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Original scientific paper

GENETIC DIVERSITY AND COMBINING ABILITIES FOR ROOT TRAITS OF SUGAR BEET POLLINATORS

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Information about genetic diversity and combining abilities of sugar beet parental components are of a great importance for hybrid creation. The aim of this research was to evaluate genetic diversity among sugar beet pollinators from different breeding programs and their combining abilities for main root traits of sugar beet, root weight, sugar content and sugar yield. As plant material were used eight pollinators originating from three different USDA-ARS breeding programs and four from Institute of field and vegetable crops Novi Sad. The analysis of variance and Duncan's multiple range test revealed significant differences (p = 0.05) among pollinators for all investigated traits. Pollinator CR10 differs from all others in terms of quantitative traits and in terms of combining ability. Despite small root weight CR10 had significantly positive GCA for that trait and showed that genotypes with small root should not be automatically discarded. Pollinators from Institute of field and vegetable crops used in this research had negative GCA for root weight and should be used only as hosts for introduction of new germplasm in future breeding program.

Key words: genetic diversity, sugar beet, pollinator, breeding

INTRODUCTION

The biennial nature of the sugar beet is a major limitation to improve sugar beet breeding. During the first year of vegetation sugar beet produce root, while in second it flowers and bring seeds. The commercial production from seed to seed takes about 11 months. This period can be shortened to ca. 9 months vernalizing six weeks old seedlings (MCGRATH, 2010).

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Sugar beet belongs to open pollinated plant species, sensitive to self-pollination – inbreeding, due to the presence of self-sterility gene (MCGRATH *et al.* 2007), which disables genotypes to pass more than two to three cycles of selfing. Simultaneously, with the discovery and description of the self-sterility system, was found and described self-fertility in sugar beet (OWEN, 1942). Results of this research indicate that the self-fertility is controlled by single dominant gene S^fS^f. Plants carrying the dominant allele of this gene produce 90-95% selfed seeds even in the presence of large amounts of unrelated pollen. The presence of self-fertility genes in the breeding material allows the efficient production of inbred lines.

Sugar beet pollinators depending on the presence of self-sterility or self-fertility genes can be divided into two groups: open pollinated populations and inbred lines. Genetic diversity among open pollinated population as well as open pollinated groups and inbred lines can be very high. Because of that knowing the genetic diversity is the basic information for the breeders and future crop improvement. Genetic diversity can be detected by pedigree analysis and morphological, physiological or cytological markers as well as biometric analysis of quantitative and qualitative traits (MELCHINGER, 1999). The development of DNA markers enabled easier, faster and more accurate evaluation of genetic diversity, where different types of markers can be used for different purposes in many crops (MILADINOVIĆ *et al.* 2011; NAGL *et al.* 2011a; NAGL *et al.* 2011b).

Besides of knowing genetic diversity of breeding material and its morphological traits, in creation of sugar beet hybrids it is also important to have a reliable information/estimation about/of combining abilities. General combining ability (GCA) is the mean value of one parent in crosses with other parents. Specific combining ability (SCA) represents the value of parent X in crossing with parent Y (BOROJEVIĆ, 1981). GCA and SCA effects are important indicators of the potential value of inbred lines in hybrid combinations. There are many methods for determination of combining abilities in inbred lines, but the most important are method of diallel crossing, topcross and polycross method (MARINKOVIĆ *et al.* 2003). For examination of combining abilities in huge number of inbred lines the most suitable method is polycross, which is based on the use of one or two joint testers. This method is less extensive compared to the diallel crossing.

The aim of this study was to assess genetic diversity among sugar beet pollinators from Institute of Field and Vegetable Crops Novi Sad and USD-ARS breeding programs and their combining abilities for the following traits: root weight, sugar content and sugar yield.

MATERIALS AND METHODS

In this research were included 4 pollinators from Institute of Field and Vegetable Crops, Novi Sad and 8 pollinators from USDA-ARS breeding program. All pollinators were multigerm and have resistance to rhizomania. Depending on the presence of self-fertility genes, there were three types of pollinators: self-sterile pollinators (S^sS^s), self-fertile (S^fS^f) and pollinators segregating for this trait ($S^f\_$) (table 1).

