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Combining abilities and mode of inheritance for some root characteristics in sugar beet

Živko Ćurčić*, Dario Danojević, Nevena Nagl
Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia

Summary: Sugar beet breeding is very complex because it involves numerous sugar beet root traits that must be measured and investigated, as a basis to create hybrids with high yield, high sugar content and appropriate root shape. In this paper were investigated combining abilities and mode of inheritance for root weight, root diameter and dry matter content of different sugar beet genotypes. Combining abilities were assessed by line x tester method. The mode of inheritance was assessed by evaluation of hybrids versus parents mean. For the estimation of combining abilities and mode of inheritance of analyzed traits were used 8 monogerm pollinators, 3 monogerm cms lines and their 24 F_1 hybrids. The mode of inheritance for root weight and root diameter for most hybrid combinations was dominance of better parent. For inheritance of dry matter content intermediate level and partial domination of one parent were obtained.
Key words: combining abilities, dry matter, inheritance, root weight, root diameter, sugar beet.

Introduction

Sugar beet is the most significant industrial plant for sugar production in continental climatic area. Sugar beet breeding is very complex because of many of sugar beet root traits that must be measured and investigated in order to create hybrids with high yield, high sugar content and appropriate root shape. Superior genotypes must also be resistant to diseases that cause significant economical damage, like rhizomania, rhizoctonia and *Cercospora beticolla* Sacc (Stančić et al. 1995, Stančić et al. 1997b).

In sugar beet production is used F_1 hybrid generation, so it is important to know combining abilities and mode of inheritance for the most significant root traits: root weight and sugar content (Jovanović et al. 1994). Root weight is qualitative trait highly influenced by environment and highly variable (Campbell 2002, Khan et al. 2005). Studying gene effect, in some studies it was determined that inheritance of root weight is controlled with non additive genetic variance (Scaracis & Smith 1984, Stančić et al. 1997a), while in the others there was higher influence of additive component (Helmerick et al. 1963, Kovačev 1985). Root diameter has high positive correlation with root weight (Campbell & Cole 1986), so this trait could be used as breeding criterion for high root yield. Sugar content and dry matter content have high positive correlation because sucrose constitutes the biggest part of dry matter, so the mode of inheritance of these two traits is similar.

The aim of this research was to examine GCA of inbred lines and mode of inheritance for root weight, root diameter and dry matter content.

Materials and methods

The trial was set up at the experimental field of Institute of Field and Vegetable Crops,

*autor za kontakt / corresponding author
(zivko.curcic@ifvcns.ns.ac.rs)

Novi Sad, during 2005 in randomized block design with three replications. The field trial included 8 monogerm diploid pollinators resistant to rhizomania, 3 monogerm diploid *cms* lines susceptible to rhizomania and their 24 F_1 hybrids. Row-to-row distance was 50 cm, with 20 cm distance between the plants. The standard agricultural practice for sugar beet growing was applied.

Specific and general combining abilities and mode of inheritance were analyzed for following traits: root weight, root diameter and dry matter content. Samples consisted of 15 plants per replication.

Specific and general combining abilities were assessed by line x tester method (Singh & Chaudhary 1976).The mode of inheritance was estimated by using the significance test of mean values in the F_1 generation as compared to the mean values of their parents (Borojević, 1965).

Results and discussion

General combining abilities

The results of the analysis of root weight, root diameter and dry matter content revealed that the line L6 had the highest average value for dry matter content and the lowest for root diameter, while lines L6 and L7 had the highest value for weight. The line L7 was in the group of lines with low dry matter content (Table 1.).

