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The effect of additional fertilization with liquid complex fertilizers and growth regulators on potato productivity

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Field tests were carried out at the Research Station of LUA during the period of 2004–2006. The effect of complex fertilizers and growth regulators on potato growth, tuber development and productivity was investigated.

It was determined that the greatest addition to the potato yield (8–9 t ha^{-1}) was produced and approximately 60 % of bulky potatoes per one plant grew after additional foliar fertilization at the end of bud stage with liquid complex fertilizers Atgaiva-2 or Atgaiva-P from "ARVI fertis".

After spraying the potatoes with solutions of growth regulators Penergetic-P_{lapams} or Stilitas-123, bulky potatoes constituted 55–58 % of yield structure. Under the influence of the above mentioned growth regulators, potato yield significantly increased by 5–6 t ha^{-1} or 16–19 % in comparison with the control variants.

It is advisable to fertilize table potatoes additionally with the blend of complex fertilizer Atgaiva-2 and growth regulator Humicop. After additional foliar fertilization with this blend, bulky potatoes constituted even 78 % of yield structure, while small potatoes were almost not found (only 0.5 %) at all. Under the influence of the aforesaid additional fertilization, potato yield reliably increased by 4.7 t ha^{-1} or 14.8 % in comparison with the control variants.

Key words: potatoes, liquid complex fertilizers, growth regulators, productivity.

Introduction. In the current market, consumers demand both rich and top quality potato harvest. Productive and high quality potato seed is the first essential provision to get rich and steady potato yield (Department of Statistics of the Republic of Lithuania). In addition to agrotechnical measures, significance of exogenous growth regulators with regard to development of vegetal productivity has been continuously growing. Growth regulators are synthetic compounds, physiological analogues of natural phytohormones that control the processes of growth and development as well as strengthen an immune system of the plant. These substances cannot be replaced by watering or fertilixing plants with microelement fertilizers (Венскутонене et al., 2004). Root development, stem growth, blooming time or plant maturity can be stimulated subject to the usage conditions of growth regulators, concentration thereof and physiological state of the plant itself. In this way, growth regulators may alter the speed of ontogenesis, however, the direction of ontogenesis remains unchanged since it is determined by genetic information. Physiological activity of phytoregulators is expressed by their ability to affect a particular component of a phytohormone system: to increase the amount of a

particular phytohormone through introduction of a physiological analogue of a plant into its organism, to stimulate or inhibit biosynthesis of phytohormones, to block the movement of phytohormones inside the plant, etc. (Меркис et al., 1994).

The activity of growth regulators mostly depends on the time of their application, i. e. on the stage of plant growth and development, on the ability of plant tissues to receive an external signal and integrate it both into the ways of a receptor system of phytohormones and further transduction ways in order to induce the growth and development of a separate part (Darginavičienė et al., 2002). Appropriate application of growth regulators in potato growing technologies enable to control the time of stolone formation, to effect their growth intensity, the process of tuber formation and transportation of assimilants to tubers, as well as to increase starchiness of potato tubers and productivity thereof (Венскутонене et al., 2004).

After spraying potato tubers with growth regulator stilite solutions, they sprout faster and grow more intensely, the greater number of eyes form sprouts, the number of stems of one plant increases. After moistening the seed tubers with stilite solutions of 90 mg l^{-1} concentration, the significant yield growth amounts to 1.6–2.3 t ha^{-1}. The tests carried out on the basis of many years have demonstrated that after spraying potato plants with stilite solutions during the bud stage, productivity increases by approximately 2–2.5 t ha^{-1} in comparison with the control tubers not treated with growth regulators. Growth regulators may be sprayed onto the crops together with liquid complex fertilizers. This provides new possibilities for control of potato growth and productivity thereof (Jakienė, 2006; Makaravičiūtė, 2003).

The aim of the field tests is to determine the effect of growth regulators and liquid complex fertilizers on formation of potato tubers and yield thereof.

Object, methods and conditions. Field tests were performed in the deep glay carbonate leached soil of light clay loam (*Balhihylogleyi – Calc(ar)ic Luvisol)* at the Research Station of LUA during the period of 2004–2006. The soil is neutral (pH_{Hcl} 7.1), of medium humusness (2.5 per cent), phosphorous and of medium calcareousness.

