Effect of organic and mineral fertilizers on the yield and quality of different potato varieties

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Abstract. The effect of different fertilizers on potato tuber yield and its quality was investigated at the Elmininkai Research Station of the Lithuanian Institute of Agriculture during 1997-1999. Potatoes of 10 varieties belonging to different maturity groups were grown on plots with different fertilization. The following potato varieties were investigated: the extra early 'Venta' and 'Ukama', the early 'Voke', the medium early 'Mirta' and 'Karolin', the medium late 'Hertha', 'Saturna' and 'Agria', and the late 'Aistes' and 'Speci'.

It was established that different fertilizers, varietal properties and meteorological conditions during the potato vegetation period significantly influenced the yield and quality of different potato varieties. The highest potato tuber yields (20.1–29.6 t ha^{-1}) of all the tested varieties were harvested when one-component and complex mineral fertilizers with microelements had been applied, the lowest (14.6–21.7 t ha^{-1}) when manure (60 t ha^{-1}) had been used in spring. The highest starch and dry matter content had potatoes of the following varieties: the early 'Voke' (up to 16.3% and 22.6%, respectively), the medium early 'Karolin' (up to 15.6% and 21.8%, respectively), the medium late 'Saturna' (up to 17.4% and 23.7%, respectively) and the late 'Speci' (up to 16.3% and 22.6%, respectively). The 1998 vegetation period was the most favourable for potato tuber yield, and the 1997 vegetation period for the accumulation of starch and dry matter. The vegetation period of 1999 was the most unfavourable both for potato tuber yield and the accumulation of starch and dry matter.

Key words: potato, variety, fertilizers, chemical composition

INTRODUCTION

Potato chemical composition is an important factor in potato processing industry (potato chips, fry potatoes, etc.) which has increased in the Baltic countries during the last years. A lot of potato varietes were introduced to Lithuania from abroad. Some of them, grown under Lithuania's climatic conditions, do not meet the requirements of the processors. Very little research work, concerning quality of processing potatoes, has been conducted in Lithuania. This field of research is becoming more urgent in our days.

Potato quality depends on various factors. The most important requirements for potatoes suitable for processing into chips, are the suitability of the variety and good storage quality (Maag & Reust, 1992). Chips, produced from suitable potatoes, must have light, golden yellow colour, without any marks of turning brown (Becius & Masyte, 1974).

Chemical composition of potatoes determines the quality of the final product (Sirtautaite et al., 1996). It benefits from a high starch and dry matter content as well as low reducing sugar content (Hak & Markus, 1990; Pisarev et al., 1978; Rogozinska, 1995; Sirtautaite et al., 1996; Zarova & Kniazev, 1982). Dry matter content influences the yield of the final product. For the production of chips preference is given to potatoes with a dry matter content no less than 20.0–22.0% (Pisarev et al., 1978, Putz, 1995; Zarova & Kniazev, 1982). Dry matter content in potato tubers depends on the environmental conditions and their changes, however, the highest possible amount of dry matter is limited by genetic characteristics of the potato variety. Only matured potato tubers can accumulate a maximum amount of dry matter in optimum growing conditions (Vlasiuk et al., 1979).

Potatoes are plants with a long vegetation period, therefore they assimilate nutrients from organic and mineral fertilizers rather intensively (Simanaviciene et al., 1995). Content of dry matter, starch, proteins, sugar in potato tubers can increase or decrease, depending on the mineral fertilizer forms and rates as well as their correlation. The most important factors in fertilizing potatoes are proper relations between different nutritional elements, since they influence potato vegetation period and maturity stage of potato tubers (Zarova & Kniazev, 1982).

In this article we are trying to evaluate the effect of different fertilizers on the yield and quality of different potato varieties registered in Lithuania, suitable for processing into chips, and belonging to different maturity groups.

MATERIALS AND METHODS

During 1997–1999, a series of field trials was conducted at the Elmininkai Research Station of the Lithuanian Institute of Agriculture on gleyic sod-podzolic (in the deep layer-carbonated mucky soil), sandy moraine light loam, containing available phosphorus (P_2O_5) 107–147 mg/kg and available potassium (K_2O) 116–185 mg/kg, total nitrogen (N) 0.095–0.110%, pH_{KCl}-5.6–6.8, combined acidity 0.62–0.79 mekv/kg, humus 1.70–1.87%.

Potatoes were grown in a six-field crop rotation: winter wheat, potato, barley, barley with under-crop, perennial grasses (a mixture of red clover with timothy) of the first year, perennial grasses (a mixture of red clover with timothy) of the second year. Conventional cultivation practices were used (stubble breaking, autumn ploughing, three-time cultivation-harrowing, seedbed preparation before planting).

Seed potatoes were prepared before planting in spring. Potatoes of all the investigated varieties were planted in the first half of May, using a two-row potato-planting machine. Seed spacing was 0.3 m with a row width of 0.7 m.

