INFLUENCE OF ORGANIC PRODUCT EXTRACTS ON THE POTATO YIELD AND QUALITY IN THE CONVENTIONAL GROWING SYSTEM

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Abstract
Agricultural farms in modern production system are specialized;therefore, animal-origin organic fertilizers are not available for many of them. Researches on the use of organic products in agriculture to restrict the use of pesticides and mineral fertilizers have been performed for a long time. Nowadays different organic preparations that are acquired as a result of complex processes are produced, ensuring ready-to-use biologically active substances in them and also activating their properties. One of the purposes of the research was to evaluate the impact of extracts from organic products on the potato (*Solanum tuberosum*) yield and tuber quality in the conventional cultivation system. A field experiment using cultivars 'Borodyansky Rozovij' (early maturity) and 'Lenora' (mid-early maturity) was arranged in the State Stende Cereals Breeding Institute in 2011 and 2012. Peat elixir and vermicompost extract obtained at different temperatures: + 45 °C and + 95 °C, as well as a mixture of these extracts were used for treatment of tubers and plants. The research included 24 treatments in total, including control (without treatment) and a standard potato cultivation technology. Tubers were treated immediately before planting, but plants were treated three times during the vegetation period. Average two-year research results showed that the use of organic product extracts significantly ($p<0.05$) affected the tuber yield in different treatments for both cultivars 'Borodyansky Rozovij' and 'Lenora'. The content of nitrates in tubers, using extracts, did not exceed the allowable level (160 mg kg^{-1}) in any of treatments.
Key words: potatoes, crop, organic product extracts, peat elixir, vermicompost extract, nitrates.

Introduction

According to the data of the Central Statistical Bureau, in the last three years (2010 – 2012) potatoes (*Solanum tuberosum*) are cultivated in Latvia on about 30 000 ha or occupy 2.7% from the total planting area (http://www.csb.gov.lv/statistikastemas/lauksaimniecība-galvenieraditaji30325.html). Potatoes are one of the most important field crops, because of wide opportunities of their use (Skrabule, 2003). To obtain a high potato yield, it should be noted that crop is very demanding to growing management. It is important to obtain not only high yield, but also good quality tubers, and it might be possible by using environment-friendly fertilizers. To obtain a high and good quality crop yield, we need to take care of soil sanitation and soil fertility recovery (Köpke, 2007). Scientists do researches with environment-friendly organic products and their extracts in many places of the world.

Many products of different humic substances are available in Latvia as well as in the world. Their preparation is based on treatment of peat, compost or some other organic material with potassium hydroxide (Purmalis and Šīre, 2012).

Humic fertilizers produced from organic products are not traditional in Latvia; however, interest in them has been increasing during the last years. The most widespread sources for producing of humic substances are peat, brown coal or lignite, coal, leonardite, sapropel, sludge, worm biohumus or vermicompost (Chen et al., 2004; Theunisen et al., 2010). Currently more and more researches are being done in the world regarding the use of organic products in agriculture. New organic products are created by composting organic fertilizers, plant residues and household waste (Ndegwa and Thompson, 2001). Many countries – the USA, Russia, India, Belarus, etc. study the use of earthworms for processing of these organic residues (Aira et al., 2006; Pathasarathi et al., 2007). Latvia is rich in peat resources that may be used in agriculture. Peat is a valuable source of organic matter for agricultural soils and contains 7-61% of humic substances (Kuršs and Stinkule, 1997). To obtain organic products appropriate to modern agricultural technologies, in Latvia extracts from peat and vermicompost are produced, though there are just a few researches on the impact of these products on the yield and development of cultivated plants.

Peat elixir and vermicompost extract obtained at different temperatures: + 45 °C and + 95 °C, as well as a mixture of these extracts were used in this research. A goal of this investigation was to study the impact of extracts, which were obtained from the products of organic origin, on potato yield in the conventional growing system.

