Agronomy Research **7**(Special issue I), 269–276, 2009

Fertilization of sugar beetroot with ecological fertilizers

E. Jakiene, V. Venskutonis and V. Liakas

Lithuanian University of Agriculture

Abstract. Field trials were carried out on *Balhihylogleyi-Calc(ar)ic Luvisol* soils of the experimental station of the Lithuanian University of Agriculture. The aim of field trials was to estimate the influence of additional fertilization on sugar beetroot productivity. 'Ernestina' variety sugar beetroots were grown. At the stage of six paired leaves (BBCH 18 – 19) trial variants were additionally leaf-spray fertilized with Humicop solution, a solution of growth stimulator Penergetic-P and a solution of liquid complex fertilizers Atgaiva-P. Control variants were leaf-sprayed with water.

The findings of the research revealed that additional leaf-spray fertilization with humic fertilizers Humicop resulted in by 4.5 t ha^{-1} or 7.4% significantly higher root productivity, significant increase in saccharinity by 0.07 percent units, and by 0.61 t ha^{-1} higher than in the control white sugar yield. Leaf-spray of the sugar beetroot seedlings with Penergetic-P solution resulted in significant sugar beetroot productivity increase by 8.8 t ha^{-1} or by 14.5%, and saccharinity increase by 0.31 percent units, and by 1.34 t ha^{-1} higher than in the control white sugar yield. Additional leaf-spray fertilization with the solutions of the liquid complex fertilizer Atgaiva-P resulted in significant sugar beetroot productivity increase by 11.5 t ha^{-1} or by 18.9%, and saccharinity increase by 0.91%, and by 2.13 t ha^{-1} or 27% higher than in the control white sugar yield.

INTRODUCTION

At different development periods and in different conditions, plants feature different demand for nutrients. Some nutrients are found in soil, however, they are sometimes lacking during vegetation. At certain phenologic development stages, additional leaf-spray fertilization of plants helps to balance the satisfaction of demand for nutrients and to form both quantitative and qualitative indicators of harvest.

Leaf-spray fertilization of plants offers a range of advantages: it allows regulating growth and development of plants taking into account meteorological conditions and state of the plants, removing physiologic diseases of plants quickly when the lack of nutrients is observed, fertilizing plants when nutrients in the soil are blocked. Formerly, leaf-spray fertilizers of plants were used to eliminate the lack of nutrients, whereas today they are preselected considering 1) the ability of specific plants to assimilate individual nutrients, and 2) the influence of possible agroclimatic factors on assimilation of nutrients. The biological, physiological or morphological peculiarities of plants, varieties, and often cultivars of cultivated plants respond to leaf-spray fertilizers very differently (Darginavičienė et al., 2002).

According to average data of the experiments carried out at the Experimental Station of the Lithuanian University of Agriculture during three years, the increase in harvest of sugar beetroot tubers with application of leaf-spray fertilization amounted to

2.6–4.9%. In no year did leaf-spray fertilization decrease the harvest of tubers, i.e. growth tendencies were observed over all years of the experiments (Staugaitis, 2008).

In today's plant growing, application of growth-stimulating materials that affect physiological processes of plants has been continuously spreading. Growth stimulators used in growing technologies of outdoor plants activate plant cells participating in metabolism, stimulate growth of a root system, optimize assimilation of nutrients and the transport of assimilates from leaf to other organs. Plants become more resistant to negative environmental factors as greater and better quality harvest of outdoor plants are obtained (Kazlauskas et al., 2007; Jakienė, 2008).

Chlorophylls and carotenoids are the key pigment system components participating in the photosynthesis process. They are responsible for the absorption of the light quanta and energy transmission to the reaction centers of the photo system, where light quanta energy is transformed into chemical energy and used to assimilate carbon dioxide. The amount of chlorophyll is closely related to the physiological activity of the plant and accumulation of the photosynthates. The higher the concentrations of the chlorophylls and carotenoids, the higher amount of the dry matter is assimilated by the plants and the more consistently and rapidly are the photosynthates transmitted to the roots; the result is higher sugar content (Guidi et al., 1997).

