Effect of soil potassium on yield and quality of diverse sugar beet genotypes

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ABSTRACT

Aiming at determination differences in leaf and root potassium concentration of diverse sugar beet genotypes as well as its effect on sugar beet root quality and yield. Investigations comprising 15 sugar beet genotypes (five multigerm lines, five hybrids and five monogerm lines) were carried out on two soil types (Calcic luvisol: L-1 and L-3 and Calcic gleysol: L-2 and L-4) during two growing seasons. Root yield of the investigated genotypes on Calcic luvisol (50 t/ha) was higher, than on Calcic gleysol (34 t/ha). In general, multigerm lines were known for the highest leaf potassium concentration (2.75%), lowest root one (3.78 mmol/100 g root), highest sugar content (13.8%) and best root extractable sugar (1.5%). Monogerm lines had the lowest leaf potassium concentration (2.51%), highest root one (4.24 mmol/100 g root), lowest sugar content (12.9%), and the poorest extractable sugar (10.7%). Root yield of the investigated hybrids (48 t/ha) was higher by 16% compared to multigerm lines yield (42 t/ha) and as much as 35% higher compared to monogerm lines (36 t/ha). Sugar beet root potassium was in significantly negative correlation with sugar content at three localities (L-1: $r = -0.485^{**}$, L-2: $r = -0.096$, L-3: $r = -0.687^{**}$, L-4: $r = -0.337^{**}$) whereas at all four localities it was in negative correlation with extractable sugar (L-1: $r = -0.634^{**}$, L-2: $r = -0.407^{**}$, L-3: $r = -0.930^{**}$, L-4: $r = -0.749^{**}$). Potassium concentration in sugar beet leaf was in significant positive correlation with sugar content at three localities (L-1: $r = 0.382^{**}$, L-2: $r = 0.231$, L-3: $r = 0.717^{**}$, L-4: $r = 0.516^{**}$).

Keywords: sugar beet; potassium; genotype; monogerm line; multigerm line; hybrid; yield; quality

Sugar beet yield and quality depend on genotype as well as on growing conditions. Europe today is characterized by widespread monogerm triploid hybrids more often originated from crossing mother's monogerm line and father's multigerm line. Both monogerm and multigerm lines have their advantages and disadvantages. A successful choice of parent components should result in high-yielding sugar beet hybrid of top quality. It is known that sugar beet requires much potassium for its growth and development. Lack of soil potassium might negatively affect sugar beet yield and quality (Loue 1985, Draycot 1996). At the same time potassium, sodium and harmful nitrogen (Burba 1996, Švachula et al. 1996, Rastija et al. 1998) represent root molasses-forming elements (Brůhová et al. 1995). It means that they interfere with root sugar extraction. Potassium improves sugar beet health condition (Anonymous 1990). Results of former investigations showed that genotypes respond to certain production conditions in a different way since each genotype has its specific demands (Marschner et al. 1981, Burba 1996, Wendenburg and Koch 1996).

These investigations aim at determination of a genotype effect on potassium concentration in sugar beet leaf and root, yield and quality of five multigerm lines, five hybrids and five monogerm lines as well as correlation between potassium concentration in sugar beet leaf and root, and sugar beet yield and quality.

MATERIAL AND METHODS

Field experiments

In 1994 and 1996 field experiments comprising 15 sugar beet genotypes were set up on two soil types (FAO 1998): Calcic Luvisols (Localities l and 3) and Calcic Gleysols (Localities 2 and 4) in east Croatia. Genotypes were domestic and foreign origin: five multigerm lines (genotype 1 = OD-184/414-275, genotype 2 = OY-192/442-426, genotype 3 = OK-205/580-436, genotype 4 = OM-225/556-579 and genotype 5 = OO-134/483-476-78); five hybrids (genotype 6 = OS Nada, genotype 7 = OS Sana, genotype 8 = KW Maja, genotype 9 = KW Lena and genotype 10 = OS Optima), and five monogerm lines (genotype 11 = MO-70/244-132, genotype 12 = M-85-11/557, genotype 13 = MN-5x2843/71, genotype 14 = M-85-1/460 and genotype 15 = M-88/670-30). The experiments were set up in a randomised block design with five replicates. The main plot size was 15 m^2. Sugar beet sowing was carried out at the beginning of April. Root yield and quality were determined at the time of sugar beet harvest, in October. Sugar content was determined by means of a saccharimeter and potassium with a flamephotometer. Middle leaves in rosette were taken for chemical analyses in early July (Bergman 1992). Leaf potassium concentration after wet digestion was determined by atomic absorption