Tab. 1. Mean values of the characteristics of sugar beet lines
Tab. 1. Prosečne vrednosti osobina linija šećerne repe

Lines *Linija*	Root weight *Masa korena* (g)	Root diameter *Prečnik korena* (cm)	Dry matter content *Sadržaj suve materije* (%)
L1	408.6	6.19	19.37
L2	383.2	5.87	19.91
L3	425.4	6.10	20.38
L4	363.4	5.87	20.31
L5	375.1	6.92	20.65
L6	495.4	5.40	21.20
L7	498.1	6.68	19.42
L8	402.3	6.39	20.49
$LSD_{0,05}$	84.2	0.94	1.08
$LSD_{0,01}$	116.8	1.31	1.18

The analysis of GCA for selected sugar beet traits showed a significant difference between lines only for root weight, while lines L4 and L7 had significantly positive values and the line L8 had significantly negative value (Table 2). The information about GCA is valuable for further breeding. The lines with negative GCA are eliminated from breeding material, unless they possessed some desirable trait.

Tab. 2. GCA of the characteristics of sugar beet lines
Tab. 2. OKS za osobine linija šećerne repe

Lines *Linija*	Root weight *Masa korena* (g)	Root diameter *Prečnik korena* (cm)	Dry matter content *Sadržaj suve materije* (%)
L1	-4.6	0.028	0.113
L2	-16.8	0.075	-0.349
L3	0.0	-0.156	0.301
L4	39.7*	0.182	-0.116
L5	-35.9	0.045	0.347
L6	14.6	-0.104	0.052
L7	55.4**	-0.033	0.029
L8	-52.4**	-0.036	-0.377
$LSD_{0,05}$	39.3	0.392	0.507
$LSD_{0,01}$	52.2	0.522	0.674

Among the testers, the line NS 6 *ms* had significantly lower value for root weight and root diameter compared to two other lines. The line NS 6 *ms* also had a significantly higher value for dry matter content as compared to the line NS 172 *ms*. Lines NS 11547 and NS 172 *ms* had significantly different mean value only for dry matter content (Table 3).

Tab. 3. Mean values of the characteristics of sugar beet testers
Tab. 3. Prosečne vrednosti osobina testera šećerne repe

Lines *Linija*	Root weight *Masa korena* (g)	Root diameter *Prečnik korena* (cm)	Dry matter content *Sadržaj suve materije* (%)
NS 172 *ms*	857.1	10.98	18.15
NS 6 *ms*	673.2	9.28	19.11
NS 11547 *ms*	804.6	10.48	19.61
$LSD_{0,05}$	112.5	0.83	0.88
$LSD_{0,01}$	186.5	1.38	1.46

The testers had either significantly positive or negative values of GCA for all analysed traits (Table 4). The GCA values of testers showes high diversity of used lines, which is one of the preconditions for using topcross method.

Tab. 4. GCA of the characteristics of sugar beet testers
Tab. 4. OKS za osobine testera šećerne repe

Testers	Root weight (g)	Root diameter (cm)	Dry matter content (%)
NS 172 *ms*	-5.4	0.243*	-0.480**
NS 6 *ms*	-60.1**	-0.678**	0.332*
NS 11547 *ms*	65.5**	0.435**	0.148
$LSD_{0,05}$	24.0	0.240	0.310
$LSD_{0,01}$	32.0	0.319	0.413

Specific combining abilities

The analysis of SCA for root weight extricated three combinations, namely L3 x NS 172 *ms*, L7 x NS 11547 *ms* and L6 x NS 11547 *ms* with a high positive value. The combination L8 x NS 11547 *ms* had significant positive value, while the combination L3 x NS 6 *ms* had significant negative value of SCA for root weight (Table 5).

The analysis of SCA for root diameter and dry matter content did not show significant differences between hybrid combinations (Table 5). The absence of differences between hybrid combinations could not be considered as negative, because crossing was made between diploid monogerm lines, while in the commercial development the hybrids are made with crossing monogerm cms line and multigerm pollinator.

