure a positive balance of NPK. It is impossible to ensure a positive NPK balance only by growing legumes without application of organic and mineral fertilisers (Table 2).

Investigations of the influence of organic farming on soil agrochemical characteristics determined decrease of organic carbon (0.22–0.25 percent units), mobile phosphorus (16.5–37.1 mg kg^{-1}), mobile potassium (44.0–47.3 mg kg^{-1}), and calcium (120.0–240.0 mg kg^{-1}) in the soil of the organic farm. The amount of magnesium increased by 42 mg kg^{-1} in crop rotation I and decreased by 34 mg kg^{-1} in crop rotation II. The change in soil pH was insignificant and was influenced by the removal of nutrients output with the yield and application of organic fertilisers (Table 3).

Table 2. The economical balance of NPK on the organic farm of Agroecological centre, 1997–2001

	Crop rotation I			Crop rotation II		
	N	P	K	N	P	K
Applied with organic fertilisers and fixated atmospheric nitrogen, kg ha^{-1}	159.98	39.99	192.04	70.0	–	–
Accumulated in the yield, kg ha^{-1}	563.78	71.59	466.64	441.0	65.32	340.24
Balance ± kg ha^{-1}	–403.8	–31.6	–274.6	–371.0	–63.52	–340.24

Table 3. The impact of the organic farming system on soil agrochemical characteristics on the organic farm of Agroecological centre, LUA, 1999–2001

Parameter	1997	2001	Difference 2001–1997
Crop rotation I			
Organic carbon %	1.64±0.06	1.42±0.06	–0.22
P_2O_5, mg kg^{-1}	231.4±18.67	214.9±17.47	–16.5
K_2O, mg kg^{-1}	217.0±19.0	172.6±15.28	–44.0
Ca, mg kg^{-1}	3522.0±142.2	3402.0±204.6	–120.0
Mg, mg kg^{-1}	420.0±23.6	462.0±0.06	+42.0
pH_{KCl}	6.6±0.13	6.7±0.21	+0.10
Crop rotation II			
Organic carbon, %	1.47±0.05	1.22±0.06	–0.25
P_2O_5, mg kg^{-1}	145.4±9.78	108.3±2.33	–37.1
K_2O, mg kg^{-1}	155.1±4.07	107.8±3.64	–47.3
Ca, mg kg^{-1}	4918.0±402.2	4678.0±374.2	–240.0
Mg, mg kg^{-1}	563.0±50.3	529.0±38.0	–34.0
pH_{KCl}	7.2±0.16	7.0±0.20	–0.20

Conclusions

Organic farming influenced decrease in the amount of organic carbon (0.22–0.25 percent units), mobile phosphorus (16.5–37.1 mg kg^{-1}), mobile potassium (44.0–47.3 mg kg^{-1}), and calcium (120.0– 240.0 mg kg^{-1}). The amount of magnesium increased by 42 mg kg^{-1} in crop rotation I and decreased by 34 mg kg^{-1} in crop rotation II. The cange in soil pH was insignificant.

The NPK balance was negative in both crop rotations. A marked negative balance of nitrogen was estimated in the field of crop rotation I, that of phosphorus and potassium – in the field of crop rotation II.

Single application of 40 t ha^{-1} of litter manure did not ensure a positive balance of NPK. It is impossible to ensure a positive NPK balance only by growing legumes without application of organic and mineral fertilisers.

References

1. Bagdonienė V. (1997) Sėjomainos augalų derliaus, jo kokybės bei dirvožemio agrocheminių savybių kitimas sunkios granuliometrinės sudėties dirvoje biologinės ir chemizuotos žemdirbystės sąlygomis. Žemdirbystė, 58, 36–48.
2. Granstedt A. (1995) Studies of the flow, supply and losies of nirtogen and other nutrient in conventional and ecological systems in Sweden. Biological Agriculture & Horticulture, 51–67.
3. Janušienė V. (1995) Biologinė medžiagų apykaita natūraliose ir kultūrinėse biocenozėse. Žemdirbystė, 49, 59–67.
4. Mažvila J., Vaišvila Z. *et al.* (1992) Ilgalaikio tręšimo mineralinėmis trąšomis įtaka derliui, dirvožemio agrocheminėms savybėms, maisto medžiagų išplovimui. Antropogeninių veiksnių įtaka dirvožemio derlingumui, Vilnius, 52–57.
5. Niggli U., Alföldi T. *et al.* (1995) DOK – Versuch: vergleichende Langzeituntersuchungen in der drei Anbausystemen biologisch – Dynamisch, Organisch – biologich und Konvertionel. VI. Synthese, 1 und 2. Fruchtfolgeperiode. Schweizerische Landwirtschaftliche Forschung, Sonderhelft DOK, 4, 1–34.
6. Niggli U., Fließbach A., Mäder P. (1999) Yield of grass clover crop rotation and soil fertility in organic and conventional farning systems. On the way to Europe with organic products, 92–102.
7. Oberson A., Fardeau J.C. *et al.* (1993) Soil phosphorus dynamics in cropping systems managed according to conventional and biological agricultural methods. Biology and Fertility of Soils, 16, 111–117.
8. Pekarskas J., Kučinskas J. *et al.* (1999) Tręšimo problemos ir jų sprendimo būdai Lietuvos ekologiniuose ūkiuose. Su ekologiškais produktais į Europą, Kaunas, 78–91.
9. Riesinger P. (1998) Efficient and sustainable Agriculture. Master's Thesis. – Sweden, SLU, 200.
10. Švedas A. (1992) Miežių auginimo technologijų dirvožemio humuso ir azoto kiekio dinamikai. Antropogeninių veiksnių įtaka dirvožemio derlingumui, Vilnius., 1992, 68–71.

