The results of the polynomial regression demonstrate that the optimal nitrogen fertilizer rates applied in soils with different granulometric contents after various preceding plants were from 45 to 120 kg ha^{-1}.

With economically optimal nitrogen fertilizer rates, all the variants, except the variant after potatoes in sandy loam, provided a crude protein content within the grain above 11.5 %.

The crude protein content within different tipes of grainhe increased, in direct ratio, with the increase of nitrogen rate – up to 200, 250 kg ha^{-1}.

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SLĀPEKĻA MĒSLOJUMA IETEKME UZ VASARAS KVIEŠU GRAUDU RAŽU UN KOPPROTEĪNA SATURU

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Latvijas teritorijā vasaras kviešu lauki gan augsnes auglības gan kultūraugu produktivitātes ziņā ir dažādi. Tādejādi pastāv ieinteresētība lietot dažādas minerālmēslu normas. Šī pētījuma mērķis ir noskaidrot likumsakarības starp graudu ražu, kopproteīna saturu un dažādu slāpekļa normu izmantojot graudu ražas datu regresijas analīzi slāpekļa mēslojuma normas optimizēšanai vasaras kviešiem.

Slāpekļa mēslojuma efektivitātes noteikšanai Skrīveros, Latvijas Lauksaimniecības Universitātes aģentūras Zemkopības Zinātniskā Institūta dažāda granulometriskā sastāva (mālsmilts un smilšmāla) Luvisol tipa augsnēs no 1999. līdz 2001. gadam tika ierīkoti lauka izmēģinājumi ar vasaras kviešiem ‘Munk’ pēc atšķirīgiem priekšaugiem – zālāja, graudaugu un kartupeļiem ar dažādām slāpekļa minerālmēslu normām (0; 50; 100; 150; 200; 250; kg ha^{-1}).

Slāpekļa mēslojums būtiski ietekmēja graudu ražu. Slāpekļa mēslojuma normas palielināšana no 50 līdz 100 un 150 kg ha^{-1} bija būtiska, bet turpmākai slāpekļa normas palielināšanai nebija būtiska. Visi pētītie priekšaugu varianti arī būtiski ietekmēja graudu ražu. Pieaugošs slāpekļa mēslojums lineāri palielināja kopproteīna saturu vasaras kviešu graudos, kas bija atkarīgs no priekšauga un augsnes granulometriskā sastāva.

THE AGRONOMIC AND QUALITY CHARACTERISTICS OF SPRING CEREALS GROWN AT DIFFERENT INPUT LEVELS OF FERTILIZERS AND CHEMICALS

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Abstract

The spring cereals are the most important grains in Estonian farming. The input of fertilizers and chemicals used by farmers for spring cereal production is quite different. Successful farmers prefer high input. They utilize high levels of fertilizers, herbicides, fungicides, insecticides and growth regulators (Ministry of Agriculture, 2008).

The aim of this paper was to investigate the influence of the different levels of fertilizers and chemicals to the agronomic and quality characteristics of spring wheat, barley and oats.

The trial was established with two varieties of each spring cereal at the Jõgeva Plant Breeding Institute during 2006-2007. Two input levels of fertilizers and chemicals (high and low input) were used. Four fertilizer doses, treatment by herbicides and insecticides were carried out in low input level (LI). The same fertilizer rates, treatments by fungicides, insecticides, leaf fertilizers and growth regulator were included in high input level (HI). Unfavourable weather conditions (drought) for cereals were observed. The results of this trial showed that there were significant differences between the agronomic and quality parameters of spring cereals at different input levels. Significant yield decrease and protein content increase was estimated in HI conditions. The plant height of wheat and oat varieties decreased with use of HI. There was no significant influence of the inputs to the length of the growing period in drought conditions.

Key words: spring cereals, fertilizers, chemicals, agronomic and quality characteristics

Introduction

The spring cereals are the most important grains in Estonian farming. In the production of spring cereals farmers are advised to utilize high input of fertilizers and chemicals by sales-companies. Large amounts of chemicals and fertilizers play an important role in environmental pollution (Muurinen *et al*., 2006). Moreover, the high rates of fertilizer, particularly high N rate, prolong the growing period, reduce lodging resistance and susceptibility to diseases and increase the protein content of spring cereals (Forsberg and Reeves, 1995; Araus, 2002). Therefore, it is important to apply the proper amount of chemicals and fertilizers for minimizing the pollution risk.