Investigation scheme: factor A – potato varieties, factor B – fertilizers, factor C – the year of investigation.

Factor A – potato varieties. 10 potato varieties registered in Lithuania were investigated: the extra early 'Venta' and 'Ukama', the early 'Voke', the medium early 'Mirta' and 'Karolin', the medium late 'Hertha', 'Saturna' and 'Agria', the late 'Aistes' and 'Speci'.

Table 1. Meteorological conditions during 1997–1999. LIA Elmininkai Research Station, 1997–1999.

Year of investigation	Air temperature (°C), precipitation (mm)	Month					Sum of precipitation during vegetative period (mm)
		May	June	July	August	September	
1997	°C	9.3	14.6	17.8	14.2	9.3	
	mm	69.6	86.3	18.0	37.0	78.5	289.4
1998	°C	10.4	14.5	13.5	13.4	8.4	
	mm	98.3	54.4	164.3	97.0	36.4	450.4
1999	°C	9.6	19.4	20.0	16.9	13.8	
	mm	21.4	68.0	20.6	45.5	26.3	181.8
Average of 52 years	°C	11.6	15.4	17.1	16.1	11.9	
	mm	20.7	66.4	70.8	69.0	58.6	315.5

Factor B – fertilizers. Mineral fertilizers were compared to organic fertilizers. Four fertilizers were used in the trial: 1– manure, 60 t ha^{-1}; 2 – chopped straw + one-component mineral fertilizers at a rate of $N_{45}P_{45}K_{90}$ (ammonium nitrate, 35% N; granular superphosphate, 19% of P_2O_5; potassium sulphate, 50% of K_2O); 3 – one-component mineral fertilizers at a rate of $N_{90}P_{90}K_{180}$ (ammonium nitrate, 35% N; granular superphosphate, 19% of P_2O_5; potassium sulphate, 50% of K_2O); 4 – complex mineral fertilizers at a rate of $N_{90}P_{90}K_{180}$ with microelements: Mg 4.1%; S 11.0%; B 0.15%; Cu 0.1%; Fe 0.1%; Mn 0.7%; Mo 0.01%; Zn 0.1%; Se 0.0006% (Kemira Horti 3). Winter wheat straw in the second treatment was chopped during harvesting and ploughed up with a shallow layer of soil. Prior to this, 10 kg of nitrogen (in the form of urea) per tonne of straw were spread. Mineral fertilizers and manure were applied in spring.

Factor C – the year of investigation. The investigation was conducted during 1997–1999. Meteorological conditions during every vegetation period have been presented in Table 1.

Conventional crop management practices were applied (2–3-time pre-emergence cultivation-harrowing, 2-time postemergence hilling). Fungicides against late blight were used according to the warning of NegFry negative prognosis.

Potato tubers were harvested at the time of plant maturity and evaluated for yield (t ha^{-1}), starch (%) and dry matter (%) content. Starch and dry matter contents were determined according to the specific gravity method.

RESULTS AND DISCUSSION

1. Effect of fertilization on the tuber yield of different potato varieties. Due to the late spring, in 1997 potato planting was started only on 14th of May. By that time, seed potatoes, kept in a storage without cooling equipment, had sprouted, and the germinating power of potato tubers had diminished. Emergence of such seed potatoes, planted in the coolish soil, was delayed. Potatoes started to emerge only at the end of the first ten-day rainy period of June. The soil was very dry during the rest of June and July. August was dry and coolish. September was not very warm, too. Under such adverse meteorological conditions during the potato vegetation period and because of the exhausted seeds, planted in spring, very low yields of potato tubers, especially of early varieties, were harvested. In the group of late maturity, the varieties most sensitive to the factors mentioned above were 'Speci' and 'Aistės'.

According to the experimental results (Table 2), the lowest yields of all the investigated potato varieties were harvested in 1997 when farmyard manure had been applied in spring. These yields fluctuated from 11.5 t ha^{-1} to 17.5 t ha^{-1}.

Potato tuber yields of the early varieties with chopped straw+$N_{45}P_{45}K_{90}$ treatment were almost equal to the yields of manured potatoes. Potatoes of the medium late and late maturity groups (except 'Saturna' and 'Speci') produced significantly higher yields with chopped straw + $N_{45}P_{45}K_{90}$ treatment. The yield increase fluctuated from 2.3 t ha^{-1} to 6.5 t ha^{-1}.

The highest potato tuber yield of all the investigated varieties in 1997 was harvested when complex and one-component mineral fertilizers, at a rate of $N_{90}P_{90}K_{180,}$ had been applied. The effect of microelements was not revealed because of the low yields. Somewhat more distinct effects of mineral fertilizers with and without microelements were noticed in the early potato variety 'Mirta'. The potato tuber yield of 'Mirta' was significantly higher when case one-component mineral fertilizers had been applied.