EVALUATION OF POTATO VARIETIES FOR ORGANIC FARMING

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Abstract
The suitability of potato varieties for organic farming was evaluated in certificated organic fields. Two medium early varieties ('Sante', 'Lenora') and four medium late varieties ('Brasla', 'Bete', 'Zile', 'Magdalena') were estimated during two years. The tests were carried out in three trial places: Priekuli, Vecauce, Skrīveri. The influence of growing conditions and variety were significant on potato tuber yield. The yields of medium early varieties mostly did not differ significantly in each place both years. The highest average yield between medium late varieties was observed for variety 'Bete'. Leaf resistance of medium early variety 'Lenora' to late blight (*Phythophthora infestans* (Mont.) de Bary) exceeded resistance of the variety 'Sante'. Medium late varieties 'Bete' and 'Zile' had comparatively high resistance to late blight. The starch content of variety 'Brasla' was more than 15% (acceptable for starch production) in each place both years. The comparatively less common scab (*Streptomyces scabies* (Thaxter) Waksman and Henrici) damages were observed on tubers of variety 'Lenora', and black scurf (*Rhizoctonia solani* Kuhn) blemishes – on variety 'Sante' tubers. The most suitable for organic farming were varieties 'Lenora' and 'Zile', but for specific utilisation purposes (starch production or cookery) 'Sante', 'Brasla' and 'Bete' were acceptable.

Key words: potato, organic farming, variety

Introduction

The organic agriculture in Latvia as in other European countries is developing quite fast in the last years. The area of certified land for organic farming was 48 000 ha in 2004. Farmers – producers of organic products – look for productive crop varieties, suited to their local climatic and soil conditions and that are not susceptible to disease and pest attack. Actually, organic agriculture standards recommend the cultivation of site-adapted crop varieties (El Hage Scialabba and Hattam, 2002). Before producing commercial potato seed for organic farmers, the most suitable varieties have to be chosen (Bonnel, 2004; Koppel, 2001). The organic farming growing conditions requires adaptability and stability of potato varieties (Haase *et al.*, 2002). The most important traits for suitable variety in organic farming are: stronger rooting system, quicker haulm development, stability of yielding, stable and high starch content, durable resistance to main diseases (Haase *et al.*, 2002; Koppel, 2001). Mostly the acceptable characteristics are found in the older native cultivars (El Hage Scialabba and Hattam, 2002). Several experiments suggest that modern varieties are well-adapted to harsh environment and present a good level of disease resistance, frequently higher than the one of old varieties and landraces (Le Buanec, 2004). The recent varieties are more acceptable to consumer's demands than the old ones.

The aim of the research was to evaluate suitability of potato varieties to organic farming.

Materials and Methods

The suitability of potato varieties for organic farming was evaluated in certificated organic fields during 2003 and 2004. The growing methods were used according to regulations of organic agriculture settled by the Latvian Council of Ministers.

Tested varieties are described in Table 1. All tested varieties are resistant to nematodes (*Globodera rostochiensis*). All varieties are suitable for market, variety 'Brasla' is used for starch production, too. The used seed material corresponded to basic seed potato quality requirements.

The traits were estimated according to the State Plant Protection Service methodology for evaluation of economical characteristics. The main stress was put on yield, starch content, and resistance to main diseases.

Table 1. The characteristics of tested potato varieties

No.	Variety	Maturity	Country of origin	Year of realization
1.	Sante	Medium early	The Netherlands	1981
2.	Lenora	Medium early	Latvia	1995
3.	Brasla	Medium late	Latvia	1990
4.	Bete	Medium late	Latvia	1994
5.	Zile	Medium late	Latvia	1984
6.	Magdalena	Medium late	Latvia	2001

The tests were carried out in three trial places: Priekuli, Vecauce and Skrīveri. Mostly the soil characteristics were acceptable for potato growing in every trial place (Table 2). Available for plants potassium and phosphorus in the soil in Vecauce was lower than in other places. The soil texture in Priekuli was lighter than in other places. Oil rape as green manure was used in two sites thus improving growing conditions for plants. The difference between trial sites influenced the results and made possible to access varieties in varied growing conditions.

Table 2. The characteristics of soil in trial places in 2003 and 2004

Place	Priekuli		Vecauce		Skrīveri	
Year	2003	2004	2003	2004	2003	2004
Soil characteristics:						
pH_{KCl}	6.4	6.1	6.8	7.1	6.7	6.4
humus g kg^{-1}	21	30	32	19	33	36
P, mg kg^{-1}	64	78	40	34	71	65
K, mg kg^{-1}	149	107	66	71	106	124
texture	sandy loam	sandy loam	loam	loam	loam	loam
Pre-crop	oil rape – green manure	winter rye	oat	oil rape – green manure	winter rye	oat