The aim of this study was to investigate the effect of different input levels of fertilizers and chemicals to grain yield, quality, length of growing period, plant height and the number of productive tillers of spring cereals.

Materials and Methods

The trial was carried out with two wheat (Vinjett, Monsun), barley (Anni, Class) and oat (Villu, Flämingsprofi) varieties at the Jõgeva Plant Breeding Institute on Calcaric (Eutric) Cambisol (FAO classification) soil (clay loam, pH_{KCl} 5.5) in 2006–2007. The trial was established on 9 m^2 plots in three replications. The plots were sown at density of 600 (wheat, oat) and 500 (barley) germinating seeds per m^2. For both inputs 4 levels of fertilization (N0 K0 P0 kg ha^{-1}; N60 P13 K23 kg ha^{-1}; N100 P22 K39 kg ha^{-1}; N140 P31 K54 kg ha^{-1}) were applied. N0 P0 K0 kg ha^{-1} was the control level. The complex fertilizer (containing 18 g kg^{-1} N, 4 g kg^{-1} P and 7 g kg^{-1} K) at the rates of 0, 333, 556, 778 kg ha^{-1} before sowing was used. Two chemical treatments – low (LI) and high input (HI) were utilized.

Low input. Herbicide Lintur 0.12 kg ha^{-1} + MCPA 0.5 l ha^{-1} in stage BBCH 13-14 in 2006 and 2007. Insecticide Danadim 40 EC 1.0 l ha^{-1} in stage BBCH 33-34 in 2006 and Proteus OD 0.6 l ha^{-1} in stage BBCH 13-14 in 2007.

High input. Low input plus:

1.growth regulator Kemira CCC 1.0 l ha^{-1} for wheat and for barley in stage BBCH 21-29 and for oat in stage BBCH 31-32;

2.leaf fertilizer in stage BBCH 21-25 by Folicare (12 g kg^{-1} N, 20 g kg^{-1} P, 7 g kg^{-1} K) 8 kg ha^{-1};

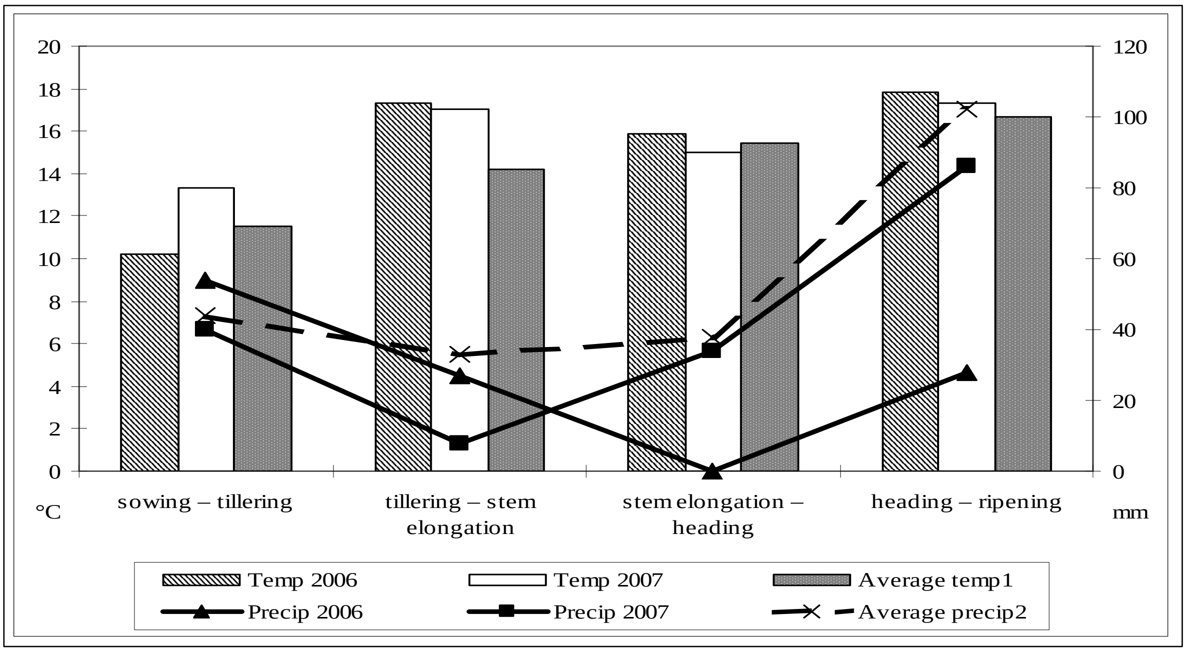
3.leaf fertilizer in stage BBCH 51-56 by Folicare (18 g kg^{-1} N, 8 g kg^{-1} P, 15 g kg^{-1} K) 8 kg ha^{-1};