In the treatments where complex and one-component mineral fertilizers had been applied the most productive ones of the group of early maturity were 'Mirta' potatoes (22.5–24.8 t ha^{-1}). In the group of medium late maturity, the most productive ones were 'Hertha' potatoes (18.9–24.6 t ha^{-1}), and in the group of late maturity – 'Aistes' potatoes (16.9–18.1 t ha^{-1}).

At the end of April and at the beginning of May, in 1998, sunny weather lasted almost three weeks and brought sudden spring to the fields and seed potato storage. It stimulated the sprouting of seed potatoes and had no negative influence on their quality.

During the potato vegetation period (June, July, August), quite satisfactory meteorological conditions prevailed. The potato tuber yields of all the investigated varieties were high enough.

According to the experimental results from 1998 (Table 2), the lowest tuber yields of all the investigated potato varieties, except 'Mirta', were harvested in cases when manure had been used in spring (17.6–31.7 t ha^{-1}). In the treatment with chopped straw+$N_{45}P_{45}K_{90}$ potatoes produced 0.3–8.7 t ha^{-1} higher yields in comparison with manured potatoes. Potatoes of all the investigated varieties, except 'Agria' and 'Karolin', produced significant extra yields with the above mentioned treatment.

Table 2. Influence of organic and mineral fertilizers on potato tuber yield (t ha^{-1}). LIA Elmininkai Research Station, 1997–1999.

Variety *Factor A*	Fertilization *Factor B*	Potato tuber yield t ha^{-1} / Year of investigation *Factor C*			Average t ha^{-1}
		1997	1998	1999	
1	2	3	4	5	6
'Venta'	Manure (60 t ha^{-1})	12.6	21.5	13.8	16.0
	Straw+$N_{45}P_{45}K_{90}$	12.5	26.0	12.8	17.1
	$N_{90}P_{90}K_{180}$	21.6	26.5	12.3	20.1
	$N_{90}P_{90}K_{180}$+microelements	23.0	31.2	13.3	22.5
LSD_{05}		1.78**	0.42**	0.30**	6.60ns
'Ukama'	Manure (60 t ha^{-1})	13.9	17.6	12.4	14.6
	Straw+$N_{45}P_{45}K_{90}$	15.7	23.4	12.5	17.2
	$N_{90}P_{90}K_{180}$	19.8	26.7	14.7	20.4
	$N_{90}P_{90}K_{180}$+microelements	18.9	28.7	15.6	21.1
LSD_{05}		1.63**	0.20**	0.10**	3.73*
'Vokė'	Manure (60 t ha^{-1})	11.9	23.5	18.3	17.9
	Straw+$N_{45}P_{45}K_{90}$	12.2	31.0	21.5	21.6
	$N_{90}P_{90}K_{180}$	16.7	36.1	18.0	23.6
	$N_{90}P_{90}K_{180}$+microelements	16.7	39.2	19.1	25.0
LSD_{05}		2.45**	0.26**	0.95**	7.50ns
'Mirta'	Manure (60 t ha^{-1})	16.9	26.9	18.3	20.7
	Straw+$N_{45}P_{45}K_{90}$	17.7	25.7	17.3	20.2
	$N_{90}P_{90}K_{180}$	24.8	43.4	20.6	29.6
	$N_{90}P_{90}K_{180}$+microelements	22.5	44.5	17.5	28.2
LSD_{05}		1.52**	0.26**	0.54**	9.89ns
'Karolin'	Manure (60 t ha^{-1})	17.5	24.8	15.9	19.4
	Straw+$N_{45}P_{45}K_{90}$	17.1	25.4	15.6	19.4
	$N_{90}P_{90}K_{180}$	19.8	36.1	17.6	24.5
	$N_{90}P_{90}K_{180}$	20.3	37.5	17.0	24.9
LSD_{05}		1.97*	0.49**	0.34**	6.46ns
'Hertha'	Manure (60 t ha^{-1})	13.7	28.6	14.3	18.9
	Straw+$N_{45}P_{45}K_{90}$	16.0	29.9	14.9	20.3
	$N_{90}P_{90}K_{180}$	24.6	30.9	15.9	23.8
	$N_{90}P_{90}K_{180}$+microelements	18.9	36.3	14.1	23.1
LSD_{05}		1.47**	0.48**	0.43**	5.99ns
'Saturna'	Manure (60 t ha^{-1})	11.5	25.9	11.4	16.3
	Straw+$N_{45}P_{45}K_{90}$	13.4	30.3	13.4	19.0
	$N_{90}P_{90}K_{180}$	15.5	30.3	15.2	20.3
	$N_{90}P_{90}K_{180}$+microelements	15.4	32.7	15.6	21.2
LSD_{05}		2.23**	0.37**	0.20**	1.60**