Results of the tests carried out at the Experimental Station of the Lithuanian University of Agriculture over many years demonstrate that spraying sugar beetroots with growth stimulating solutions when beetroots are at the six-paired-leaf stage leads to more intensive growth of seedlings, faster formation of the maximum leaf assimilation area, more intensive photosynthesis and metabolism. All this directly influences fertility of tubers and quality of harvest. (Jakienė et al., 2004).

The use of the physiologically active materials of biologic origin to solve the problems of the plant organogenesis, metabolism, generative development and productivity regulation is a new area in plant science (Gavelienė et al., 2007).

TECHNIQUE

Tests were carried at the Experimental Station of the Lithuanian University of Agriculture during the period 2006-2008. Soil – carbonate shallow gleyic leached *(Calcari – Epihypogleyic Luvisols).* Soil was neutral pH $_{HCh}$ 7.1–7.3 containing 238–315 mg kg^{-1} of mobile phosphorus (P_2O_5), 154–172 mg kg^{-1} of mobile potassium (K_2O), 1.70–2.45% of humus. Winter wheat served as a pre-crop for sugar beetroots.

In spring, after the soil had dried up slightly, complex fertilizers NPK were spread at a rate 11:13:30 (450 kg ha^{-1}). On the same day, the soil surface was sprayed with the herbicide Pyramin Turbo, 4.5 l ha^{-1}; the soil was cultivated; on 16 April, sugar beetroots of the cultivar Ernestina were sowed. Sowing was carried out by the pneumatic sowing-machine PTO MAX-540 spreading seeds every 16 cm, with a 45-cm space between rows.

With renewal of mass germination of weeds, herbicides Betanal Expert 1.25 l ha^{-1} and Lontrel 0.30 l ha^{-1} were sprayed. For additional fertilization of sugar beetroots (Stage 16–17 by BBCH scale), ammonium nitrate N_{30} (200 kg ha^{-1}) was used. When seedlings were at six-paired-leaf stage (BBCH 18-19), trial variants were additionally leaf-spray fertilized with the solution of humic fertilizers Humicop (60 l ha^{-1}), solutions of the growth stimulator Penergetic-p_{lapams} (100 ml ha^{-1}) and liquid complex fertilizers Atgaiva-P (60 l ha^{-1}). Control test sectors were sprayed with water.

On 28–29 September, the tuber harvest was taken in manually, using a tractor lift.During harvesting, samples were taken in order to detect saccharinity. Saccharinity of tubers was established at Marijampolė Sugar Factory employing the P. N. Silin method of the cold digestion, saccharometer SU-4 (Reinefeld et al., 1974).

Chlorophyll concentration in sugar beetroot leaves was determined employing the spectro-photometric method according to the amount of the light the pigment extract absorbs (Schreiber, 1997).

Tests were carried out by the following scheme:

1. NPK 11:13:30 before sowing + N_{30} at the stage of 3-4 leaf (background)
2. Background + seedlings sprayed with H_2O
3. Background + seedlings sprayed with the solution of Humicop 60 l ha^{-1}
4. Background + seedlings sprayed with the solution of Penergetic-p_{lapams} 100 ml ha^{-1}
5. Background + seedlings sprayed with the solution of Atgaiva-P 60 l ha^{-1}

To 1 ha, 300 l of an operating solution was sprayed.

The test was carried out in four repetitions. Initial area of a test sector was 27 m^2; the area of an estimated sector was 24 m^2. Distribution of sectors was systemic.

During the test, fertilizers and growth stimulating materials were analyzed.

Humicop is an extract of humat and fulvous acids and microelements. This preparation does not increase the amount of humus in soil, however, humat acids contained by Humicop improve soil cohesion, integrity, stability and structure, ensure better air exchange in soil, activate and enhance development of soil microflora, have a positive impact on the seed germination process and root system development, and stimulate growth of plants. As a growth stimulator, Humicop is recommended for application in outdoor plant growing technologies for additional leaf-spray fertilization of plants.

