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THE EFFICIENCY OF FOLIAR BORON FERTILIZATION OF TWO SUGAR BEET VARIETIES PART I. THE YIELDING AND TECHNOLOGICAL QUALITY OF ROOTS

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ABSTRACT

In 2005–2006, at the Agricultural Experiment Station of the Warsaw University of Life Sciences in Żelazna, the effect of foliar boron (1.89 kg B·ha^{-1}) on yield and technological quality of roots of two sugar beet varieties (Esperanza, Henrike) compared to control (0 B·ha^{-1}) was investigated. Sugar beet was cultivated after sugar beet in crop rotation: sugar beet - sugar beet - spring wheat. After two years on average, foliar fertilization resulted in a significant increase of root yield (by 25.1%), biological yield of sugar (by 14.0%) and the technological yield of sugar (by 20.8%) compared to control. Boron foliar fertilization also resulted in a significant decrease in sucrose content in roots (by 0.4%), purified sugar content (by 0.5%), productivity of sugar (by 1.2%) and rate of alkalinity W_A (by 0.37). On average, for the entire study period, Henrike variety was characterized by significantly higher yields: roots (by 12.1%), leaves (by 44.0%), biological sugar (by 15.9%) and technological sugar (by 17.1%) than Esperanza variety. Roots of Henrike variety were also characterized by significantly higher content of sucrose (by 0.6%), purified sugar (by 0.7%), productivity of sugar (1.0%) and less of sodium (1.02 mmol·kg^{-1}) than Esperanza variety.

Key words: sugar beet, yield, technological quality of roots, boron

INTRODUCTION

Boron deficiency in the soil is a worldwide problem [Gupta and Solanki 2013]. Boron is the most scarce micronutrient in Polish soils [Grześkowiak 1996]. A research by Wróbel and Obojski [1997], carried out in fields with high productivity, in which sugar beets were cultivated, shows that 83% of them were characterized by a low content of assimilable boron in the soil.

Sugar beet has high nutritional needs relative to boron [Gupta 2006]. This microelement can be supplied to the soil or by foliar spraying [Jaszczołt 1998]. Foliar boron fertilization is a standard procedure in many countries [Cermak et al. 2002 Grzebisz 2005]. With a yield of roots of 85 Mg·ha^{-1} the maximum uptake of boron by a beet is 0.25 kg·ha^{-1} [Fardeau et al. 2002]. Poor nutrition of beets with microelements, including boron, reduces the possibility of the use of nitrogen by the plants [Grzebisz and Barłóg 2002]. Boron deficiency can cause a reduction in the yield of sugar beet roots by 50% and sugar content by a few percent compared to well-nourished plants [Grzebisz 2006].

Boron fertilization of sugar beets is of particular importance in crop rotations with a high saturation of plants with high nutritional needs with respect to boron, such as rapeseed and sugar beet.

The aim of the study was to evaluate the effectiveness of foliar boron fertilization on yield and technological quality of the roots of two varieties of sugar beets grown after sugar beets in crop rotation: sugar beets - sugar beets – spring wheat.

MATERIALS AND METHODS

An experiment was conducted at the Agricultural Experiment Station of the Warsaw University of Life Sciences in Żelazna (51 ° 52' N and 20 ° 08' E), 183 m above sea level, on soil belonging to the order of podzolic soils (L), type podsolic (LW), with a particle size of loamy sand class IVa, good rye complex. Sugar beet grown in the position of the sugar beet in crop rotation: sugar beet - sugar beet - wheat. The soil was characterized by a

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slightly acidic pH (5.5 and 5.6) and the following content of digestible nutrients (mg·kg^{-1}): P – 97–135, K – 158–212, Mg – 79–94, B – 0,8–0,9, Cu – 0,6–5,7, Zn – 12,7–16,3, Mn – 136–223, Fe – 999–1090.
In both years, rainfall was inadequate, particularly in 2005, when it was less than optimal by 30.5% and by 26.7% less than the multi-year (Tab. 1). The most favorable sum of the average daily temperature for the cultivation of sugar beet during the growing period is 2400-2800 ° C [Wisniewski 1991]. In both years, the sum of the average daily temperature was higher than optimal, especially in 2006. Sielianinov's hydrothermal coefficient (K) calculated according to the methodology specified by Molga [1986] had the optimal value (K = 1.1-2.0) only in July 2005 and April 2006.

