The effect of sugar beet seed treatments on their vigour

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ABSTRACT

Sugar beet seeds of three varieties (Jastra, Jamira, PNMono1) were rubbed, primed, washed and primed after rubbing. All used methods of seed treatment changed pericarp characteristics such as water potential, density, moisture and content of chemicals resulting in electrical conductivity of water extract from the seeds. Seed treatments also improved the ability and rate of germination. Their efficiency was more significant in an excess and shortage of water in germination medium than in optimum water conditions. The lower the initial seed vigour, the larger the vigour improvement. Seed priming had the best effect on the course of germination. Primed seeds were most resistant to different moisture conditions during germination. The largest differences in germination ability after four days in different water conditions were 5.1 and 7.4% for primed and primed after rubbing seeds, respectively, while the difference for control ones was 26.8%. Priming also caused an increase in seed respiration intensity. Rubbing and washing removed chemicals from the pericarp, which resulted in an increase in water potential, and consequently in vigour improvement.

Keywords: sugar beet; seeds; germination; vigour; treatment; priming; washing; rubbing

The introduction of monogerm sugar beet varieties and drilling to stand had a catastrophic influence on the plant population through poor establishment. Accordingly, an improvement of the course of germination and field emergence was necessary.

A series of experiments was conducted to evaluate the effectiveness of different technologies of pre-sowing treatment of three sugar beet varieties differing in their ploidy level. There was also an attempt to explain the results of seed treatments. This study tries to explain how some fruit properties affect germination and field emergence.

Pericarp and botanical seed characteristics determine the properties of sugar beet fruit. The pericarp consists of three layers: the two inner ones consist of thick-wall sclereids containing crystals of salts. In the presence of water they form an osmotic solution which has a low water potential. Just before radicle emergence the level of the water potential of seed pericarp is about –1.0 MPa. If this level is achieved faster, seed germination will be faster (Podlaski and Chrobak 1997)

The process of rubbing removes the most porous, outer layer of parenchyma resulting in an increase in pericarp density and removal of a part of chemicals. Similar effects can be obtained by seed washing.

In the last years seed companies have exerted an enormous pressure on researchers to develop new, effective technologies of seed quality improvement, especially seed priming. Priming consists in wetting seeds to the moisture level that enables early processes leading to germination but is too low for radicles to emerge. It is obvious that priming changes mostly the properties of botanical seed. In 2002 primed seeds were sown on 30% of the area under sugar beet in Great Britain. As a result an improvement of germination and field emergence rate were observed, but there was no influence on the final plant stand (Draycott et al. 2002).

Despite of commercial application of different seed treatment methods there is still little information on the causes of obtained effects. Moreover a high diversity of treated seed properties is still a problem and it implicates the effectiveness of applied technologies.

MATERIAL AND METHODS

Seeds of three sugar beet varieties from a Polish breeding company: Kutnowska Hodowla Buraka Cukrowego: PNMono1, Jastra and Jamira were treated by four different methods: partial rubbing of pericarp, washing, priming and priming in combination with washing. Primed seeds were put on blotting paper (65% of water capacity) for 24 h and air dried. The control was raw seeds not treated in any of the described ways. In laboratory experiments these characteristics were measured in 100 seeds in three replications: germination ability, rate and spread of germination after four and 14 days, water potential of pericarp and electrical conductivity of water extracts from the seeds. Germination was examined on the blotting paper in three different water conditions: 40, 65 and 100% of water capacity of blotting paper. Experiments lasted for three years, analysis of variance was done with *T*-Student's test.

To assess the germination rate and spread Pieper's coefficient was used, i.e. the mean time of germination of one seed (or plant emergence) determined by the formula:

$$\text{Pieper's coefficient} = \Sigma(d_n.a_n)/\Sigma a_n \text{ (number of days)}$$

where: d_n is a current germination day, and a_n is a current day number of germinated seed (Lityński 1977).

When assessing the rate of germination, the sowing day is assumed to be the first day of germination d_1, whilst when spread of germination is assessed, the assumption is that the first day of germination d_1 is the day when the first radicles germinated from a given seed sample (Podlaski 1990).

Moreover, the intensity of seed respiration during the first three days of germination was measured using an apparatus LICOR-6200, manufactured by LICOR, Nebraska USA.

Water potential of pericarp was assessed using Vescor with sample chamber C-52. Measurements were carried out in 14 seeds in three replications. Equilibration time in the sample chamber was 30 minutes.

Electrical conductivity of water extracts from sugar beet seeds was measured using the method described by Podlaski and Chrobak (1984).

