The effect of foliar fertilization with marine calcite in sugar beet

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ABSTRACT

The effect of marine calcite (containing calcium and silicon mainly) foliar fertilization on the sugar beet root yield and technological quality relative to the control (treatment 0) was investigated. Study was conducted in 2011–2012 in the southeastern region of Poland, in Sahryń (50°41'N, 23°46'E). The cultivar of sugar beet was Danuśka KWS. Two treatments of foliar fertilization: (1) treatment (in the stage of 4–6 sugar leaves – 262.0 g Ca/ha, 79.9 g Si/ha, and three weeks later – 524.0 g Ca/ha, 159.8 g Si/ha); and (2) treatment (in the stage of 4–6 sugar leaves – 524.0 g Ca/ha, 159.8 g Si/ha, three weeks later – 524.0 g Ca/ha, 159.8 g Si/ha). Calcium and silicon foliar fertilization resulted in increases of: (1) the root yield (average for both treatments about 13.1%; (2) the leaf yield (about 21.0%); (3) the biological sugar yield (about 15.5%), and (4) technological yield of sugar (about 17.7%) compared with the control treatment. At the same time a positive effect on the roots technological quality was found. It was a significant reduction of alpha-amino-nitrogen content and tended to reduce the content of potassium and sodium.

Keywords: calcium; root yield; silicon; technological quality of roots; *Beta vulgaris*

The limitation of sugar production in the EU will be finished in 2017. Therefore the increase of sugar production and lower prices for beet roots are expected. Therefore the new, more effective solutions for better sugar yield are necessary. However, they must be environmentally safe. Silicon application is a novel idea of fertilization. Its favourable effect on many plant species growth and development was found by some researchers (Matichenkov and Calvert 2002, Raven 2003, Fauteux et al. 2005, Hou et al. 2006, Yamaji et al. 2008). However, the role of silicon in crops is not particularly well understood (Casey et al. 2003). Silicon plays a very important role in the reduction of the plants vulnerability to biotic and abiotic environmental stress (Fauteux et al. 2005, Mitani and Ma 2005, Ma and Yamaji 2006, Liang et al. 2006, Gunes et al. 2007, Sacała 2009). This component increases the plants' resistance to pathogens and pests (Samuels et al. 1993, Fawe et al. 1998, Raven 2003, Henriet et al. 2006, Cai et al. 2009). One of the most important beneficial effects of silicon on plant growth is related to increased resistance under water stress conditions (Ma et al. 2004, Sacała 2009). Sugar beet is one of seven plant species that are classified as silicon bio-accumulators (Guntzer et al. 2012). Herbagreen basic (other name – Megagreen) is one of foliar fertilizers containing significant amounts of silicon. This is a marine micronized calcite. Calcium carbonate ($CaCO_3$) decomposes to calcium oxide (CaO) and carbon dioxide (CO_2) in leaves stomata, and this carbon dioxide increases the intensity of photosynthesis. The positive effects of Herbagreen basic application on lettuce in Serbia inform Ugrinović et al. (2011). Although, there are many popular publications suggesting positive effects of silicon and calcium fertilization in sugar beets, but no scientific documentation of such effects is available. The aim of the study was to evaluate the effectiveness of calcite foliar fertilization on sugar beet roots yield and technological quality of cv. Danuśka KWS.

Table 1. Soil conditions in 2011–2012

Year	C_{org} (g/kg)	pH_{KCl}	NO_3^--N	NO_4^+-N	P	K	Mg	B	Cu	Fe	Mn	Zn
					(mg/kg)							
2011	7.54	7.20	7.54	2.68	109.0	95.5	63.0	1.18	6.5	780	129	7.0
2012	8.10	6.70	8.22	4.61	82.4	78.9	45.0	1.19	3.5	710	190	5.3

MATERIAL AND METHODS

In 2011–2012, the experiment was carried out in the southeastern part of Poland in the village of Sahryń (50°41'N, 23°46'E). The soil was classified as Chernozem (FAO 2006). Soil condition characteristics are listed in Table 1. The amount of rainfall during both growing seasons (April–October) was similar, 531 mm in 2011 and 532 mm in 2012 (Table 2). It was approximately 30% more than the optimal need for sugar beet under Polish conditions and 21% more than the average rainfall of several years. The average daily air temperature was higher than in the multi-year period, in the each of the studied years, particularly in 2012.

Foliar fertilization of silicon and calcium contained in the Herbagreen basic fertilizer was the factor of the experiment (Table 3). The fertilizer is approved for use in organic farming in Poland and it may be used for fertilization of organic sugar beet too. This is micronized marine calcite ($CaCO_3$). The native content of elements is as follows (% m/m): Ca – 26.2, Si – 7.99, Fe – 2.38, Mg – 1.45, K – 0.42, Na – 0.37, Ti – 0.3, P – 0.22, S – 0.16, Mn – 0.08 and trace amount of B, Co, Cu and Zn. This fertilizer was applied as a solution to the term: (1) first term (BBCH 14–16) – with 0.4% concentration in the first treatment and with 0.8% in the second one; (2) second term (3 weeks later) with 0.8% concentration in both treatments. The amount of water for spraying was 0.25 m^3 per ha, each time. Single plot area was 43.2 m^2 (for harvest – 21.6 m^2). Number of replication is 4.