Tabela 1. Warunki pogodowe w okresie wegetacji w latach 2005–2006
Table 1. Weather conditions in vegetation period during 2005–2006

Lata Years	Miesiąc – Month							Suma–Sum IV–X
	IV	V	VI	VII	VIII	IX	X	
Temperatura – Temperature (ºC)								
2005	8,9	13,9	16,3	19,9	17,2	15,0	11,9	3156,1
2006	8,8	13,9	17,9	22,8	17,6	15,5	14,9	3409,9
1921–2004*	7,6	13,5	16,5	18,4	17,5	13,4	8,3	–
Opady – Rainfalls (mm)								
2005	22,3	71,9	35,4	96,0	38,3	16,5	3,4	283,8
2006	45,9	41,0	35,4	16,7	154,3	22,9	18,8	335,0
1921–2004	38,8	53,4	62,4	81,0	67,2	47,4	37,2	387,4
Optymalny rozkład opadów (Dzieżyc i in. 1987) – Optimal rainfall (Dzieżyc et al. 1987)								
	18	65	74	85	78	54	34	408
Współczynnik Sielianinowa – Selyaninov's coefficient								
2005	0,9	2,2	0,8	1,5	0,8	0,4	0,1	–
2006	1,8	0,9	0,7	0,2	2,8	0,5	0,5	–

* – Mercik i Stępień [2005] – Mercik and Stępień [2005]

Two-factors' experiment was set up in 3 replications in a split-plot design. The first factor (A) was the variety of sugar beet (Esperanza, Henrike) and the second one (B) foliar fertilizer FOLIAREL 21% Bor (control - 0 kg B·ha^{-1} · 9 kg of fertilizer ha^{-1} - 1.89 kg B·ha-^{1}). FOLIAREL 21% Bor is a foliar fertilizer containing 21.0% B and 14.7% Na (sodium octaborate). Spraying was performed as beet plants had 6-8 proper leaves (BBCH 16-18).
The total number of plots was 12. Each plot consisted of 6 rows with a length of 16 m and the surface of 43.2 m2 (for harvesting - 21.6 m2).
The forecrop of beet was sugar beet. After its harvesting, the leaves were ground and plowed by deep pre-winter plowing. Leaves yield in 2004 amounted to 52.3 Mg·ha^{-1} and in 2005, 53.5 Mg·ha^{-1}. The doses of phosphate and potassium fertilizers were determined in accordance with the recommendations that take into account the content of available phosphorus and potassium in the soil and the expected yield of roots of at least 50 Mg·ha-1 · [Gutmański 1991b]. Before performing plowing, fertilizers in the form of high-percentage potassium salt (49.8% K) in dose 120 kg K·ha^{-1} were applied over the entire experiment. In spring, mineral fertilizers were applied in the form of ammonium phosphate (18 kg N·ha^{-1} and 20 kg P·ha^{-1}) and calcium ammonium nitrate (54 kg N·ha^{-1}), which was mixed with the soil using a cultivator. Ammonium nitrate was applied as top dressing (54 kg N·ha^{-1}) when the beet plants had 4-6 leaves (BBCH 14-16). The total mineral nitrogen fertilization was 126 kg N·ha^{-1}. Row spacing of 0.45 m, distances in a row of 0.18 m, sowing depth of 2-2.5 cm. Seeding was performed in 2005, on April 7, in 2006, on April 22. Protection of plants was carried out in accordance with the Recommendations to protect plants from IOR Poznan [2005, 2006]. Harvesting of beets was carried out in 2005 on October 17, and in 2006 on October 24. The length of the vegetation period amounted accordingly to 193 and 185 days.