RESULTS AND DISCUSSION

Figures 1, 2 and 3 show sugar beet seeds in cross-section. Radicles and cotyledons are visible. Rubbing causes a decrease in the pericarp thickness (Figures 4–9) through parenchyma removal, equalisation of fruit shape and better exposition of basal pore which is the main water supply to the seed (Podlaski 1990).

Photographs 650 × 723 × 16M

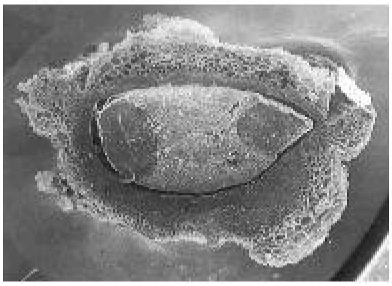

Figure 1. Raw sugar beet fruit in cross-section

Figure 2. Rubbed sugar beet fruit in cross-section

Figure 3. Intensively rubbed sugar beet fruit in cross-section

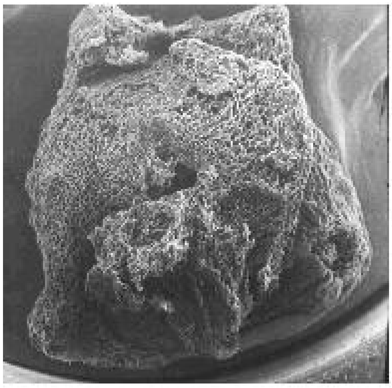

Figure 4. Whole raw sugar beet fruit

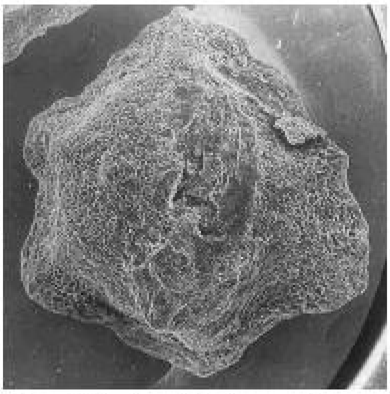

Figure 5. Whole rubbed sugar beet fruit

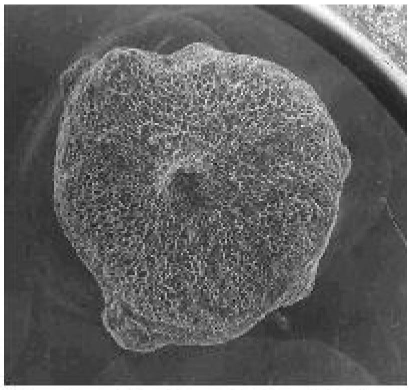

Figure 6. Whole intensively rubbed sugar beet fruit

Figure 7. The pericarp of raw fruit in cross-section

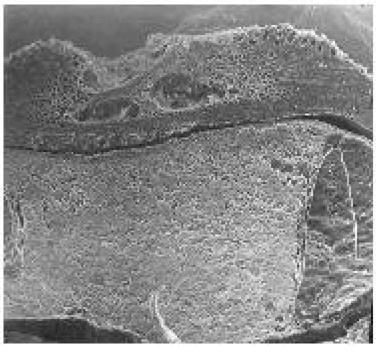

Figure 8. The pericarp of rubbed fruit in cross-section

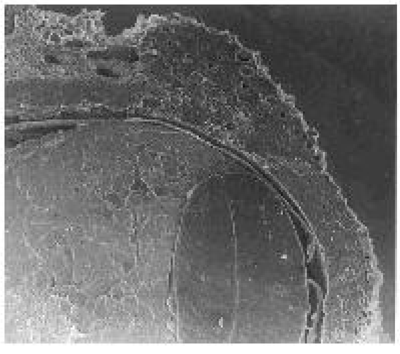

Figure 9. The pericarp of intensively rubbed fruit in cross-section

Table 1. Influence of seed treatment method on seed and pericarp characteristics

Method of seed treatment	Electrical conductivity of seed water extract (mS/cm)	Pericarp density (g/cm)	After 24 h from germination test start		
			water potential of pericarp (MPa)	moisture (% of fresh matter)	
				seeds	fruits
Control	4.50	0.77	–2.86	32.1	92.1
Rubbing	2.10	0.86	–2.75	35.2	93.2
Washing	1.61	0.68	–2.58	45.6	105.0
Priming	1.82	0.72	–2.72	50.5	103.5
Rubbing + priming	1.75	0.82	–2.45	51.2	102.1
LSD, p = 0.05	0.05	0.03	0.10		

The pericarp of control seeds had the significantly highest level of water extract electrical conductivity and the lowest water potential (Table 1). Rubbing of the parenchymal part of pericarp caused a significant decrease in electrical conductivity of water extracts, increase in water potential and pericarp density. The cause was the removal of a part of chemicals that in contact with water give a solution of low osmotic potential (Podlaski and Chrobak 1997). Consequently the water content in seeds increased; it can be an indicator of accelerated germination.

