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Impact of sugar beet seed priming on molasses components, sugar content and technological white sugar yield

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Abstract: The impact of non-treated and primed seeds on molasses components, sugar content and technological white sugar yield of the same cultivar of sugar beet root was investigated. The study was conducted in 2012–2014 at the Experiment Field Station of Warsaw University of Life Sciences – SGGW in Skierniewice (51°97'N, 20°19'E) in the central region of Poland. The use of primed seeds resulted in a higher technological white sugar yield with higher sugar content and lower content of α-amino nitrogen in the roots. Also, seed priming increased the technological value of the roots by a lower share in the root yield fractions of the root weight less than 300 g, characterized by lower sugar content and a higher content of α-amino nitrogen.

Keywords: *Beta vulgaris* provar. *altissima*; seed quality; production; sucrose content; quality parameters of roots

The sugar beet yield and quality formation is a very complicated process involving a lot of factors (Pačuta et al. 2017 and 2018 etc.). At the turn of the 20th and the 21st century, in the cultivation of sugar beet in Europe, the sowing date is accelerated by about 10–20 days to extend the vegetation period and increase the root yield. Pavlů et al. (2017) reported that prolongation of the vegetation period in spring by 13 days increased sugar beet root yield by 10.9%. Sowing sugar beet seeds into the soil with a lower temperature requires improving their characteristics which guarantee high, fast and even plant emergence (Draycott 2006). The method that allows for improvement of these characteristics is seed priming. Seed priming is one of the most important developments to help rapid and uniform germination and emergence of seeds and to increase seed tolerance to adverse environmental conditions, although the general principles of seed priming vary depending on the species and the seed quality (Bradford 1986, Taylor et al. 1998, Copeland and McDonald 2001). Seed priming was defined as a pre-sowing treatment in water or in an osmotic solution that allows the seed to imbibe water to proceed to the first stage of germination but prevents radicle protrusion through the seed coat (Halmer 2003). Harris et al. (2007) reported that seed priming led to better establishment and growth, earlier flowering, increase in seed tolerance to the adverse environment and greater yield in maize. The beneficial effects of seed priming were demonstrated for many field crops such as corn, sunflower, etc. (Afzal et al. 2002, Hussain et al. 2006). Rehman et al. (2011) reported that seed priming is a cost-effective technology that can enhance early crop growth leading to earlier and more uniform stand with yield-associated benefits in many field crops including oilseed crops. Seed priming of sugar beet facilitates early and synchronized germination which usually improves rate, percentage, and uniformity of germination (Durrant and Jaggard 1988, Capron et al. 2000, Sadeghian and Yavari 2004). Continued field experiments also provide evidence, that prim-

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ing of sugar beet seeds results in rapid and uniform emergence, but the field emergence is not significant (Durrant et al. 1983, Thomas et al. 1994, Michalska-Klimczak et al. 2018).

The final and most important criterion for the effectiveness of the sugar beet seed priming process is the final root yield and technological white sugar yield. An increase in the latter by 5% has already been shown as a result of extended growing period (Durrant et al. 1993, Mukasa et al. 2003). It was enabled by the use of primed seeds, which can be sown up to 10 days earlier (Thomas et al. 1994). The British seed company Germain's has shortened the time of plant emergence by up to 50% by using seed priming (Burks 2008). The economic effects of seed priming in the UK have caused an increase in root yield by 4% and in technological white sugar yield by 5% (Jaggard et al. 2009). Thus the demand for commercial primed seeds can also be noticed in other parts of Europe and the USA. For example, in the UK already 75% of the sown seed was primed, while in Finland this index reached 10%.

In sugar beet fields, large differences in the final root mass of individual plants are often observed, which together with plant density decide on the yield of this species (Cakmakci et al. 1998). Large variation in the size of individual beet plants in the field is regarded as unfavourable both due to losses in yield weight during harvest and deterioration in the technological value of the raw material caused by the unfavourable chemical composition of small and large roots (Ostrowska et al. 2002). The roots considered non-standard are those that are smaller than 200–300 g and greater than 1200–1500 g, and roots with the best technological value are those weighing 600–900 g. The root yield structure consisting of their separated fractions determines both the root yield and quality (Rozbicki and Kalinowska-Zdun 1993).

The objective of this study was to determine the impact of primed and non-primed seeds of the same sugar beet cultivar on root quality components, and technological white sugar yield and technological value of root yield structure expressed as a share of root fraction of defined sugar beet root mass.

MATERIAL AND METHODS

The considered sugar beet field experiment was conducted in the years 2012–2014. It was located at an experimental field of the Department of Agronomy. The field's geographical location is Skierniewice (51°97'N, 20°19'E), central Poland, at the Experimental Station of the Faculty of Agriculture and Biology of the Warsaw University of Life Sciences – SGGW.