4.leaf fertilizer in stage BBCH 73-75 by Folicare (10 g kg^{-1} N, 2 g kg^{-1} P, 33 g kg^{-1} K) 8 kg ha^{-1};

5A.fungicide in 2006: Tilt 250 EC 0.5 l ha^{-1} for all cereals in stage BBCH 29-30;

5B.fungicides in 2007: Folicur EW 250 1.0 l ha^{-1} in stage BBCH 13-14 for barley and in stage BBCH 50-51 for oat. Two fungicide applications for wheat: Falcon 0.8 l ha^{-1} in stage BBCH 30-31 and Folicur EW 250 0.6 l ha^{-1} in stage BBCH 45-46.

The weather conditions were unfavourable for spring cereals during the testing years. High air temperature and deficiency of precipitation for spring cereals were observed. The most heavy drought conditions were estimated during the period from stem elongation to heading in 2006 and from tillering to stem elongation in 2007 (Figure 1).



[1] – average of long-term temperature (1922–2005), [2] – average of long-term precipitation (1922–2005)

Figure 1. The average air temperature and precipitation in different growing stages during 2006–2007

The yields of spring cereals were weighed and converted to 860 g kg^{-1} dry matter content. Grain protein content was measured by total nitrogen using the Kjeldahl method (N*6.25). Data was analyzed by factorial analysis of variance using the Agrobase statistics software (Agrobase^{TM}, 1999).

Results and Discussion

The results show that there were significant differences between the agronomic and quality parameters of spring cereals at different input levels.

Factors influencing yield and quality. Grain yield was the influenced most by the fertilizer rate (coefficient of determination 55%) (Table 1). The influence of other factors turned out to be much less. The results of the trial indicated that the number of productive tillers depended primarily on two factors – species (61%) and fertilizer rate (23%). The variation of 1000 kernel weight was influenced equally by the year and species (40 and 44% accordingly). The variation of volume weight almost entirely depended on the species (96%). The husk of the kernels reduced the weight volume weight and this was the reason why wheat volume weight was higher than barley and oat (Halverson and Zeleny 1988; Brouwer and Flood, 1995).

Oats showed the lowest level of this trait. Protein content in the kernels was mostly determined by the fertilizer rate (76%). Wheat had the highest protein content. The length of the growing period was influenced by the species (65%) and by the year (28%). Barley had the shortest growing period (average 91 days) followed by oats (94 days) and wheat (100 days). Variation of plant height was determined mainly by input (29%), fertilizer rate (28%) and species (21%). Oat plants were the longest and barley remained the shortest.

Table 1. Relative importance of factors (coefficients of determination) and their probability[1]

Characteristics of spring cereals	Coefficients of determination %							
	Year	Species	Input	Fertilizer rate	Fertilizer rate x input	Species x year	Species x input	Species x ferti-lizer rate
Yield	–	9***	10***	55***	10***	9***	2**	–
Productive tillers	–	61***	1*	23***	–	7***	–	4**
1000 kernel weight	40***	44***	–	–	–	5*	–	–
Volume weight	1***	96***	1***	–	–	1***	–	–
Protein content	–	6***	8***	76***	–	–	–	–
Growing period	28***	65***	–	–	–	2*	–	–
Plant height	–	21***	29***	28***	3**	5***	8***	–

[1] probability *** P≤0.001; ** 0.001<P≤0.01; * 0.01<P≤0.05

Comparison of inputs. HI had a significant negative effect on the yield of the wheat varieties (Vinjett, Monsun) (Table 2). The differences were -631 kg ha^{-1}and -415 kg ha^{-1}, accordingly. The same effect on barley (Anni difference -596 kg ha^{-1}, Class -448 kg ha^{-1}) (Table 3) and especially on oat (Villu difference -1,088 kg ha^{-1}, Flämingsprofi -1,164 kg ha^{-1}) varieties was observed (Table 4).