The trial was conducted at the experimental field of Institute of Field and Vegetable Crops on Rimski Šančevi, Novi Sad, Serbia (45° 20' N, 19° 51' E) in 2011. It was established in a randomized block design with three replications, with the basic plot size of 30 m^2. Sowing was performed in optimal time in the third decade of March. Spacing between plants after hand thinning was 50 X 20 cm. During the growing season were applied regular cultural practices for sugar beet. Main characteristic of climatic conditions in 2011 was severe drought in second half of the vegetation period (table 2). Compared to long term average, precipitation amount was lower for 215 mm. The roots were harvested manually at the beginning of October. Ten plants per replication were taken for root analysis. Sugar content was determined in the Laboratory for root quality testing at the Institute of Field and Vegetable Crops, Novi Sad according to standard methodology.

Table 1. Material origin and presence of self-sterility and self-fertility genes

Pollinator	Self-fertility Self-sterility	Origin
EL0204	$S^s S^s$	USDA-ARS (Michigan)
EL53	$S^s S^s$	USDA-ARS (Michigan)
NS1	$S^s S^s$	IFVCNS
NS2	$S^s S^s$	IFVCNS
NS4	$S^s S^s$	IFVCNS
C51BM	$S^s S^s$	USDA-ARS (Salinas)
CR10	$S^J S^J$	USDA-ARS (Salinas)
C930-35	$S^J S^J$	USDA-ARS (Salinas)
CZ25-9	$S^J S^J$	USDA-ARS (Salinas)
NS3	S^J _	IFVCNS
FC220	S^f _	USDA-ARS (Fort Collins)
FC221	S^f _	USDA-ARS (Fort Collins)

Table 2. Weather conditions during 2011

	Precipitation (mm)		Average monthly temperature (°C)	
	2011	1995-2010	2011	1995-2010
April	22.8	46.3	12.3	12.2
May	62.4	67.4	16.9	17.6
Jun	36.9	95.6	20.2	20.6
July	61.5	76.0	23.1	22.1
August	1.5	66.1	21.9	21.8
September	25.4	63.8	16.1	16.6
Total	210.5	415.2	-	
Average	-	-	18.4	18.5

Collected data were analyzed by ANOVA followed with Duncan's multiple range test using program MSTAT-C. An unweighted pair group arithmetic mean method (UPGMA) cluster analysis was performed in the statistical software Statistica for Windows ver. 10, *Statsoft Inc*., using Euclidean distances. General combining abilities were assessed by line x tester method (SINGH and CHAUDHARY, 1976).

RESULTS AND DISCUSSION

Mean values for root weight were ranged from 388.4 g (NS4) to 780.2 g (EL53). The highest sugar content 18.43% had pollinator NS4 which had lowest root weight. Pollinator CR10 had significantly lower sugar content compared to all other pollinators except FC221. Pollinator CZ25-9, registered as high sucrose variety (LEWELLEN, 2002) expressed that characteristic in our trial with sugar content of 18.11%. Results of our research were in agreement with study of PANELLA *et al.* (2008), where FC220 had higher sucrose concentration than FC221. Pollinators from East Lansing, Michigan USDA-ARS research station, EL0204 and EL53, had highest root weight and sugar yield (table 3).

Table 3. Mean values of sugar beet root weight, sugar content and sugar yield

Pollinator	Root weight (g)	Sugar content (%)	Sugar yield (g)
EL0204	733.4 **ab***	17.01 **ab**	102.1 **a**
EL53	780.2 **a**	16.89 **ab**	102.5 **a**
NS1	610.6 **abcd**	16.57 **ab**	85.0 **ab**
NS2	620.1 **abcd**	16.80 **ab**	86.0 **ab**
NS3	604.1 **abcde**	17.24 **ab**	85.6 **ab**
C51BM	638.4 **abcd**	16.47 **ab**	88.0 **ab**
CR10	422.2 **de**	14.25 **c**	45.3 **c**
C930-35	654.5 **abc**	17.11 **ab**	94.8 **a**
CZ25-9	565.1 **abcde**	18.11 **a**	87.0 **ab**
NS4	388.4 **e**	18.43 **a**	60.1 **bc**
FC221	550.7 **bcde**	15.65 **bc**	71.0 **abc**
FC220	478.0 **cde**	17.75 **ab**	71.8 **abc**
LSD 0.05	194.1	1.897	28.12
0.01	263.8	2.578	38.22