Seed washing had the greatest influence on pericarp properties. Washing caused a decrease in electrical conductivity of water extracts and pericarp density. At the same time, water potential of pericarp and seed moisture increased.

Seed priming, especially in combination with rubbing, caused an increase in water potential and pericarp moisture. This phenomenon can be an effect of easier water access to the seeds, which results in their respiration intensity. Primed seed respiration was most intensive after two days of germination (Figure 10). The respiration intensity of seeds treated in the other ways also increased during the time of germination, but this increase was slower. Seeds of the variety PNMono1 showed a higher level of respiration intensity than seeds of the other two varieties.

Changes in pericarp and seed properties had an influence on biological properties of seed such as the ability, rate and spread of germination. The excess and shortage of water in germination medium caused a significant decrease in germination ability after four days (Table 2), to 75.3 and 75.0%, respectively, while in optimum conditions germination ability was 86.9%. The blocking of oxygen uptake by the seed probably caused a negative reaction to water excess (Lexander 1981). On the other hand, in the case of water shortage the influence of low water potential on the germination process was visible.

All methods of seed treatment caused an increase in germination ability after four days compared to the control. But the effect of seed treatment depended on germination conditions. Under water stress conditions the process of rubbing improved germination ability by 10.6 and 22.2% while in optimum conditions only by 6.7% compared to the control seeds. Similarly, seed priming improved germination ability under stress conditions (excess and shortage of water) by 25.3 and 36.5%, respectively, while in optimum conditions by 17.0%.

Priming alone and in combination with rubbing improved seed tolerance to unfavourable environmental conditions. Germination ability after four days at three different levels of water content differed only by 7.4 and 5.1% while in control seeds by 26.8%.

Excess of water caused a decrease in germination ability of washed seeds after four days from 12.0 to 12.9% compared to primed and primed after rubbing seeds. It is possible that such a reaction was caused by higher porosity of washed seeds. The pores filled with water restrict oxygen access to the seeds.

Different variety reactions were observed for the used seed treatment methods. In the varieties Jastra and PNMono1 the best results were obtained by seed priming; germination ability of primed seeds was within the range of 88.0%. In the variety Jamira a similar effect was also obtained by washing.

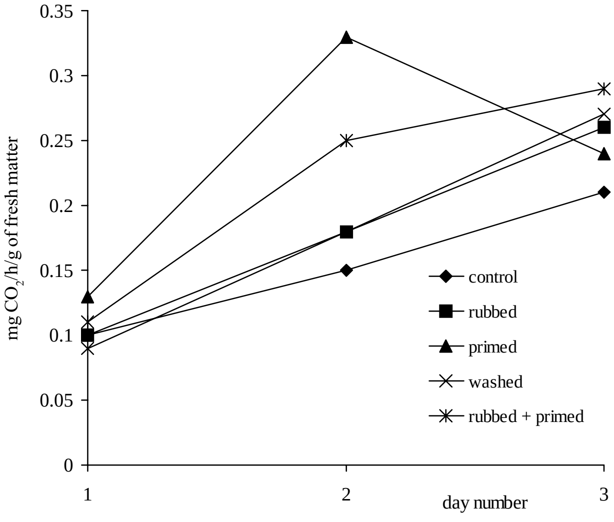

Figure 10. Respiration intensity of seeds treated by different methods during the first three days of germination

Table 2. Germination ability (%) (after four days) of sugar beet seeds treated by five methods in different water conditions (mean of 1996–1998)

Amount of water in germination medium (A)	Variety (C)	Method of seed treatment (B)					$\bar{x}$	$\bar{x}$	*LSD* (A)
		control	rubbed	primed	washed	rubbed + primed			
40% FWC shortage	Jamira	53.3	71.6	84.0	87.1	86.2	76.4	75.3	
	Jastra	47.6	72.9	89.0	83.7	85.2	75.7		
	PNMono1	45.9	68.9	83.1	84.6	86.0	73.7		
$\bar{x}$		48.9	71.1	85.4	85.2	85.8			
65% FWC optimum	Jamira	76.7	85.2	95.5	95.7	87.4	88.1	86.9	
	Jastra	72.1	82.7	90.9	92.9	93.3	86.4		1.28
	PNMono1	78.4	79.2	91.6	90.4	91.9	86.3		
$\bar{x}$		75.7	82.4	92.7	93.0	90.9			
100% FWC excess	Jamira	65.2	70.2	84.0	80.7	80.1	76.0	75.0	
	Jastra	57.6	69.9	84.1	72.9	90.5	75.0		
	PNMono1	57.1	71.7	87.8	66.3	87.8	74.1		
$\bar{x}$		60.0	70.6	85.3	73.3	86.2			
$\bar{x}$		61.5	74.7	87.8	83.8	87.6			
LSD (B)				1.92					