Harvesting included 3 rows per plot. Plants were topped manually with topping machines, and then leaves were weighed. Roots were counted, dug by hand, cleaned and weighed. On the harvest day, representative samples of roots taken in accordance with PN-R-74452 [1999], to determine the technological quality (sucrose content, Na-amine, K and Na), which were made on an automated line Venema in Straszkow (KHBC). Based on the obtained results, the following were measured:

• biological yield of sugar ($Mg \cdot ha^{-1}$) = root yield ($Mg \cdot ha^{-1}$) × sucrose content in roots (%);
• loss of sugar yield (%) = standard molasses loss (%) + 0.6 (%),
• standard molasses loss (%) = 0.12 x (K + Na) + 0.24 (N-α-amine) + 0.48 [Buchholz et al. 1995], where: K, Na, and N-α-amines, are given in $mmol \cdot 100\ g^{-1}$ of the pulp,
• technological yield ($Mg \cdot ha^{-1}$) = root yield ($Mg \cdot ha^{-1}$) x (cont. sucrose (%) - sugar yield losses (%) [Buchholz et al., 1995],
• refined sugar content (%) = sucrose content (%) - sugar yield losses (%) [Trzebiński 1991],
• productivity of sugar = sugar content - loss of performance / sugar content (%),
• alkalinity ratio (WA) was calculated using the following formula: WA = (K + Na): N-αamin., where K, Na, and N-α-amine are expressed in $mmol \cdot kg^{-1}$ [Trzebiński 1991].

The results were statistically analyzed using analysis of variance and Tukey's multiple comparisons procedure, and to compare the mean, a significance level α = 0.05 was adopted. Calculations were performed in SAS 9.1 software, using the GLM procedure. The evaluation of the correlation between the measured traits was based on the simple Pearson correlation coefficients. The significance of correlation was assessed at $p \leq 0.05$ and $p \leq 0{,}01$. For selected pairs of features, an analysis of simple linear regression was performed to determine the cause-effect relationships between them. Moreover, the basic parameters of the variables tested were also calculated, i.e. the average, standard deviations, coefficients of variation, and minimum and maximum values. These calculations were performed in an Excel spreadsheet.

RESULTS

In the entire study period, plant density at harvest was similar in both cultivars and amounted to 81.9 thousand $pcs \cdot ha^{-1}$ in Esperanza variety and 85.0 thousand $pcs \cdot ha^{-1}$ in Henrike variety and from 81.9 thousand $pcs \cdot ha^{-1}$ on the control object, and 85.1 thousand $pcs \cdot ha^{-1}$ with foliar fertilization with boron. Foliar boron fertilization resulted in a significant increase in the yield of the two varieties of sugar beet roots by 25.1%, biological yield of sugar by 14.0% and the technological yield of sugar (20.8%) compared to the control (Tab. 2). In the entire study period Henrike variety was characterized by significantly higher yields: roots (12.1%), leaves (44.0%), biological sugar (15.9%) and technological sugar (17.1%) than Esperanza variety.

Tabela 2. Plon buraka cukrowego zależnie od odmiany i stosowania boru (średnie z lat 2005–2006)
Table 2. Sugar beet yield depending on variety and applying of boron (means from years 2005–2006)

Odmiana – Variety (A)	Bor – Boron ($kg \cdot ha^{-1}$) (B)		Średnia Mean
	0	1,89	
Plon korzeni – Roots yield ($Mg \cdot ha^{-1}$)			
Esperanza	53,9	71,2	62,6
Henrike	64,0	76,3	70,2
Średnia – Mean	59,0	73,8	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 7,2; B – 11,1; A/B – r.n.; B/A – r.n.		
Plon liści – Yield of leaves ($Mg \cdot ha^{-1}$)			
Esperanza	35,7	44,7	40,2

Henrike	57,2	58,6	57,9
Średnia – Mean	46,4	51,6	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 7,2; B – r.n.; A/B – r.n.; B/A – r.n.		
Plon biologiczny cukru – Biological sugar yield ($Mg \cdot ha^{-1}$)			
Esperanza	9,11	11,63	10,37
Henrike	11,05	12,99	12,02
Średnia – Mean	10,08	12,31	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 1,18; B – 1,65; A/B – r.n.; B/A – r.n.		
Plon technologiczny cukru – Technological sugar yield ($Mg \cdot ha^{-1}$)			
Esperanza	7,82	9,86	8,84
Henrike	9,57	11,14	10,35
Średnia – Mean	8,69	10,50	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 0,99; B – 1,41; A/B – r.n.; B/A – r.n.		

