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Original scientific paper

GENETIC POTENTIAL OF APPROVED SUGAR BEET CULTIVARS IN THE REPUBLIC OF SERBIA

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ABSTRACT: On the basis of eight-year studies (2001-2008) on the performance of approved sugar beet cultivars the followings were concluded: root yield had a growing tendency over period 2001-2005, after which a slight decline was noted. The maximal root yield in 2005 was high reaching a figure of 92.036 t/ha. Considering sugar content in root, an increasing tendency was observed in the 2001-2008 period. Yield of granulated sugar had an increasing tendency, too with a maximal value reached in 2005 (12.280 t/ha). Similar trends were observed for other technological parameters whereas non-sugar compounds had a decreasing trend.

Keywords: sugar beet, cultivar, yield, technological quality

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INTRODUCTION

Yield is the major economic category, very complex in character. For most crops, it is dependant on genetic factors, environ-mental factors as well as their interactions, as was shown by Čačić et al. (2005). Under our environmental conditions, productive cultivation of sugar beet is impossible without cultivars highly tolerant to rhizomania. The first record of the presence of rhizomania in our country dates back to 1977. Larger areas infected with rhizomania were detected in Srem and Banat, and somewhat later in Bačka. This disease is manifested with leaf chlorosis, prolongation and narrowwing of leaf petioles, roots bearding and constriction. Rhizomania is caused by beet necrotic yellow vein virus (BNYVV). Rhizomania has been present in all areas cultivated with sugar beet (Table 1).

According to data reported by Bürcky (1995), a rapid rise in areas infected with rhizomania was observed in France. In Serbia, 5900 ha and 47700 ha of land were affected by the disease in 1983 and 1993, respectively.

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Table 1.
Land under sugar beet crop and total area infested with rhizomania in 2004

Country	Area under sugar beet crop	Infested area	
	ha	%	ha
Austria	50 000	1,5	750
Belgium	100 000	1	1 000
France	400 000	5	20 000
Germany	445 000	4	18 000
Greece	45 000	3,5	1 575
Italy	240 000	1	3 600
The Netherlands	115 000	15	17 250
Spain	165 000	8	13 200
Hungary	60 000	10	6 000
Turkey	360 000	1	3 600
Chile	50 000	47	23 500
USA	600 000	35	210 000
Total			318 475

*According to data of Strube, Germany.

Today, rhizomania is wide spread in Serbia which has been confirmed by numerous field trials. Jasnić et al. (1999) reported that the infected area increased from 1357 ha in 1997 to 3790 ha in 1998 in the Province of Vojvodina. Beside rhizomania, land under sugar beet crop has been affected by other diseases such as Rhizoctonia solani.

Accurate data on Rhizoctonia solani infected area in Serbia is missing but it has been estimated that around 8% or 6400 ha of the land under sugar beet has been affected. Approved cultivars of sugar beet investigated in the study were double tolerant to diseases (cercospora and rhizomania) and some of them were, in addition, tolerant to Rhizoctonia solani.

MATERIAL AND METHODS

In the observed period (2001-2008), varietal microtrials were conducted with sugar been cultivars passing the phase of official registration and approval. Total of 94 microtrials were set, each trial was replicated four times. Each cultivar was planted in four rows and harvested in two rows. The size of the basic plot was 20 m^2 and the harvesting plot was 10 m^2.

The investigated sugar beet cultivars were provided from the selections of KWS (Germany), Strube-Dieckmann (Germany), Hillechög (Sweden), Lion Seeds (England), Ses-Van der Have (Belgium, the Netherlands), Danisco (Denmark), Institute of Field and Vegetable Crops (Serbia) and "Selection" from Aleksinac (Serbia).

Laboratory analyses were done in the laboratory of the Institute for Food Technology, Novi Sad, Serbia according to the following methods:

- Sugar content in beet by the method of cold digestion;
- Alpha amino nitrogen according to V. Stanek - P. Pavlas (1934/35);
- Potassium and sodium content by Atomic Absorption Spectrophotometry (AAS).