Table 1. Agrochemical soil fertility indicators (0–30 cm depth) of the investigated localities (L-1 = locality 1, L-2 = locality 2, L-3 = locality 3, L-4 = locality 4), by EUF-method

Element	The growing season of 1994				The growing season of 1996			
	L-1		L-2		L-3		L-4	
	20°	80°	20°	80°	20°	80°	20°	80°
	EUF-extraction (mg/100 g soil)							
N_{org}	1.84	1.04	2.11	0.54	1.49	1.18	1.12	0.35
P	1.79	1.35	1.89	1.40	0.85	0.60	2.04	1.42
K	10.81	7.18	4.14	3.58	5.81	2.95	2.07	1.70
Ca	43.1	46.0	44.7	64.7	27.8	15.66	48.7	53.4
Mg	4.99	2.14	4.35	2.31	3.75	2.16	4.61	2.50
Na	8.96		1.43		4.43		1.61	
	Other analyses							
Humus (%)	2.20		1.90		1.20		2.60	
pH (KCl)	6.66		6.91		5.80		7.04	
Clay	61.54		64.75		62.52		66.64	

Table 2. Amount of applied mineral nutrients per localities

Year	Locality	Accomplished mineral fertilization (kg/ha)		
		N	P	K
1994	L-1	100	58	111
	L-2	120	57	149
1996	L-3	130	45	85
	L-4	135	55	137

spectrophotometer. Extractable sugar was calculated according to Braunschweiger formula (Buchholz et al. 1995).

Chemical soil properties

Agrochemical soil fertility indicators of the investigated localities were determined by EUF method (Table 1). Soil samples for chemical analyses were taken in autumn before sugar beet fertilization.

Fertilization of the experimental plots was conducted with common used amounts in sugar beet production at analyzed areas. Thus, addition of nutrients differentiated according to localities (Table 2).

Weather conditions did not significantly differ between the two localities whereas differences between the investigated years were noticeable (Table 3).

Weather conditions in 1994 were less favourable for sugar beet growing compared to 1996. The temperature during the growing season in 1994 was higher than optimum for sugar beet and precipitation distribution was unfavourable. Especially unfavorable weather was during July when is the period of the highest water requirement of sugar beet (19 mm rainfall and 2.7°C higher temperatures compared to 90-year mean and even by 5°C higher than the optimum for sugar beet). In September this drought period was followed by high precipitation which together with high temperatures, caused regrowth. The year 1996 was more favourable for sugar beet growing, but September was rather wet, which adversely affected maturation and beet extraction.

Table 3. Weather conditions in 1994 and 1996 in the investigated localities (Osijek Weather Bureau)

Month	Investigated years				90-year average (1900–1990)	
	1994		1996			
	mm	°C	mm	°C	mm	°C
April	52	11.8	82	11.5	56	11.2
May	35	17.0	78	18.0	63	16.8
June	88	20.2	30	21.1	88	19.4
July	19	23.9	95	19.9	66	21.2
August	84	22.6	77	20.6	61	20.4
September	120	19.4	157	13.0	46	16.8
October	58	9.9	61	11.5	56	10.8
Total	756		861		680	
Average		17.9		16.5		16.7

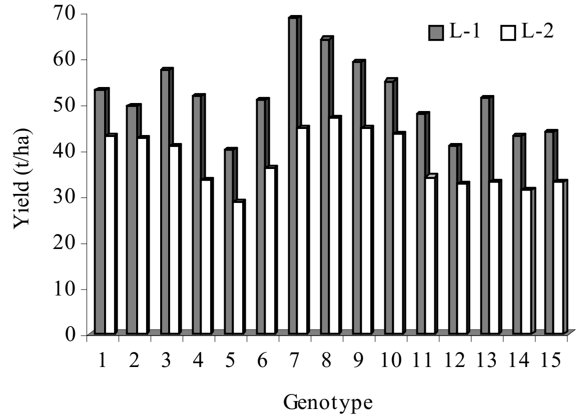

Figure 1. Yield of the investigated sugar beet genotypes in different localities (L-1 and L-2) in 1994 growing season