Table 2 continued

1	2	3	4	5	6
'Agria'	Manure (60 t ha^{-1})	14.6	30.4	17.8	20.9
	Straw+$N_{45}P_{45}K_{90}$	17.5	30.7	18.2	22.1
	$N_{90}P_{90}K_{180}$	22.5	35.9	23.0	27.1
	$N_{90}P_{90}K_{180}$+microelements	21.9	35.1	23.2	26.7
LSD_{05}		1.34**	0.26**	1.33**	1.48**
'Speci'	Manure (60 t ha^{-1})	16.6	31.7	16.7	21.7
	Straw+$N_{45}P_{45}K_{90}$	17.0	40.4	14.3	23.8
	$N_{90}P_{90}K_{180}$	17.8	43.7	15.4	26.5
	$N_{90}P_{90}K_{180}$+microelements	17.9	47.3	20.1	28.4
LSD_{05}		2.29ns	0.41**	0.39**	7.31ns
'Aistes'	Manure (60 t ha^{-1})	12.8	25.8	18.7	19.1
	Straw+$N_{45}P_{45}K_{90}$	16.5	30.4	16.1	21.0
	$N_{90}P_{90}K_{180}$	16.9	33.8	18.0	22.9
	$N_{90}P_{90}K_{180}$+microelements	18.1	34.7	18.3	23.7
LSD_{05}		1.32**	0.30**	0.33**	4.50ns

LSD_{05} A = 0.27** LSD_{05} B = 0.17** LSD_{05} C = 0.15** LSD_{05} AB = 0.54**
LSD_{05} AC = 0.47** LSD_{05} BC = 0.47** LSD_{05} ABC = 0.94**

Note. ** significant at $P = 0.01$, * significant at $P = 0.05$, ns – not significant

In 1998 the highest tuber yields of all the investigated potato varieties were harvested when complex mineral fertilizers, at a rate of $N_{90}P_{90}K_{180}$, had been applied. Complex mineral fertilizers were more effective than one-component mineral fertilizers in cases when yields were high. Potatoes of all the investigated varieties produced 0.3–5.4 t ha^{-1} higher yields with complex mineral fertilizers applied than with one-component mineral fertilizers. The lowest significant extra yield was harvested in the varieties 'Aistes' (0.9 t ha^{-1}) and 'Mirta' (1.1 t ha^{-1}), and the highest in the variety 'Hertha' (5.4 t ha^{-1}).

In 1998, in treatments with one-component and complex mineral fertilizers, the most productive ones in the group of early maturity were 'Mirta' potatoes (43.4–44.5 t ha^{-1}), and in the group of medium late maturity 'Hertha' potatoes (30.9–36.3 t ha^{-1}). In the group of late maturity, the highest yields were produced by the potatoes of the variety 'Speci' (43.7–47.3 t ha^{-1}).

Although in the spring of 1999 potatoes were planted in the first ten-day period of May, they emerged very slowly because of the coolish weather and lack of moisture. Droughts in June and July disturbed the normal development of the potatoes. Potatoes of early varieties started to form flower buds before their leaves had covered spaces between rows. As a result of the drought, most flower buds fell down just before blossoming, and the potatoes that blossomed out did not raise normal canopies. 1999 was the year of exhausting drought. Weather conditions were very unfavourable for potato growth.

The potato tuber yields of 1999 were very low. Only potatoes of the medium late variety ‘Agria’ exceeded the yield limit of 20.0 t ha^{-1} when mineral fertilizers had been applied.

According to the experimental results from 1999 (Table 2), potato fertilization, using manure in spring, when the vegetation period was very dry, had a greater positive effect on tuber yield than fertilization with chopped straw combined with a half rate of mineral fertilizers. Most of the investigated potato varieties produced higher yields when manure had been used in spring, compared to the application of chopped straw combined with $N_{45}P_{45}K_{90}$. In some cases the yields were almost equal.

Compared with manured potatoes, significantly higher potato tuber yields of most of the investigated varieties were harvested when one-component and complex mineral fertilizers had been applied. But this regularity was not so distinct as it had been in 1997 and 1998.

The results presented above show that all the investigated factors (varieties, fertilizers and meteorological conditions) influenced the tuber yields of the investigated potato varieties. The highest yields (up to 47.3 t ha^{-1}) were harvested in the 1998 vegetation period, and the lowest – in the 1999 vegetation period (up to 23.2 t ha^{-1}).

According to the experimental findings of the three years, manured potatoes of most of the investigated varieties (eight varieties from ten investigated) produced lower yields in comparison with potato tuber yields with the other fertilizer treatments used in the experiment (Table 2). Depending on the variety, these yields fluctuated from 14.6 t ha^{-1} to 21.7 t ha^{-1}. Chopped straw combined with a half rate of one-component mineral fertilizers had a greater positive influence on the potato tuber yields than the application of manure in spring. Potatoes produced 0.9-3.7 t ha^{-1} extra yields in cases where chopped straw with a half rate of mineral fertilizers had been applied, compared with manured potatoes.