Growth stimulator Penergetic-p_{lapams} activates plant cells participating in metabolism, and creates favourable conditions for assimilation of nutrients. All this positively affects fertility and improves quality of the harvest. The main component of this preparation is molasses processed by a special technology. The product contains no other chemical substances; it is eco-friendly and harmless.

Composition of liquid complex fertilizers Atgaiva-P: total nitrogen (N) 7%, nitrate nitrogen (NO_3N) 0.9%, amide nitrogen (NH_2N) 4.3%, ammonium nitrogen (NH_4-N) 1.8%, phosphorus (P_2O_5) 3.8%, potassium (K_2O) 3.5%, manganese (Mn) 0.05%, growth stimulator – Penergetic-p.

RESULTS

At the beginning of vegetation, seedlings of sugar beetroots grow slowly. The use of growth-stimulating materials in this period leads to faster formation of the maximum leaf assimilation area, increase of concentration of photosynthetic pigments in beetroot leaf, more intensive photosynthesis processes and transport of assimilates from leaf to tuber (Novickienė L., 1994; Šlapakauskas V. et al, 2008).

Additional leaf-spray fertilization of sugar beetroots with liquid complex fertilizers and growth stimulators influenced more intensive accumulation of photosynthesis pigments (Table 1).

Research results demonstrated that by spraying sugar beetroot seedlings with solutions of stimulating materials, concentration of chlorophylls in beetroot leaf increased significantly and reliably. In sugar beetroot leaf sprayed with the solution of growth stimulators Penergetic-p, Humicop and liquid complex fertilizers Atgaiva-P, chlorophyll concentration *a* had significantly increased by 0.08, 0.20 and 0.32 mg g^{-1} respectively or by 1.4–5.7%, whereas chlorophyll concentration *b* had significantly increased by 0.18, 0.23 and 0.28 mg g^{-1} respectively or by 13.4–20.9% compared to chlorophyll concentration in leaf of beetroots in control sectors (Table 1).

Table 1. Chlorophyll accumulation in sugar beetroot leaf at growth stage 21-22 by BBCH scale.

Average data of 2006–2008

Trial variants	Concentration of chlorophyll *a*			Concentration of chlorophyll *b*			Concentration of hlorophylls *a+b*
	mg g^{-1}	Difference compared to unfertilized plants		mg g^{-1}	Difference compared to unfertilized plants		
		mg g^{-1}	%		mg g^{-1}	%	
NPK 11:13:30 + N_{30} (background)	5.61	-	-	1.36	-	-	6.97
Control (background + H_2O)	5.64	-	100.0	1.34	-	100.0	6.98
Background + Humicop	5.72	0.08	101.4	1.52	0.18	113.4	7.24
Background + Penergetic	5.84	0.20	103.5	1.57	0.23	117.2	7.41
Background + Atgaiva-P	5.96*	0.32	105.7	1.62*	0.28	120.9	7.58*
R_{05}	0.005			0.057			

The concentration established in sugar beetroot leaf before harvesting illustrated that the highest concentration of chlorophyll *a* remained after spraying seedlings with solutions of the growth stimulator Humicop and fertilizers Atgaiva-P. In the leaf of the sugar beetroots grown in these test sectors, concentration of chlorophyll *a* was 0.88–0.57 mg g^{-1} or 13.3–8.6% higher compared to the plants not fertilized additionally (Table 2).

Significantly higher concentration of chlorophyll *a* was also established after using the growth stimulator Penergetic for additional leaf-spray fertilisation. Under influence of this fertilization, concentration of chlorophyll *a* in beetroot leaf was 0.37 mg g^{-1} or 5.6% higher compared to concentration in the leaf of the sugar beetroots grown in test sectors (Table 2).