Materials and Methods

To study the impact of extracts from organic products on the potato yield, a field experiment in the conventional cultivation system was arranged in the State Stende Cereals Breeding Institute in 2011 – 2012 . The experiment was arranged in 3 replications treatments were arranged randomly. The size of plots was 25.6 m^2, including a yield registration area – 16 m^2. The planting rate was 46 000 tubers per ha. An early-season potato cultivar 'Borodyansky

Rozovij' (Ukraine) and an early-mid-season cultivar 'Lenora' (Latvia) were selected for the research. The experiment was arranged in gleyic sod-podzolic soil, that is characterized by soil acidity pH KCl – 5.34, content of organic substances – 19 g kg^{-1} of soil, content of available nutrients for plants P – 414 mg L^{-1} and K -255 mg L^{-1} of soil in the year 2011, and pH KCl 5.55, content of organic substances – 19 - 21 g kg^{-1} of soil, content of available nutrients for plants P – 447 mg L^{-1} and K – 195 mg L^{-1} of soil in the year 2012. A low content of N, S, Mg, Zn and B was stated in the soil. The amount of nutrients present in the soil was determined in the Laboratory of Plant Mineral Nutrition of the Institute of Biology of the University of Latvia, using methods of G. Riņķis et al. (Риньки и др., 1987). Before the arrangement of the research, the fields were leveled in April and loosened using a cultivator– a chisel-tiller KR – 4. Before planting potatoes, furrows were made with a furrower with the spacing between furrows - 0.80 m. The potatoes were manually planted in the third decade of May keeping the spacing of 0.3 m between tubers. During the vegetation period, the potato plantation was harrowed twice with a chain harrow – on 8th and 14th day after planting, and it was also loosened twice with a row-crop hoe RKT – 2 on 7th and 14th day after planting. Before planting, complex mineral fertilizer NPK 11:9:21 was given at the rate – 550 kg ha^{-1} (pure matter N – 61 kg ha^{-1}, P – 22 kg ha^{-1}, K – 96 kg ha^{-1}). Before sprouting, the experimental field was sprayed with herbicide Mistral 70 d.g. (metribuzin, 700 g kg^{-1}), dose 0.5 kg ha^{-1}.

According to the methodology, the treatment with organic product extracts was done.

Groups of used organic products:

1. control – without treatment with extracts from organic products;
2. standard cultivation technology, without treatment with extracts from organic products, but with the use of pesticides;
3. treatment of potato tubers with extracts from organic products before planting;
4. treatment of potato tubers with extracts from organic products and pesticide: Maxim 025 s.c. (fludioxonil, 25 g L^{-1}) dose 0.2 L t^{-1} before planting;
5. treatment of plants with extracts from organic products three times per season after sprouting, when the plants reached 10 cm height, before blooming and after the blooming stage;
6. treatment of potato tubers with extracts from organic products before plantating and treatment of plants with these products three times per season in the above mentioned times;

Treatment with organic products:

1. peat elixir – two variants: the product obtained at + 45 °C and + 95 °C (K 45), (K95);
2. vermicompost extract – two variants: the product obtained at + 45 °C and + 95 °C (V45), (V95);
3. mixtures of the two extracts (mixture ratio 1:1) – peat elixir, obtained at + 95 °C and vermicompost extract, obtained at + 45 °C (KV);
4. mixture of vermicompost extracts (mixture ratio 1:1) – vermicompost extract, obtained at + 95 °C, and vermicompost extract, obtained at + 45 °C (VV).

Tubers were treated with the extracts on the planting day using a back-pack sprayer JACTO HD 300, the dose of extracts was 150 mL t^{-1}, but the total spray material consumption was 5 L t^{-1}. The dose sprayed on the plants after sprouting of potatoes, before and after blooming was 1.5 L ha^{-1}. Extracts from organic products were sprayed with a special experimental bike-type sprayer Birchmeier Spray-Matic 10 S. The sprayer is equipped with a flat jet nozzle with the pressure 250 kPa and spray material consumption - 250 L ha^{-1}. Extracts of organic products were sprayed in the evening when the air temperature did not exceed + 20 °C. Before tuber harvesting, tops were mowed with a haulm cutter. The potato yield was harvested in the beginning of September, using a two-row potato digger KTN-2V; potatoes were gathered manually. For the registration of yield 2 medium furrows (16 m^2) were collected from the four planted furrows of one plot. Potato was weighted and yield was converted to t ha^{-1}. To determine one of quality indicators – the content of nitrates in tubers, tuber samples were collected from each treatment and analyzed in the Laboratory of Food and Environmental Investigations of the Institute of Food Safety, Animal Health and Environment BIOR (according to SDA 83 nitrate determination method).