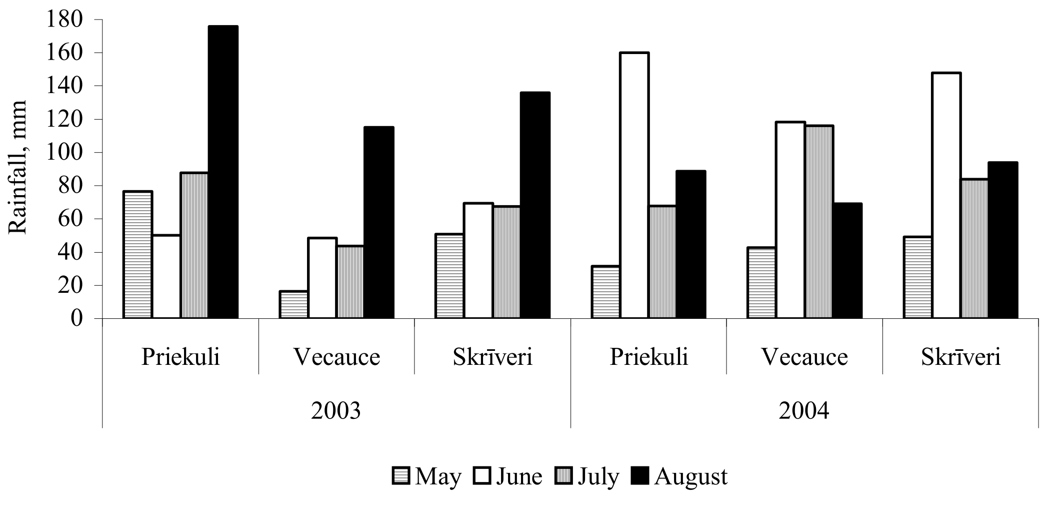

Figure 1. The rainfall in trial places during the 2003 and 2004 growing periods

The weather conditions were different from place to place every year. The average day temperatures did not differ essentially between trial places each year, but temperature in 2004 during the growing period was lower than in 2003, except for August. The average daily temperature in May, June, and July during 2003 was 12.2 ^{o}C, 14.1 ^{o}C and 19.7 ^{o}C, respectively. During the same months in 2004, the average daily temperature was from 0.6 ^{o}C to 3.3 ^{o}C lower – 10.3 ^{o}C, 13.4 ^{o}C, and 16.4 ^{o}C, respectively, which influenced potato growing. The development of plants in 2004 was slower than in 2003. Only August in 2004 was wormer than the same month in the previous year; the average daily temperature in August was 15.8 ^{o}C in 2003 and 17.5 ^{o}C in 2004.

The rainfall was different in every trial place each year (Fig. 1). The least rainfall was observed in Vecauce in 2003, comparatively, the rainfall in Priekuli was twice as in Vecauce in July 2003. The quite high rainfall in August made harvesting difficult during 2003. The high rainfall and low temperature during May in Priekuli made favourable conditions for disease development at the beginning of the growing period in 2004. The quite high rainfall during June and the heavy soil texture in Skrīveri resulted in an extremely high soil humidity that dwarfed plant development in 2004.

Results

The influence of variety and growing conditions on potato yield was significant in both years ($p<0.01$, except for variety influence in 2004 – $p=0.03$). It proves the necessity for a proper choice of the variety and the growing place, but does not deny the significance of weather conditions.

The growing conditions in 2004, mainly weather conditions, were not so favourable as in the previous year. The average potato yield was 19.6 t ha^{-1} in 2004 (comparatively in 2003 – 26.1 t ha^{-1}). Comparing the trial places in 2003, the highest potato yield was obtained in Priekuli, but the lowest in Skrīveri (Table 3). The difference of potato yields between growing places in 2004 was significant and high, the average yield in Skrīveri was about two times less than in other places. The comparatively forceful rainstorm during June made loam soil very wet and heavy that was unfavourable for potato plant development in Skrīveri.

Table 3. The yield of potato varieties, t ha^{-1}, in trial places during 2003 and 2004

Variety	2003			2004		
	Priekuli	Vecauce	Skrīveri	Priekuli	Vecauce	Skrīveri
Bete	31.7	34.3	30.1	20.8	23.8	11.6
Brasla	30.7	27.8	24.2	21.4	29.8	10.1
Lenora	29.0	24.2	20.3	23.5	29.9	10.2
Sante	23.5	27.3	19.9	23.5	34.8	7.8
Zile	31.7	22.8	22.4	21.4	22.7	12.0
Magdalena	25.3	23.1	20.8	18.9	25.9	11.4
Mean	*28.6*	*26.6*	*22.9*	*21.6*	*27.8*	*10.5*
	γ_B=1.6, γ_{AB}=3.8			γ_B=1.7, γ_{AB}=4.1		

A – varieties, B – trial places, *p<0.05.*

The average potato yields between varieties differed significantly; the amplitude was from 19.9 to 34.3 t ha^{-1} in 2003 and from 7.8 to 34.8 t ha^{-1} in 2004 (Table 3). The ML variety 'Bete' had the highest yield in each trial place in 2003. The yield of two other ML varieties – 'Brasla' and 'Zile' – exceeded 30 t ha^{-1} in Priekuli. The yield of the same varieties was higher than the yield of ML variety 'Magdalena' and of both ME varieties in Skrīveri, too. But in Vecauce, the yield of ME variety 'Sante' was similar to that of the ML variety 'Brasla'; together with 'Bete' they exceeded other varieties in Vecauce. In 2004, the situation was different. The highest yield was reported for ME varieties in Vecauce, and variety's 'Sante' yield exceeded that of 'Lenora'. The yields of both varieties were similar in Priekuli and exceeded the yield of other varieties. The yield of potato varieties in Skrīveri was extremely low due to unfavourable growing conditions. In general, the highest average yield in both years was observed to ML variety 'Bete' (Fig. 2). There was no significant difference between the average yields of ME varieties 'Lenora' and 'Sante' in each year separately. The yields of varieties 'Brasla' and 'Zile' were not significantly different in each year separately. The lowest average yield in both years was obtained for variety 'Magdalena'.