Table 2. The average characteristics of wheat varieties at two inputs

Characteristics of wheat	Vinjett			Monsun			$LSD_{0.05}$
	LI[1]	HI[2]	Difference	LI[1]	HI[2]	Difference	
Yield, kg ha^{-1}	3,966	3,335	-631*	3,739	3,324	-415*	270
Productive tillers, pcs m^{-2}	373	358	-15	364	344	-20	22
1000 kernel weight, g	35.7	33,8	-1.9*	41.7	42.8	1.1*	0.9
Volume weight, g l^{-1}	747	695	-52*	727	715	-12*	7
Protein content, g kg^{-1}	134	139	5*	128	136	8*	4
Growing period, days	99	99	0	101	101	0	0.9
Plant height, cm	76.0	48.9	-27.1*	67.5	54.6	-12.9*	2.3

* probability at 0.05; [1] – low input, [2] – high input

HI had no significant effect on the number of the productive tillers of wheat varieties Vinjett and Monsun. A negative influence was found on the barley variety Anni (difference -25 pieces m^{-2}) and the oat variety Villu (difference -32 pieces m^{-2}). Impact of HI on varieties Class (barley) and Flämingsprofi (oat) was not observed.

Table 3. The average characteristics of barley varieties at two inputs

Characteristics of barley	Anni			Class			$LSD_{0.05}$
	LI[1]	HI[2]	Difference	LI[1]	HI[2]	Difference	
Yield kg ha^{-1}	4,085	3,489	-596*	3,520	3,072	-448*	242
Productive tillers pcs m^{-2}	588	563	-25*	534	516	-18	23
1000 kernel weight g	44.4	45.6	1.2*	45.7	46.0	0.3	1.2
Volume weight g l^{-1}	695	689	-6	689	686	-3	8
Protein content g kg^{-1}	119	134	15*	126	131	5*	4
Growing period days	90	90	0	92	92	0	0.3
Plant height cm	57.9	53.8	-4.1	56.9	54.4	-2.5	6.3

* probability at 0.05; [1] – low input, [2] – high input

There was no significant effect of HI to 1000 kernel weight of oats varieties Villu and Flämingsprofi, but affected the wheat varieties (Vinjett, Monsun) and the barley variety Anni. HI decreased grain weight of the variety Vinjett (difference with LI -1.9 g). On the other hand, grain weight of the varieties Monsun and Anni increased (differences 1.1 g and 1.2 g, accordingly).

A decline in the volume weight of the wheat varieties (Vinjett -52 g l^{-1}, Monsun -12 g l^{-1}) and the oat varieties (Villu -23 g l^{-1}, Flämingsprofi -20 g l^{-1}) occurred in HI. There was no significant decrease of volume weight of the barley varieties.
Using HI the increase of the protein content of all the varieties was observed. The differences betweenthe two inputs were for the wheat varieties 5 g kg^{-1} (Vinjett), 8 g kg^{-1} (Monsun), for barley 15 g kg^{-1} (Anni), 5 g kg^{-1} (Class) and for oat 12 g kg^{-1} (Villu), 11 g kg^{-1} (Flämingsprofi).
The length of the growing period of spring cereals was not prolonged because of the use of different inputs.

