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THE INFLUENCE OF PRE-SOWING STIMULATION OF SEEDS ON CHANGES IN CHEMICAL COMPOSITION AND SUCROSE CONTENT IN SUGAR BEET

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Abstract

The changes of chemical composition and sucrose content in sugar beet beet after seeds stimulation were investigated. The seeds came from the energ'hill technology (Eh) and were subject to laser irradiation. The experiments were conducted in the laboratory and in field conditions in 2008-2010. In the experiment the researchers used the seed material of Tiziana variety (sugar type) in standard version (control) and stimulated: prepared in the energ'hill technology and irradiated. Irradiation with laser light was applied in the following doses: the 5-time multiplied (in the study marked as D5) and 7-time multiplied (in the study D7) of the basic dose 2.5 10^{-1}J cm^{-2}. The content of nitrogen, phosphorus, potassium, sodium, magnesium and calcium in leaves and roots samples collected in the first weeks of July, August, September and October. Pre-sowing stimulation with use of energ'hill technology and laser light irradiation resulted in an increase in leaf concentration of nitrogen, potassium, sodium and magnesium and the content of these elements positively correlated with sucrose content of mature roots. Pre-preparation (sprouted) clusters energ'hill technology and laser irradiation had a positive effect on sucrose content and its performance.

Key words: sugar beet, seeds stimulation, mineral macronutrients, sucrose.

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WPŁYW PRZEDSIEWNEJ STYMULACJI NASION NA ZMIANY SKŁADU CHEMICZNEGO I ZAWARTOŚĆ CUKRU W BURAKU CUKROWYM

Abstrakt

Zmiany składu chemicznego i zawartości sacharozy w buraku cukrowym analizowano pod wpływem przedsiewnej stymulacji nasion przygotowanych w technologii energ'hill i naświetlanych światłem lasera półprzewodnikowego. W badaniach polowych i laboratoryjnych przeprowadzonych w latach 2008 – 2010, z odmianą Tiziana, wysiewano kłębki standardowe (niestymulowane) i kondycjonowane w technologii energ'hill oraz naświetlane światłem lasera półprzewodnikowego w dawkach pięciokrotnej (D5) i siedmiokrotnej (D7) w stosunku do dawki podstawowej (2,5 10^{-1}J cm^{-2}). Zawartość azotu, fosforu, potasu, magnezu, sodu i wapnia w korzeniach i liściach analizowano w pierwszych tygodniach lipca, sierpnia, września i października. Przedsiewna stymulacja nasion w technologii energ'hill i naświetlanie światłem lasera powodowały w liściach wzrost koncentracji azotu, potasu, sodu oraz magnezu, a zawartość tych pierwiastków dodatnio korelowała z zawartością sacharozy w korzeniach dojrzałych. Przedsiewne przygotowanie (kondycjonowanie) kłębków w technologii energ'hill i naświetlanie światłem lasera wpłynęły pozytywnie na zawartość sacharozy i jej wydajność.

Słowa kluczowe: burak cukrowy, stymulacja przedsiewna, makroskładniki mineralne, sacharoza.

INTRODUCTION

In the process of sugar beet seeds improvement mechanical and chemical methods are commonly used. The former specify the calibration and shape of beet seed balls and the latter protect seedlings against pathogens in the early stages of their development. Researchers also analyze the possibility of pre-sowing stimulation of sugar beet by other methods, such as the influence of the electric field, magnetic field, microwave radiation, ionizing radiation, visible light, millimeter radiation and laser radiation (Hernandez et al. 2010, Kacharava et al. 2009, Koper et al. 1996, Marinković 2008, Pietruszewski, Wójcik 2000a,b, Prośba et al. 2011, Rochalska 2005, Rochalska, Orzeszko-Rywka 2008, Vasilevski 2003, Wójcik 2006, Wójcik et al. 2004). The results of the experiments show the beneficial effects of these methods on yield and some features of the technological quality of roots. The study also highlights the beneficial effects of pre-sowing stimulation especially in stressful conditions or in conditions that are unfavorable for the emergence and the early development. The impact of pre-sowing stimulation of seeds according to researchers depends on the weather during the emergence, the vegetation conditions as well as on the genotype of the variety and fertilization.

In the studies on the effects of pre-sowing beet seeds stimulation on the content and efficiency of sugar the following features were analyzed: the changes in macro-mineral elements in roots and leaves during active accumulation of mass yield and in mature roots as well as the relationship between the content of these elements in roots and leaves and the sucrose concentration.

