THE EFFECT OF MINERAL AND ORGANIC FERTILIZERS ON POTATO TUBER YIELD AND QUALITY

Baniuniene A., Zekaite V.
Lithuanian Institute of Agriculture's Perloja Experimental Station, Perloja,Varena dist.,LT-65373.
phone: +37031047624, e-mail: aleb@perloja.lzi.lt

Abstract
Experiments were conducted at the Lithuanian Institute of Agriculture's Perloja Experimental Station during the period 1994-2005. They were designed to estimate the effects of organic and mineral fertilizer combinations on potato tuber yield and quality. The soil of the experimental site is sandy loam *Hapli Albic Luvisol.* In the long-term experiment the tests were done in a four – course crop rotation. Potatoes were grown without and with farmyard manure (40 t ha^{-1}) combined with various mineral fertilization ($N_0P_0K_0$; $N_{90}P_{90}$; $P_{90}K_{120}$; $N_{90}K_{120}$; N_{90} $P_{90}K_{120}$).
The long-term experimental data suggest that farmyard manure (FYM) increased potato tuber yield by 35 - 82 %, depending on fertilizer combinations. Mineral fertilizer efficacy on the background without FYM was by 28 % higher. The highest tuber yield increases (3.8–6.0 t ha^{-1}) were obtained having used fertilizer combinations with nitrogen. These combinations increased tuber yield on both backgrounds by 32-93 %. Potato crops applied with only mineral fertilizers contained higher starch and dry matter contents in tubers compared with those applied with FYM and mineral fertilizers. Fertilizer combinations with potassium tended to reduce starch and the dry matter content in tubers.

Key words: potatoes, starch, dry matter, farmyard manure, mineral fertilizers

Introduction
Organic and mineral fertilization improves light-textured soils' physical properties and water and warmth regime. Systematic fertilization not only increases crop yield but also alters its quality, and results in the higher buildup of nutrients in the yield (Bagdoniene *et al.,* 1998). Crop yield and mineral fertilizer efficacy depend on the contents of available phosphorus, potassium and mineral nitrogen in the soil (Simanaviciene *et al.,* 1996, Shield *et al.,* 1997). It has been found that nutrients present in mineral fertilizers are more effective than the equivalent amount of these nutrients present in farmyard manure (Bagdoniene *et al.,* 1998), therefore mineral fertilizer efficacy for potatoes was noticeably higher than that of organic fertilizer (Antanaitis *et al.,* 2000). Depending on the mineral fertilizer forms, rates and nutrient ratios, the contents of dry matter, starch, protein and other substances may either increase or decrease. Excessive nitrogen fertilization reduces starch, dry matter and sugar contents in tubers and potatoes go bad more rapidly during storage (Simanaviciene *et al.,* 1996). This results from the fact that nitrogen promotes growth of potato vines, and when lasting drought occurs, the vines that have grown the largest, are most dramatically affected and the growing season is extended, therefore by the time of harvesting, tubers may not have been able to mature completely and reach maximal dry matter content, the starch is accumulated less rapidly, and part of it is used for respiration (Amberger *et al.,* 1997). Dry matter content is affected by various factors, among which the most significant are the following ones: tuber maturity, growth character, plant nutrient and water uptake (Haris, 1992). They were designed to estimate the effects of organic and mineral fertilizer combinations on potato tuber yield and quality.

Materials and Methods
The long term tests were done in a four-course crop rotation (1. winter rye, 2. potatoes, 3. spring barley, 4. lupine and oats mixture for green manure). Potatoes were grown with and without farmyard manure (FYM), according to the following mineral fertilization scheme: 1. N_0 P_0K_0 2. $N_{90}P_{90}$ 3.$P_{90}K_{120}$ 4. $N_{90}K_{120}$ 5.N_{90} $P_{90}K_{120}$.
The soil of the experimental site is sandy loam *Hapli Albic Luvisol.* Soil agrochemical characteristics: pH – 4.1-5.7, P_2O_5 - 187-320, K_2O– 193-251 mg kg^{-1}, humus – 1.10-1.34 %.