Tab. 5. SCA of the characteristics of sugar beet hybrid combinations
Tab. 5. PKS za osobine hibridnih kombinacija šećerne repe

Hybrid combination *Hibridna kombinacija*	Root weight *Masa korena* (g)	Root diameter *Prečnik korena* (cm)	Dry matter content *Sadržaj suve materije* (%)
L1 x NS 172 *ms*	14.0	-0.092	0.102
L1 x NS 6 *ms*	-30.6	0.576	-0.563
L1 x NS 11547 *ms*	16.6	-0.483	0.461
L2 x NS 172 *ms*	12.2	0.361	0.434
L2 x NS 6 *ms*	-25.5	0.012	-0.211
L2 x NS 11547 *ms*	10.3	-0.373	-0.223
L3 x NS 172 *ms*	102.9**	0.156	0.094
L3 x NS 6 *ms*	-74.8*	0.007	0.766
L3 x NS 11547 *ms*	-28.1	-0.162	-0.860
L4 x NS 172 *ms*	-37.5	-0.173	-0.706
L4 x NS 6 *ms*	-30.4	-0.099	0.259
L4 x NS 11547 *ms*	67.9	0.272	0.447
L5 x NS 172 *ms*	28.9	-0.082	-0.208
L5 x NS 6 *ms*	-16.5	0.002	0.634
L5 x NS 11547 *ms*	-12.4	0.080	-0.426
L6 x NS 172 *ms*	-51.0	0.110	-0.420
L6 x NS 6 *ms*	-57.3	-0.412	-0.062
L6 x NS 11547 *ms*	108.3**	0.302	0.482
L7 x NS 172 *ms*	-65.5	-0.148	0.756
L7 x NS 6 *ms*	-45.6	-0.103	-0.942*
L7 x NS 11547 *ms*	111.1**	0.251	0.185
L8 x NS 172 *ms*	-18.3	-0.131	-0.052
L8 x NS 6 *ms*	-58.4	0.017	0.117
L8 x NS 11547 *ms*	76.7*	0.114	-0.066
$LSD_{0,05}$	68.0	0.679	0.878
$LSD_{0,01}$	90.4	0.903	1.167

The hybrid combinations showed high differences and variability in all examinated traits. The average root weight in hybrids varied from 636.2 g in the combination L5 x NS 6 *ms* to 1036.5 g in the combination L7 x NS 11547 *ms*. The average root diameter varied from 8.18 cm in the combination L5 x NS 6 *ms* to 10.73 cm in the combination L5 x NS 11547 *ms*. The average dry matter content varied from 17.78 % in the combination L4 x NS 172 *ms* to 20.23% in the combination L1 x NS 11547 *ms* (Table 5).

Mode of inheritance

Mode of inheritance for root weight in the most hybrid combinations was dominance of better parent. In all three combinations where heterosis was expressed, mother component was NS 11547 *ms* (table 6.).

Tab. 6. Mean values and mode of inheritance of the characteristics in sugar beet hybrid combinations

Tab. 6. Prosečne vrednosti i način nasleđivanja ispitivanih osobina hibridnih kombinacija šećerne repe

Hybrid combination *Hibridna kombinacija*	Root weight *Masa korena* (g)	Root diameter *Prečnik korena* (cm)	Dry matter content *Sadržaj suve materije* (%)
L1 x NS 172 *ms*	869.6 d	9.74 pd	18.98 pd
L1 x NS 6 *ms*	778.4 d	9.14 d	19.46 d
L1 x NS 11547 *ms*	882.0 d	9.54 pd	20.23 h
L2 x NS 172 *ms*	866.1 d	10.36 d	18.92 i
L2 x NS 6 *ms*	780.4 d	8.73 d	19.09 pd
L2 x NS 11547 *ms*	817.1 d	9.38 pd	19.16 pd-
L3 x NS 172 *ms*	964.3 d	10.01 d	19.12 i
L3 x NS 6 *ms*	716.2 d	8.39 pd	20.65 d
L3 x NS 11547 *ms*	841.5 d	9.68 pd	18.91 pd-
L4 x NS 172 *ms*	850.1 d	9.82 d	17.78 d-
L4 x NS 6 *ms*	888.4 d	8.96 d	19.79 i
L4 x NS 11547 *ms*	972.6 h	10.42 d	19.80 i
L5 x NS 172 *ms*	792.1 d	9.77 d	18.68 i
L5 x NS 6 *ms*	636.2 d	8.18 i	20.44 i
L5 x NS 11547 *ms*	955.1 d	10.73 d	19.39 pd-
L6 x NS 172 *ms*	789.7 d	9.81 d	18.47 i
L6 x NS 6 *ms*	764.6 d	8.37 pd	19.64 i
L6 x NS 11547 *ms*	1032.7 h	10.23 d	20.00 i
L7 x NS 172 *ms*	755.5 d	9.62 pd	19.62 d
L7 x NS 6 *ms*	733.7 d	8.75 d	18.49 h-
L7 x NS 11547 *ms*	1036.5 h	10.27 d	19.68 d
L8 x NS 172 *ms*	713.8 pd	9.56 pd	18.69 i
L8 x NS 6 *ms*	673.7 d	8.86 d	19.39 d
L8 x NS 11547 *ms*	878.0 d	9.80 d	18.17 h-
$LSD_{0,05}$	156.1	1.00	1.32
$LSD_{0,01}$	208.4	1.33	1.76