* mean separation in columns by Duncan's multiple range test at 5% level

The analysis of variance revealed significant differences (p = 0.05) among pollinators for all investigated traits (table 4). Absence of higher differences could be due to severe drought that struck Serbia in second period of vegetation. In those conditions there was a reduction in the phenotypic variation of studied traits, masking the genetic sources of variation, as in OBER *et al.* (2005).

Obtained cluster was based on the data of all quantitative traits which were used in this research (figure 1). On Euclidean distance around 2 there were identified tree cluster groups. First group was the biggest and was comprised of tree sub-groups. In first subgroup there were two pollinators from East Lansing, Michigan. Second sub-group was the largest and there were included three self-sterile pollinators from Novi Sad, and three pollinators from Salinas, California. Third sub-group separately formed pollinator FC220. Second group formed two pollinators, NS3 and FC221. Pollinator CR10 forms separate group and with other genotypes is joined at the highest hierarchical level.

Table 4. Analysis of variance for root yield, sugar content and sugar yield

Source of variation	*DF*	*Root yield*			*Sugar content*			*Sugar yield*		
		SS	*MS*	*F test*	*SS*	*MS*	*F test*	*SS*	*MS*	*F test*
Replication	*2*	*78410.2*	*39205.1*	*2.98*	*0.93*	*0.464*	*0.37*	*1114.2*	*557.1*	*2.02*
Genotype	*11*	*444560.9*	*40414.6*	*3.07**	*40.68*	*3.698*	*2.95**	*9391.6*	*853.8*	*3.09**
Error	*22*	*289055.2*	*13138.9*		*27.61*	*1.255*		*6068.2*	*275.8*	
Total	*35*	*812026.3*			*69.22*			*16574*		

* - significant at 0.05 level of probability

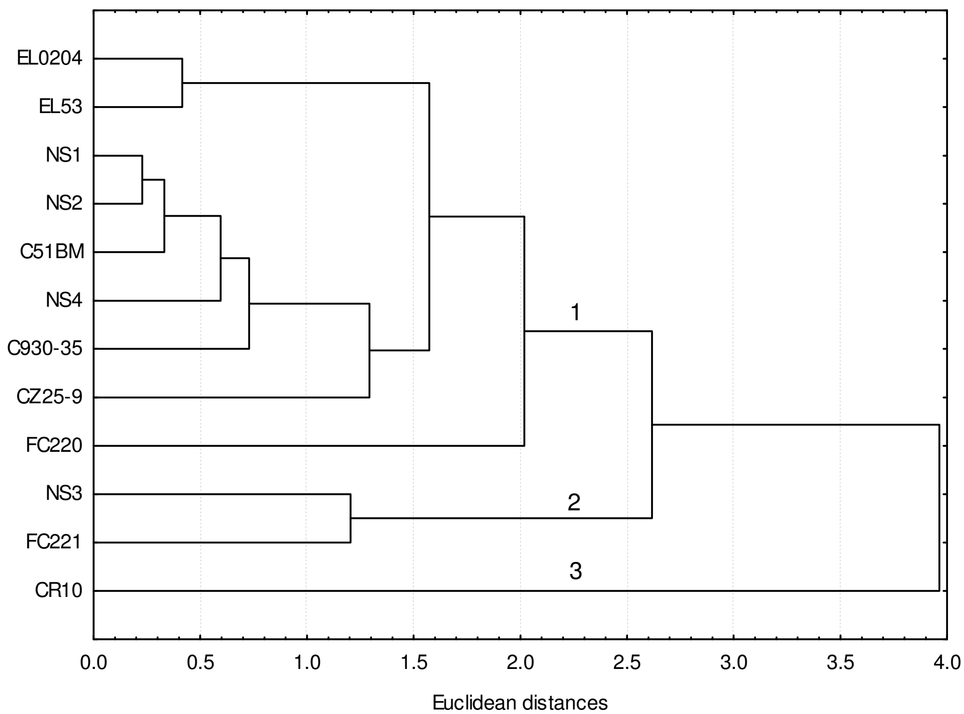

Figure 1. UPGMA dendrogram for cluster analysis of morphological traits in observed sugar beet pollinators