LSD (A/B) = 2.86, *LSD* (B/A) = 3.33, *LSD* (A/C) = *LSD* (C/A) = 2.21
LSD (A/BC) = *LSD* (B/AC) = *LSD* (C/AB) = 4.95

Average (for three moisture levels in germination medium) germination ability of control seeds was 61.4, 70.7 and 52.5% in 1996, 1997 and 1998, respectively. On the other hand, in 1996–1998 germination ability of primed and primed after rubbing seeds oscillated from 85.0 to 89.2% and from 85.9 to 90.3%, respectively. It is obvious that priming equalises seed germination in different water conditions and efficiency of this treatment depends on the initial level of germination ability. The lower the germination ability, the higher the efficiency of priming.

Table 3. Rate of germination (days) – Pieper's coefficient (after 14 days) of sugar beet seeds treated by five methods in different water conditions (mean of 1996–1998)

Amount of water in germination medium (A)	Variety (C)	Method of seed treatment (B)					$\bar{x}$	$\bar{x}$	*LSD* (A)
		control	rubbed	primed	washed	rubbed + primed			
40% FWC shortage	Jamira	4.40	3.80	3.19	3.37	2.91	3.53	3.74	
	Jastra	4.70	4.07	3.38	3.69	3.03	3.77		
	PNMono1	4.80	4.22	3.64	3.73	3.14	3.91		
$\bar{x}$		4.63	4.03	3.40	3.60	3.03			
65% FWC optimum	Jamira	3.71	3.17	2.69	2.59	2.61	2.95	3.18	
	Jastra	4.03	3.46	2.97	3.21	2.61	3.26		0.05
	PNMono1	4.02	3.60	3.05	3.23	2.70	3.32		
$\bar{x}$		3.92	3.41	2.90	3.01	2.64			
100% FWC excess	Jamira	4.03	3.40	2.73	3.12	2.54	3.16	3.30	
	Jastra	4.26	3.70	2.91	3.52	2.63	3.41		
	PNMono1	4.16	3.59	2.65	3.71	2.58	3.34		
$\bar{x}$		4.15	3.56	2.76	3.45	2.59			
$\bar{x}$		4.23	3.67	3.02	3.35	2.75			
LSD (B)				0.07					

LSD (A/B) = 0.10, *LSD* (B/A) = 0.12, *LSD* (A/C) = *LSD* (C/A) = 0.08
LSD (A/BC) = *LSD* (B/AC) = *LSD* (C/AB) = 0.18

Table 4. Spread of germination (days) – Pieper's coefficient of sugar beet seeds treated by five methods in different water conditions (mean of 1996–1998)

Amount of water in germination medium (A)	Variety (C)	Method of seed treatment (B)					$\bar{x}$	$\bar{x}$	*LSD* (A)
		control	rubbed	primed	washed	rubbed + primed			
40% FWC shortage	Jamira	3.51	2.47	2.19	2.04	1.91	2.42	2.54	
	Jastra	3.47	2.74	2.38	2.36	2.03	2.60		
	PNMono1	2.91	2.89	2.64	2.40	2.14	2.60		
$\bar{x}$		3.30	2.70	2.40	2.27	2.03			
65% FWC optimum	Jamira	2.38	1.84	1.69	1.59	1.61	1.82	1.96	
	Jastra	2.59	2.12	1.97	1.88	1.61	2.03		0.06
	PNMono1	2.24	2.27	2.05	1.90	1.70	2.03		
$\bar{x}$		2.40	2.08	1.90	1.79	1.64			
100% FWC excess	Jamira	3.03	2.40	1.73	2.12	1.54	2.16	2.21	
	Jastra	2.93	2.36	1.91	2.52	1.63	2.27		
	PNMono1	2.83	2.25	1.65	2.71	1.58	2.20		
$\bar{x}$		2.93	2.34	1.76	2.45	1.59			
$\bar{x}$		2.88	2.37	2.02	2.17	1.75			
LSD (B)				0.10					

LSD (A/B) = 0.14, *LSD* (B/A) = 0.17, *LSD* (A/C) = *LSD* (C/A) = 0.11
LSD (A/BC) = *LSD* (B/AC) = *LSD* (C/AB) = 0.25

After 14 days of germination the differences in germination ability of seeds treated in different ways diminished. However the results were similar to those after four days. All treatment methods improved germination ability from 2.3 to 5.3% (*LSD* = 1.18). The best results of treatments were observed for the excess of water in germination medium. Then priming and priming with rubbing improved germination ability from 10.7 to 11.7%.