The influence of potato variety on starch content was significant ($p<0.01$) during the trial. The trial years influenced the potato starch content with 82% maximal probability. The influence of trial site in 2003 was significant with more than 99% probability, but in 2004 – 66% maximal probability. The results proved the importance of variety choice for obtaining an advisable starch yield. The starch content of varieties in Priekuli varied from 10.0 to 16.1% in 2003 and from 9.9 to 17.6% in 2004, the lowest starch content was for variety 'Bete', but the highest for variety 'Brasla' in both years. The variety's 'Zile' starch content was slightly lower than that of the variety 'Brasla' and exceeded 15%, i.e., 15.6 in both years. The starch content of both ME varieties and ML variety 'Magdalena' was medium and varied from 12.2% to 14.2% in Priekuli.

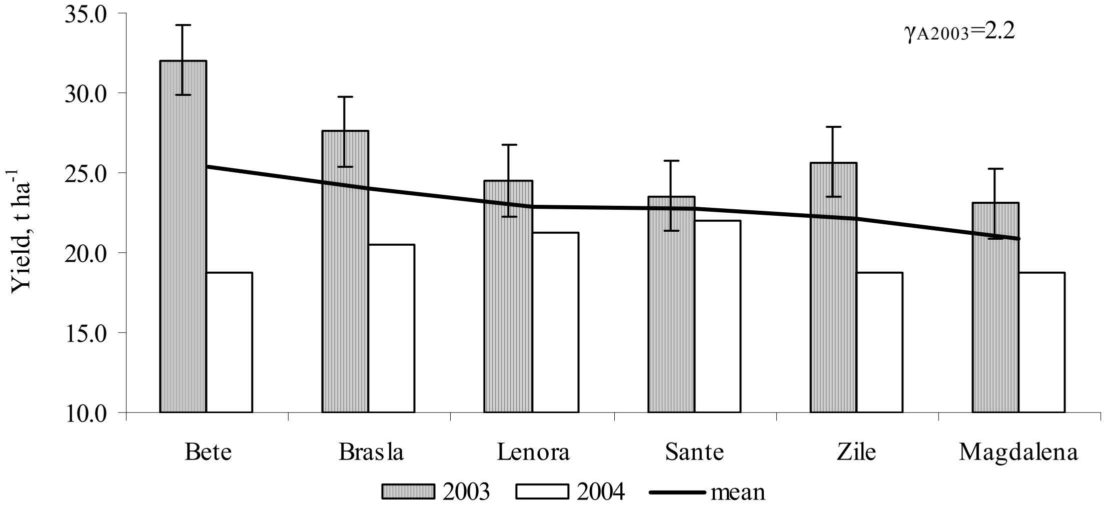

Figure 2. The average yield of potato varieties in 2003 and 2004

The starch content in Skrīveri varied from 11.8 to 16.2% in 2003 and from 10.6 to 16.6% in 2004. The lowest starch content in both years was for variety 'Bete', but highest for varieties 'Lenora' and 'Brasla', respectively. The starch content of ML varieties 'Brasla' and 'Zīle' and ME variety 'Lenora' in both years and of ML variety 'Magdalena' in 2003 exceeded 15%. The variance was between 15.1% and 16.2%. The varieties' starch content in Vecauce was in general higher than in other places – from 11.0 to 18.7% in 2003 and from 10.6 to 18.8% in 2004. As in other places, the lowest starch content was observed for variety 'Bete'. The varieties 'Brasla' and 'Zile', respectively, had the highest starch content in Vecauce, and in both years the starch content of both mentioned varieties exceeded 18%. The starch content of both ME varieties and ML variety 'Magdalena' in 2003 was higher than 15% (15.7–17.8%), but in 2004 it varied between 12.4 and 14.4%. The average starch content of ME varieties in all places did not differ significantly in each trial year (Table 4). The highest starch content from ML varieties was detected for variety 'Brasla' in both years; variety's 'Zile' starch content was lower in both years, but difference was not significant. The variety 'Bete' starch content was the lowest in both years; the difference with other varieties was significant.

Table 4. The average starch content of potato varieties

Variety, maturity (ME –medium early, ML – medium late)	Starch content, %		
	2003	2004	Mean
Brasla (ML)	16.9	17.4	17.2
Zile (ML)	16.4	16.7	16.6
Lenora (ME)	15.9	14.2	15.1
Magdalena (ML)	15.3	13.7	14.5
Sante (ME)	14.3	12.9	13.6
Bete (ML)	10.9	10.4	10.7
$\gamma_{0.05}$	3.6	2.0	3.9

The late blight (*Phythophthora infestans* (Mont.) de Bary) infection on potato leaves was not observed in Vecauce in 2003. Hot and comparatively dry weather during July was unfavourable for late blight development. The observations were not collected in Skrīveri this year. The beginning of late blight infection on potato leaves in Priekuli was observed on July 21, 2003. The first infection spots on leaves were observed on July 2 in Skrīveri and in the second decade of July in Priekuli and Vecauce in 2004. The assessment of varieties resistance in all places was similar (Table 5). Comparing ME varieties, less damage was observed for variety 'Lenora'. Varieties 'Bete' and 'Zile' had less late blight damages on leaves than other ML varieties.

Table 5. The average main disease damages of potato varieties

Disease damage	Year	Varieties						Mean
		Sante	Lenora	Brasla	Zile	Bete	Magdalena	
Late blight, % of damaged leaf area in the middle of epidemiology	2003	93*	65*	85*	52*	32*	87*	–
	2004	97	57	65	22	22	80	–
Black scurf, % of damaged tubers	2003	15	21	13	10	9	38	18
	2004	14	25	25	48	27	41	30
Common scab, % of damaged tubers	2003	25	4	7	15	13	11	13
	2004	21	9	24	20	17	15	18
Late blight, % of damaged tubers	2003	0	0	0	0	0	0	0
	2004	0.5	0.15	0	0.2	0.4	0	0.2
Healthy tubers, % of totally tested	2003	25	43	43	41	35	22	35
	2004	46	52	37	29	43	23	38

* assessment in Priekuli.