Before harvesting, concentration of chlorophyll *b* in beetroot leaf was also significantly higher. The greatest content of chlorophyll *b* in sugar beetroot leaf was established after using solutions of growth stimulators Penergetic or fertilizers Atgaiva-P for additional fertilization. Here, concentration of chlorophyll *b* was 0.19–0.17 mg g^{-1} or 8.6–7.7% higher compared to concentration in the plants not fertilized additionally (Table 2). Higher concentrations of chlorophylls *a+b* remained until harvesting in leaf of the beetroots the seedlings of which were additionally fertilized with solutions of the analyzed growth stimulators and complex fertilizers (Table 2).

Table 2. Accumulation of chlorophylls in sugar beetroot leaf before harvesting.

Average data of 2006–2008

Trial variants	Concentration of chlorophyll *a*			Concentration of chlorophyll *b*			Concentration of chlorophylls *a+b*
	mg g^{-1}	Difference compared to unfertilized plants		mg g^{-1}	Difference compared to unfertilized plants		
		mg g^{-1}	%		mg g^{-1}	%	
NPK 11:13:30 + N_{30} (background)	6.42	-	-	2.12	-	-	-
Control (background + H_2O)	6.62	-	100.0	2.20	-	100.0	8.82
Background + Humicop	7.50*	0.88	113.3	2.25	0.05	102.3	9.75*
Background + Penergetic	6.99	0.37	105.6	2.39*	0.19	108.6	9.38
Background + Atgaiva-P	7.19*	0.57	108.6	2.37*	0.17	107.7	9.56
R_{05}	0.152				0.034		

Additional leaf-spray fertilization also stimulated more intensive accumulation of carotenoids in the sugar beetroot leaf. It has been established that two weeks after additional fertilization (growth stage 21–22 by BBCH scale), the greatest concentration of carotenoids was observed in leaf of the beetroots the seedlings which were sprayed with solutions of growth regulators Penergetic-P and Humicop at the beginning of vegetation. Under influence of this fertilization, concentration of carotenoids in beetroot leaf was 0.21–0.23 mg g^{-1} or 10.9–11.9% significantly higher compared to the concentration in unfertilized plants. Higher concentration of carotenoids was also established using complex liquid fertilizer Atgaiva-P for additional fertilization. Concentration of carotenoids in leaf of the sugar beetroots grown in these test sectors was 0.16 mg g^{-1} or 8.3% higher compared to the concentration in leaf of the beetroots not fertilized additionally (Table 3).

Due to spraying of sugar beetroot seedlings with solutions of growth stimulators and liquid complex fertilizers, more intensive accumulation of carotenoids took place in beetroot leaf by the very harvesting. The highest concentration of carotenoids before harvesting was established in leaf of the sugar beetroots additionally fertilized with solutions of the growth regulator Humicop and fertilizers Atgaiva-P. Under influence of this fertilization, concentration of carotenoids in beetroot leaf was 0.29–0.18 mg g^{-1} or 10.9–6.8% significantly higher compared to concentration in leaf of the sugar beetroots grown in test sectors (Table 3).

Table 3. Accumulation of carotenoids in sugar beetroot leaf.

Average data of 2006–2008

Trial variants	Concentration of carotenoids			Concentration of carotenoids		
	$mg\ g^{-1}$	Difference compared to unfertilized plants		$mg\ g^{-1}$	Difference compared to unfertilized plants	
		$mg\ g^{-1}$	%		$mg\ g^{-1}$	%
NPK 11:13:30 + N_{30} (background)	Stage 21-22 by BBCH scale			Before harvesting		
	1.80	-	-	2.57	-	-
Control (background + H_2O)	1.92	-	100.0	2.65	-	100.0
Background + Humicop	2.15	0.23	111.9	2.94*	0.29	110.9
Background + Penergetic	2.13	0.21	110.9	2.73	0.08	103.0
Background + Atgaiva-P	2.08	0.16	108.3	2.83	0.18	106.8
R_{05}	0.053			0.045		