The variety had a low effect on seed treatment efficiency.

Pieper's coefficient showing the mean time of seed germination depended on the water content in germination medium. The respective values for shortage, excess and optimum of water were 3.74, 3.30 and 3.18 days (Table 3).

The method of seed treatment had a critical influence on their germination rate. The fastest germination was recorded for primed with rubbing seeds (2.75 days), followed by primed seeds (3.02 days), washed (3.35 days) and rubbed (3.67 days) (*LSD* = 0.07).

The efficiency of seed treatment was more visible under stress germination conditions. In optimum conditions washing and priming speeded up seed germination by 0.91 and 1.02 days, respectively, compared to control seeds. However, under the shortage and excess of water the acceleration of germination of the same seeds was 1.03 and 0.70 days, 1.23 and 1.39 days, respectively.

Seeds of different sugar beet varieties differed significantly in their germination rate. During the three years at three moisture levels the average rate of germination of PNMono1 seeds was 4.55 days, Jamira 4.05 days and Jastra 4.01 days (*LSD* = 0.07). The efficiency of seed treatment depended on initial seed quality. The worse the seed vigour, i.e. the slower the germination, the higher the efficiency of seed treatment. Priming and priming in combination with rubbing accelerated the germination of the best control seeds (variety Jamira) by 0.99 and 1.30 days, respectively. The same time acceleration of germination in the slowest germinating seeds of variety PNMono1 was 1.31 and 1.68 days, respectively.

The spread of germination in shortage, excess and optimum of water in germination medium was 2.21, 2.54 and 1.96 days, respectively (*LSD* = 0.06) (Table 4).

In all environmental conditions the best germination rate was obtained for primed after rubbing seeds. In optimum and shortage of water washed seeds took the second position. However, in the excess of water the spread of germination of washed seeds was much worse. It indicates higher sensitivity of washed seeds to the excess of water in germination medium.

In the three years of experiments the most uniform germination (on average) was recorded in rubbed and primed seeds (spread of germination 1.75 days), primed (2.02 days) and washed ones (2.17 days) (*LSD* = 0.11).

The germination of seeds of PNMono1 variety was slowest (4.55 days) but most uniform (spread of germination 2.66 days) and vice versa. The fastest germinating seeds (4.01 days) of Jastra variety germinated least uniformly (spread of germination 3.0 days).

Priming and priming with rubbing of seeds of PNMono1 variety caused the lowest improvement of germination spread: 0.55 and 0.85 days.

The same treatment of seeds of the varieties Jamira and Jastra improved spread of germination by 0.91 and 1.1 days, 1.24 and 1.29 days, respectively.

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ABSTRAKT

Vliv způsobů ošetření osiva cukrovky na jeho vitalitu

K ošetření osiva tří odrůd cukrovky (Jastra, Jamira, PNMono1) jsme použili obrušování, priming, promývání a priming po obroušení. Všechny způsoby ošetření osiva změnily vlastnosti perikarpu, jako např. vodní potenciál, hustotu, vlhkost a obsah chemických látek, což se projevilo v konduktometrické vodivosti vodního extraktu osiva. Ošetření osiva rovněž zvýšilo klíčivost a rychlost klíčení. Jeho účinnost byla významnější při nadbytku a nedostatku vody v médiu během klíčení než za optimálních vláhových podmínek. Čím byla počáteční vitalita osiva nižší, tím většího zlepšení životnosti jsme dosáhli. Na průběh klíčení měl nejvyšší účinek priming osiva. Osivo ošetřené primingem bylo při klíčení odolnější k rozdílným vláhovým podmínkám. Největší rozdíly v klíčivosti po čtyřech dnech při různých vláhových podmínkách činily 5,1 a 7,4 % u osiva ošetřeného primingem, resp. primingem po obroušení, zatímco u kontrolního osiva rozdíl činil 26,8 %. Priming rovněž zvýšil intenzitu dýchání osiva. Obrušování a promývání vedlo k odstranění chemických látek z perikarpu, což zvýšilo vodní potenciál, a v důsledku toho se zlepšila vitalita osiva.

Klíčová slova: cukrovka; osivo; klíčivost; vitalita; ošetření; priming; promývání; obrušování

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