Approximately 0–3% of plants of each potato variety were damaged by virus diseases in every trial place both years, except for variety 'Zile' in Vecauce – 23% damaged plants in 2003 and 36% in 2004.

On average, disease damage on tubers in 2003 was observed less than in 2004. Actually, in Vecauce, comparatively less damage of common scab (*Streptomyces scabies* Thaxter Waksman and Henrici was observed in 2004. More durable to black scurf (*Rhizoctonia solani* Kuhn) were both ME varieties and ML variety 'Brasla'. The variety 'Lenora' had less common scab damages than other varieties. Very few damages of late blight on tubers were observed during the investigation. The average amount of healthy tubers was similar in both years; between varieties it varied from 22 to 52%.

Discussion

In organic farming it is important to choose an acceptable variety. It is impossible to avoid the influence of changeable weather conditions on tuber yield. The same variety, ME 'Bete', gave the highest yield in each place in 2003. However, also the yield of ML variety 'Brasla' was close behind, and variety 'Zīle' was successful in two trial places. The reason of the quite low variety's 'Zile' yield in Vecauce could be the comparatively high viruse diseases spread on the plants. The ME varieties were more successful in Priekuli and Vecauce during 2004.

The choice of the variety with acceptable starch content for potato production is very important. The varieties 'Brasla' and 'Zile' had a high and stable starch content and the variety 'Bete' had the lowest starch content each place in both the years. The growing conditions did not influence the range of the varieties' starch content as much as the variety. But the results in Vecauce proved that favourable weather conditions (less rainfall than in other places and, subsequently, more sunny days in 2003) could provide a comparatively higher starch accumulation. The choice of variety depends on potato utilization after harvest: varieties with a high starch content could be used for starch production, catering, market, but varieties with a medium and low starch content – for market and for catering, cooking certain dishes.

The late blight damages on potato leaves depended on variety resistance. The choice of a more resistant variety is acceptable. But the yield of both ME varieties ('Lenora and 'Sante') and medium late variety 'Brasla' was quite acceptable in spite of the high late blight damage on leaves, interrupting plant vegetation. It means that varieties are able to produce tuber yield comparatively fast. ME varieties and varieties producing tubers could be successfully grown in organic fields quite early in spite of susceptibility to late blight. The leave damage substantially influenced plant development, but late blight damage on tubers during the trial years was very small.

The quite large spread of virus diseases in Vecauce on variety's 'Zile' plants could be explained by distribution of virus infection during transporting, planting and ridging. There is no enough data for evaluating resistance of varieties to virus diseases in the current trials, but the spread of virus diseases made us pay attention to the fact. This should be taken into account before choosing 'Zile' for growing.

The disease damage on tubers spoil the tuber quality. The choice of more resistant varieties for organic farming is acceptable. The black scurf and common scab development depended on growing conditions. The quite dry soil in Vecauce could be the reason for a comparatively higher spread of common scab infection in 2003. The use of some agronomical practices could be desirable to avoid damage. The variety 'Lenora' had less disease damage and could be more suitable to obtain good quality tubers in organic farming. The largest average amount of healthy tubers was observed to varieties ‘Lenora’ and ‘Brasla’ in 2003, and to ‘Lenora’ in 2004. The amount of healthy tubers depended on growing conditions; the range of varieties was different in some cases. The amount of variety’s ‘Sante’ healthy tubers in Vecauce in 2004 exceeded other varieties twice (‘Sante’ – 73%, other varieties – from 15 to 49%).

Conclusions

The most suitable for organic farming (acceptable yield, starch content, resistance to late blight) were ME variety ‘Lenora’ and ML variety ‘Zile’, but for specific utilisation purposes (starch production or cookery) ‘Brasla’ and ‘Bete’ were acceptable. However, noted distribution of virus diseases on variety ‘Zile’ and black scurf on variety ‘Bete’ in Vecauce demands very careful attention to seed quality. The yield level of two varieties – medium early variety ‘Sante’ and medium late ‘Brasla’ – was acceptable in spite of sensitivity to late blight; these varieties could be used in organic farming if plant protection activities are done. The least amount of disease damaged tubers was for variety ‘Lenora’.

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References

1. Bonnel E. (2004) Organic potato seed: questions to the future of it. In: Lammerts van Bueren E., Ranganathan R., Sorensen N. (eds) Challenges and opportunities for organic agriculture and the seed industry. Proceedings of the first world conference on organic seed. Knotenpunkt, Hunsruck, Germany, 103–105.
2. El Hage Scialabba N. and Hattam C. (eds) (2002) Organic agriculture, environment and food security FAO, Rome, Italy, 252.
3. Haase T., Schuler C., Kolsch E., Heb J. (2002) The influence of variety, stand density and tuber seed size on yield and grading of potatoes (*Solanum tuberosum* L.) in organic farming. In: Wenzel G. and Wulfert I. (eds) Potatoes today and tomorrow. 15th triennial conference of EAPR. WPR communication GmbH and co KG, Hamburg, Germany, 106.
4. Koppel M. (2001) Selection of potato varieties for organic growing. In: Abstracts of conference papers, EAPR Patology section meeting. Bonin, Poland, 73–74.
5. Le Buanec B. (2004) Plant breeding and diversity in seeds. In: Lammerts van Bueren E., Ranganathan R., Sorensen N. (eds) Challenges and opportunities for organic agriculture and the seed industry. Proceedings of the first world conference on organic seed. Knotenpunkt, Hunsruck, Germany, 51–54.