Mathematical processing of data was performed using analysis of variance, Microsoft Excel data processing software.

Meteorological conditions in 2011 and 2012 were characterized by frequent precipitation and moderately warm summers. Excess moisture at the end of summer and the beginning of autumn of 2011 stimulated rotting of tubers in the soil. An earlier development of late blight (*Phytophtora infestans*) was noted in 2012 if compared to 2011.

Results and Discussion

Impact of organic product extracts on tuber yield

An average two-year potato yield of cultivar 'Borodyansky Rozovij' was in the range from 22.26 t ha^{-1} to 31.95 t ha^{-1}, using extracts from organic products (Table). Results of the analysis of variance showed that the use of organic product extracts

significantly ($p<0.05$) affected the tuber yield of 'Borodyansky Rozovij' cultivar in several treatments.

In the control, where potatoes were not treated with extracts from organic products, the average two-year yield of the cultivar 'Borodyansky Rozovij' was 22.26 t ha^{-1}. Yield significantly ($p<0.05$) increased in fourteen treatments from twenty four (Table) when tubers were treated with extracts from organic products. Ten treatments did not provide a significant increase in the yield. Even a slight decrease of tuber yield was observed in treatments 9, 14, 19, if compared to the control, however, the decrease was within the

Table

Impact of extracts from organic products on the average potato yield and the nitrate content in tubers, 2011- 2012 in Stende

Versions	Borodyansky Rozovij			Lenora		
	yield		nitrate content, mg kg^{-1}	yield		nitrate content, mg kg^{-1}
	t ha^{-1}	± control		t ha^{-1}	± control	
1. Control	22.26	0.00	36.00	21.81	0	56.00
2. Standard cultivation	36.77	14.51	37.00	30.84	9.03	73.00
3. Processing of tubers with K (+45 °C)	25.92	3.66	37.50	24.37	2.56	41.00
4. Processing of tubers with K (+95 °C)	29.60	7.34	39.50	30.84	9.03	108.00
5. Processing of tubers with V (+45 °)	23.90	1.64	48.50	23.17	1.36	36.00
6. Processing of tubers with V (+95 °C)	28.11	5.85	38.00	24.15	2.34	74.00
7. Processing of tubers with KV	31.95	9.69	48.00	25.80	3.98	48.00
8. Processing of tubers with VV	29.65	7.39	78.50	26.32	4.51	49.00
9. Processing of tubers with pesticide +K (+45 °C)	22.09	-0.17	45.50	24.06	2.25	61.00
10. Processing of tubers with pesticide + K (+95 °C)	27.65	5.39	45.50	23.70	1.89	49.00
11. Processing of tubers with pesticide +V (+45 °C)	22.34	0.08	50.50	25.76	3.95	86.00
12. Processing of tubers with pesticide +V (+95 °C)	30.00	7.74	63.00	24.84	3.03	36.00
13. Processing of tubers with pesticide +KV	22.27	0.01	48.50	24.68	2.87	44.00
14. Processing of tubers with pesticide +VV	22.08	-0.18	67.50	30.76	8.95	39.00
15. Processing of plants with K (+45 °C)	26.75	4.49	66.50	23.46	1.65	74.00
16. Processing of plants with K (+95 °C)	22.60	0.34	48.00	24.35	2.54	63.00
17. Processing of plants with V (+45 °C)	22.84	0.58	41.50	26.42	4.61	90.00
18. Processing of plants with V (+95 °C)	28.05	5.79	36.00	23.96	2.15	99.00
19. Processing of plants with KV	22.16	-0.10	40.00	30.13	8.32	45.00
20. Processing of plants with VV	28.78	6.52	73.00	30.01	8.20	59.00
21. Processing of tubers and plants with K (+45 °C)	26.37	4.11	72.00	21.78	-0.03	67.00
22. Processing of tubers and plants with K (+95 °C)	28.98	6.72	55.00	22.48	0.67	69.00
23. Processing of tubers and plants with V (+45 °C)	27.76	5.50	49.00	26.40	4.59	96.00
24. Processing of tubers and plants with V (+95 °C)	31.90	9.64	48.50	25.16	3.35	37.00
25. Processing of tubers and plants with KV	24.70	2.44	36.50	30.40	8.59	61.00
26. Processing of tubers and plants with VV	25.17	2.91	92.50	30.48	8.67	50.00
$LSD_{0.05}$	3.10	×	×	3.82	×	×