The average data of the three-year investigation showed that the highest tuber yields (20.1–29.6 t ha^{-1}) were gained by applying complex mineral fertilizers with microelements and one-component mineral fertilizers at a rate of $N_{90}P_{90}K_{180}$. Complex mineral fertilizers with microelements had an essential advantage, compared to one-component mineral fertilizers, when the fertilizers had been applied at equivalent amounts according to nutrients.

According to the averaged experimental data of the three years, the most productive ones in the group of early maturity were potatoes of the varieties ‘Mirta’ (24.7 t ha^{-1} on the average) and ‘Voke’ (22.0 t ha^{-1} on the average). In the group of medium late maturity, the most productive ones were ‘Agria’ potatoes (24.2 t ha^{-1} on the average), and in the group of late maturity – ‘Speci’ potatoes (25.1 t ha^{-1} on the average).

2. Effect of fertilization on dry matter and starch content in potato tubers of different varieties. Experimental findings showed that different fertilizers used in the trial had a significant impact on the content of dry matter and starch in potato tubers in 1997. Most potatoes (the varieties ‘Venta’, ‘Ukama’, ‘Voke’, ‘Mirta’, ‘Agria’, ‘Speci’ and ‘Aistes’) accumulated the highest content of starch and dry matter (13.9–18.9% and 20.4–25.5%, respectively) when chopped straw+$N_{45}P_{45}K_{90}$ had been used in spring (Table 3 and Table 4). Mineral fertilizers, compared to organic fertilizers, (manure 60 t ha^{-1}) significantly increased the content of starch and dry matter in ‘Ukama’, ‘Voke’, ‘Mirta’, ‘Hertha’, ‘Saturna’, ‘Speci’ and ‘Aistes’ potatoes. Compared to manure, the use of complex mineral fertilizers significantly decreased the amount of starch and dry matter (12.4% and 18.5%; 12.8% and 19.2%, respectively) in ‘Venta’ potatoes. The use of one-component and complex mineral fertilizers decreased the amount of starch and dry matter in ‘Karolin’ potatoes, compared to manured potatoes. Compared to manure, the use of chopped straw+$N_{45}P_{45}K_{90}$ and one-component mineral fertilizers significantly decreased the content of starch and dry matter in ‘Saturna’ potatoes. According to the results presented above, the content of starch and dry matter in 1997 depended on varietal properties and fertilization.

1998 was the year of high yields but potatoes of all the investigated varieties accumulated lower amounts of starch and dry matter (12.4–18.0% and 18.1–23.7%, respectively) compared to those in 1997 (12.1–19.7% and 18.5–26.3%, respectively). The 1997 vegetation period was the most favourable for the accumulation of starch and dry matter in potato tubers of all the investigated potato varieties, except the extra early ‘Venta’. The effect of different fertilizers in 1998 was not as significant as in 1997. Fertilization had no significant influence on the content of starch and dry matter in ‘Venta’, ‘Agria”, and ‘Aistes’ potatoes. ‘Ukama’ potatoes had the highest amount of starch and dry matter (12.9% and 18.7%, respectively) in manure treatment. Compared to manure, the use of chopped straw+$N_{45}P_{45}K_{90}$ significantly decreased the amount of starch and dry matter in ‘Hertha’ potatoes (16.1% and 21.7%, respectively), and the amount of dry matter in ‘Saturna’ potatoes (23.4%). Compared to manure, the use of chopped straw+$N_{45}P_{45}K_{90}$, one-component and complex mineral fertilizers significantly increased the amount of starch and dry matter in ‘Mirta’ and ‘Speci’ potatoes. The use of one-component and mineral fertilizers, compared to applying manure, significantly increased the amount of starch and dry matter in ‘Voke’ and ‘Karolin’ potatoes.

During the vegetative growth period in 1999, following the exhausting drought, potatoes were growing and maturing under abnormal conditions. This year was the most unfavourable for the accumulation of starch and dry matter (10.6–15.2% and 16.9–21.8%, respectively). Because of the drought, potato tubers became early physiologically old and started to grow secondary tubers in the autumn. Secondary tubers used dry matter and starch of the main potato tubers. Under the drought conditions, the effect of different fertilizers on the content of starch and dry matter was not significant. Compared to manure, one-component mineral fertilizers significantly decreased the amount of starch and dry matter in ‘Voke’ potatoes, and increased the amount of these substances in ‘Mirta’ potatoes. Different fertilizers used in the trial had no significant influence on the content of starch and dry matter in potatoes of the rest of the varieties investigated.

According to the results presented above, the amount of starch and dry matter in potato tubers depended on the varietal properties, meteorological conditions and fertilization. Under favourable meteorological conditions, chopped straw combined with a half rate of one-component mineral fertilizers, one-component and complex mineral fertilizers increased the amount of starch of starch and dry matter in the potato tubers of the investigated varieties, compared to manured potatoes.