In spring, when the soil surface dried, the soil was heavy harrowed. Later, the field was cultivated and harrowed twice. Before planting potatoes, the field was fertilized with complex fertilizer NPK 17:17:17. Early potatoes of cultivar 'Karlen' were planted during the first ten days of May. Sprouts appeared on the soil surface during the first week of June. After the complete sprouting of potatoes, test sectors were determined. The area of the test sector was 3 m^2. The test was carried out in three repetitions; distribution of test cultivars was systemic.

When potato plants were 5–8 cm high, the test plants were sprayed with herbicide Zenkor (0.4 l ha^{-1}). When Colorado beetles appeared, Decis was used (0.15 l ha^{-1}). Later, potatoes were sprayed with Fastak (0.1 l ha^{-1}). During the bud stage, test sectors were sprayed according to the schedule provided in tables with liquid complex fertilizers Atgaiva-2 and Atgaiva-P, solutions of growth regulators Stilitas-123, Penergetic-p_{lapams}, Humicop and of the blend of the latter regulator and complex fertilizer.

In order to grow and develop, potatoes demand a lot of nutrients. Besides nitrogen,

phosphorus and kalium fertilizers that are required in terms of complexity, potatoes need such microelements as magnesium (Mg), sulphur (S), boron (B), etc. The tested liquid complex fertilizer Atgaiva-2 is in compliance with these requirements as besides the main NPK it is enriched with the above-mentioned microelements. This fertilizer is also very suitable for plants affected by stress (e. g. spring frost).

Complex liquid fertilizer Atgaiva-P is enriched with growth regulator Penergetic; it is recommended for potatoes at the beginning of the bud stage in order to control the processes of tuber formation.

At the Department of Organic Chemistry, Kaunas University of Technology, growth regulator's Stilitas-123 structural formula whereof is similar to that of endogenous phytohormones are synthesized. Usually, these are formations of α, β,_γ amino acids with the connected different radicals of water-soluble salines. After entering the plant, these synthetic growth regulators stimulate activity of natural endogenous phytohormones, thus changing intensity of physiologic processes of the plant and energising metabolism thereof. More active metabolism stimulates the physiological processes that naturally take place in the plant when growth regulators are applied. Even very small concentrations of these compounds (10 g of the regulator in 100 l^{-1} H_2O) result in more intensive growth of plants, faster formation of the maximum assimilation surface of leaves, more intense processes of photosynthesis, and more rapid transportation of assimilants from leaves to the tuber, therefore plant productivity increases (Jakienė et al., 2008). The tested growth regulator Stilitas-123: N was replaced with β alanine sodium saline.

Potatoes are planted into lighter humous soils. Insufficient amount of humus leads to worse physical and mechanical performances of soils (Ražukas, 2002; Simanavičienė, 1999). The substance Humicop applied for the test does not increase the amount of humus in soil, however, humat and fulvous acids contained by Humicop activate and enhance development of soil microflora, improve assimilation of NPK that is specially important for potato roots of weak permeability.

By supplementing the liquid complex fertilizer Atgaiva-2 with growth regulator Humicop, the plants assimilate nutrients better, they grow and develop more intensely (Jakienė, 2006).

Solution concentrations used for field tests are the following:

Atgaiva-2 65 l ha^{-1}

Atgaiva-P 25 l ha^{-1}

Humicop 60 l ha^{-1}

Stilitas-123 30 g ha^{-1}

Penergetic-P_{lapams} 100 ml ha^{-1}

One hectare was sprayed with 300 l^{-1} of operating solution.

The sectors of control tubers were sprayed with water.

The potatoes started to bloom at the beginning of July. The potatoes were harvested in the second ten days of September. During the harvesting, potatoes of every plant were grouped according to fractions and weighed. Statistic analysis of the obtained test data was carried out by applying computer software ANOVA from package SELEKCIJA (Tarakanovas et al., 2003).

Results. The obtained test results have shown that what concerns cultivation of early potatoes, it is advisable to fertilize them additionally through leaves during the bud stage with liquid complex fertilizers and growth regulators. Additional foliar fertilization with the blend of solutions of complex fertilizer Atgaiva-2 and growth regulator Humicop led to particular increase in potato productivity.