r.n. – różnice nieistotne – no significant differences

On average, two years of foliar application of boron resulted in a significant reduction of sucrose content in roots (0.4%), refined sugar (0.5%), sugar yield (1.2%) and the ratio of alkalinity WA (about 0.37) compared to the control (Tab. 3). Henrike variation was characterized by significantly higher contents of sucrose (0.6%) of purified sugar (0.7%) yield of sugar (1.0%) and less of sodium (1.02 $mmol \cdot kg^{-1}$) than Esperanza variety.

Tabela 3. Jakość korzeni buraka zależnie od odmiany i stosowania boru (średnie z lat 2005–2006)
Table 3. Quality of sugar beet roots depending on variety and applying of boron (means from years 2005–2006)

Odmiana – Variety (A)	Bor – Boron ($kg \cdot ha^{-1}$) (B)		Średnia Mean
	0	1,89	
Zawartość sacharozy – Sucrose content (%)			
Esperanza	16,7	16,2	16,4
Henrike	17,1	16,9	17,0
Średnia – Mean	16,9	16,5	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 0,3; B – 0,3; A/B – r.n.; B/A – r.n.		
Zawartość azotu-α-aminowego ($mmol \cdot kg$ miazgi^{-1})– α-amine nitrogen content (mmol per kg of pulp)			
Esperanza	24,6	26,6	25,6
Henrike	21,0	25,6	23,3
Średnia – Mean	22,8	26,1	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – r.n.; B – r.n.; A/B – r.n.; B/A – r.n.		
Zawartość potasu ($mmol \cdot kg$ miazgi^{-1})– Potassium content (mmol per kg of pulp)			
Esperanza	54,9	59,0	56,9

Henrike	55,6	58,3	56,9
Średnia – Mean	55,2	58,6	–
$NIR_{0,05}$ – $LSD_{0.05}$	A –r.n.; B – r.n.; A/B – r.n.; B/A – r.n.		
Zawartość sodu (mmol·kg miazgi^{-1})– Sodium content (mmol per kg of pulp)			
Esperanza	4,18	4,42	4,30
Henrike	3,12	3,45	3,28
Średnia – Mean	3,65	3,93	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 0,47; B – r.n.; A/B – r.n.; B/A – r.n.		

Tabela 3. cd.
Table 3. cont.

Zawartość cukru oczyszczonego – Refined sugar content (%)			
Esperanza	14,3	13,7	14,0
Henrike	14,9	14,5	14,7
Średnia – Mean	14,6	14,1	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 0,3; B – 0,2.; A/B – r.n.; B/A – r.n.		
Wydajność cukru – Productivity of sugar (%)			
Esperanza	85,7	84,5	85,1
Henrike	86,7	85,5	86,1
Średnia – Mean	86,2	85,0	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – 0,7; B – 0,6; A/B – r.n.; B/A – r.n.		
Straty wydajności – Losses of productivity (%)			
Esperanza	2,38	2,48	2,43
Henrike	2,29	2,44	2,36
Średnia – Mean	2,33	2,46	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – r.n.; B – r.n.; A/B – r.n.; B/A – r.n.		
Współczynnik alkaliczności – Rate of alkalinity ($W_{A)}$			
Esperanza Henrike	2,73 2,97	2,54 2,42	2,64 2,70
Średnia – Mean	2,85	2,48	–
$NIR_{0,05}$ – $LSD_{0.05}$	A – r.n.; B – 0,28; A/B – r.n.; B/A – r.n.		

r.n. – różnice nieistotne – no significant differences

Most of the features, with the exception of the sucrose and refined sugar content and sugar yields, evaluated in the experiment were characterized by a lower volatility in combination with the use of foliar fertilization than in the control combination (Tab. 4). Productivity of sugar was characterized by the lowest variability.