Potatoes accumulated the highest amounts of starch and dry matter in the 1997 vegetation period (up to 19.7% and 26.3%, respectively) and the lowest in the 1999 vegetation period (up to 14.9% and 21.8%, respectively).

Table 3. Influence of organic and mineral fertilizers on starch content (%) in potato tubers. LIA Elmininkai Research Station, 1997–1999.

Variety *Factor A*	Fertilization *Factor B*	Starch content % / Year of investigation *Factor C*			Average %
		1997	1998	1999	
1	2	3	4	5	6
'Venta'	Manure (60 t ha^{-1})	12.8	14.3	11.6	12.9
	Straw+$N_{45}P_{45}K_{90}$	13.9	14.0	11.0	13.0
	$N_{90}P_{90}K_{180}$	12.8	14.2	11.0	12.7
	$N_{90}P_{90}K_{180}$+microelements	12.1	14.0	12.2	12.8
LSD_{05}		0.52**	0.63ns	2.39ns	1.30ns
'Ukama'	Manure (60 t ha^{-1})	13.8	12.9	12.2	13.0
	Straw+$N_{45}P_{45}K_{90}$	16.6	12.4	12.6	13.9
	$N_{90}P_{90}K_{180}$	15.7	12.5	11.9	13.4
	$N_{90}P_{90}K_{180}$+microelements	15.4	12.8	11.9	13.4
LSD_{05}		0.39ns	0.26**	2.07ns	1.50ns
'Voke'	Manure (60 t ha^{-1})	16.2	15.6	14.9	15.6
	Straw+$N_{45}P_{45}K_{90}$	17.3	15.8	12.9	15.3
	$N_{90}P_{90}K_{180}$	16.6	17.0	15.2	16.3
	$N_{90}P_{90}K_{180}$+microelements	17.0	17.2	14.4	16.2
LSD_{05}		0.59*	1.14*	1.81ns	1.61ns
'Mirta'	Manure (60 t ha^{-1})	17.7	15.2	10.9	14.6
	Straw+$N_{45}P_{45}K_{90}$	18.5	15.6	11.0	15.0
	$N_{90}P_{90}K_{180}$	18.1	15.4	14.1	15.9
	$N_{90}P_{90}K_{180}$+microelements	18.1	15.3	12.5	15.3
LSD_{05}		0.60**	0.38*	2.84ns	1.77ns
'Karolin'	Manure (60 t ha^{-1})	17.8	17.0	11.4	15.4
	Straw+$N_{45}P_{45}K_{90}$	17.8	16.6	10.6	15.0
	$N_{90}P_{90}K_{180}$	17.4	17.2	11.5	15.4
	$N_{90}P_{90}K_{180}$	17.0	17.5	12.2	15.6
LSD_{05}		0.21**	0.71ns	2.52ns	1.04ns
'Hertha'	Manure (60 t ha^{-1})	14.6	16.4	12.0	14.3
	Straw+$N_{45}P_{45}K_{90}$	16.1	16.1	12.2	14.8
	$N_{90}P_{90}K_{180}$	16.9	16.4	12.0	15.1
	$N_{90}P_{90}K_{180}$+microelements	16.0	16.2	12.9	15.0
LSD_{05}		0.73**	0.12**	1.99**	1.23ns
'Saturna'	Manure (60 t ha^{-1})	19.0	17.8	14.9	17.2
	Straw+$N_{45}P_{45}K_{90}$	16.4	17.6	14.0	16.0
	$N_{90}P_{90}K_{180}$	19.7	17.8	14.8	17.4
	$N_{90}P_{90}K_{180}$+microelements	18.1	18.0	14.0	16.7
LSD_{05}		0.50**	0.62ns	1.94**	1.46ns

Table 3 continued

1	2	3	4	5	6
'Agria'	Manure (60 t ha^{-1})	15.2	15.4	14.0	14.9
	Straw+$N_{45}P_{45}K_{90}$	16.5	15.0	13.1	14.9
	$N_{90}P_{90}K_{180}$	14.9	15.6	11.2	13.9
	$N_{90}P_{90}K_{180}$+microelements	14.9	16.2	14.0	15.0
LSD_{05}		1.07**	0.47**	2.84ns	1.88ns
'Speci'	Manure (60 t ha^{-1})	17.2	17.4	14.3	16.3
	Straw+$N_{45}P_{45}K_{90}$	18.9	17.6	11.6	16.0
	$N_{90}P_{90}K_{180}$	18.3	17.6	11.9	15.9
	$N_{90}P_{90}K_{180}$+microelements	18.4	17.8	12.4	16.2
LSD_{05}		0.39**	0.38ns	2.84ns	1.96ns
'Aistes'	Manure (60 t ha^{-1})	16.2	17.2	12.7	15.4
	Straw+$N_{45}P_{45}K_{90}$	18.1	17.4	12.6	16.0
	$N_{90}P_{90}K_{180}$	17.2	17.1	13.4	15.9
	$N_{90}P_{90}K_{180}$+microelements	16.4	17.6	14.1	16.0
LSD_{05}		0.52**	0.50ns	2.02ns	1.40ns