The other quality parameters were calculated according to the following formulas:

- Sugar content in molasses (SM) (% on root) according to Reinelfeld et al. (1974):
- SM = 0.343 x (K+Na)+0.094 x alpha amino N-0.31. where K, Na and alpha amino N are given in mmol/100 g.

Sugar utilization (SU) (% on root) according to Reinelfeld et al. (1974):

- SU = D-SM-0.6 where D is sugar content (%). SM is sugar content in molasses (%). 0.6 refers to total losses.

Thick juice purity (Q) according to Wieninger and Kubadinov (1971):

- Q = 99.36-0.1427 x (K+Na+alpha amino N) where K, Na and alpha amino N are given in mmol/100^{O}S.
- Polarized sugar yield (PSY) (t/ha):
  PSY = RY x D. where RY is root yield (t/ha). D is sugar content (%).
- Granulated sugar yield (GSY) (t/ha):
  GSY = RY x SU.

Statistical analysis was performed using two-way ANOVA procedures according to Hadživuković (1973).

Agroecological conditions

Average monthly air temperatures during the vegetation period, averaged over eight years, were generally higher compared to several-year means (Table 2, Figure 1).

Lower average monthly air temperature in comparison to several-year mean was recorded in September (-0.3 °C). Observing the average figures over the entire vegetation period, temperatures were higher by 1.1 °C, as compared to several-year means. Mean monthly winter precipitation in the observed period (Table 3, Figure 2), slightly differed from the several-year means. Average precipitations over eight years were higher by 18.0 mm in the winter period, 19.0 mm in the vegetation period and 37.0 mm for total precipitations, as compared to several-year means Monthly sum of sunshine hours in the vegetation period, during the first four months (April-July), were higher than the several-year means in contrast to the last three months when they were lower (Table 4, Figure 3).

Table 2.
Average monthly air temperatures (ºC) during vegetation, for period 2001-2008 (T) and their deviations (A) from means, for period 1975-2000

No.	Year	Months														Mean values in vegatation period	
		Apr		May		Jun		Jul		Aug		Sep		Oct			
		T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A
1.	2001	11.4	0.0	18.1	+1.6	18.5	-1.1	22.4	+1.2	23.3	+2.2	15.5	-1.8	14.1	+1.9	17.6	+0.6
2.	2002	11.6	+0.2	19.5	+3.0	21.9	+2.3	24.0	+2.8	22.3	+1.2	17.3	0.0	13.2	+1.0	18.5	+1.5
3.	2003	11.2	-0.2	20.7	+4.2	24.0	+4.4	22.8	+1.6	24.7	+3.6	17.6	+0.3	10.6	-1.6	18.8	+1.8
4.	2004	12.7	+1.3	15.4	-1.1	20.0	+0.4	22.1	+0.9	21.7	+0.6	16.6	-0.7	14.6	+2.4	17.6	+0.6
5.	2005	12.1	+0.7	17.0	+0.5	19.7	+0.1	22.1	+0.9	20.6	-0.5	18.2	+0.9	13.3	+1.1	17.6	+0.6
6.	2006	13.5	+2.1	17.0	+0.5	20.0	+0.4	24.0	+2.8	20.7	-0.4	19.0	+1.7	15.1	+2.9	18.5	+1.5
7.	2007	13.5	+2.1	18.9	+2.4	22.5	+2.9	24.0	+2.8	23.4	+2.3	15.5	-1.8	11.3	-0.9	18.4	+1.4
8.	2008	12.9	+1.5	18.5	+2.0	21.7	+2.1	22.0	+0.8	23.0	+1.9	15.9	-1.4	13.7	+1.5	18.2	+1.2
Mean:		12.4	+1.0	18.1	+1.6	21.0	+1.4	22.9	+1.7	22.5	+1.4	17.0	-0.3	13.2	+1.0	18.1	+1.1
Several-year mean (1975-2000)		11.4		16.5		19.6		21.2		21.1		17.3		12.2		17.0	