MATERIALS AND METHODS

In the field experiment, established by split–plot method in three replications and in the laboratory studies conducted in 2008–2010, the changes in concentration of mineral macronutrients and the sucrose content and yield under the influence of seeds laser stimulation and seeds improvement in the energ'hill technology (at work Eh) were analyzed. In the experiment the researchers used the seed material of the variety Tiziana (sugar type) in standard – unstimulated version and stimulated – prepared in Eh technology and irradiated. The energ'hill technology is based on priming that triggers a seed to initial phases of germination. As a result the enzymes synthesizing proteins are activated and the metabolism of spare materials begins. Irradiation with laser light was applied in the following doses: the 5-time multiplied (in the study marked as D5) and 7-time multiplied (in the study D7) of the basic dose 2.5 10^{-1} J cm^{-2}. Beet seeds balls irradiation with the use of semiconductor laser light (model CTL – 1106 MX) was carried out on the very day when the field experiment was being established and the irradiated surface was determined by the use of the scanner (model CTL 1202 S) co–operating with the laser.

The field experiment was carried on the soils classified as Haplic Luvisols (FAO WRB 2007) developed from sandy loam underlain by a sandy clay loam (soil texture – according to Polish classification of soil grain size distribution, PTG, 2008, based on USDA). Soils were slightly acidic in reaction (pH 5.9-6.4). The soil was characterized by a good abundance of assimilable phosphorus (77-99 mg P kg^{-1}), potassium (158-240 mg K kg^{-1}) and magnesium (57-67 mg Mg kg^{-1}).

Thermal conditions during the study did not impede the sugar beet vegetation and temperatures were close to average temperatures of the last 30 years (Figure 1). Precipitation distribution, however, was characterized by large fluctuations, especially in the years 2009 and 2010 during the rapid growth of the root mass and accumulation of sucrose. Rainfall exceeding twice the average monthly amount for the last 30 years occurred in July and August in 2009 and in August and September in 2010.

The content of nitrogen, phosphorus, potassium, sodium, magnesium and calcium in the dry-mineralized leaves and roots samples collected in the first weeks of July, August, September and October in all field reps was marked on the 210VGP Atomic Absorption Spectrophotometer. The sucrose content and other characteristics of the technological quality of mature roots were determined on the automatic line Venema.

The content of the analyzed elements (separately for each consecutive month) as well as the sucrose content and yield were analyzed statistically by the means of the analysis of variance. To compare the mean values Duncan's test was used and the correlation at the level of confidence $\alpha = 0.05$,

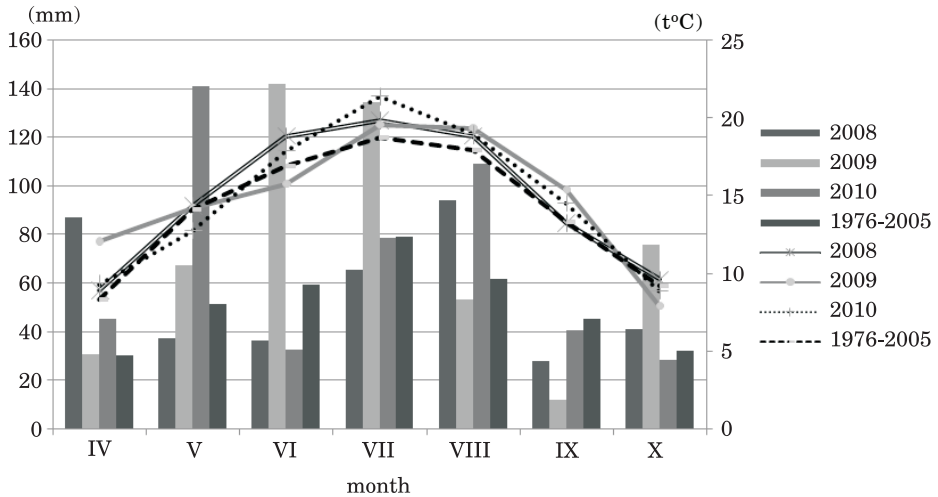

Fig. 1. Average monthly temperature and precipitation on the background of the multi-year average

$\alpha = 0.01$ and $\alpha = 0.001$ was calculated. The paper presents the content of macronutrients in the elemental form as average results for the years of research and for the objects of the experiment.

RESULTS AND DISCUSSION

The content of nitrogen and minerals in sugar beet has been the subject of numerous experiments in which their variability due to fertilizing, tillage, varieties and weather conditions was observed. The authors have demonstrated proven relationship between the level of concentration of mineral nitrogen and macronutrients and certain features of technological value of roots, especially sugar and molasses forming substances – α-amino nitrogen and sodium and potassium cations (Allison et al. 1997, Słowiński et al. 1997, Barłóg et al. 2002, Barłóg, Grzebisz 2004, Diatta 2004, Prośba-Białczyk 2003, 2005a,b, Prośba-Białczyk, Mydlarski 2001).