Table 1. The effect of additional foliar fertilization on the bigness of potato tubers

1 lentelė. Papildomo tręšimo per lapus įtaka bulvių gumbų stambumui

Research Station of LUA, Average data of the period 2004–2006

LŽŪU Bandymų stotis, vidutiniai 2004–2006 m. duomenys

Test variants Bandymo variantai	Average number of tubers per one plant Vidutinis bulvių skaičius kere						Total number of tubers per one plant Bendras bulvių skaičius kere	
	bulky (> 80?g) stambių (> 80 g)		medium (40–80 g) vidutinių (40–80 g)		small (< 40 g) smulkių (< 40 g)		pcs. vnt.	%
	pcs. vnt.	%	pcs. vnt.	%	pcs. vnt.	%		
Control (H_2O) Kontrolė	5.0	39.0	3.6	28.2	4.2	32.8	12.8	100
Atgaiva-2	6.3	60.0	1.9	18.1	2.3	21.9	10.5	100
Atgaiva-P	5.8	59.2	2.5	25.5	1.5	15.3	9.8	100
Penergetic	6.1	55.9	2.7	24.8	2.1	19.3	10.9	100
Humicop	5.9	52.7	2.8	25.0	2.5	22.3	11.2	100
Stilitas-123	6.2	58.4	2.6	24.5	1.8	17.1	10.6	100
Atgaiva-2 + Humicop	5.2	78.8	1.3	19.7	0.1	1.5	6.6	100

As the data in Table 1 demonstrate, the biggest potato tubers were provided by the test variants additionally fertilized through leaves with the blend of solutions of complex fertilizer Atgaiva-2 and growth regulator Humicop. Additional fertilization with this blend resulted in as much as 78.8 % of bulky tubers in one plant and almost no small potatoes were found. Medium sized potatoes amounted to 19.7 % of all potato tubers of one plant. Just 1.5 % of small potatoes were present. This additional fertilization resulted in less tubers of one plant but they were all bulky and weighed over 80 g each.

58–60 % of bulky tubers have also grown after additional fertilization with liquid fertilizer Atgaiva-2, Atgaiva-P and after applying growth regulator Stilitas-123. Amount of medium size potatoes found in test variants was 18–25 %. After additional fertilization of potatoes with complex fertilizer Atgaiva-P and solution of Stilitas-123 (15.3–17.1 % accordingly), amount of small tubers was less since growth regulator Penergetic contained by this fertilizer and growth regulator Stilitas-123 stimulated more intense growth of potato tubers. After applying liquid complex fertilizer Atgaiva-2, the amount of small potatoes found was 21.9 % (Table 1).

After spraying the potato plants in the bud stage with the solutions of growth regulators Penergetic-P_{lapams} or Humicop , over 50 % of bulky potatoes per plant was found, whereas the rest of the tubers contained approximately the equal number of medium sized and small potatoes.

The greatest number of tubers, however, the smallest ones has grown in the control test sections where the plants were not additionally fertilized through leaves.

Table 2. The effect of additional foliar fertilization on the potato yield
2 lentelė. Papildomo tręšimo per lapus įtaka bulvių derliui

Research Station of LUA, average data of the period 2004–2006
LŽŪU Bandymų stotis, vidutiniai 2004–2006 m. duomenys

Test variants Bandymo variantai	Productivity Derlingumas (t ha^{-1})	Difference in comparison with the control variants Skirtumas palyginus su kontrole	
		t ha^{-1}	%
Control (H_2O) Kontrolė	32.18	-	100
Atgaiva-2	40.72	8.54	126.5
Atgaiva-P	41.30	9.12	128.3
Penergetic	37.52	5.34	116.6
Humicop	33.10	0.92	102.8
Stilitas-123	38.46	6.28	119.5
Atgaiva-2 + Humicop	36.94	4.76	114.8
R_{05} / LSD_{05}	1.537		

The greatest yield was achieved after additional foliar fertilization with liquid complex fertilizer Atgaiva-P and Atgaiva-2 (Table 2). Under the influence of the aforesaid additional fertilization, the yield significantly increased by 8–9 t ha^{-1} or 26–28 % in comparison with the control variants. Additional foliar fertilization of potatoes with the solutions of growth regulators Penergetic and Stilitas-123 as well as with the blend of solutions of complex fertilizer Atgaiva-2 and growth regulator Humicop also provided good results. The above mentioned test variants produced a significantly greater (by 4.76–6.28 t ha^{-1} or 14.8–19.5 %) potato yield.

In the test variants, where for additional fertilization growth regulator Humicop solely was applied, the potato yield increased just slightly (0.92 t ha^{-1} or 2.8 %) and not significantly.