Table 4. The average characteristics of oat varieties at two inputs

Characteristics of oat	Villu			Flämingsprofi			$LSD_{0.05}$
	LI[1]	HI[2]	Difference	LI[1]	HI[2]	Difference	
Yield, kg ha^{-1}	4,722	3,634	-1,088*	4,931	3,767	-1,164*	265
Productive tillers, pcs m^{-2}	500	468	-32*	552	538	-14	23
1000 kernel weight, g	36.2	35.7	-0.5	38.6	39.1	0.5	1.0
Volume weight, g l^{-1}	516	493	-23*	470	450	-20*	11
Protein content, g kg^{-1}	121	133	12*	116	127	11*	3
Growing period, days	94	94	0	94	94	0	0.3
Plant height, cm	78.7	61.0	-17.7*	77.0	61.3	-15.7*	3.3

* probability at 0.05; [1] – low input, [2] – high input

HI caused a significant decline of the plant height of wheat and oat. The shortening of plant height was considerable for the wheat variety Vinjett (difference -27.1 cm) and the oat variety Villu (difference -17.7 cm). The plant height of the barley varieties had no significant decrease.
Plant development in the both trial years was influenced by drought conditions during the growth stages from tiller emergence to stem elongation (in 2007) and from heading to ripening (in 2006). Therefore, during both testing years the weather conditions affected negatively the yield and the quality of the cereals. This was the reason why the fertilizer rates influenced yield more than the year as a factor. Drought caused a stress-situation in plants and spraying with chemicals caused additional stress. Stress can reduce the duration of the photosynthetic area and that limits the yield of biomass (Araus, 2002). The contribution of assimilates to final grain yield depends on environmental conditions during the grain-filling period (Moral *et al.*, 2002). According to our results, the HI decreased the yield of spring cereals, especially of oat varieties. Nutrient requirements for oats are less than those for wheat or barley, but oat is more sensitive to climatic factors when applying chemicals (Forsberg and Reeves, 1995). The average level of grain yield of the oat varieties turned out to be the highest in the testing years. Wheat and barley are more suitable for soil pH_{KCl} up to 6.0, acidic soil reduces their yield due to less assimilable nitrogen, phosphorus, and other elements of nutrients (Loide, 2006). In our trial soil pH_{KCl} 5.5 was more suitable for oat cultivation.
The number of productive tillers per plant, the grain number per spike and grain weight are important features of cereals in determining the yield potential (Moral *et al.*, 2002). High air temperature with water deficiency can reduce the final number of productive tillers and lead to the mortality of a part of them. On the other hand soil nitrogen supply is one of the most important environmental factors influencing the number of productive tillers (Lersten, 1987; Brouwer and Flood, 1995). By our trial results barley had higher tiller production than wheat and oats. A minor decrease of the productive tillers of oat and barley occurred in HI condition.
Producing high yield and quality spring cereals in middle latitudes demands favourable temperature and moisture conditions (Forsberg and Reeves, 1995). According to Brouwer and Flood (1995) the decrease of grain weight was determined by unfavourable weather conditions. The most important are the environmental conditions during the grain filling period (Simmons, 1987; Moral *et al.*, 2002). Drought during that period decreased grain size in 2006 in our trial. Input as factor did not have a significant impact on grain size. Barley had the biggest 1000 kernel weight.
The volume weight is mostly dependent on kernel size, density and shape. Drought and heavy lodging considerably reduce the volume weight of spring cereals (Halverson and Zeleny, 1988;

Brouwer and Flood, 1995). HI decreased significantly the volume weight of wheat and oat varieties, but did not have a significant effect on barley varieties.
Growth conditions, genotype and the application of fertilizers, especially N-fertilizers, affected the level of protein content. Wheat contained considerably more protein, on average, than other cereals (Orth and Shellenberger, 1988). In this trial HI increased the protein content of all the spring cereals. Leaf fertilization (application of N-fertilizer) during kernel development, according to Halverson and Zeleny (1988), increased the protein content of grains. Higher fertilizer doses in the both HI and LI conditions caused the rise of the protein content of all the crops.
The length of the growing period was influenced mainly by species and year. The spring oat and wheat develope more slowly than barley (White, 1995) and barley had the shortest growing period in the trial. Drought from heading to ripening (2006) decreased the length of the growing period more than early drought from tillering to stem elongation (2007).
Air temperature is one of the major components of the environmental factors affecting the development of cereals (Moral *et al*., 2002). Growth regulators affected the height of cereal plants more than temperature (Simmons, 1987). In this trial HI significantly reduced the height of oat and wheat plants. Barley had the shortest average plant height. HI had no influence on the height of barley plants.