limits of experimental error. The most substantial increase in the tuber yield, compared to the control, for this cultivar was observed in the treatments, when tubers were treated with a mixture of peat elixir and verimicompost extract (+9.69 t ha^{-1}) before planting, and when both tubers were treated and plants were treated three times during the vegetation period (+9.64 t ha^{-1}). In both treatments (Table, treatments 7 and 24) the yield increased by 43% compared to the control. The treatments when tubers were treated with pesticide and vermicompost extract (+95 °C) were also effective (Table, treatment 12); in this version the tuber yield was 30 t $ha^{-1,}$ i.e. significantly higher than in the control. If plants were treated 3 times during the vegetation period, then a significantly higher yield was obtained by applying peat elixir (+45 °C), vermicompost extract (+95 °C) and a mixture of vermisompost extracts (Table, treatments 15, 18, 20) ($p<0.05$). Significantly ($p<0.05$) lower yield of the cultivar 'Borodjansky Rozovij' was obtained in all treatments with organic extracts if compared with standard growing technology (Table, treatment 2, 36.77 t ha^{-1})

The average two-year yield of potato cultivar 'Lenora', varied from 21.81 t ha^{-1} (in the control) to 30.84 t ha^{-1} (treatments 2 and 4, Table). Results of the analysis of variance proved that the use of organic product extracts significantly ($p<0.05$) increased the yield of the cultivar 'Lenora' in 11 treatments from 24. The cultivar 'Lenora' had significantly higher ($p<0.05$) tuber yeild, when tubers were treated with peat elixir (+95 °C), a mixture of peat elixir and vermicompost extract and with a mixture of vermicompost extracts (Table, treatments 4, 7, 8). The treatment with pesticide on tubers and a mixture of vermicompost extracts has also significantly increased crop of this cultivar (treatment 14, Table, +8.95 t ha^{-1}). While processing plants with organic products, the highest increase in yield was observed, when they were sprayed with a mixture of the two products (Table, treatments 19, 20). A similar increase in the yield was observed, when tubers and plants were treated three times during the vegetation period (Table, treatments 25, 26) ($p<0.05$). The cultivar 'Lenora' similarly to the cultivar 'Borodyansky Rozovij' had a significantly ($p<0.05$) higher yield in the standard cultivation variant (Table, treatment 2) if compared with the control. The average increase in two-year yield in the standard was identical to the one obtained, if tubers were treated with peat elixir prepared at the temperature of +95 °C. Tuber yield did not significantly differ in other treatments with extracts from organic products (Table, treatments 3, 5, 6, 9, 10, 12, 13, 15, 16, 18, 21, 22, 24).