Taking into account the purpose of the grown potatoes, it advisable to spray potatoes grown for industrial processing with the solutions of growth regulators Stilitas-123 or Penergetic-P_{lapams} after additional foliage fertilization thereof with liquid complex fertilizer Atgaiva-P at the beginning of the bud stage. Under the influence of this additional fertilization, the potato yield increases by approximately 5.34–9.12 t ha^{-1} or 16.6–28.3 %. In the yield structure, medium sized potatoes and bulky potatoes make up 25 and 55–59 %, respectively.

In the yield structure of potatoes grown for food, bulky potatoes should dominate. In this case, it is advisable to apply the blend of solutions of complex fertilizer Atgaiva-2 and growth regulator Humicop for additional foliar fertilization. In the test variants, where this blend of fertilizer and growth regulator was applied, 78 percent of bulky potatoes in one plant were found, whereas almost no small potatoes were present. Nevertheless, the number of tubers per plant was by half smaller compared to the number of tubers grown in control test sectors. Under the influence of this additional fertilization, the potato yield increased by approximately 4.76 t ha^{-1} or 14.8 % in comparison with the control variants.

Having no possibilities to fertilize table potatoes additionally with the blend of complex fertilizer Atgaiva-2 and growth regulators Humicop, good results are also achieved by additional foliar fertilization with liquid complex fertilizer Atgaiva-2 solely. Under the influence of this additional fertilization, bulky potatoes made up 60 % of the yield structure, whereas the rest of the yield contained 40 % of small and medium sized potatoes. Under the influence of complex fertilizer, a greater number of tubers per plant develop compared to the case when the blend of Atgaiva-2 and Humicop is applied. After additional foliar fertilization with fertilizer Atgaiva-2 solely, the yield significantly increased by 8.54 t ha^{-1} or 26.5 % in comparison with the control variants.

Discussion. The investigations of the phytohormones at molecule, cell and plant organism level makes it possible to solve the problem of growth regulators in plant growing. Long-term data on various potato varieties ('Vokė', 'Nida', 'Vilma', etc.) with respect to ripening time revealed that treatments with optimum growth regulator TA – 12, TA – 14 concentrations and optimum treatment time (4^{th} organogenesis stage) resulted in activation of the organogenesis process. It is well established that these combinations modify both the formation and growth of the stolons not only quantatively but also stimulate earlier root formation through shortening the period of the stolon growth what has positive effect on potato productivity (Dargevičienė et al., 2002).

Leaf spray fertilization with complex fertilizers also stimulated more intensive potato growth and formation of the structural yield elements. Additional fertilization with complex mineral fertilizers with microelements (Rainys et al., 2005) contributed to higher potato productivity. Even better results were obtained using growth regulators at the time of additional leaf spray fertilization. Growth regulators stimulated metabolism processes, the plants assimilated nutrients better and in turn formed higher and better quality yield (Jakienė et al., 2008).

Treatments with growth regulators have been more and more widely used in plant growing. The treatments of the winter wheat with growth regulators resulted in longer wheatears and increase in 1 000 grain mass. Chlorophyll biosynthesis was more intensive and higher chlorophyll concentration was determined in the plant leaves (Aupkalnienė, 2005).

Growth regulators had significant effect on cabbage biometric parameters, improved their productivity and disease resistance. Treatments of the cabbage leaves with the considered growth regulator (epin, lizar) solutions 1.5 × 10 – 4 % during vegetation period resulted in 10 cm plant height increase, 8 mm flower diameter increase, 62 % pulse increase. The yield was by 230 kg ha^{-1} or by 32.9 % higher, ripe seeds were of better quality (Danilevič, 2005).

More and more often liquid complex and microelement fertilizers have been used for additional fertilization in plant growing technologies. Leaf spray fertilization of the beetroot spouts with calcium saltpeter, nitrabor or nutrifol + microelements during the first part of the vegetation resulted in root and diameter increase (Bundinienė et al., 2007). It is well established that leaf spray fertilization with various nutritive and biologically active substances affect summer rape biomass, seed quality and profitability. The most profitable was found to be rape fertilization with the fertilizer 'Aton AZ' containing microelements and amino acid, and "Boramin Ca" – the profit from one hectare in the considered years made at the average 62 Lt (Staugaitis et al., 2007).

The experiments on additional winter wheat spray fertilization and growth regulator use carried out on the experimental station at Lithuanian University of Agriculture revealed that two time fertilization with 30 kg ha^{-1} nitrogen resulted in 4.27–4.84 t ha^{-1} yield increase on the plots of mean intensity technologies, and up to 7.33–9.25 t ha^{-1} on the plots of the intensive technologies. On the plots of the intensive technologies the most effective was found to be fertilization with microelement complex nutrifol and growth regulator cycocel. The yield in this variant made 9.25 t ha^{-1}. The grain contained 15.8 % of protein and 30.1 % gluten (Šiuliauskas et al., 2002).