THE INFLUENCE OF AGROTECHNICAL MEASURES ON THE SPRING BARLEY GRAIN YIELD AND QUALITY IN ORGANIC FARMING

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Abstract

Field trials were carried out on organic farming fields at the Research Institute of Agriculture of the Latvia University of Agriculture (LLU). The influence of pre-crop (red clover, winter rye for grain, bare fallow, bare fallow and green manure), use of stable manure (60 t ha^{-1} or without) and harrowing (without harrowing, before shooting, at the stage of tillering, before shooting, and at the stage of clustering) on the yield of spring barley 'Sencis' were tested during 2003–2004. Depending on the variants the grain yield in the field trial varied from 1.56 to 3.85 t ha^{-1}. Data show that previous plants and stable manure influenced barley grain yields significantly. The highest yields in barley were obtained after red clover. Harrowing increased the yields of barley only after winter rye for green manure by using stable manure, but the time of harrowing had no influence on the yield of barley. The thousand grain weight was medium – 33.5–38.4 g, medium was also volume weight – 609.0–633.5 g l^{-1}. The content of crude protein was satisfactory to good – 96–117 g kg^{-1}.

Key words: spring barley, grain quality, stable manure, harrowing, previous plants, organic farming

Introduction

Organic farming plays a very important socio-economic role in rural areas, bringing new possibilities for the increase of the competitiveness of the agricultural output and relevant operational activities in the rural areas of Latvia. Besides, organic farming is a means of reorganizing agriculture into an environmentally friendly production system and leads to sustainable development of the national economy (Baraskina, 2003).

There are several important factors that influence the growing and development of barley and its quality in the organic farming: deficiency of nutrients and weeds.

Including of crops that are able to fix nitrogen through a symbiotic relationship with nodulating nitrogen-fixing bacteria in the crop rotation enables organic farming systems to be self-sufficient in nitrogen (Younie *et al.*, 1996). Non-leguminous green manure can also be used to help maintain soil fertility, particularly if they maintain ground cover over winter and conserve nitrogen that would otherwise be leached. Crops such as winter rye are often used for this purpose (Thorup-Kristensen, 1993).

Weeds in organic farming require careful management if compared to conventional farming because of less effective control measures. Mechanical weed control has to be combined with crop rotation, crop competitiveness, tillage tactics and others prophylactic measures to obtain satisfactory weed management. So far, research on weed ecology and control in organic farming has been focused on annual weed species (Rasmussen, 1999).

The aim of the field trial was to investigate the influence of different agrotechnical measures: crop rotation, time of harrowing and use of stable manure on the spring barley grain yields and its quality in the organic farming.

Materials and Methods

The three-factorial field trials were carried out on certified organic fields during 2003 and 2004. The factors: factor A – previous plants (red clover, winter rye for grain, bare fallow, bare fallow and green manure), factor B – time of harrowing (without harrowing, before shooting (EC 7, after Zadok), in the stage of clustering (EC 23), before shooting and in the stage of tillering (EC 7 and EC 23)), factor C – use of stable manure (without and stable manure 60 t ha^{-1}). The depth of harrowing – 3 cm, and direction of harrowing – across sowing direction.

The field trials were carried out on turf podsolic soil: pH_{KCl} – 6.75, P_2O_5 – 162 mg kg^{-1}, K_2O – 158 mg kg^{-1}, organic matter content – 32.5 g kg^{-1}, and N_{total} – 1.1 g kg^{-1}. The content of nitrogen was determinated before sowing of barley in spring.

The object of research: spring barley 'Sencis'. Seed rate was 500 germinating seeds per m^2. Before sowing, grains were treated with 1.5 kg of ashes of foliage trees and 1.5 l of water per 100 kg of grain.

Sowing date was 19.05.2003. and 30.04.2004. The number of replications was four, random plot layout, plot size – 42 m^{-2}, and testing plot size – 26.18 m^{-2}. The harvest was done on 11.08.2004. and 10.08.2004.

After previous plant bare fallow + green manure, 15 t ha^{1} (2004) and 17 t ha^{-1} (2003) of biomass of winter rye were incorporated in soil (Table 1). Winter rye was sown in autumn (10.09.2002. and 15.09.2003.) but incorporated in spring at the stage of tillering. In the trial, variants with stable manure (Table 1) were included (60 t ha^{-1}).

Table 1. Characteristics of winter rye biomass and stable manure, 2003–2004

Indices	Winter rye biomass		Stable manure	
	2003	2004	2003	2004
Dry matter, g kg^{-1}	178.3	169.0	169.7	387.7
P_2O_5, mg kg^{-1}	65	60	88	64
K_2O, mg kg^{-1}	302	254	183	97
Nitrates, mg kg^{-1}	1358.10	720.00	611.07	1203.78

Meteorological conditions are given in Figure 1.