LSD_{05} A = 0.34** LSD_{05} B = 0.21** LSD_{05} C = 0.18** LSD_{05} AB = 0.68**
LSD_{05} AC = 0.58** LSD_{05} BC = 0.58** LSD_{05} ABC = 1.17**

Note. ** significant at $P = 0.01$, * significant at $P = 0.05$, ns – not significant

The amount of starch and dry matter in potato tubers also depended on varietal properties. In the group of early maturity, the highest amounts of starch and dry matter were accumulated by 'Voke' potatoes. Even in the year of drought (1999) these potatoes accumulated 12.9–15.2% of starch and 19.4–21.8% of dry matter. The other potato varieties of early maturity, such as 'Mirta' and 'Karolin', were more sensitive to the changes of meteorological conditions.

For example, the starch and dry matter content of manured 'Karolin' potatoes fluctuated from 17.8% and 24.5%, respectively, in 1997 to 11.4% and 17.8%, respectively, in 1999.

According to the experimental data in the group of early maturity, the highest amounts of starch and dry matter were accumulated by 'Voke' potatoes (15.3–16.3% and 21.7–22.6%, respectively). In the group of medium early maturity, the highest amounts of starch and dry matter were accumulated by potatoes of varieties 'Karolin' (15.0–15.6% and 21.2–21.8%, respectively) and 'Mirta' (14.6–15.9% and 20.8–22.2%, respectively). In the group of medium late maturity, the highest content of starch and dry matter had 'Saturna' potatoes (16.0–17.4% and 22.3–23.7%, respectively), in the group of late maturity – 'Speci' potatoes (15.9–16.3% and 22.3–22.5%, respectively).

According to the experimental findings, different fertilizers had irregular influence on the content of starch and dry matter in potato tubers of different varieties (Table 3 and Table 4). The effect depended on the meteorological conditions and varietal properties. In most cases, one-component and complex mineral fertilizers increased the amount of starch and dry matter in potato tubers, compared to manured potatoes.

Table 4. Influence of organic and mineral fertilizers on dry matter content (%) in potato tubers. LIA Elmininkai Research Station, 1997–1999.

Variety *Factor A*	Fertilization *Factor B*	Dry matter content % / Year of investigation *Factor C*			Average %
		1997	1998	1999	
1	2	3	4	5	6
'Venta'	Manure (60 t ha^{-1})	19.2	20.1	18.0	19.1
	Straw+$N_{45}P_{45}K_{90}$	20.4	19.8	17.4	19.2
	$N_{90}P_{90}K_{180}$	19.2	19.9	17.4	18.8
	$N_{90}P_{90}K_{180}$+microelements	18.5	19.8	19.1	19.1
LSD_{05}		0.55**	0.30ns	1.18*	1.55ns
'Ukama'	Manure (60 t ha^{-1})	20.2	18.7	18.6	19.2
	Straw+$N_{45}P_{45}K_{90}$	23.1	18.1	19.1	20.1
	$N_{90}P_{90}K_{180}$	22.2	18.2	18.3	19.6
	$N_{90}P_{90}K_{180}$+microelements	22.0	18.5	18.3	19.6
LSD_{05}		0.48**	0.10**	2.22ns	1.58ns
'Voke'	Manure (60 t ha^{-1})	22.8	21.3	21.5	21.9
	Straw+$N_{45}P_{45}K_{90}$	24.0	21.6	19.4	21.7
	$N_{90}P_{90}K_{180}$	23.3	22.7	21.8	22.6
	$N_{90}P_{90}K_{180}$+microelements	23.6	23.0	21.1	22.6
LSD_{05}		0.59**	1.01*	1.82ns	1.67ns
'Mirta'	Manure (60 t ha^{-1})	24.3	20.9	17.2	20.8
	Straw+$N_{45}P_{45}K_{90}$	25.0	21.3	17.3	21.2
	$N_{90}P_{90}K_{180}$	24.7	21.2	20.8	22.2
	$N_{90}P_{90}K_{180}$+microelements	24.8	21.3	19.0	21.7
LSD_{05}		0.10**	0.11**	2.66ns	1.92ns
'Karolin'	Manure (60 t ha^{-1})	24.5	22.6	17.8	21.6
	Straw+$N_{45}P_{45}K_{90}$	24.4	22.4	16.9	21.2
	$N_{90}P_{90}K_{180}$	24.1	23.0	17.9	21.7
	$N_{90}P_{90}K_{180}$	23.6	23.2	18.7	21.8
LSD_{05}		0.24**	0.28**	2.98ns	1.14ns
'Hertha'	Manure (60 t ha^{-1})	21.2	22.2	18.4	20.6
	Straw+$N_{45}P_{45}K_{90}$	22.8	21.7	18.6	21.0
	$N_{90}P_{90}K_{180}$	23.5	22.2	18.4	21.4
	$N_{90}P_{90}K_{180}$+microelements	22.6	21.9	19.4	21.3
LSD_{05}		0.75**	0.33*	2.36ns	1.30ns
'Saturna'	Manure (60 t ha^{-1})	25.6	23.6	21.5	23.6
	Straw+$N_{45}P_{45}K_{90}$	22.9	23.4	20.5	22.3
	$N_{90}P_{90}K_{180}$	26.3	23.5	21.4	23.7
	$N_{90}P_{90}K_{180}$+microelements	24.8	23.7	20.5	23.0
LSD_{05}		0.48**	0.12**	2.05ns	1.52ns