In the study the content of nitrogen and mineral macroelements in plants – the roots and leaves – depending on the pre-sowing stimulation of seeds was analyzed (Table 1–6). The plants developed from Eh stimulated seeds and those developed from irradiated beet seed balls were characterized (in the leaves and roots) by higher concentrations of nitrogen than the plants emerged from standard seeds. The nitrogen content in leaves in the consecutive months – July, August, September and October – positively correlated with the sucrose content. Nitrogen in roots – from July to Septem-

ber – also positively affected the accumulation of sucrose, whereas in mature roots negative correlation between the content of nitrogen and sucrose was observed (Table 7).

Table 1

Effect of stimulation of seeds on the nitrogen content in dry mater in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	31.05	23.05	19.55	18.83	12.44	8.28	7.70	6.70
Energ'hill	32.15	26.15	23.08	22.54	13.55	8.85	8.65	7.00
Laser D5	33.10	28.10	23.53	22.05	14.04	9.37	8.80	7.40
Laser D7	32.50	28.78	22.55	21.50	13.90	9.04	9.09	7.05
LSD	1.53	1.26	2.50	2.55	0.85	0.56	0.60	0.65

The phosphorus content in leaves showed no differences under the influence of seeds preparation in Eh technology and laser irradiation in comparison with unstimulated seeds. In roots, however, the influence of stimulation was observed. From August until the end of the growing season, the roots developed from the irradiated seeds were characterized by the higher amount of phosphorus (Table 2). Phosphorus accumulated in the leaves in July and August did not correlate with the content of sucrose. Yet, in September and October in leaves, and in all months in roots, a positive influence of phosphorus on sucrose content was noted (Table 7). Significant positive correlation between the content of phosphorus in the roots and the concentration of sucrose was also found in other studies (Prośba-Białczyk 2005b).

Table 2

Effect of stimulation of seeds on the phosphorus content in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	1.74	1.88	2.05	1.90	0.90	1.75	1.75	1.80
Energ'hill	1.85	1.95	2.05	2.08	0.79	1.80	1.85	1.86
Laser D5	1.80	1.95	2.10	1.95	0.83	1.84	2.08	2.15
Laser D7	1.86	2.02	2.28	1.90	0.85	2.02	2.05	2.14
LSD	i. d.	i. d.	i. d.	i. d.	i. d.	0.25	0.25	0.25

Pre-sowing stimulation of seeds had impact on (from July to harvest) the concentration of potassium in leaves and roots (Table 3). The leaves of plants developed from Eh seeds and laser irradiated seeds contained more potassium than the leaves developed from unstimulated seeds. The content of this element in leaves significantly and positively correlated with sugar content in mature roots. In the roots from the irradiated seeds the concen-

Table 3

Effect of stimulation of seeds on the potassium content in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	32.28	34.16	27.47	25.85	12.56	8.55	8.54	8.55
Energ'hill	33.87	35.65	28.96	27.95	13.55	9.05	8.55	8.07
Laser D5	34.95	35.45	29.25	29.03	14.18	9.96	9.58	8.06
Laser D7	34.15	36.05	29.85	29.50	13.85	9.75	9.56	8.25
LSD	1.25	1.25	1.28	1.58	1.05	0.88	0.46	0.57

Table 4

Effect of stimulation of seeds on the sodium content in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	5.85	9.66	9.86	6.95	0.86	1.00	0.73	0.50
Energ'hill	6.57	11.53	11.58	7.94	1.14	1.55	0.65	0.45
Laser D5	6.57	11.28	11.83	8.56	1.35	1.44	0.65	0.38
Laser D7	6.58	10.90	12.05	8.35	1.25	1.55	0.69	0.39
LSD	0.65	1.05	0.95	0.84	0.44	0.38	i. d.	i. d.

tration of potassium (in July, August and September) was higher than in the roots developed from unstimulated seeds. In mature roots, however, the lowest potassium level was observed when they developed from Eh seeds and laser irradiated at D_5 dose. Potassium in roots significantly and negatively affected the sucrose content (Table 7).

Preparation of seeds in Eh technology and laser stimulation of seeds modified the sodium content in plants. The leaves of plants from stimulated seeds were characterized by (from July to the end of vegetation) higher

sodium content than the leaves of plants developed from standard seeds. In roots significant differences in sodium content under the influence of stimulation were noted in July and August during the period of intensive growth of root mass. In these months the roots of plants from stimulated seeds contained more sodium cations than the roots of plants developed from unstimulated seeds.The sodium content in leaves in the consecutive months – July, August, September and October – had positive influence on sucrose content. However, in roots a significant correlation between sodium and sucrose was observed in August and September. In mature roots, on the other hand, sodium negatively correlated with sucrose content. Therefore the study confirmed the significant effect of sodium concentration on the sucrose content (PROŚBA-BIAŁCZYK, MYDLARSKI 2001).