Additional leaf spray fertilization using liquid complex fertilizers and growth regulators had positive effect on potatoes. Growth regulators Penergetic-P and Stilite-123 activated the cells participating in metabolism process and the plants assimilated nutrients better. Potato productivity under the influence of these regulators was by 9.12 t ha^{-1} or by 28 % (Penergetic-P) and by 6.28 t ha^{-1} or 19.5 % (Stilite-123) higher than in the control. Additional potato fertilization with the mixture of the liquid fertilizers Atgaiva-2 and growth regulator Humicop modified the growth of the tubers effectively. Big potatoes on the potato bushes on these plots made 78 %. The productivity was by 4.76 t ha^{-1} or by 14.8 % higher than in not fertilized variants.

Conclusions. 1. In the process of potato growing, it is advisable to apply for potatoes additional foliar fertilization with the blend of complex fertilizers and growth regulators within the bloom formation stage.

2. The greatest addition to the yield (8.54–9.12 t ha^{-1}) and the bulkiest potatoes (approximately 60 % of potatoes weighed over 80 g each) has grown after additional fertilization with liquid complex fertilizers Atgaiva-2 and Atgaiva-P.

3. After spraying the potatoes during the bud stage with the solutions of growth regulators Stilitas-123 or Penergetic-P, bulky potatoes made up 55.9–58.4 % of the yield structure, whereas the rest of the tubers contained approximately the equal number of medium sized and small potatoes. The productivity under the influence of these growth regulators significantly increased by 5.34–6.28 t ha^{-1} or 16.6–19.5 % in comparison with the control variants.

4. It is advisable to fertilize table potatoes additionally through leaves with the blend of solutions of complex fertilizer Atgaiva-2 and growth regulator Humicop. After additional fertilization of potatoes with this blend, bulky potatoes made up even 78.8 % of the yield structure, whereas medium sized potatoes amounted just to 19.7 % and small potatoes were almost not found (1.5 %) at all. Under the influence of this additional fertilization, the potato yield significantly increased by 4.76 t ha^{-1} or 14.8 % in comparison with the control variants.

5. After additional spraying of potatoes with the solution of growth regulator Humicop solely, bulky potatoes made up app. 52.7 % of the yield structure, whereas the rest of the tubers contained the equal shares of medium sized and small potatoes. Application of this regulator had no any significant effect on productivity.

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Papildomo tręšimo skystosiomis kompleksinėmis trąšomis ir augimo reguliatoriais įtaka bulvių produktyvumui

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Santrauka

Tyrimai atlikti 2004–2006 metais Lietuvos žemės ūkio universiteto bandymų stotyje. Tirta skystųjų kompleksinių trąšų ir augimo reguliatorių įtaka bulvių augimui, stiebagumbių formavimuisi ir derlingumui.

Nustatyta, kad didžiausias derliaus priedas (8,54–9,12 t ha^{-1}) gautas ir apie 60,0–59,2 proc. stambių bulvių kere užaugo žiedų formavimosi tarpsnio pabaigoje bulves papildomai per lapus patręšus „ARVI fertis“ skystosiomis kompleksinėmis trąšomis Atgaiva-2 arba Atgaiva-P.

Bulves apipurškus augimo reguliatorių Penergetic-P_{lapams} arba Stilito-123 tirpalais, stambios bulvės derliaus struktūroje sudarė 55,9–58,4 proc. Derlius šių augimo reguliatorių įtakoje patikimai padidėjo 5,34–6,28 t ha^{-1} arba 16,6–19,5 proc., lyginant su kontrole.

Maistui auginamas bulves tikslinga papildomai patręšti kompleksinių trąšų Atgaiva-2 ir reguliatoriaus Humicop mišiniu. Papildomai per lapus patrępus šiuo mišiniu, stambios bulvės derliaus struktūroje sudarė net 78,8 proc., o smulkių beveik nerasta (tik 1,5 proc.). Bulvių derlius šio papildomo tręšimo įtakoje patikimai padidėjo 4,76 t ha^{-1} arba 14,8 proc., lyginant su kontrole.

Reikšminiai žodžiai: augimo reguliatoriai, bulvės, produktyvumas, skystos kompleksinės trąšos.