The relationship between the characteristics of the yield on the control object and the object with foliar application of boron are shown in Table 5. It can be seen that in the case of several pairs of features, they are different, for example, root yield and sucrose content, roots yield and the content of N-α-min., root yield and K content, root yield and refined sugar content, root yield and sugar productivity, root yield and sugar yield losses and root yield and the ratio of alkalinity. This can be explained with root crop variations.

Tabela 4. Statystyczna charakterystyka zmienności cech buraka cukrowego (średnie dla obu odmian) w latach 2005–2006
Table 4. Statistical characterization variability of sugar beet (means for two varieties) in years 2005–2006

Zmienne Variables		Plon korzeni Roots yield ($Mg \cdot ha^{-1}$)	Plon liści Yield of leaves ($Mg \cdot ha^{-1}$)	Plon biolologiczny cukru Biological sugar yield ($Mg \cdot ha^{-1}$)	Plon technologiczny cukru Technological sugar yield ($Mg \cdot ha^{-1}$)	Zawartość – Content					Wydajność cukru Productivity of sugar (%)	Straty wydajności Losses of productivity (%)	Współczynnik alkaliczności Rate of alkalinity
						Sacharozy Sucrose (%)	N-α-amin. N-α-amine nitrogen ($mmol \cdot kg^{-1}$)	K ($mmol \cdot kg^{-1}$)	Na ($mmol \cdot kg^{-1}$)	cukru oczyszczonego refined sugar (%)			
Średnia Mean	0	59,0	46,5	10,1	8,7	16,9	22,8	55,2	3,65	14,6	86,2	2,33	2,85
	1	73,8	51,6	12,3	10,5	16,5	26,1	58,6	3,93	14,1	85,0	2,46	2,48
SD	0	14,5	15,5	2,98	2,59	1,11	6,82	6,01	0,79	1,05	0,91	0,13	0,99
	1	11,9	10,7	2,72	2,47	1,44	4,82	5,50	0,77	1,45	1,53	0,12	0,55
Cv	0	24,6	33,4	29,5	29,8	6,58	29,9	10,9	21,6	7,2	1,05	5,78	34,8
	1	16,1	20,7	22,1	23,5	8,71	18,5	9,4	19,5	10,3	1,80	4,82	22,4
Min.	0	38,7	31,6	6,13	5,25	15,1	13,4	43,6	2,8	12,8	84,6	2,04	1,54
	1	44,2	37,5	6,49	5,46	14,4	18,2	47,1	3,1	11,9	82,7	2,20	1,50
Max.	0	86,6	79,4	15,3	13,2	18,3	33,0	64,9	5,2	15,9	87,8	2,55	4,19
	1	86,3	67,0	15,7	13,8	18,2	37,3	65,0	5,7	16,0	87,9	2,65	3,81

0 – kontrola – control (0 kg $B \cdot ha_{-1}$); 1 – 1,89 kg $B \cdot ha_{-1}$,
SD – odchylenie standardowe – standard deviation; Cv – współczynnik zmienności – variation coefficient;

Tabela 5. Współczynniki korelacji między cechami plonu buraka cukrowego w zależności od stosowania boru (średnie dla obu odmian z lat 2005–2006)
Table 5. Coefficients of correlation between characteristic of sugar beet yield depending on applying boron (means for two varieties from years 2005–2006)