Additional leaf-spray fertilization of sugar beetroots applying growth stimulating materials increased beetroot productivity. The highest fertility of tubers was obtained after additional fertilization of sugar beetroots with the liquid complex fertilizers Atgaiva-P at six-paired-leaf stage (stage 16–17 by BBCH scale). Under influence of this fertilization, fertility of tubers significantly increased by 11.5 t ha^{-1} or 18.9% compared to the plants not fertilized additionally. After additional spraying of sugar beetroot seedlings with solutions of growth stimulators Humicop or Penergetic, fertility of tubers significantly increased by 4.5 t ha^{-1} and 8.8 t ha^{-1} respectively or 7.4% and 14.5% compared to the control when plants were sprayed only with water during additional fertilization (Table 3).

More intensive growth of sugar beetroots and bigger tubers were observed after additional leaf-spray fertilization of beetroots with complex fertilizers Atgaiva-P. Average weight of the tubers grown in these test sectors was established to be 177 g significantly greater compared to weight of the plants not fertilized additionally. After spraying of sugar beetroot seedlings with the solution of the growth stimulator Penergetic, average weight of a tuber significantly increased by 65 g compared to the tubers grown in control test sectors. Due to additional spraying of sugar beetroot seedlings with Humicop solution, the tubers were slightly smaller compared to the plants not fertilized additionally (Table 4).

The greatest content of sugar substances was accumulated by tubers when beetroot seedlings were additionally leaf-spray fertilized with complex fertilizers Atgaiva-P. Under influence of this additional fertilization, saccharinity of tubers significantly increased by 0.91% compared to the control. After additional fertilization of sugar beetroots with growth stimulators Humicop and Penergetic, saccharinity of tubers significantly increased by 0.27% and 0.31% respectively compared to the plants not fertilized additionally (Table 5).

Table 4. Influence of Additional Leaf-Spray Fertilization on Fertility of Sugar Beetroots. Experimental Station, Lithuanian University of Agriculture.

Average data of 2006–2008

Trial variants	Fertility $t\ ha^{-1}$	Difference compared to the plants not fertilized additionally		Number of plants, thousand 1 ha^{-1}	Average weight per tuber	
		$t\ ha^{-1}$	%		kg	Difference compared to the plants not fertilized additionally kg
NPK 11:13:30 + N_{30} (background)	60.5	-	-	-	-	-
Control (background + H_2O)	60.6	-	100.0	84.5	0.717	-
Background + Humicop	65.1	4.2	107.4	92.6	0.703	- 0.014
Background + Penergetic	69.4	8.8	114.5	88.7	0.782	+ 0.065
Background + Atgaiva-P	72.1*	11.5*	118.9	86.4	0.834*	+ 0.117
R_{05}	2.067				0.0103	

Table 5. Influence of Additional Leaf-Spray Fertilization on Saccharinity of TubersExperimental Station, Lithuanian University of Agriculture.

Average data of 2006–2008

Trial variants	Saccharinity %	Difference compared to the plants not fertilized additionally %	White sugar yield $t\ ha^{-1}$	Difference compared to the plants not fertilized additionally	
				$t\ ha^{-1}$	%
NPK 11:13:30 + N_{30} (background)	17.08	-	-	-	-
Control (background + H_2O)	17.10	-	7.77	-	100.0
Background + Humicop	17.37	0.27	8.52	0.75	109.6
Background + Penergetic	17.41	0.31	9.11	1.34	117.2
Background + Atgaiva-P	18.01*	0.91	9.90*	2.13	127.4
R_{05}	0.124		0.352		

The greatest yield of white sugar was observed after additional fertilization with the solutions of the growth stimulator Penergetic and complex fertilizers Atgaiva-P. Under influence of this additional fertilization, the yield of white sugar significantly increased by 1.34 t ha^{-1} and 2.13 t ha^{-1} or 17.2% and 27.4% respectively compared to the plants not fertilized additionally. Under influence of the activator Humicop, the yield of the white sugar received increased by 0.75 t ha^{-1} or 9.6% compared to the control when sugar beetroots were not fertilized additionally (Table 5).