The forecrop for sugar beet was winter wheat each year. Straw yield averaged 7 t/ha. Straw was crushed during harvest and mixed into the topsoil together with nitrogen fertilizer (applied in the form of ammonium nitrate at the dose of 40 kg N/ha) with post-harvest tiller. Each autumn phosphorus-potassium fertilizers were applied and covered by deep winter plough. The doses of phosphorous and potassium were determined in accordance with the recommendations based on available phosphorus and potassium content in the soil, and the expected root yields. Spring nitrogen fertilizers were applied, and mixed into the soil with cultivator. Nitrogen was also used as top dressing fertilization at the stage of sugar beet plants 4–6 leaf (BBCH 14–16). Beets were sown on following dates: 4 April, 2011; and 29 March, 2012. Row spacing was 45 cm, distance in the row was 18 cm, and sowing depth 0.2–0.25 cm. Cv. Danuśka KWS represents the sugar (C) type with a low alpha-amino-nitrogen content in the roots. Weed control and diseases protection were applied with pesticides recommended by the Institute of Plant Protection National Research Institute in Poznań. Beet harvesting was carried out on: 10 October, 2011; and 17 October, 2012 and the time of growing seasons was 189 and 202 days, respectively.

From each plot 3 rows were harvested. During harvest the parts of beet plants with leaves were cut out by hand, leaves were weighed. Roots were dug up, cleaned, counted and weighed.

The representative samples of roots for the technological root quality determination were collected during the harvest day from each plot. Sucrose, alpha-amino-nitrogen, sodium and potassium contents were determined with the Venema Automation

Table 2. Weather conditions in 2011–2012

	2011	2012	1991–2013
Total rainfall (April–October) (mm)	530.9	531.7	439.0
Average temperature (April–October) (°C)	14.7	15.2	14.2*

*2002–2013. Source: own study based on data from sugar factory Strzyżów, Poland

Table 3. Scheme of experiment

Treatment	Terms of use/dose (g/ha)		Total dose (g/ha)
	4–6 leaves stage (BBCH 14–16)	3 weeks later	
0	–	–	–
1	Ca – 262, Si – 79.9	Ca – 524, Si – 159.8	Ca – 786, Si – 239.7
2	Ca – 524, Si – 159.8	Ca – 524, Si – 159.8	Ca – 1048, Si – 319.6

Table 4. Effect of calcium and silicon foliar fertilization on sugar beet yield and quality of roots in 2011–2012

Year	Treatment of foliar fertilization			Average	*LSD*
	0	1	2		
Plant density during harvest (thousand/ha)					
2011	54.9	50.0	53.1	52.7	ns
2012	50.9	49.3	64.2	54.8	14.1*
Average	52.9	49.6	58.7	–	ns
Roots yield (t/ha)					
2011	83.15	92.98	93.55	89.89	ns
2012	57.31	68.03	63.17	62.84	ns
Average	70.23	80.50	78.36	–	ns
Yield of leaves (t/ha)					
2011	37.98	47.20	42.95	42.71	ns
2012	15.07	19.11	19.10	17.76	ns
Average	26.52	33.15	31.02	–	ns
Biological sugar yield (t/ha)					
2011	14.59	16.26	16.61	15.82	ns
2012	10.00	12.21	11.67	11.29	ns
Average	12.29	14.24	14.14	–	ns
Technological sugar yield (t/ha)					
2011	12.55	14.13	14.54	13.74	ns
2012	8.59	10.72	10.36	9.89	ns
Average	10.57	12.43	12.45	–	ns
Sucrose content (%)					
2011	17.49	17.47	17.73	17.56	ns
2012	17.52	17.93	18.48	17.98	ns
Average	17.51	17.70	18.11	–	ns
Content of alpha-amino-nitrogen ($mmol_+$/kg)					
2011	38.15	32.45	29.23	33.28	ns
2012	35.70	28.18	25.13	29.67	7.13*
Average	36.93	30.31	27.18	–	6.97*
Content of potassium ($mmol_+$/kg)					
2011	32.50	30.30	30.68	31.16	ns
2012	36.90	33.23	30.53	33.55	ns
Average	34.70	31.76	30.60	–	ns
Content of sodium ($mmol_+$/kg)					
2011	4.70	4.20	4.53	4.48	ns
2012	4.10	2.95	2.53	3.19	1.15*
Average	4.40	3.58	3.53	–	ns
Content of refined sugar (%)					
2011	15.05	15.20	15.53	15.26	ns
2012	15.09	15.74	16.40	15.74	1.13*
Average	15.07	15.47	15.96	–	0.75*