Potatoes and other crop rotation plants were cultivated following the soil and crop management practices recommended for light soils. Depending on the weather conditions, potatoes were planted at the end of April – first half of May. The tests involved potato cultivars 'Vokė' and 'Goda' planted at a seed rate of 3.5 - 4 t ha^{-1} and replicated four times.
Mineral fertilizers – ammonium nitrate, granulated superphosphate and potassium chloride were spread in spring prior to potato planting and were incorporated into the soil by a harrow. Solid FYM 40 t ha^{-1} was applied in the autumn before ploughing. Chemical plant protection agents were used according to the need against the Colorado beetle and potato late blight. Before harvesting, 5 potato plants per plot were removed for tuber sampling (in total 40 samples). The tubers were tested for starch content (g kg^{-1}) by specific weight Demin method and for dry matter content. Experimental data were processed by ANOVA and correlation-regression analysis methods.

Results and Discussion

The present paper presents the results from the last three rotations (IX (1994-1997), X (1998-2001) and XI (2002-2005). The data averaged over 12 years suggest that potato tuber yield, starch and dry matter contents varied in relation to organic and mineral fertilization and the weather conditions.
Moisture is an important factor when seeking high crop yields in light-textured soils. Comparison of the three rotations indicated that the highest yields were obtained in the XI rotation, when the precipitation amount that fell during the growing season amounted to 392 mm, while the lowest yields were obtained in the IX rotation with a mean precipitation amount of as low as 279 mm. The relationship between the yield and precipitation amount is expressed by the equation: without FYM - $y = 0.0044x + 3.6455$, $r^2 = 0.9578$; with FYM - $y = 0.0073x + 4.9076$, $r^2 = 0.9997$. Mineral fertilizer efficacy for potatoes on the background without FYM was by 28 % higher (Table 1).
Under the effect of these fertilizers potatoes yielded best having used fertilizer mixtures with nitrogen. Higher starch and dry matter contents were identified in potato tubers grown without FYM. Phosphorus did not have any appreciable effect on tuber quality. Mineral fertilizers, especially in combinations with potassium fertilizer, tended to reduce both starch and dry matter content.

Table 1. The effect of mineral and organic fertilizers on potato tuber yield, starch and dry matter contents (Perloja, data averaged over 1994-2005)

Mineral fertilizers	Organic fertilizers							
	Without manure				With manure			
	Rotation							
	IX	X	XI	average	IX	X	XI	average
	Yield t ha^{-1}							
0	5.33	6.76	7.13	6.41	10.30	11.92	12.67	11.63
$N_{90}P_{90}$	9.10	10.88	11.34	10.44	14.85	15.40	17.40	15.88
$P_{90}K_{120}$	7.73	8.07	8.44	8.08	12.05	13.57	14.75	13.46
$N_{90}K_{120}$	7.55	10.44	12.68	10.22	12.48	15.43	18.26	15.39
$N_{90}P_{90}K_{120}$	12.30	12.43	12.48	12.40	15.35	16.32	18.22	16.63
LSD_{05}	*0.83*	*0.63*	*0.91*	*2.24*	*0.94*	*1.06*	*1.23*	*1.44*
	starch content g kg^{-1}							
0	179.5	165.8	165.9	170.4	171.8	147.7	156.1	158.5
$N_{90}P_{90}$	184.5	157.7	161.5	167.9	176.8	144.9	154.1	158.6
$P_{90}K_{120}$	158.0	146.3	146.9	150.4	156.0	137.6	144.3	146.0
$N_{90}K_{120}$	151.8	149.2	144.3	148.4	152.3	130.5	141.0	141.2
$N_{90}P_{90}K_{120}$	163.0	144.1	150.3	152.5	155.3	133.3	145.5	144.7
LSD_{05}	*0.85*	*0.86*	*0.51*	*0.88*	*1.07*	*0.73*	*0.45*	*0.58*
	dry matter g kg^{-1}							
0	242.9	240.8	241.7	241.8	224.6	226.4	218.8	223.3
$N_{90}P_{90}$	247.7	243.7	239.1	243.5	224.8	232.1	219.2	225.4
$P_{90}K_{120}$	209.9	225.9	220.3	218.7	208.3	201.5	210.8	206.9
$N_{90}K_{120}$	207.5	227.0	218.6	217.7	206.1	217.9	218.4	214.1
$N_{90}P_{90}K_{120}$	215.3	225.5	222.3	221.0	210.5	205.1	211.7	209.1
LSD_{05}	*1.00*	*1.80*	*1.53*	*1.08*	*0.79*	*2.35*	*3.28*	*1.11*