Two-year research results proved that the treatment with extracts from organic products in different ways significantly affected the potato tubers' yield of both cultivars used; however, the cultivars differently reacted to these extracts and treatments with them. Researches performed in various countries all over the world also indicated the positive influence of biological products on the potato yield. Researches performed in Belarus also proved that the use of an eco-gel, biological preparation, has positively affected the tuber yield. The yield in the treatments where biological preparation was used increased by 10 – 30% compared to the control (Кравченко и др., 2009). Researches of some other countries highlight positive influence of vermicompost and its extracts on the growth, development and productivity of plants (Cavender et al., 2003; Gamaley et al., 2001). Research results also specify that high doses of vermicompost extract or vermicompost acquired from pig (*Sus scrofa domestica*) manure, negatively affected the growth of tomatoes (*Solanum lycopersicum)* and cucumbers (*Cucumis sativus)*. The growth of sorghum (*Sorghum bicolor*) reduced, when non-sterilized vermicompost was worked into soil (Cavender et al., 2003). The vermicompost acquired from sewage sludge did not reduce the incidence of diseases (*Phytophtora infestans*), but at the same time negatively affected the growth and development of tomatoes (Szczech and Smolinska, 2001). Thus both, the research data obtained in Stende and conclusions from scientific literature show that the impact of organic products – vermicompost and its extracts on the growth, productivity and plant disease incidence is not always positive.

Impact of organic product extracts on nitrate content in tubers

Section 1 of the Annex to European Commission Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs sets maximum allowable levels for nitrates in spinaches (*Spinacia oleracea*), lettuce (*Lactuca sativa*), processed cereal-based foods and foods for infants and young children. It was clarified that the nitrate content in potato tubers shall not exceed 250 mg kg^{-1}. Results of the two-year study, performing analyses of the nitrate content in tubers of both cultivars – 'Borodyansky Rozovij' and 'Lenora' – (according to SDA 83 method) proved that no treatment caused excess of the permissible nitrate content of 250 mg kg^{-1} (Table). A mixture of vermicompost extracts caused a tendency of nitrate content in all treatments of the cultivar 'Borodyansky Rozovij' to increase, though the permissible level was not exceeded. The cultivar 'Lenora' had comparatively higher nitrate content in tubers in the variant when tubers were treated with peat elixir (+95 °C); however, the tendency to increase is not to be taken into account here either.

Research results in Germany showed that the nitrate content may increase when using soluble mineral fertilizers, but if organic fertilizers are used, the nitrate content level in potatoe tubers is minimum, because organic fertilizers slowly and gradually release nutrients and ensure good supply and nutrition for plants (http://www.food.monitor.de/docs/multimedia/ oekote/Mo310kartoffeln oton. pdf.). Russian studies on the impact of fertilizers on the nitrate content showed that the use of compost significantly reduces the nitrate content, because plant residues bind excess nitrogen that is transformed into a form that may be used by plants (Андрианов и др., 2009). Research results in Belorussia with the use of an eco-gel, biological preparation, also proved that the nitrate content in the treatments with the experimental product complied with the set quality requirements and was within the limits up to 80 mg kg^{-1} (Кравченко и др., 2009). Research data of Lithuanian scientists convincingly inform about a positive impact on the nitrate content in tubers, they reduced in the versions when organic products were used (Недзинскене и Бакшене, 2009).

Although our research demonstrated that the nitrate content in tubers tends to grow if some treatments are applied, but it still does not exceedthe allowable level. Therefore, we may state that extracts from organic products do not reduce the quality of potato tubers.

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Conclusions

Potato cultivars 'Borodyansky Rozovij' and 'Lenora' differently reacted on extracts from organic products and treatment with them, but their use did not cause exceeding of the allowable nitrate level in any of treatments.

1. Peat elixir prepared at + 95 °C significantly affected ($p<0.05$) the tuber yield of both cultivars, when treating tubers before planting. The use of mixtures of extracts from organic products for treatment of tubers also provided a significant increase of yield for both cultivars.
2. The use of peat elixir prepared at +45 °C significantly increased only the yield of 'Borodyansky Rozovij' when tubers were treated, plants were treated three times during the vegetation period, and tubers and plants three times during the vegetation period were treated.
3. The use of vermicompost extract prepared at + 95 °C significantly increased only the yield of 'Borodyansky Rozovij' in different treatments, while this product did not significantly affect the yield of cultivar 'Lenora'.
4. A significant ($p<0.05$) impact of extract mixtures from organic products was observed only in 'Lenora' cultivar, when treating tubers and plants three times during the vegetation period.

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