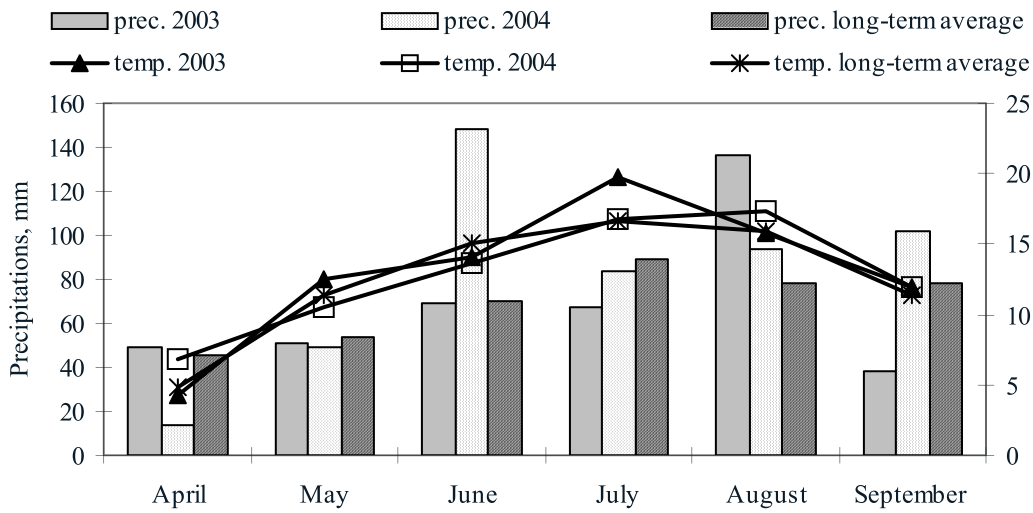

Figure 1. Climatic conditions in Latvia, 2003–2004

Meteorological conditions were different in trial years. In 2003, the sowing time of spring barley was rainy and cold. In May, the air was getting warmer gradually, and barley germinated and established quickly. Very dry conditions were observed at the beginning of June, middle of July, and in the 2nd and 3rd decades of August. The average air temperature in June was 0.7 degrees lower than the long-term average, but the amount of precipitation made only 75% of the norm. July with average air temperature 19 °C was the second warmest middle-summer month during the last 80 years in Latvia.

In April of 2004, the average air temperature was 1.7 degrees higher than the long-term average. The first decade of May was one of the warmest decades during the last 80 years in Latvia and clashed with germinating of barley. The second decade of May was 3.1 degrees but the third decade – 3.6 degrees lower than the norm. In May, the amount of precipitations made 80% of the norm. In June, the average air temperature was 1.3 degrees lower than norm, but the amount of precipitations made 152% of the norm. Very wet conditions were observed in the third decade of June (223% of the norm). As a result, barley established quickly and made dense herbage, which suppressed weeds. In August, the average air temperature was 1.7 degrees higher than the norm. The time of harvest was sunny and did not influence the quality of grain.

Crude protein content was determined by Kjeldahl method. ANOVA (two-factor with replication) was used for data analysis.

Results and Discussion

Depending on the variants, the yields in the field trial varied from 1.56 to 3.85 t ha^{-1} (Fig. 2).

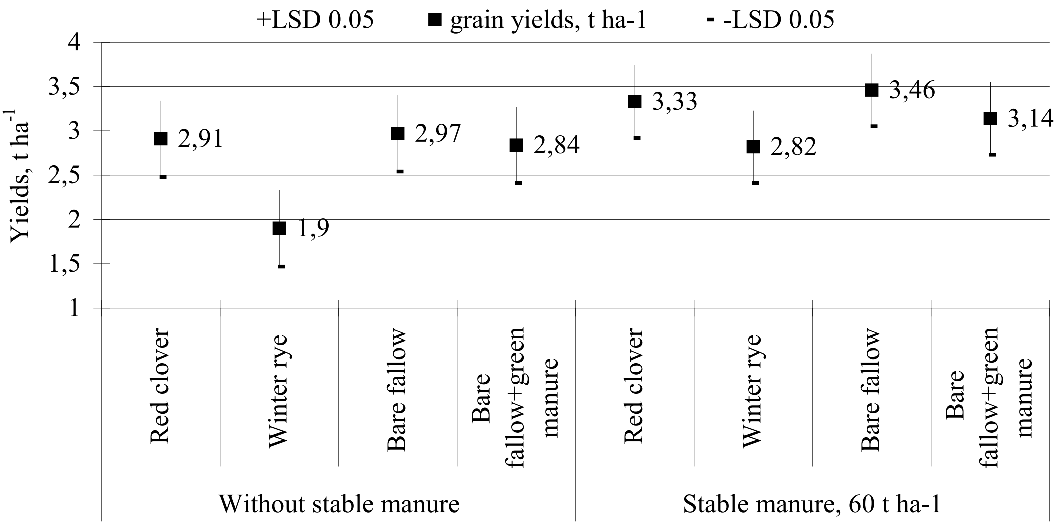

Figure 2. The grain yields of spring barley 'Sencis' during 2003–2004

Two-year trial results (Fig. 2) show that the highest grain yields were obtained after red clover (2.91 t ha^{-1} without use of stable manure and 3.33, t ha^{-1} in variants with stable manure) and bare fallow (2.97 and 3.46 t ha^{-1}).

The influence of previous plants on the spring barley yield was significant (p-value < 0.0001) and differed during the years (p-value < 0.0001, η^2 = 46% in 2003, and 82% in 2004). In 2003, the highest yields were obtained after bare fallow + winter rye for green manure (on average 3.30 t ha^{-1}). The increase in grain yields after winter rye for green manure can be explained by the activity of microorganisms decomposing biomass. The biomass of winter rye contained high amount of nitrates – 1358.10 mg kg^{-1}, which was a sufficient amount of nitrogen for growing and development. In 2004, the grain yield after this pre-plant was significantly lower – only 2.69 t ha^{-1}.

The low grain yield after red clover (only 2.54 t ha^{-1}) can be explained by sparsity and weediness in sowings. There were established perennial weeds Elytrigia repens (L.) Nevski and Sonchus arvense L. The number of those weeds in sowings did not influence the grain yield significantly, but weeds are competitors to nutrients in soil.