Pre-sowing seeds stimulation significantly modified the magnesium content (Table 5). The leaves and roots of plants developed from Eh seeds and from irradiated seeds from July to the end of the growing season were characterized by a higher concentration of magnesium than the leaves and

Table 5

Effect of stimulation of seeds on the magnesium content in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	12.02	13.44	9.70	8.56	2.00	2.00	2.04	2.20
Energ'hill	12.95	14.35	10.40	9.36	2.65	2.55	2.55	2.48
Laser D5	13.58	14.82	10.55	9.45	2.75	2.74	2.75	2.40
Laser D7	13.72	14.54	10.45	9.28	2.85	2.50	2.50	2.55
LSD	0.44	0.80	0.42	0.45	0.36	0.45	0.47	0.36

roots developed from the standard seeds. Magnesium accumulated in leaves during the whole vegetation period significantly and positively affected the sucrose content while magnesium in roots did not correlate with the content of sucrose (Table 7). The increased amount of magnesium in the leaves of plants from stimulated seeds can be connected with the bigger amount of carotenoids and chlorophyll in the plants developed from stimulated seeds (PROŚBA-BIAŁCZYK et al. 201).

The calcium content under the influence of pre–sowing seeds stimulation varied the leaves – in August, September and October. The leaves of plants developed from irradiated seeds were characterized by a lower level of calcium than the leaves of plants developed from Eh seeds and standard seeds (Table 6). Calcium accumulated in leaves had a positive impact on the sucrose content (Table 7).

Table 6

Effect of stimulation of seeds on the calcium content in leaves and roots of sugar beet (g kg^{-1})

Method of stimulation	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Control	13.00	12.60	6.70	6.09	0.75	0.66	0.60	0.50
Energ'hill	13.30	12.70	6.55	6.20	0.70	0.65	0.50	0.53
Laser D5	13.15	11.85	5.87	5.13	0.85	0.40	0.58	0.44
Laser D7	13.38	12.04	5.30	5.15	0.88	0.44	0.48	0.48
LSD	i. d.	0.58	0.45	0.50	i. d.	i. d.	i. d.	i. d.

Table 7

Simple correlation coefficients between the content of macroelements in roots and leaves and sucrose content

Elements	Designation term							
	leaves				roots			
	VII	VIII	IX	X	VII	VIII	IX	X
Nitrogen	0.28**	0.30***	0.34***	0.28**	0.20*	0.28**	0.23**	- 0.15*
Phosphorus	0.13	0.13	0.26**	0.32**	0.15*	0.33***	0.44***	0.45***
Potassium	0.30***	0.44***	0.49***	0.55***	-0.20*	-0.34***	- 0.56***	- 0.49***
Sodium	0.44***	0.37***	0.32***	0.44***	0.10	0.30***	0.28**	- 0.23**
Magnesium	0.49***	0.46***	0.44***	0.15*	0.10	0.15*	0.10	0.10
Calcium	0.32**	0.45***	0.55***	0.32**	-0.12	0.09	0.09	0.13

* $\alpha = 0.05$
** $\alpha = 0.01$
*** $\alpha = 0.001$

Pre-sowing seed stimulation resulted in significant changes in the sucrose content and yield (Table 8). The plants developed from seeds prepared in Eh technology and laser-irradiated were characterized by higher content and higher yield of sucrose than the plants developed from un-stimulated seeds. The results confirm the positive impact of laser irradiation on the yield and sugar content as also shown in earlier studies of beet seed stimulation (Koper et al. 1996, Siddiqui et al. 2006, Hernandez et al. 2010, Prośba-Białczyk et al. 2011). Moreover, in our research the positive influence of Eh technology was observed. The leaves of plants emerged from the Eh beet seed balls were characterized by (in the period of root growth and the accumulation of sucrose) higher nitrogen, potassium, sodium and magnesium content which in turn had a positive impact on sacharose content.

Table 8

Influence of stimulation of seeds on sugar content and yield

Method of stimulation	The sugar content	Biological productivity of sugar	Technological sugar yield
Control	16.70	9.82	8.65
Energ'hill	16.13	11.18	10.35
Laser D5	16.30	11.05	10.05
Laseer D7	16.49	11.03	9.95
LSD	0.18	1.05	1.18

CONCLUSIONS

1. Pre-sowing stimulation in the energ'hill technology and semiconductor laser irradiation in the period of intensive growth of plants modified their chemical composition and sucrose content.

2. Stimulating seeds in the energ'hill technology and laser irradiation resulted in an increased concentration of nitrogen, potassium, sodium and magnesium in leaves and the content of these elements positively correlated with the sucrose content of mature roots.

3. Pre-preparation (priming) of beet seed balls with the use of the energ'hill technology and laser irradiation had a positive effect on sucrose content and its yield.

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