Analysis of GCA for sugar yield did not show differences between genotypes (table 5). Genotype CR10 had positive GCA ($p = 0.05$) for root weight, despite small root weight. Results of our research confirmed study of DANOJEVIĆ *et al.* (2011) that the parents with the lowest root weight per se, produce the test hybrid with the greatest root weight. This showed that genotypes with low root weight should not be automatically discarded, at least not before information about GCA. Genotype NS3 had negative GCA ($p = 0.05$) for sugar content. All genotypes from Institute of Field and Vegetable Crops breeding program used in this research had negative GCA for root weight. This suggests that it should be continued with introduction of new germplasm into this breeding material.

Table 5. General combining abilities of sugar beet pollinators for analyzed traits

Pollinator	GCA for root weight	GCA for sugar content	GCA for sugar yield
EL0204	36.3	0.559	9.57
EL53	-8.6	-0.267	-6.89
NS1	-35.62	1.016	1.59
NS2	-54.1	-0.491	-8.51
NS3	-7.7	-1.577*	-12.41
C51BM	58.5	-0.647	6.08
CR10	157.2*	-0.561	13.37
C930-35	-14.1	-0.124	-3.75
CZ25-9	-107.3	-0.227	-16.21
NS4	-97.5	0.693	-8.1
FC221	54.1	0.976	17.15
FC220	18.9	0.649	8.12
LSD 0.05	139.4	1.326	20.88
0.01	185.4	1.764	27.78

* - significant at 0.05 level of probability

CONCLUSION

Analysis of variance showed differences ($p = 0.05$) between sugar beet pollinators for all quantitative traits. Severe drought influenced on level of significance between pollinators for all quantitative traits as also on GCA.

Pollinator CR10 differs from all others in terms of quantitative traits and in terms of combining ability. Despite small root weight CR10 had significantly positive GCA for that trait and showed that genotypes with small root should not be automatically discarded.

Pollinators from sugar beet breeding program at the Institute of Field and Vegetable Crops used in this research had negative GCA for root weight and should be used only as hosts for introduction of new germplasm.

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GENETSKA DIVERGENTNOST I KOMBINACIONE SPOSOBNOSTI OPRAŠIVAČA ŠEĆERNE REPE ZA GLAVNA SVOJSTVA KORENA

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Izvod

Informacije o genetskoj divergentnosti i kombinacionim sposobnostima roditeljskih komponenti šećerne repe su od izuzetnog značaja za proizvodnju hibrida. Cilj ovog istraživanja je bio ocena genetske divergentnosti oprašivača šećerne repe iz različitih oplemenjivačkih programa kao i kombinacionih sposobnosti za glavne osobine korena: masu korena, sadržaj šećera i prinos šećera. Osam oprašivača vodi poreklo iz tri različita oplemenjivačka programa Američkog ministarstva poljoprivrede (USDA-ARS), a četiri iz Instituta za ratarstvo i povrtarstvo, Novi Sad. Analiza varijanse i Dankanov višestruki test intervala su pokazali značajne razlike (p = 0.05) između oprašivača za sva ispitivana svojstva. Oprašivač CR10 se izdvaja od svih ostalih kako u pogledu kvantitativnih vrednosti ispitivanih svojstava tako i u pogledu kombinacionih sposobnosti. Uprkos maloj masi korena CR10 je imao značajno pozitivnu vrednost opštih kombinacionih sposobnosti za ispitivano svojstvo i pokazao da iz oplemenjivačkog programa ne treba automatski odbacivati genotipove sa malom masom korena. Svi ispitivani oprašivači Instituta za ratarstvo i povrtarstvo u ovom istraživanju su imali negativne vrednosti opštih kombinacionih sposobnosti za masu korena i trebalo bi ih koristiti kao domaćine za uvođenje nove germplazme.

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