Zmienne Variables			Plon – Yield				Zawartość – Content					Wydajność cukru Productivity of sugar	Straty wydajności cukru Losses of productivity
			Korzeni Roots	Liści Leaves	Biologiczny cukru Biological sugar	Technologiczny cukru Technological sugar	Sacharozy Sucrose	N-α-amin. α-amine nitrogen	K	Na	Cukru oczyszczonego Refined sugar		
Plon -Yield	Liści Leaves	0	0,63*										
		1	0,53										
	Biologiczny cukru Biological sugar	0	0,99**	0,56*									
		1	0.95**	0,47									
	Technologiczny cukru Technological sugar	0	0,99**	0,56*	1,00**								
		1	0,94**	0,47	1,00**								
Zawartość – Content	Sacharozy Sucrose	0	0,75**	0,18	0,83**	0,84**							
		1	0,67*	0,24	0,87**	0,88**							
	N-α-amin. α-amine nitrogen	0	0,68*	0,05	0,73**	0,72**	0,76**						
		1	0,27	-0,32	0,32	0,29	0,42						
	K	0	-0,34	0,18	-0,44	-0,45	-0,76**	-0,61*					
		1	-0,60*	-0,16	-0,71**	-0,73**	-0,75**	-0,28					
	Na	0	-0,37	-0,26	-0,42	-0,44	-0,56	0,00	0,44				
		1	-0,35	-0,34	-0,50	-0,52	-0,63*	0,03	0,34				
	Cukru oczyszczonego Refined sugar	0	0,71**	0,17	0,79**	0,80**	0,99**	0,69*	-0,77**	-0,63*			
		1	0,67*	0,27	0,87**	0,89**	1,00**	0,34	-0,76**	-0,65*			
Wydajność cukru Productivity of sugar		0	0,22	0,07	0,30	0,33	0,61*	0,00	-0,62*	-0,86**	0,70*		
		1	0,61*	0,38	0,79**	0,82**	0,90**	0,00	-0,77**	-0,70*	0,93**		
Straty wydajności cukru Losses of productivity		0	0,62*	0,14	0,62*	0,60*	0,48	0,89**	-0,18	0,30	0,38	-0,40	
		1	-0,10	-0,43	-0,12	-0,16	-0,06	0,82**	0,31	0,30	-0,14	-0,49	
Współczynnik alkaliczności Rate of alkalinity		0	-0,75**	-0,13	-0,80**	-0,80**	-0,84**	-0,98**	0,71**	0,16	-0,78**	-0,16	-0,80**
		1	-0,63*	0,00	-0,68*	-0,66*	-0,68*	-0,86**	0,64**	0,26	-0,63*	-0,38	-0,47

0 – kontrola – control (0 kg B·ha^{-1}); 1 – 1,89 kg B·ha^{-1}
**, * – istotne współzależności przy p≤0,01 i 0,05 – significant correlation at p≤ 0.01 and 0.05

Relation between biological yield of sugar and roots yield, and between technological yield of sugar and roots yield was stronger for the control object than after foliar application of boron. This contrasts with the relation between biological yield of sugar and sucrose content in roots and between technological yield of sugar and sucrose content of the roots. Simple linear regression equations for the two pairs of traits were as follows:

- for biological yield of sugar and root yield y = 0,203x - 18904, R^2 = 0.98 (control); 0,2183x y = - 3.7958, R^2 = 0.90 (the object with boron foliar feeding); where y = biological yield of sugar; ($p \leq 0.05$);
- for biological yield and sucrose content of sugar in the roots y = 2,2111x - 27.294, R^2 = 0.68 (control); y = 1.636 x - 14.753, R^2 = 0.75 (the object of boron foliar feeding); where y = yield of biological sugar; ($p \leq 0.05$);
- for technological sugar yield and root yield y = 0,1764x - 1.7109, R^2 = 0.98 (control); 0,1952x y = - 3.9062, R^2 = 0.88 (the object of boron foliar feeding); where y = yield of sugar technology; ($p \leq 0.05$);
- for technological sugar yield and sucrose content in the roots of y = 1,9489x - 24.25, R^2 = 0.70 (control); y = 1,508x - 14.447, R^2 = 0.77 (the object of boron foliar feeding); where y = yield of sugar technology; ($p \leq 0.05$).

DISCUSSION

The varieties of sugar beets that have been studied in this research belong to different types of performance; Esperanza represents the normal-fertile (NF) type, Henrike - the sugar type (S) [Siódmiak and Heimann 2003, 2004]. This can be explained by differences in yield and technological quality of roots of both cultivars. Similar results with the same variations were obtained by Artyszak [2012].

The beneficial effect of boron application on yield of sugar beet roots is observed by many authors [Hellal et al. 2009 Kristek et al. 2006 Pospišil et al. 2005]. Research by Obojski and Wróbel [1997] showed a significant effect of boron content in soil on crop yields of sugar beet roots. The researchers emphasize that despite the use of rational organic and mineral fertilization, there is a need for additional boron fertilization. Other authors confirm it [Krauze et al. 1986].