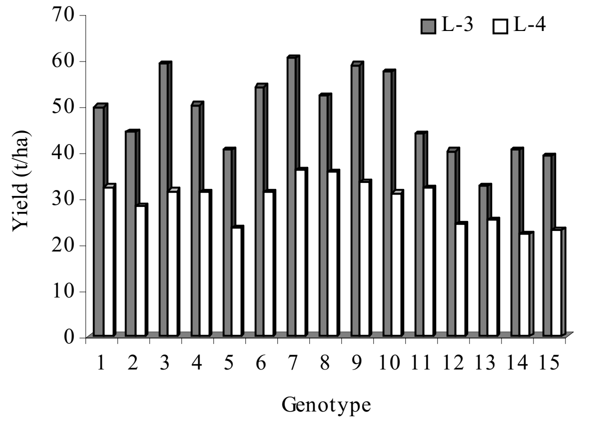

Figure 2. Yield of the investigated sugar beet genotypes in different localities (L-3 and L-4) in 1996 growing season

Results were processed by modern statistical methods (ANOVA and multiple correlation) using computer program by Vukadinović (1985).

RESULTS AND DISCUSSION

The results showed significant differences in sugar beet root yield (Figures 1 and 2) and quality among the investigated years, localities and genotypes.

Root yield was significantly higher on Calcic luvisol at the localities L-1 (51.8 t/ha) and L-3 (48.2 t/ha) compared to Calcic gleysol: localities L-2 (37.9 t/ha) and L-4 (29.4 t/ha). This result may be due to different supply with nutritive elements, especially potassium (Table 1). The highest average root yield of the investigated sugar beet genotypes was accomplished at locality L-1 where the highest potassium soil supply (10.81 mg/100 g EUF K_{20}) was determined. The lowest yield was found at locality L-4 where potassium soil supply was the lowest (2.07 mg/100 g EUF K_{20}). Wiklicky *(*1982) claimed that soil supply of 11–15 mg/100 g EUF K_{20} should be ensured for achieving sugar yield of 9 t/ha. Similar recommendations were also given by von Braunschweig *(*1980) who stated that 12–14 mg/100 g EUF K_{20} should be ensured for deep loessive soils. According to available soil potassium (Table 1) and pedophysical soil properties of the investigated localities potassium fertilization should have been significantly higher compared to accomplished one (Table 2) to achieve yield of 50 t/ha of root. Since soil potassium shortage was not compensated for by fertilization obtained root yield was considerably lower compared to the genetic potential of the investigated genotypes.

Average sugar content was significantly higher in 1996 (L-3 = 14.3%, L-4 = 15.1%) compared to 1994 (L-1 = 13.1%, L-2 = 10.9%). Differences between the localities and genotypes were significant (Figures 3 and 4).

Lower root sugar content in 1994 is the result of unfourable weather conditions – dry and hot summer as well as rainy and warm autumn (Table 3) that resulted in summer leaves drying and intensive autumn regrowth causing higher sugar consumption from sugar beet root.

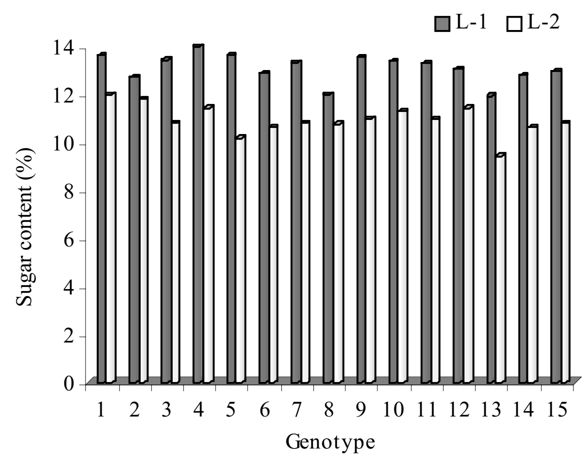

Figure 3. Sugar contents of the investigated sugar beet genotypes in different localities (L-1 and L-2) in 1994 growing season