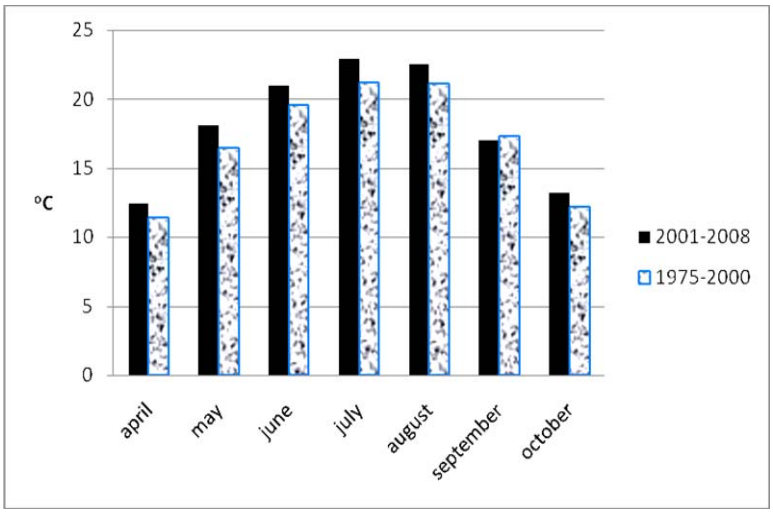

Figure 1. Average monthly air temperatures during vegetation period

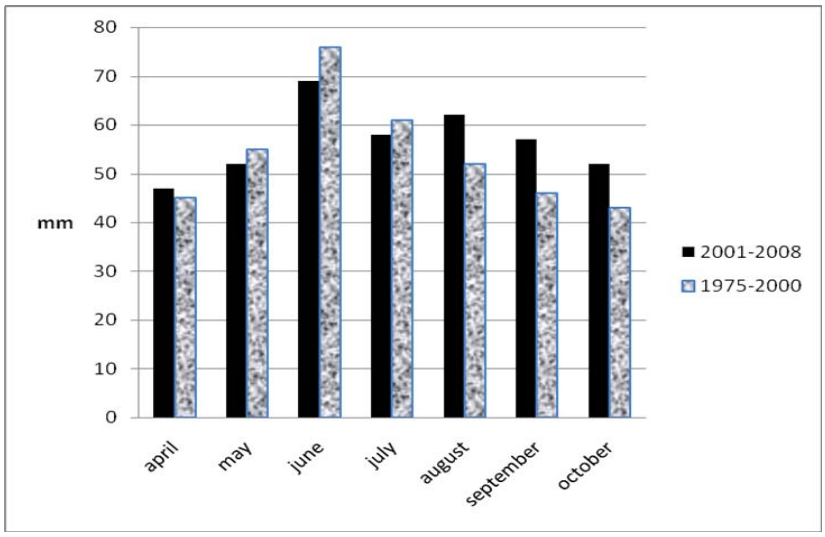

Figure 2. Average precipitations (mm) during vegetation period

Table 3.
Precipitations (mm) in winter period, vegetation period, and total over 2001-2008 years in Vojvodina

No	Year	Winter precipitation (XI-III)	Months							Total prec. in vegetation period (IV-X)	Total annual precipitation (XI-X)
			Apr	May	Jun	Jul	Aug	Sep	Oct		
1	2001	270	33	26	20	24	5	52	13	173	443
2	2002	132	46	57	64	64	94	60	63	448	580
3	2003	149	18	34	28	81	14	59	124	358	507
4	2004	186	89	65	82	77	65	43	61	482	668
5	2005	281	58	49	95	109	129	61	11	512	793
6	2006	247	88	42	115	32	115	20	22	434	681
7	2007	221	4	92	84	30	52	72	101	435	656
8	2008	225	42	48	67	47	22	91	21	338	563
Mean		214	47	52	69	58	62	57	52	397	611
Several-year mean (1975-2000)		196	45	55	76	61	52	46	43	378	574

Table 4.
Monthly sum of sunshine hours over period 2001-2008, during sugar beet vegetation period in Vojvodina