Table 4 continued

1	2	3	4	5	6
‘Agria’	Manure (60 t ha^{-1})	21.9	21.2	20.6	21.2
	Straw+$N_{45}P_{45}K_{90}$	23.1	21.0	19.6	21.2
	$N_{90}P_{90}K_{180}$	21.5	21.3	17.6	20.1
	$N_{90}P_{90}K_{180}$+microelements	21.5	21.9	20.6	21.3
LSD_{05}		0.93*	1.46ns	3.05ns	1.87ns
‘Speci’	Manure (60 t ha^{-1})	23.9	23.1	20.8	22.6
	Straw+$N_{45}P_{45}K_{90}$	25.5	23.3	18.0	22.3
	$N_{90}P_{90}K_{180}$	25.5	23.3	18.2	22.3
	$N_{90}P_{90}K_{180}$+microelements	25.1	23.6	18.8	22.5
LSD_{05}		0.48**	0.16**	2.93ns	2.09ns
‘Aistes’	Manure (60 t ha^{-1})	22.8	23.0	19.3	21.7
	Straw+$N_{45}P_{45}K_{90}$	24.8	23.1	19.2	22.4
	$N_{90}P_{90}K_{180}$	23.9	22.9	20.0	22.3
	$N_{90}P_{90}K_{180}$+microelements	23.0	23.4	20.7	22.4
LSD_{05}		0.52**	0.50ns	2.02ns	1.40ns

$LSD_{05}A$=0.34** $LSD_{05}B$=0.21** $LSD_{05}C$=0.18** $LSD_{05}AB$=068**
$LSD_{05}AC$=058** $LSD_{05}BC$=0.58** $LSD_{05}ABC$=1.17**

Note. ** significant at P = 0.01, * significant at P = 0.05, ns – not significant

CONCLUSIONS

1. According to the average data of the three-year experiment, different fertilizers influenced the tuber yield of all the investigated potato varieties:
a) the lowest potato yields (14.6–21.7 t ha^{-1}) were harvested when manure (60 t ha^{-1}) had been applied in spring;
b) the highest potato tuber yields (20.1–29.6 t ha^{-1}) were harvested when both one-component and complex mineral fertilizers, at a rate of $N_{90}P_{90}K_{180}$, had been applied.

2. According to the average data of the three-year experiment, the most productive were potatoes of the following varieties:
a) the early ‘Voke’ (17.9–25.0 t ha^{-1}) and the medium early ‘Mirta’ (20.7–28.2 t ha^{-1});
b) the medium late ‘Agria’ (20.9–27.1 t ha^{-1}) and the late ‘Speci’ (21.7–28.4 t ha^{-1}).

3. Meteorological conditions during vegetation period had an impact on the potato tuber yields. The highest yields were harvested in the 1998 vegetation period – up to 47.3 t ha^{-1}, the lowest in 1999 vegetation period – up to 23.2 t ha^{-1}.

4. Different fertilizers used in the investigation and the meteorological conditions of the vegetation period had irregular effects on the content of starch and dry matter in potato tubers of all the investigated varieties. Under favourable meteorological conditions, chopped straw combined with one-component mineral fertilizers, at a rate of $N_{45}P_{45}K_{90}$, one-component and complex mineral fertilizers, at a rate of $N_{90}P_{90}K_{180}$, mostly increased the amount of starch and dry matter in potato tubers of the investigated varieties.

5. Potatoes accumulated the highest amounts of starch and dry matter in the 1997 vegetation period (up to 19.7% and 26.3%, respectively), and the lowest in the 1999 vegetation period (up to 14.9% and 21.8%, respectively).

6. According to the average data of the three-year experiment, the highest content of starch and dry matter was accumulated by potatoes of the following varieties:
a) the early 'Voke' (15,3–16,3% and 21.7–22.6%, respectively), the medium early 'Karolin' (15.0–15.6% and 21.2–21.8%, respectively);
b) the medium late 'Saturna' (16.0–17.4% and 22.3–23.7%, respectively) and the late 'Speci' (15.9–16.3% and 22.3–22.6%, respectively).

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