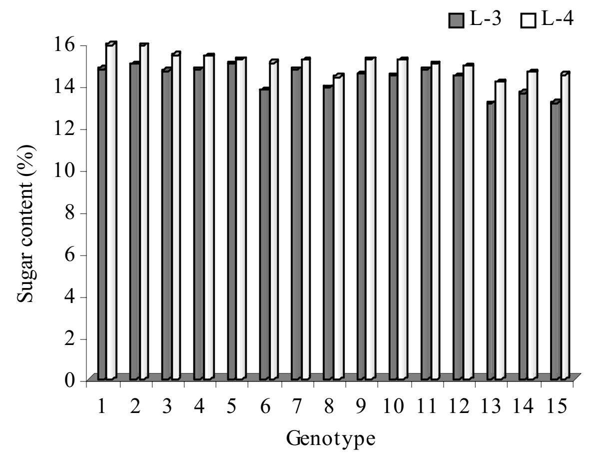

Figure 4. Sugar contents of the investigated sugar beet genotypes in different localities (L-3 and L-4) in 1996 growing season

Table 4. Potassium concentration in sugar beet root and leaf in different genotypes

Sugar beet	Potassium in root (mmol/100 g root)				Potassium in leaf (%)			
	1994		1996		1994		1996	
	L-1	L-2	L-3	L-4	L-1	L-2	L-3	L-4
				Multigerm lines				
1	4.28	3.06	4.82	3.37	3.74	2.02	3.85	2.12
2	3.94	2.75	4.85	3.27	3.30	1.78	3.64	2.35
3	4.33	2.61	5.10	3.23	3.23	1.72	3.67	2.04
4	4.17	2.97	5.21	3.77	3.51	1.76	3.60	1.87
5	3.86	2.78	4.15	3.07	3.46	1.73	3.46	2.15
Average (1–5)	4.12	2.83	4.82	3.34	3.44	1.80	3.64	2.11
				Hybrids				
6	4.70	3.25	5.32	3.55	3.38	1.99	3.29	2.29
7	4.87	3.50	5.12	3.29	3.17	1.59	3.62	2.18
8	4.76	3.31	5.20	3.42	3.18	1.69	3.19	1.76
9	3.97	2.80	4.75	3.10	3.18	1.63	3.47	2.19
10	4.65	3.13	4.88	3.54	3.15	1.65	3.53	2.02
Average (6–10)	4.59	3.20	5.06	3.38	3.22	1.71	3.42	2.08
				Monogerm lines				
11	4.77	2.89	5.04	3.32	3.43	1.62	3.54	1.98
12	4.51	3.10	4.73	3.34	3.42	1.54	3.38	2.04
13	5.58	3.63	6.18	3.96	3.00	1.43	2.95	1.72
14	4.27	3.12	5.14	3.51	3.16	1.90	3.16	2.01
15	4.81	3.52	5.53	3.80	3.19	1.56	3.14	1.96
Average (11–15)	4.79	3.25	5.32	3.59	3.24	1.62	3.23	1.95
Total average (1–15)	4.50	3.10	5.07	3.44	3.30	1.71	3.43	2.04
Ploidity *LSD* 5%	0.16	0.22	0.26	0.11	0.23	0.10	0.06	0.06
LSD 1%	0.24	0.32	0.38	0.17	0.35	0.15	0.09	0.10
Genotype *LSD* 5%	0.15	0.15	0.14	0.11	0.19	0.10	0.08	0.09
LSD 1%	0.19	0.19	0.19	0.15	0.26	0.12	0.11	0.11

Multigerm lines were known for the highest leaf potassium concentration, the lowest root one, and the best root extractable sugar. Monogerm lines had the lowest leaf potassium concentration, the highest root one, and the poorest extractable sugar (Tables 4 and 5).