No.	Year	Months							Sum for vegetation period (IV-X)
		Apr	May	Jun	Jul	Aug	Sep	Oct	
1.	2001	344	268	238	277	298	151	188	1764
2.	2002	198	238	290	275	226	166	142	1535
3.	2003	193	283	333	289	325	218	133	1772
4.	2004	164	233	259	272	297	194	137	1557
5.	2005	173	254	293	277	198	190	156	1542
6.	2006	175	254	253	344	206	231	219	1682
7.	2007	318	264	309	354	289	199	115	1847
8.	2008	164	298	279	300	326	195	134	1694
Mean (2001-2008):		216	261	282	298	271	193	153	1674
Several-year mean (1975-2000)		183	239	262	293	275	204	159	1615

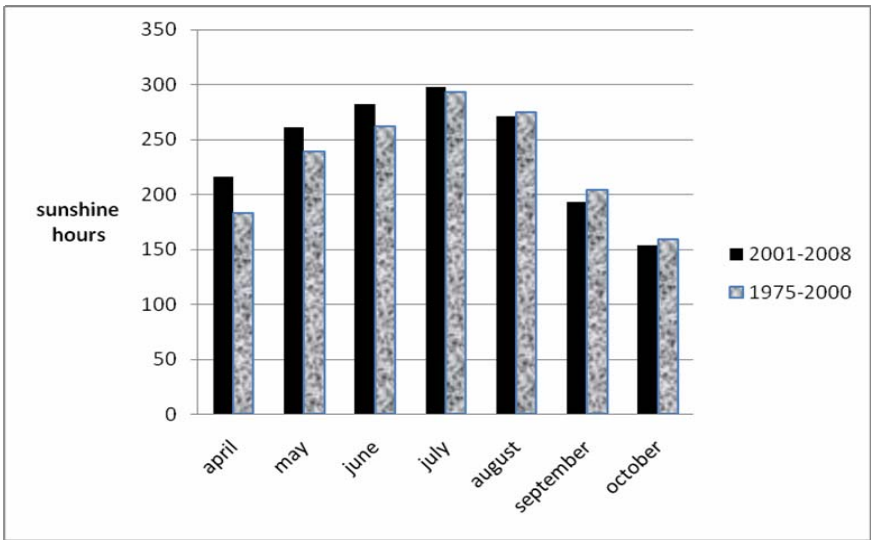

Figure 3. Monthly sum of sunshine hours during vegetation period

RESULTS AND DISCUSSION

The lowest root yield (45.643 t/ha) was recorded for cultivar 11 in 2001 (Table 5). The highest root yield (95.967 t/ha) was achieved by cultivar 12 in 2005. The variation in the root yield between the extreme records was 50.324 t/ha or 110.26% (Figure 4).

Sugar content in root ranged from 14.62% (cultivar 2, in 2004) to 17.27% (cultivar 11, in 2008). The maximal differrence in sugar content was 2.65% absolute or 15.34% relative (Figure 4). The highest granulated sugar yield amounted to 12.902 t/ha in 2005 (cultivar 17) and the lowest was 5.841 t/ha in 2001 (cultivar 14).

The difference in this parameter within the extremely ranked cultivars was 7.061 t/ha or 120.89% (Figure 5). Related to sugar utilization (expressed in % on beet), the highest figure (15.75%) was recorded for cultivar 19 in 2007 and the lowest of 12.18% for cultivar 2 in 2004.

The extreme difference in this parameter was 3.57% absolute or 22.67% relative. The highest thick juice purity of 95.39 was recorded in 2007 for cultivar 19 and the lowest (90.83) for cultivar 2 in 2004 which reflected a maximal difference of 4.56.

The lowest sugar content in molasses (0.86%) was achieved by cultivar 19 in 2007 and the highest (2.09) by cultivar 12 in 2001. The maximal difference within cultivars was 1.23%.

The lowest potassium content for the observed period was 13.65 mmol/100°S in the case of cultivar 19 in 2007 and the highest was 27.07 mmol/100°S by cultivar 12 in 2001. The maximal difference in this parameter was distinguished and amounted to 13.42 mmol/100S.