Conclusions

During the drought years HI decreased significantly the grain yield and increased the protein content of spring cereals. There was no significant influence of inputs on the length of growing the estimated period. The plant height of wheat and oat varieties was reduced while using HI. The plant height of barley varieties had no significant decrease. A decline in the volume weight of wheat and oat occurred in HI conditions. HI had no effect on the number of productive tillers of the wheat varieties. The influence to oat and barley was unclear and needs further testing. Significant influence of input to kernel weight of oat was not observed. The effect of HI on barley and wheat depended on the variety.
This study needs to be continued during a longer period to investigate the characteristics of spring cereals cultivated in different input conditions.

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MĒSLOJUMA UN ĶIMIKĀLIJU DEVAS IETEKME UZ VASARĀJU LABĪBU AUGŠANU UN KVALITĀTI

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Vasarāju labības ir visnozīmīgākie graudaugi Igaunijas lauksaimniecībā. Minerālmēslu un ķimikāliju nodrošinājums saimniecībās ir atšķirīgs. Sekmīgie zemnieki dod priekšroku intensīvai audzēšanai, viņi izlieto lielus minerālmēslu, herbicīdu, fungicīdu, insekticīdu un augšanas regulatoru daudzumus (Ministry of Agriculture, 2008).
Pētījuma mērķis bija noteikt dažādu minerālmēslu un ķimikāliju devu ietekmi uz vasaras kviešu, miežu un auzu agronomiskām un kvalitātes īpašībām.
Izmēģinājums tika ierīkots ar katras vasarāju labības divām šķirnēm Jõgevas laukaugu selekcijas institūtā laikā no 2006.-2007. gadam. Tika izmantoti divi minerālmēslu un ķimikāliju foni (augsts un zems). Zemajā fonā (LI) tika pārbaudītas četras minerālmēslu devas, apstrāde ar herbicīdiem un insekticīdiem. Tās pašas minerālmēslu normas, apstrādes ar fungicīdiem, insekticīdiem, kā arī lapu mēslojums un augšanas regulatori tika iekļauti augstajā fonā (HI). Tika novēroti labībām nelabvēlīgi klimatiskie apstākļi (sausums). Izmēģinājuma rezultāti parādīja, ka dažādos minerālmēslu un ķimikāliju fonos starp vasarāju labību agronomiskajiem un kvalitātes rādītājiem atšķirības bija būtiskas. HI apstākļos tika novērots būtisks ražas samazinājums un proteīnu satura pieaugums, kā arī kviešu un auzu šķirņu augu augstuma samazinājums. Sausos apstākļos neizpaudās pārbaudīto fonu ietekme uz augšanas perioda ilgumu.

THE INFLUENCE OF CROP ROTATION AND PLANT-PROTECTION-COMPLEX ON BUCKWHEAT AND POTATIO YIELD

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Abstract
Buckwheat and potato research has been carried out within the long-term crop rotation stationary that was established in 1969 as a part of the Research Institute of Agriculture. The buckwheat proportion within the particular crop rotations went up to 22%, the proportion of potatoes - up to 16%. The highest buckwheat yields were obtained from the buckwheat variants that were cultivated after the winter rye, and within the buckwheat monoculture experimental plots. A considerable yield decrease was observed when cultivating the buckwheat after the potatoes. Weeds in the buckwheat sowings were effectively brought under control by the herbicide Butisane 400 (1,5 l ha^{-1}), applied immediately after sowing.
The highest potato yields were obtained when cultivated after winter rye, as compared to potato monoculture growing. A considerable yield decrease was observed within the crop rotations that contained the buckwheat. Herbicide Titus (50g ha^{-1}) treatment on the potatoes provided an increase of yield up to 17% and, a fourfold dose of fungicides increased the yield up to 37%. In the potato monoculture experimental plots we observed up to 4 times more perennial weeds, moreover – the use of pesticides did not provide the increase of the yield which could be obtained while growing the potatoes in a proper crop rotation.

Key words: crop rotation, monoculture, potatoes, buckwheat, weediness, herbicides.