Investigated multigerm lines had the highest sugar content (13.8%) and monogerm lines had the lowest sugar content (13.0%). The highest average root yield (48.2 t/ha) and tehnological sugar yield (5.28 t/ha) (Table 5) were attained by the hybrids whereas the lowest root yield (35.8 t/ha) and technological sugar yield (3.79 t/ha) were achieved by monogerm lines. Although monogerm lines had the lowest root yield as well as the lowest sugar content. Their presence is essential in breeding since they are bearers the sugar beet monogerm seeds.

Significant impact of genotype on sugar content was noted for all localities. Genotype 13 (monogerm line) had the lowest sugar content, the highest root potassium concentration and the lowest leaf potassium concentration at all localities. Genotype 5 (multigerm line) had the lowest root potassium concentration at three localities whereas genotype 1 (multigerm line) had also the highest leaf potassium concentration at three localities. These data show that root and leaf potassium concentration in sugar beet are significantly affected by genes.

Leaf potassium concentration was in significant positive correlation with extractable sugar (L-1: $r = 0.406^{**}$, L-2: $r = 0.254$, L-3: $r = 0.694^{**}$, L-4: $r = 0.543^{**}$).

A significant positive correlation between leaf potassium concentration and sugar content at three localities (L-1: $r = 0.382^{**}$, L-2: $r = 0.231$, L-3: $r = 0.717^{**}$, L-4: $r = 0.516^{**}$) was determined. However, higher average leaf potassium concentration was obtained at localities with higher potassium soil supply, which is in accordance with the results accomplished by Kristek et al. (1996). According to Bergman (1992) leaf potassium concentration at localities L-1 and L-3 were close to optimum values whereas values obtained at localities L-2 and L-4 were under low limit value.

According to literature (Wiklicky 1982, Loue 1985), the soil potassium concentration increase resulted in sugar beet root potassium increase.

Relatively higher average sugar beet root potassium concentration in 1996 (although the localities had lower potassium soil supply and less potassium was added in compared to 1994) might be in connection with weather conditions. The 1996 was wetter and colder compared to 1994, and from the literature it is known that plants growing in continental and northern climate soils take up potassium better than those in Mediterranean countries

Table 5. Extractable sugar and technological sugar (white sugar) yield of the investigated sugar beet genotypes in different localities

Sugar beet genotype	Extractable sugar (%)				Technological sugar yield (t/ha)			
	1994		1996		1994		1996	
	L-1	L-2	L-3	L-4	L-1	L-2	L-3	L-4
Multigerm lines								
1	11.08	9.23	12.69	13.91	5.84	3.96	6.45	4.41
2	9.94	9.36	12.90	13.94	5.02	4.01	5.56	4.09
3	10.82	8.44	12.49	13.53	6.26	3.60	7.45	4.16
4	11.44	8.69	12.39	13.37	5.81	2.89	6.32	4.05
5	11.26	7.90	12.93	13.22	4.52	2.38	5.03	3.09
Average (1–5)	10.91	8.72	12.68	13.59	5.49	3.37	6.16	3.96
Hybrids								
6	10.48	8.23	11.46	13.03	5.30	2.97	6.26	4.10
7	10.95	8.40	12.58	13.12	7.41	3.67	7.53	4.64
8	9.31	8.15	11.59	12.28	5.85	3.77	6.20	4.39
9	11.30	8.63	12.45	13.35	6.76	3.79	7.17	4.51
10	11.06	9.03	12.12	13.01	5.98	4.09	7.07	4.01
Average (6–10)	10.62	8.49	12.04	12.96	6.26	3.66	6.85	4.33
Monogerm lines								
11	10.86	8.55	12.59	13.13	5.24	2.87	5.36	3.96
12	10.87	9.08	12.38	12.96	4.47	2.99	4.76	3.26
13	9.41	7.09	10.63	11.99	4.70	2.34	3.42	3.02
14	10.60	8.36	11.47	12.57	4.59	2.59	4.75	3.73
15	10.51	8.46	10.91	12.38	4.63	2.78	4.32	2.88
Average (11–15)	10.45	8.31	11.60	12.61	4.73	2.72	4.52	3.17
Total average (1–15)	10.66	8.51	12.11	13.05	5.49	3.25	5.84	3.82
Ploidity *LSD* 5%	0.28	0.18	0.22	0.61	0.42	0.38	0.41	0.37
LSD 1%	0.42	0.27	0.34	0.98	0.63	0.58	0.62	0.57
Genotype *LSD* 5%	0.39	0.65	0.31	0.29	0.42	0.61	0.37	0.31
LSD 1%	0.51	0.85	0.40	0.38	0.56	0.81	0.48	0.41