Extremely low sodium content (2.38 mmol /100°S) was determined in cultivar 12 in 2008 whereas significantly higher content (14.38 mmol/100°S) was found in cultivar 5 in 2005. The observed difference in the sodium content within the extremely ranked cultivars was high: 12.00 mmol/100°S or six-folded.

Cultivar 19 was the lowest in alpha-amino content in 2007 (10.21 mmol/100°S) whereas cultivar 9 was the highest with a figure of 24.98 mmol/100°S in 2002. The differrence in this parameter within the cultivars was significant and elevated: 14.77 mmol/-100°S or 2.45-folded.

Averaged over period 2001-2008 and within 117 approved cultivars and 94 micro trials, mean root yield was 73.097 t/ha. This mean root yield was higher by 24.13 t/ha or 33.02% as related to the lowest obtained in 2001 (Table 6). The mean root yield was positively correlated to the mean precipitations, with a coefficient of correlation of 0.66.

Table 5. Extreme figures (the best and worst) of the results obtained from the sugar beet field trials over period 2001-2008.

	Indicators		Year of approval	Value	Cultivar code
During period 2001-2008	The best	Root yeild (t/ha)	2005	95.967	12
	The worst		2001	45.643	11
	The best	Sugar content (%)	2008	17.27	11
	The worst		2004	14.62	2
	The best	Gran.sugar yield (t/ha)	2005	12.902	17
	The worst		2001	5.841	14
	The best	Sugar utilization (% on beet)	2007	15.75	19
	The worst		2004	12.18	2
	The best	Thick juice purity	2007	95.39	19
	The worst		2004	90.83	2
	The best	Sugar content in molasses (%)	2007	0.86	19
	The worst		2001	2.09	12
	The best	K (mmol/100^{o}S)	2007	13.65	19
	The worst		2001	27.07	12
	The best	Na (mmol/100^{o}S)	2008	2.38	12
	The worst		2005	14.38	5
	The best	α-amino N (mmol/100^{o}S)	2007	10.21	19
	The worst		2002	24.98	9

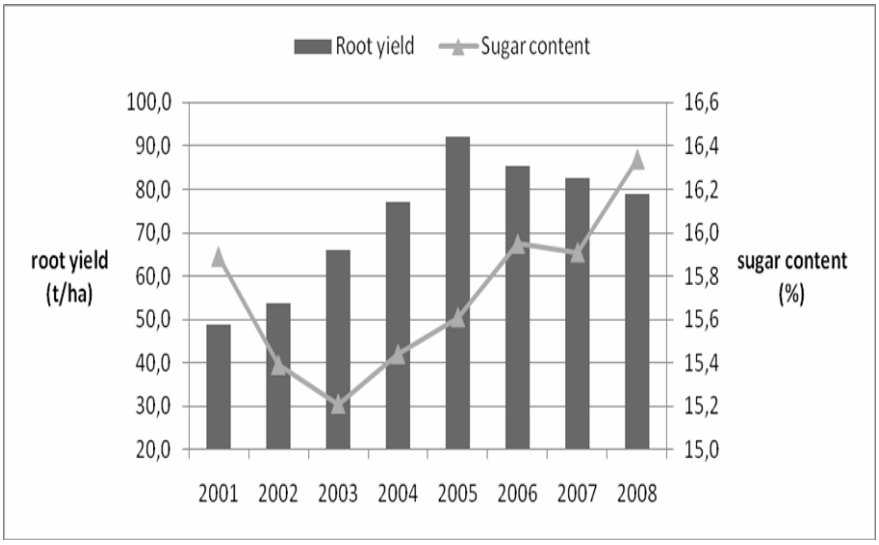

Figure 4. Average sum root yield and sugar content over period 2001-2008

Mean content of sugar in root, averaged over years, localities and cultivars was 15.72% and was higher than the minimal record (in 2003) by 0.51% absolute or 3.24% relative.

However, the established correlation coefficient between the mean sugar content and average precipitations was negative and amounted to -0.33.