The significant increase in yields of: roots, biological and technological sugar under the influence of foliar boron fertilization that has been obtained in our study, can be explained by low levels of boron in the soil and drought, which limits its assimilation [Grześkowiak 1996 Gutmański 1991a]. Wróbel [1997] when applying soil fertilization with boron at a dose of 2 kg $B \cdot ha^{-1}$ obtained a significant increase in root yield of 5.5% relative to the object without the use of boron. However, throughout the entire experience manure fertilization was applied, which is the source of many micronutrients. The beneficial effects of combined use of foliar boron or manganese with herbicide in sugar beet manure-free cultivation were observed by Wróbel and Domaradzki [2006]. In our study, the yield of the leaves did not differ significantly depending on the foliar boron. Lack of such differentiation with boron fertilization to the soil was observed by Wróbel [1997].

The reduction of sucrose content in roots under the influence of foliar boron in the present study confirms earlier results of Wróbel [1997], who applying 2 kg $B \cdot ha^{-1}$ to the soil obtained a reduction of this component from 17.8% (on object control) to 17.6%. Domaradzki and Wróbel [2012] found that the combined use of herbicides and foliar manganese and boron had no significant effect on the quality of the technological roots (sucrose content and melassigenic ingredients).

Technological sugar yield depends primarily on root yield, to a lesser extent on the sucrose content and slightly on the content of melassigenic ingredients [Artyszak 2012, Artyszak et al. 1999, Rozbicki et al. 1997]. In our study, despite the deterioration of technological roots, resulting in a decrease in sucrose content, while increasing root yield achieved a significant increase in the yield of technological sugar. Kristek et al. [2006] after the foliar application of boron in a dose of 1 kg $B \cdot ha^{-1}$ observed an increase in root yield by 19.4%, in sugar content by 1.46%, and in sugar yield by 39.5% compared to the control.

CONCLUSIONS

1. Foliar boron fertilization of sugar beet in the position of sugar beet in a dose of 1.89 kg B ha^{-1} increases root yield, biological yield of sugar and technological yield of sugar in relation to the control (0 $B \cdot ha^{-1}$).

2. Foliar boron fertilization reduces the sucrose content in the roots, not exerting any significant impact on the content of melassigenic ingredients (Na-amine, K and Na). It also results in a significant reduction in the refined sugar content, sugar efficiency and the value of alkalinity.
3. Henrike variety has a higher yield of roots, of better technological quality and greater biological and technological yield of sugar than Esperanza variety.

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THE EFFICIENCY OF FOLIAR BORON FERTILIZATION OF TWO SUGAR BEET VARIETIES PART I. THE YIELDING AND TECHNOLOGICAL QUALITY OF ROOTS

ABSTRACT

In 2005–2006, at the Agricultural Experiment Station of the Warsaw University of Life Sciences in Żelazna, the effect of foliar boron (1.89 kg B·ha^{-1}) on yield and technological quality of roots of two sugar beet varieties (Esperanza, Henrike) compared to control (0 B·ha^{-1}) was investigated. Sugar beet was cultivated after sugar beet in crop rotation: sugar beet - sugar beet - spring wheat. After two years on average, foliar fertilization resulted in a significant increase of root yield (by 25.1%), biological yield of sugar (by 14.0%) and the technological yield of sugar (by 20.8%) compared to control. Boron foliar fertilization also resulted in a significant decrease in sucrose content in roots (by 0.4%), purified sugar content (by 0.5%), productivity of sugar (by 1.2%) and rate of alkalinity W_A (by 0.37). On average, for the entire study period, Henrike variety was characterized by significantly higher yields: roots (by 12.1%), leaves (by 44.0%), biological sugar (by 15.9%) and technological sugar (by 17.1%) than Esperanza variety. Roots of Henrike variety were also characterized by significantly higher content of sucrose (by 0.6%), purified sugar (by 0.7%), productivity of sugar (1.0%) and less of sodium (1.02 mmol·kg^{-1}) than Esperanza variety.

Key words: sugar beet, yield, technological quality of roots, boron

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