The grain yields after bare fallow were high and similar in both testing years – 2.92 (2003) and 3.02 t ha^{-1} (2004) without using stable manure and 3.39–3.53 t ha^{-1} after using stable manure.

Winter rye typically impoverishes the soil. The output of nutrients by spring barley grains is: nitrogen – 1.60 kg, phosphorus – 0.34 kg, and potassium – 0.47 kg per 100 kg of product (Kārkliņš, 2001). An especially low grain yield after winter rye was obtained in 2004 – only 1.56 t ha^{-1}.

Stable manure is a widespread fertilizer in farms with cattle. The influence of stable manure on spring barley yield was significant (p-value < 0.0001). Grain yields increased by 0.47–0.99 t ha^{-1} (2003) and 0.33–0.87 t ha^{-1} (2004) on average. Use of stable manure for barley after winter rye provided the highest yield increase by 0.92 t ha^{-1} on average during 2003–2004. The influence of stable manure (η^2 %) on the formation of grain yield was 40% (2003) and 12% (2004).

In 2003, harrowing increased the grain yields significantly only after winter rye for green manure with stable manure, whereas time of harrowing had no significant influence on the grain yield. In 2004, the influence of harrowing was not significant.

Depending on the variants, the thousand grain weight (TGW) varied from 33.5 to 38.4 g and was medium during 2003-2004. The highest TGW was obtained after red clover and winter rye in both variants, with stable manure and without it. The influence of the use of stable manure (p-value = 0.0004 < 0.05, η^2_C = 33.6%) on TGW was significant. The use of stable manure provided increase in TGM by 1.40 g on average.

The grain volume weight varied from 612.5 to 650.0 g L^{-1}. The influence of previous plants (p-value = 0.03 < 0.05, η^2_A = 12.2%) and the use of stable manure (p-value = 0.04 < 0.05, η^2_C = 7.1%) on the volume weight were significant. The highest volume weight was obtained after red clover and winter rye. The use of stable manure increased the volume weight on average by 6.65 g. The harrowing did not influence significantly neither the grain volume weight nor TGM.

The crude protein varied from 96 to 117 g kg^{-1} and was satisfactory to good for malting quality in 2003. The influence of previous plants (p-value < 0.05, η^2_A = 94%) and use of stable manure (p-value 0.02 < 0.05) on crude protein was significant. The highest increase of crude protein was obtained after red clover (increase of 0.3%) and winter rye (+0.4%). The influence of harrowing on crude protein was not significant (p-value = 0.58).

Table 2. Grain quality of spring barley 'Sencis'

Previous plant (factor A)	Stable manure (factor C)	TGW, g (on average 2003–2004)	Volume weight, g L^{-1} (on average 2003–2004)	Crude protein, g kg^{-1} (2003)
1. Bare fallow	without	34.4	619.3	116
	60 t ha^{-1}	36.0	623.6	117
	on average	35.2	621.4	117
2. Red clover	without	34.8	622.6	96
	60 t ha^{-1}	35.6	632.4	99
	on average	35.2	627.5	98
3. Bare fallow and winter rye for green manure	without	34.5	617.6	115
	60 t ha^{-1}	34.9	619.8	116
	on average	34.7	618.7	116
4. Bare fallow and winter rye for grain	without	34.4	623.3	94
	60 t ha^{-1}	35.8	628.4	98
	on average	35.4	625.9	96
$\gamma_{0.05}$		1.42	9.50	3.5
$\gamma_{0.05}$ A		1.00	6.72	2.5
$\gamma_{0.05}$ C		0.71	4.75	1.8
$\gamma_{0.05}$ AC		1.41	9.50	3.5

Conclusions

The yields in the field trial varied from 1.56 to 3.85 t ha^{-1}. The influence of previous plant and use of stable manure on the spring barley grain yields was significant. Use of stable manure provided increase in yields by 0.99 t ha^{-1} on average. The highest grain yields were obtained for barley after pre-plants: bare fallow and red clover.

The influence of harrowing on spring barley grain yield was significant only in the year 2003, whereas time of harrowing had no significant influence on the grain yield.

The amplitude of crude protein was 96–117 g kg^{-1} and was satisfactory to good for variety 'Sencis' (malting barley) in 2003. The influence of previous plants and use of stable manure on spring barley were significant during 2003–2004. The highest TGW during 2003–2004 and crude protein in 2003 were obtained after red clover and winter rye.

Acknowledgements

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References

1. Kārkliņš A. (2001) Augu barības vielu iznesas kā lauksiamniecības agroekoloģiskais indicators. Agronomijas vēstis, 3, 14–19.
2. Baraškina I. (2003) Economic and Financial conditions of Organic Farm Development in Latvia. In: Economic Science for rural Development. Part II., International Scientific Conference, Latvia University of Agriculture, Jelgava, Latvia, 375–379.
3. Rasmussen I. (1999) Plant Protection in an organic rotation experiment for grain production, In: Design and testing crop rotations for organic farming. Proceedings from an international workshop. Danish Research Centre for Organic Farming, 321–335.
4. Younie D., Watson C. A. *et al.* (1996) A comparison of crop rotations in organic farming: agronomic performance. Aspects of Applied Biology 47, Rotations and Cropping Systems, 379–382.
5. Thorup-Kristensen K. (1993) The effect of nitrogen catch crops on the nitrogen nutrition of a succeeding crop I. Effects through mineralization and pre-emptive competition. Acta Agric. Scand. 43, 74–81.