The mean granulated sugar yield, averaged over years, localities and cultivars was very high (9.906 t/ha). It was higher by 3.483 t/ha or 35.16% as compared to that in 2001. The granulated sugar yield positively correlated to the mean precipitations over the observed period with a correlation coefficient of 0.58.

The mean sugar utilization (% beet root) averaged over years, localities and cultivars, was 13.57% and it was higher by 0.48% absolute or 3.54% relative as related to the minimal values recorded in 2002.

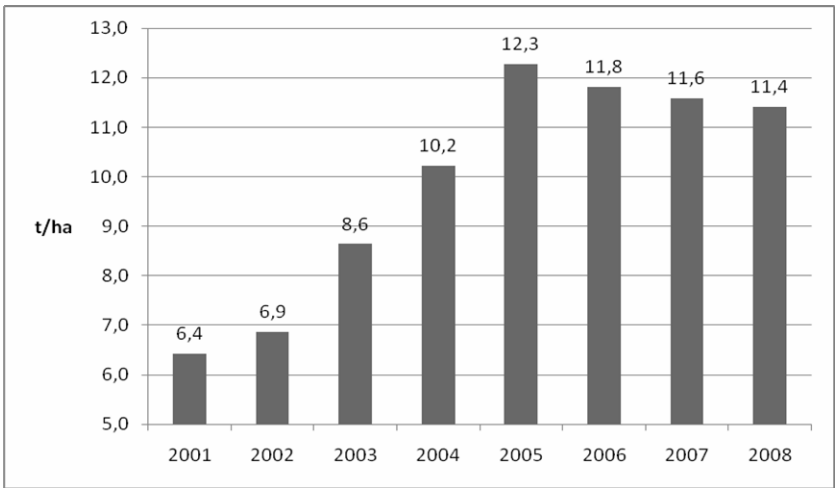

Figure 5. Average sum granular sugar over period 2001-2008

Table 6.
Average results of sugar beet micro-trials over period 2001-2008

Year of approval	No of approved cultivars	Root yield (t/ha)	Sugar content (%)	Granular sugar yield (t/ha)	Sugar utilization (% on beet)	Thick juice purity	Sugar content in molasses (% on beet)	K	Na	α-amino N
								m mol/100ºS		
2001	6	48.964	15.89	6.423	13.39	91.54	1.90	25.75	9.41	19.64
2002	7	53.731	15.39	6.867	13.09	91.64	1.71	23.77	8.98	21.34
2003	11	66.024	15.21	8.642	13.10	92.35	1.51	20.70	9.14	19.29
2004	19	77.179	15.44	10.230	13.20	91.90	1.64	21.60	10.19	20.48
2005	21	92.036	15.61	12.280	13.29	92.06	1.72	23.12	10.34	17.70
2006	18	85.320	15.95	11.806	13.89	93.26	1.46	20.70	7.96	14.12
2007	15	82.615	15.91	11.595	14.09	93.84	1.24	18.19	6.52	13.98
2008	20	78.909	16.34	11.411	14.49	93.75	1.24	17.70	5.63	16.03
Mean:	Σ=117	73.097	15.72	9.906	13.57	92.54	1.55	21.44	8.52	17.82
SD:	-	15.384	0.37	2.312	0.52	0.94	0.24	2.74	1.70	2.84
CV (%):	-	21.045	2.36	23.343	3.86	1.01	15.14	12.77	19.91	15.95

The overall mean thick juice purity was good and reached the figure of 92.54. It was higher by 1.00 when compared to the minimal value registered in 2001.

The average content of sugar in molasses (% on beet), averaged over all factors, was 1.55% which is by 0.35% better in quality in comparison to the lowest value registered in 2001. The mean contents of potassium, sodium and alpha-amino nitrogen, averaged over years, localities and cultivars, were significantly better than those recorded in 2001.

Variation in the root yield for the observed period, ranged between 26.48% in 2001 to 12.98% in 2005, depending on the cultivar. The overall mean was 18.40%. The observed variation in the root yield was higher than that reported by Märländer (1991).