Weather conditions for each vegetation period of the experiment and soil conditions were described in the paper of Michalska-Klimczak et al. (2018). Winter wheat was the forecrop for sugar beet in each year of the experiment. Following harvest, stubble breaking with harrowing was applied as means of cultivation. Fertilization in the form of cattle manure (35 t/ha), as well as phosphorus and potassium (35.2 kg P/ha, 132.8 kg K/ha), was delivered by fall ploughing to a depth of 25–30 cm, without upright furrow-slice.

The study was a one-factor experiment, and there were 4 replications. Seed material diversification was introduced as the experimental factor and involved the same cultivar of sugar beet (cv. Janosik). Typical, traditionally prepared and non-primed seeds, as well as primed seeds, were used for sowing. The used cultivar – Janosik – was obtained from the Kutno Sugar Beet Breeding Ltd. in Poland. These seeds were resistant to rhizomania and represented the normal (N) type characterized by high root yield and technological white sugar yield with low molasses component contents in the roots. Primed seeds were obtained by solid matrix priming (SMP, also known as matrix conditioning). This method is used by the supplier of the seed material and is patented. The seed material is available under the vendor name of 'Quick Beet'. The priming enables to control water uptake – during the procedure the seeds are mixed with a solid and insoluble matrix of particles and water. As a result, the seeds reach an equilibrium hydration level just below what is required for radicle protrusion (Halmer 2003). Pelleting of both primed and non-primed seeds was performed according to the Kutno Sugar Beet Breeding Ltd. (Poland) guidelines.

A total of 8 plots were established in the experiment. Each plot included 6 rows, 16 m in length, with an area of 43.2 m^2. Edge strips of 0.5 m were reserved in the external rows of plots 1 and 6. The harvested area was 21.6 m^2. Size of either primed or non-primed sugar beet balls was in the range of 3.5–4.75 mm. The seeds were sown at 17.2 cm intervals in a row.

At harvest, sugar beet roots were counted at each plot and divided into mass fractions of ≤ 300, 301–600, 601–900, 901–1200 and > 1200 g. Each fraction was weighed. This enabled to evaluate the characteristics such as plant density, mean root mass, root yield and

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its structure. Randomly selected root samples from individual plots and root samples from the fractions, separately from primed and non-primed seeded plots, were analysed using a Venema Automation beet analysing system at the Kutno Sugar Beet Breeding Ltd. in Straszków (Poland). This allowed determining the content of sodium, potassium, α-amino N and sucrose, further enabling assessment of root quality, as well as the calculation of the technological white sugar yield (t/ha). The root technological value was compared in the separated fractions for the combinations the non-primed and primed seeds.

Statistical analysis of the obtained results was performed using the computer software Statgraphics 4.1 (Warrenton, USA) and MS Excel 2016 (Redmond, USA). Variance analysis and multiple comparisons using the Tukey's test approach were implemented to determine the influence of the experimental factor on the investigated traits. All averages were compared assuming the significance level of α = 0.05.

Table 1. Sucrose content, α-amino nitrogen (N), sodium and potassium content in years 2012–2014

Method of seed treatment	2012	2013	2014	2012–2014
Sucrose content (%)				
Non-primed	17.6	18.6	16.0	17.4
Primed	18.1	18.4	16.9	17.8
Mean	17.9	18.5	16.5	17.6
$LSD_{0.05}$	ns	ns	0.55*	0.21*
Content of α-amino N (mmol/kg)				
Non-primed	33.5	11.5	30.3	25.1
Primed	29.4	13.8	28.3	23.8
Mean	31.5	12.7	29.3	24.5
$LSD_{0.05}$	ns	ns	ns	ns
Sodium content (mmol/kg)				
Non-primed	3.9	2.2	2.4	2.8
Primed	3.6	2.0	3.0	2.9
Mean	3.8	2.1	2.7	2.9
$LSD_{0.05}$	ns	ns	ns	ns
Potassium content (mmol/kg)				
Non-primed	41.5	36.1	37.9	38.5
Primed	39.5	37.0	42.0	39.5
Mean	40.5	36.6	40.0	39.0
$LSD_{0.05}$	ns	ns	ns	ns

*Significant mean difference at the level α = 0.05; ns – not significant mean difference at the level α = 0.05; *LSD* – least significant difference

RESULTS AND DISCUSSION

On average, for the three years of the study (2012–2014) and in 2014, a significantly higher sugar content in roots was obtained from the combination with primed seeds and it was higher by 0.4% and 0.9% (absolute value), respectively, in comparison with roots with non-primed seeds (Table 1). There was no significant effect of seed priming on the other quality traits of beet roots. They were more heavily modified by weather conditions during the study years than by the type of seed. Similar results regarding the technological value of roots under the influence of seed priming were obtained in the study by Mukasa et al. (2003).