CONCLUSIONS

1. Additional fertilization of sugar beetroots with the solutions of growth stimulators Humicop and Penergetic and liquid complex fertilizers Atgaiva-P increased concentration of chlorophylls *a* and *b* as well as of carotenoids in leaf. Higher concentrations of these photosynthetic pigments remained in beetroot leaf by the very harvesting.
2. Under influence of additional sugar beetroot fertilization with the growth stimulator Penergetic and fertilizers Atgaiva-P, fertility of tubers significantly increased by 8.8–11.5 t ha^{-1} or 14.5–18.9%, saccharinity grew by 0.31–0.91%, whereas the yield of the white sugar received significantly increased by 1.34–2.13 t ha^{-1} or 17.2–27.4% compared to the plants not fertilized additionally.
3. Impact of the growth stimulator Humikop on productivity of sugar beetroots was lower. After spraying of sugar beetroot seedlings with the solution of this stimulator, fertility of tubers significantly increased by 4.2 t ha^{-1} or 7.4%, saccharinity increased by 0.27%, whereas the yield of the white sugar received significantly increased by 0.75 t ha^{-1} or 9.6% compared to the control when sugar beetroots were not fertilized additionally.

REFERENCES

Darginavičienė, J. &, Novickienė, L. 2002. Augimo problemos šiuolaikinėje augalų fiziologijoje. *Lietuvos mokslų akademijos leidykla. Vilnius*, pp. 42–45.

Gavelienė, V., Novickienė, L. &, Kazlauskienė, D. 2007. Effect of auxin physiological analogues on rape growth and reproductive development. *Botanica lithuanica* **13**(2), 101–107.

Guidi, L., Nali, C.,, Ciompi, S. et al. 1997. The use of chlorophyll fluorescence and leaf gas exchange as methods of studying the different responses to ozone of two beans cultivars. *Journal of Experimental Botany* **48**, 173–179.

Jakienė, E. &, Venskutonis, V. 2008. Augimo reguliatoriai augalininkystėje. – Akademija, 2008 2008, 80 p. Staugaitis G., Laurė R. Lapų trąšų įtaka cukrinių runkelių derliui, kokybei ir pelningumui. *LŽŪU Mokslo darba* **78**(31), 43–47.

Jakienė, E., Venskutonis, V. &, Mickevičius, V. 2004. The Impact of Different Concentrations of Growth Regulators – Stilits on Sugar Beet Productivity. *LŽŪU Mokslo darba* **64**(17), 26–31.

Kazlauskas, E., Šlapakauskas, V., Beresnevičius, Z., & Tumosienė, I. 2007. Effect of β-alanine hydrazide derivatives on *Phaseolus vulgaris* photochemistry and CO_2 assimilation. Biologija. *Mokslo darba*. **53**(2) 7, 13–15.

Novickienė, L. 1994. Augalų augimą, vystymąsi ir produktyvumą reguliuojančių fitohormonų ir retardantų analogų kūrimo fiziologiniai pagrindai. Vilnius, pp. 74–83.

Reinefeld, E., Emmerich, A.,, Baumgarten, G. et. al. 1974. Zur Voraussage des Melassezuckers aus Rübenanalysen. *Zucker* **27**, 2–15.

Schreiber, U. 1997. *Chlorophyll fluorescence and photosynthetic energy conversion.* Walz, Germany, p. 73.

Šlapakauskas, V., Stanys, V. &, Varkulevičienė, J. 2008. Correlation between chlorophyll fluorescence of primrose (*Primula malacoides Franch.)* and DNA polymorphic bands. Sodininkystė ir daržininkystė. *Mokslo darbai*. 2008, **27**(2), 269–275.

Staugaitis, G. &, Laurė, R. 2008.Lapų trąšų įtaka cukrinių runkelių derliui, kokybei ir pelningumui. LŽŪU Mokslo darbai, Nr. **78**(31), 43–47.