It was found that application with FYM and mineral fertilizers gave a tuber yield increase of 61 %, compared with the yield obtained using only mineral fertilizers (Repšiene *et al.,* 2006). Other authors indicate that incorporation of 50 and 60 t ha^{-1} FYM can give a tuber yield increase of 20 and 23 %, respectively (Ciganov *et al.,* 2001, Simanaviciene *et al.,* 2001).
Our experimental evidence shows that depending on the mineral fertilizer combination, FYM increased potato tuber yield by on average 35 - 82 %, compared with potatoes applied with only mineral fertilizers (Fig. 1). The effects of FYM on potato tuber yield is described by the following regression equation y = 0.8634x + 6.3874, r2 = 0.9654. FYM application improves potato growth, development and nutrition conditions, extends nutrient uptake time, which in turn results in a higher tuber yield (Birietiene *et al.*, 1994).

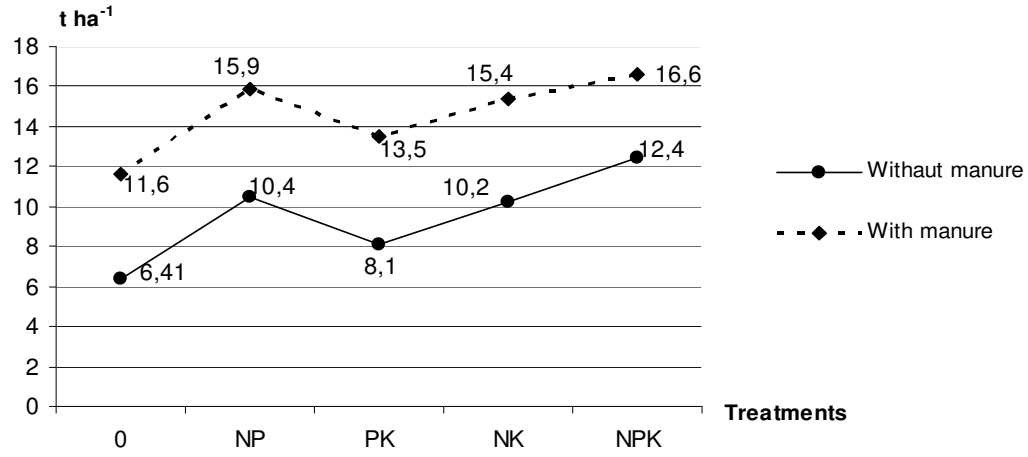

Figure 1. The effect of organic and mineral fertilizers on potato tuber yield, t ha^{-1}.