In the present study, the sowing of primed seeds significantly increased the technological sugar yield. On average, for the studied period, it was higher by 0.7 t/ha, i.e., by 7.9%, in comparison with the sugar yield in combination with sowing non-primed seeds (Table 2). This was caused by higher sugar content and lower content of α-amino N in the roots from the combination with primed seeds. Durrant et al. (1993) in their study obtained an increase in the sugar content and technological sugar yield from primed seeds as compared with traditional seeds, but these differences were not statistically significant (Heyes et al. 1997, Saunders 1998). However, no effect of priming was found on the increase in sugar content in roots and on the technological white sugar yield.

The content of sucrose, α-amino N, sodium and potassium in the sugar beet roots of specific fractions was similar in all the experimental combinations. The roots of the 601–900 g and 301–600 g fractions were characterized by the highest sucrose content and the smallest content of α-amino N as well as sodium and potassium (Table 3). Small roots weighing less than 300 g and large above 1200 g contained the least sucrose, and the most α-amino N and sodium and

Table 2. Technological white sugar yield (t/ha) in years 2012–2014

Method of seed treatment	2012	2013	2014	2012–2014
Non-primed	9.0	9.9	7.5	8.8
Primed	9.7	10.8	8.0	9.5
Mean	9.4	10.4	7.8	9.2
$LSD_{0.05}$	ns	ns	0.60*	0.49*

*Significant mean difference at the level α = 0.05; ns – not significant mean difference at the level α = 0.05; *LSD* – least significant difference

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Table 3. Sucrose content, α-amino nitrogen, sodium and potassium content in sugar beet roots of individual fractions in years 2012–2014

	Year	Method of seed treatment	Root fraction (g)				
			≤ 300	301–600	601–900	901–1200	> 1200
Sucrose content (%)	2012	non-primed	17.1	17.5	17.7	17.5	17.3
		primed	17.5	17.7	18.0	17.6	17.4
	2013	non-primed	18.1	18.13	18.68	18.58	18.43
		primed	17.6	18.3	18.43	17.79	17.60
	2014	non-primed	16.2	16.5	16.5	16.0	15.9
		primed	16.3	16.9	16.7	16.4	16.2
Content of α-amino N (mmol/kg)	2012	non-primed	38.1	36.2	31.7	32.2	34.7
		primed	32.4	33.2	31.7	31.8	32.8
	2013	non-primed	9.2	10.1	11.9	7.5	7.0
		primed	18.3	14.7	10.2	12.8	16.2
	2014	non-primed	31.5	33.5	27.9	29.5	30.1
		primed	33.4	29.2	29.8	29.7	28.0
Sodium content (mmol/kg)	2012	non-primed	3.3	3.2	4.6	5.4	5.7
		primed	3.7	3.5	3.7	3.8	4.7
	2013	non-primed	1.8	1.7	2.3	2.4	2.7
		primed	1.9	2.0	2.2	2.3	2.10
	2014	non-primed	1.8	2.0	2.3	2.3	2.7
		primed	1.9	2.0	2.2	2.3	2.8
Potassium content (mmol/kg)	2012	non-primed	37.2	38.2	40.2	40.9	46.1
		primed	41.2	37.9	37.0	41.5	44.0
	2013	non-primed	35.5	33.3	38.1	37.1	38.8
		primed	34.4	35.4	36.1	37.2	40.7
	2014	non-primed	38.0	36.2	36.7	37.8	40.9
		primed	38.1	37.5	39.4	42.0	49.2

potassium – the small proportion of the mass of the root fraction below 300 g in the root yield from the combination with primed seeds resulted in a higher sucrose content in the roots and a larger technological white sugar yield. The large differences in the content of sucrose and molasses forming substances in the roots of individual beet fractions between the years of the study resulted from diversification of the technological root value in individual years of the study. The diversity of the technological quality of roots depending on their weight is confirmed in literature (Rozbicki and Kalinowska-Zdun 1993, Ostrowska et al. 2002). In the present study, there was no effect of seed priming on the technological quality of roots depending on their mass.

Finally, it can be concluded that a higher technological white sugar yield of sugar beet was found for plants formed from primed seeds with a higher sucrose content and a smaller content of α-amino N in their roots. Priming increased the technological value of roots by a smaller proportion in the yield structure of the root mass of fractions with a weight of less than 300 g, characterized by a lower sucrose content and a higher content of α-amino N.

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