(Loue 1985, Mengel and Rahmatullah 1994). Sugar beet root potassium was in significantly negative correlation with sugar content at three localities (L-1: $r = -0.485^{**}$, L-2: $r = -0.096$, L-3: $r = -0.687^{**}$, L-4: $r = -0.337^{**}$) whereas at all four localities it was in negative correlation with extractable sugar (L-1: $r = -0.634^{**}$, L-2: $r = -0.407^{**}$, L-3: $r = -0.930^{**}$, L-4: $r = -0.749^{**}$).

CONCLUSION

Higher soil potassium supply resulted in higher potassium concentration in sugar beet root and leaf. Potassium concentration in sugar beet leaf and root is affected by genes. Root yield of the investigated hybrids was higher by 16% compared to multigerm lines yield and as much as 35% higher compared to monogerm lines. Multigerm lines were known for the highest leaf potassium concentration, and the lowest root one, highest sugar content and best root extractable sugar. Monogerm lines had the lowest leaf potassium concentration, the highest root one, the lowest sugar content and the poorest extractable sugar. A significant negative correlation between root potassium and sugar content as well as root potassium and extractable sugar was determined. Leaf potassium concentration was in significant positive correlation with extractable sugar and sugar content.

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ABSTRAKT

Vliv půdního draslíku na výnos a kvalitu různých genotypů cukrovky

Stanovili jsme rozdíly v koncentraci draslíku v chrástu a bulvách různých genotypů cukrovky a jeho vliv na kvalitu a výnos bulev. Pokusy týkající se 15 genotypů cukrovky (pět víceklíčkových linií, pět hybridů a pět jednoklíčkových linií) jsme prováděli během dvou vegetačních období na dvou půdních typech (vápenatý luvisol: L-1 a L-3, vápenatý glej: L-2 a L-4). Výnos bulev u sledovaných genotypů byl na vápenatém luvisolu (50 t/ha) vyšší než na vápenatém gleji (34 t/ha). Zjistili jsme, že víceklíčkové linie mají nejvyšší koncentraci draslíku v chrástu (2,75 %), nejnižší koncentraci v bulvách (3,78 mmol/100 g bulvy), nejvyšší cukernatost (13,8 %) a nejlépe extrahovatelný cukr z kořene (1,5 %). Jednoklíčkové linie měly nejnižší koncentraci draslíku v chrástu (2,51 %), nejvyšší v bulvách (4,24 mmol/100 kořene), nejnižší cukernatost (12,9 %) a nejhůře extrahovatelný cukr (10,7 %). Výnos bulev sledovaných hybridů (48 t/ha) byl vyšší o 16 % ve srovnání s výnosem víceklíčkových linií (42 t/ha) a o 35 % vyšší než u jednoklíčkových linií (36 t/ha). Draslík v bulvách vykazoval významnou zápornou korelaci s cukernatostí na třech lokalitách (L-1: r = –0,485**, L-2: r = –0,096, L-3: r = –0,687**, L-4: r = –0,337**), zatímco na čtyřech lokalitách byl v negativní korelaci s extrahovatelným cukrem (L-1: r = –0,634**, L-2: r = –0,407, L-3: r = –0,930**, L-4: r = –0,749**). Mezi koncentrací draslíku v chrástu a cukernatostí existovala na třech lokalitách významná kladná korelace (L-1: r = 0,382**, L-2: r = 0,231, L-3: r = 0,717**, L-4: r = 0,516**).

Klíčová slova: cukrovka; draslík; genotyp; jednoklíčková linie; víceklíčková linie; hybrid; výnos; kvalita

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