To produce 20 t ha^{-1} of tuber and 10 t ha^{-1} vine yield, potatoes utilize about 100 kg of nitrogen, 40 kg of P_2O_5 and 180 kg of K_2O from the soil (Simanaviciene *et al.*, 2001). It was determined that in the soils high in phosphorus, phosphorus fertilization did not result in any appreciable tuber yield increase (Mažvila, 1998). Research done in Germany has shown that, taking into account the status of potassium in the soil, potassium fertilizers used may not result in any yield increase, and potassium chloride may reduce starch content in tubers (Pienz, 1999). In our research the most vital element for potatoes was nitrogen. The highest yield increases (3.8-6.0 t ha^{-1}) were obtained using fertilizer combinations with nitrogen (Figure 1). The combination of only PK increased the yield only insignificantly. The highest dry matter and starch contents were accumulated in the tubers of crops fertilized with mineral, not organic fertilizers (Stimumar *et al.*, 1990).
However, other researchers have reported that higher starch contents in tubers accumulate when the crop is fertilized with only FYM or with FYM and low mineral nitrogen and potassium fertilizer rates (Lazauskas *et al.*, 2001).
Our findings suggest that tuber starch content and dry matter directly depended on FYM fertilization. These relationships can be expressed by the following equations: starch - $y = 0.7737x + 2.7637$, $r^2 = 0.9688$, dry matter - $y = 0.5957x + 7.9624$, $r^2 = 0.8643$.
Potatoes applied with only mineral fertilizers had by 4.5 – 11.9 g kg^{-1} higher starch content, by 3.6 – 18.5 g kg^{-1} higher dry matter content compared with the fertilization treatment applied with 40 t ha^{-1} FYM and mineral fertilizers. However, mineral fertilizers, compared with unfertilized treatment, reduced starch content by 1.5 -12.9 and dry matter content by 0.7 – 10.0 percent (Figure2).

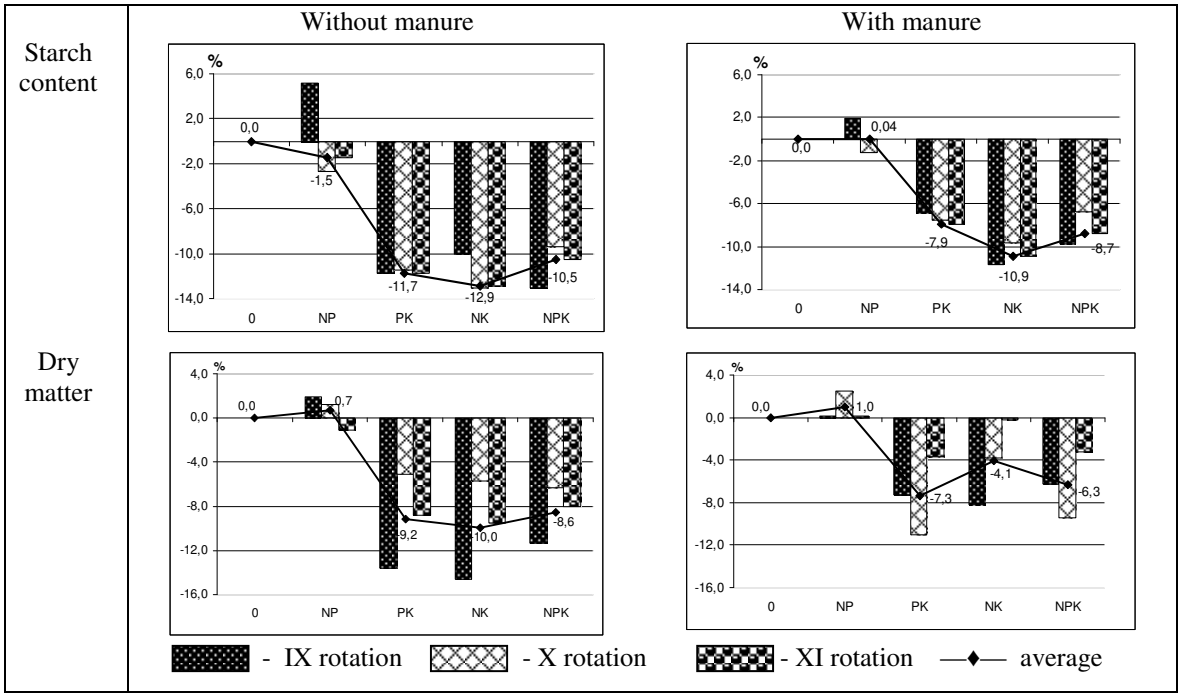

Figure 2. Starch and dry matter variation (percent) in tubers in relation to mineral fertilizer combinations.

To achieve high tuber quality it is recommended to fertilize less with nitrogen and to increase phosphorus and potassium fertilizer rates (Vos, 1999). With the application of moderate potassium fertilizer rates starch content in tubers increases, compared with that in tubers that had received low potassium fertilization. However, with more abundant potassium application the contents of starch and dry matter tend to decline (Pienz, 1999).