Mode of inheritance

h - heterosis; h- - negative heterosis; d - dominance of better parent; d- - dominance of weaker parent; pd - partial dominance; i - intermediate

The mode of inheritance for root diameter in the most hybrid combinations was dominance or partial dominance of better parent. In hybrid combination L5 x NS 6 *ms* mode of inheritance was intermediate (Table 6).

The mode of inheritance for dry matter content was very variable, from a negative heterosis in the combination L7 x NS 6 ms and L8 x NS 11547 *ms* to positive heterosis in combination L1 x NS 11547 *ms*. Intermediate

mode of inheritance was the most significant (Table 6), which agrees with Čačić et al. (1999).

Highly important are the results of crossing the lines resistant to rhizomania with susceptible lines, since the expected mode of inheritance for this trait was dominance of better parent, but it turned out to be the case only in 7 out of 24 combinations (Table 6).

Conclusions

The sugar beet line L7 had significantly high positive GCA value for root weight and positive GCA value for dry matter content. Among the testers, the line NS 11547 *ms* had significantly high positive GCA values for root weight and root diameter and positive GCA value for dry matter content. The hybrid combination of these two lines had significantly high positive SCA for root weight and highest root weight value among all other combinations. These results indicate that the line L7 could be used as parent in the development of new hybrids. The sugar beet line L7 and its *cms* analogue will be tested together with multigerm material and their hybrids should be evaluated in field trials.

The mode of inheritance for root weight was dominance of better parent in the most hybrid combinations, while only in three combinations a heterosis effect was expressed. The mode of inheritance for root diameter was partial dominance or full dominance of better parent. The mode of inheritance for dry matter content was very variable, but in the most of hybrid combinations it was intermediate and dominance of better parent.

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Kombinacione sposobnosti i način nasleđivanja nekih karakteristika korena šećerne repe

Živko Ćurčić, Dario Danojević, Nevena Nagl

Institut za ratarstvo i povrtarstvo, Maksima Gorkog 30, 21000 Novi Sad, Serbia

Izvod: Oplemenjivanje šećerne repe je izuzetno složeno zbog velikog broja osobina korena koje treba ispitati da bi se stvorili hibridi sa visokim prinosom korena, sadržajem šećera i odgovarajućeg oblika korena. U ovom radu su ispitivane kombinacione sposobnosti i način

nasleđivanja mase korena, prečnika korena i sadržaja šećera različitih genotipova šećerne repe. Analizom linija x tester utvrđene su opšte i posebne kombinacione sposobnosti roditelja. Način nasleđivanja je određen upoređenjem srednjih vrednosti hibridnih kombinacija i roditelja. Kao materijal u ovom radu korišćeno je 8 monogermnih oprašivača, tri monogermne cms linije i 24 F_1 hibrida dobijena ukrštanjem. Način nasleđivanja za masu korena i prečnik korena kod većine hibridnih kombinacije je bio dominacija boljeg roditelja. Način nasleđivanja sadržaja suve materije bio je intermedijaran i parcijalno dominantan.

Ključne reči: kombinacione sposobnosti, masa korena, nasleđivanje, prečnik korena, sadržaj suve materije, šećerna repa

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