*α = 0.05; ns – no significant differences; 0 – without Ca and Si fertilization; 1 – 786 g Ca/ha, 239.7 g Si/ha; 2 – 1048 g Ca/ha, 319.6 g Si/ha; *LSD* – least significant difference

beet-analyzing system by Kutno Sugar Beet Breeding Ltd. in Straszków. Based on the obtained results, according to Buchholz et al. (1995) we were able to calculate: biological sugar yield (t/ha); loss of sugar productivity (%); standard molasses loss (%); technological sugar yield (t/ha); the refined sugar content (%). The results were statistically analyzed using the analysis of variance and the Tukey's multiple comparisons tests, with the level of significance $\alpha = 0.05$. Statistical analyses were performed in the SAS 9.1 program (Cary, USA) using the GLM procedure. The basic parameters of the tested variables as: standard deviations, variation coefficients, minimum and maximum values were calculated. These calculations were carried out in the Excel (Redmond, USA) spreadsheet.

RESULTS AND DISCUSSION

Average plant density during harvest varied from 49.6 to 58.7 thousand pieces per ha (Table 4). It was smaller than estimated optimal (80–100 thousand pieces per ha) (Cakmakci et al. 1998, Campbell 2002), which was attributed to low-temperature time period after the beet sowing in both years of the experiment. In comparison with the control (treatment 0) foliar fertilization with calcium and silicon resulted in yields increase of: roots – 13.1%, leaves – 21.0%, biological sugar – 15.5% and technological sugar – 17.7%, but the obtained differences were not significant. The lower yields of roots and leaves observed in 2012 resulted from a very strong cercospora beticola (*Cercospora beticola* Sacc.) pressure, despite the three fungicide sprays implementation. However the symptoms of cercospora infection in both treatments with foliar calcium and silicon application were observed a few days later than in the treatment 0. Therefore Herbagreen foliar application resulted in greater increases of yields in 2012 than a year earlier. The results obtained from the two year experiment with sugar beet confirm previous reports of similar beneficial effects of such foliar fertilization. The technological root quality was significantly modified by calcium and silicon foliar application in comparison with the control – treatment 0. Therefore a significantly lower content of alpha-amino-nitrogen and tendency to the lower content of the two other molassigenic components (sodium and potassium) at two treatments with Herbagreen application was observed. From the other hand a significantly higher content of refined sugar, refined sugar productivity and smaller losses of sugar productivity were obtained.

The greatest variation of plant density was observed in treatment 0 while in both treatments with Herbagreen (treatments 1 and 2) plant density was similar (Table 5). The variability in yields of: roots, biological and technological sugar was

Table 5. Statistical characteristics of the variability of plant density during harvest, yield and quality of roots in 2011–2012

Plant density during harvest (thousands of plants per ha)		Yield (t/ha)				Sucrose (%)	Alpha-amino-nitrogen	Na	K	Refined sugar (%)
		roots	leaves	biological sugar	technological sugar		(mmol$_+$/kg)			
Minimum										
0	37.5	42.8	12.7	7.8	6.8	16.8	27.8	3.00	28.0	14.3
1	31.9	49.6	15.3	8.5	7.4	17.0	23.3	2.20	25.0	14.5
2	44.4	59.7	16.5	11.1	9.9	17.3	23.2	2.20	25.8	15.1
Maximum										
0	84.7	90.9	55.6	17.5	15.2	19.3	43.4	5.60	45.1	16.8
1	62.5	107.9	58.8	18.8	16.6	18.6	39.9	5.10	37.2	16.5
2	70.4	117.4	56.7	20.7	18.1	18.6	33.7	5.70	33.5	16.5
CV (%)										
0	30.9	24.4	57.9	25.7	25.6	5.1	15.9	23.8	15.0	6.3
1	18.9	30.0	51.7	29.6	29.1	3.3	20.3	28.8	11.7	4.0
2	15.4	26.8	46.6	25.3	24.7	2.5	12.9	35.7	9.0	3.3

CV – coefficient of variation

similar in all treatments of the experiment. The same was with the leaves yield but the *CV* value of this characteristic was doubled compared with the roots yield. The variability of other characteristics was the smallest in treatment 2 but with the exception of potassium content.

While our data from two years of studies show that Herbagreen a has positive impact on sugar yield, future long-term studies (at least 3 consecutive years) would be needed to fully validate our conclusion. Considering the importance of the observed effects and the complexity of variables that affect year-to-year agricultural yields, such long-term studies will be necessary to rigorously address this point.

In summary, the obtained results demonstrated that the use of the environmentally safe calcium and silicon foliar fertilizer (Herbagreen basic) is advantageous for the sugar beet production. Herbagreen showed the greatest benefits towards parameters as biological and technological sugar yields.

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