Our research evidence shows that potassium fertilizers reduced starch content in tubers by on average 1.3-2.2, and dry matter by 0.9-2.4 percentage units, compared with completely unfertilized or fertilized with only NP tubers (Figure 2). The variations of starch and dry matter contents in potato tubers grown on the background of FYM were lesser than those of potatoes grown without FYM.

Conclusions

Depending on fertilizer combinations, farmyard manure gave a potato tuber yield increase of 38 - 82 %.

Of mineral fertilizers, the most effective were found to be the phosphorus and potassium combinations with nitrogen fertilizer, under the effect of which the yields increased by 32-93 %.

Potatoes fertilized with only mineral fertilizers had higher starch content and the highest dry matter contents, compared with those fertilized with FYM and mineral fertilizers.

Fertilizer combinations with potassium tended to decline starch and dry matter contents in tubers.

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MINERĀLĀ UN ORGANISKĀ MĒSLOJUMA IETEKME UZ KARTUPEĻU BUMBUĻU RAŽU UN KVALITĀTI

Baniuniene A., Zekaite V.

Izmēģinājumi tika veikti Lietuvas Zemkopības institūta Perloja izmēģinājumu stacijā laika periodā no 1994.-2005. gadam. Tie tika plānoti, lai novērtētu organiskā un minerālmēslojuma kombināciju ietekmes uz kartupeļu bumbuļu ražu un kvalitāti. Ilglaicīgais izmēģinājums tika veikts smilšmāla augsnē *Hapli Albic Luvisol* četru-lauku augu sekā. Kartupeļi tika audzēti bez un ar kūtsmēsliem (40 t ha^{-1}) kombinācijā ar dažādu minerālmēslojuma devu ($N_0P_0K_0$; $N_{90}P_{90}$; $P_{90}K_{120}$; $N_{90}K_{120}$; $N_{90}P_{90}K_{120}$).

Dati liecina, ka atkarībā no mēslojuma kombinācijas kūtsmēsli (FYM) palielina kartupeļu bumbuļu ražu par 35 - 82 %. Minerālmēslu iedarbība fonā bez FYM bija līdz 28 % augstāka. Visaugstākie bumbuļu ražas pieaugumi (3.8–6.0 t ha^{-1}) tika iegūti, izmantojot mēslojuma kombinācijas ar slāpekli. Šīs kombinācijas palielināja bumbuļu ražu abos fonos par 32-93 %. Minerālmēslu fonā bumbuļiem bija augstāks cietes un sausnas saturs. Mēslojuma kombinācijas ar kāliju sekmēja cietes un sausnas saturu samazināšanos bumbuļos.

OPTIMIZATION OF ENVIRONMENTALLY FRIENDLY CULTIVATION TECHNOLOGY OF OILSEED RAPE UNDER LATVIA AGROECOLOGICAL CONDITIONS.

Borovko L.

Research Institute of Agriculture of Latvia Univeristy of Agriculture, Zemkopibas institūts 7, Skrīveri , Aizkraukle distr., Latvia, LV-5125, phone + 371 5197639, e-mail: borovko@inbox.lv

Abstract

Field trials were carried out on the soddy-podzolic sandy clay soil of the Research institute of agriculture in Skriveri. The effect of increasing the rates of nitrogen and potassium fertilizers ($N_{60}K_{60}$, $N_{80}K_{80}$, $N_{100}K_{100}$, $N_{120}K_{120}$, $N_{140}K_{140}$) kg ha^{-1} on the spring oilseed rape and quality was tested against the phosphorus background P_{70}. During the trial were tested half rates (0.5 1 ha^{-1}) of the container mixtures of growth regulators and fungicides: Moddus + Folicur, Moddus + Juventus; Cycocel + Folicur, Cycocel + Juventus, by spraying them throughout plant florescence-bud formation. The results of three-year field trials show that the application of nitrogen and potassium