Considering the sugar content in root, the variations ranged from 2.55% (2001) to 13.31% in 2007. In average, the variation in this parameter was 8.07% which conforms to the findings of Märländer and Rothe (2005). The overall mean contents of sugar in root were in negative correlation with the sugar content in molasses, potassium, sodium and alpha-amino nitrogen in root similarly to the findings of Hoffmann and Märländer (2002).

The results also confirmed great variations in other quality parameters within the cultivars which were in similar range to those reported by Radivojević (1995).

The obtained results revealed a decreasing trend in the content of sugar in molasses (from 1.90 to 1.24% on beet), potassium content (from 25.75 to 17.70 mmol/100°S), sodium content (from 10.34 to 5.63 mmol/100°S) and alpha-amino nitrogen content (from 21.34 to 13.98 mmol/100°S).

This observation harmonizes to that reported by Mahn and Hoffmann (2001).

There were also high differences in the content of alpha-amino nitrogen between the cultivars which ranged from 12.30 mmol/100°S to 19.83 mmol/100°S in 2008. Similar results were obtained from Hoffmann et al. (2002).

Variations in the granulated sugar yield between the cultivars were also significant and ranged between 10.52 in 2006 and 28.11 in 2002. The mean variation for the observed period was 16.84%. Koch (2007) reported similar results regarding granulated sugar yield.

The root yield reached the maximal value in 2005 and amounted to 92.036 t/ha or 87.97% of the yield registered in 2001. The observed rise in the root yield was much higher than that reported by Märländer (1991).

It is known that the variations in the sugar content are usually much lower than those in the root yield and granulated sugar yield. The mean variation in this parameter for the observed period was 7.43% rel. Identical variations were recorded in the study of Bongers and Bruhns (2003).

Variation in the granulated sugar yield was considerable, depending on the year observed. The lowest granulated sugar yield was recorded in 2001 at a level of 6.423 t/ha and the highest was 12.280 t/ha in 2005. Thus, the variation in the yield of granulated sugar was very high, 91.19%. Märländer (1991) reported lower variations in this parameter. Considerably lower variation in the granulated sugar content was reported by Čačić et al. (2009). Other quality parameters reached much better figures during 2007 and 2008 as compared to the first two years of study.

CONCLUSION

On the basis of numerous trials with sugar beet cultivars over period 2001-2008, conducted in the region of Vojvodina, the following conclusions were made:

- The mean root yield in the observed eight year period (averaged within cultivars and localities) was 73.097 t/ha, and was higher by 24.13 t/ha or 33.02% when compared to the lowest yield recorded in 2001. Maximal figure was registered in 2005 and this parameter was positively correlated to total precipitations.
- The sugar content in root, averaged over all factors, was 15.72% and this is by 0.51% abs. higher than that in 2003.
- The mean granulated sugar yield, averaged over all factors, was high with a figure of 9.906 t/ha. In comparison to the lowest yield registered in 2001, the granulated sugar yield was higher by 3.483 t/ha or 35.16%.
- The mean figures for sugar utilization, thick juice purity, sugar content in molasses and content of non-sugar compounds were much better than those registered in 2001.

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ГЕНЕТСКИ ПОТЕНЦИЈАЛ ПРИЗНАТИХ СОРТИ ШЕЋЕРНЕ РЕПЕ У РЕПУБЛИЦИ СРБИЈИ

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На основу утврђених вредности признатих сорти шећерне репе, у периоду од осам година (2001-2008), видљиво је следеће: утврђени принос корена шећерне репе имао је тенденцију пораста од 2001. до 2005. године, а након тога забележио је благи пад. Максимални принос корена, утврђен 2005. године, био је веома висок и износио је 92.036 t/ha. У погледу садржаја шећера у репи, видљива је тенденција пораста од 2003. до 2008. године. Међутим, остварени принос кристалног шећера, такође је имао тенденцију пораста од 2001. до 2008. године, с тим, што је највиши био 2005. године (12.280 t/ha). Остали показатељи технолошког квалитета забележили су такође тенденцију пораста, а нешећерне материје тенденцију смањења.