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COMBINING ABILITIES OF RAPESEED (*Brassica napus* L.) VARIETIES

Ana MARJANOVIĆ - JEROMELA, Radovan MARINKOVIĆ, and Dragana MILADINOVIĆ

Institute of Field and Vegetable Crops, Novi Sad, Serbia

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The global acreage under rapeseed increases steadily. Rapeseed is grown for oil for human consumption, feed and biodiesel production. For faster advances in breeding, it is necessary to know variability and combining ability of selection material i.e. modes of inheritance of certain traits.

General (GCA) and specific combining abilities (SCA) of five rapeseed varieties as well as the mode of inheritance of plant height, height to the first lateral branch, number of lateral branches and seed yield per plant were analyzed in this paper. Positive heterosis for plant height was found in five cross combinations, for the height to the first lateral branch in two combinations and for the number of lateral branches in only one combination and for seed yield in three cross combinations.

Key words: dialel, combining ability, morphometric characteristics, oilseed

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Corresponding author: Ana Marijanović-Jeromela, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21 000 Novi Sad, Serbia

INTRODUCTION

Together with sunflower (*Helianthus annuus* L.) and soybean (*Glycine max* Merr.), rapeseed is a major oil crop in Serbia. Considering the market demand for oil crops, the rapeseed acreage is Serbia should be increased. The winter type of rapeseed is preferred over the spring type due to superiority in yield. In our country as well as abroad, rapeseed is grown for oil for human consumption, feed and biodizel production.

As rapeseed is also grown for seed, it is necessary to examine seed characteristics as well as plant characteristics that affect seed yield and quality. Seed yield per plant is highly variable because it is a complex trait that comprises all yield components. This complex trait is controlled by a large number of genes, the expression of which is strongly affected by environmental factors. Plant height affects seed yield via harvest index. Reduction of this trait to an optimal height and increase of height to the first lateral branch facilitate the harvest and reduce harvest losses (SCARISBRICK and DANIELS, 1986). Increased yield per plant results from a larger number of lateral branches (CAMBELL and KONDORA, 1978). A path coefficient analysis of important agronomic characteristics of rapeseed showed a positive direct effect of number of branches on yield (MARINKOVIĆ et al., 2003).

For faster advances in breeding it is necessary to know variability and combining ability of breeding material, i.e., modes of inheritance of certain traits. Topcross, polycross and diallel crossings are used for assessment of variability and combining ability.

The objectives of this study were to assess, based on diallel crossing, general and specific combining abilities of five winter rapeseed cultivars as well as modes of inheritance and gene effects for four yield components.

MATERIAL AND METHODS

Genetic material used in this study comprised five winter rapeseed cultivars (Banaćanka, Orkan, Valesca, Aligator, Alaska). The cultivars were crossed in a diallel fashion in the course of April and May 2002. Emasculation of isolated plants that served as females, pollen collecting from isolated plants that served as males and diallel crossings were done manually.

The trial with hybrid combinations and parents was planted in random block design at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in crop season 2002/2003. Experimental material was planted manually in well prepared soil in the first half of September 2002. Row-to-row distance was 50 cm, with 5-cm distance in the row. Conventional cultural practices were applied during growing season.

In this study we analyzed general (GCA) and specific (SCA) combining abilities of the five cultivars and the modes of inheritance of plant height (cm), height to the first lateral branch (cm), number of lateral branches and seed yield per plant (g). Measurements and counts were performed at full maturity, in samples consisting of 11 plants per replication.

The analysis of variance was done according to HADŽIVUKOVIĆ (1973), analysis of diallels for combining ability according to GRIFFING (1956), method 2, model 1. Mode of inheritance was assessed by the test of mean values in the F_1 generation in relation to parents' means (BOROJEVIĆ, 1965). The crosses that showed no significant difference between the parents were not assessed for mode of inheritance. Heterosis was calculated in relation to better and worse parents (JINKS, 1954).

RESULTS AND DISCUSSION

Most of the studied winter rapeseed cultivars differed significantly in plant height. Plant height ranged from 121.7 cm (Banaćanka) to 140.3 cm (Aligator). The hybrids were somewhat taller than their parents, from 132 cm (Banaćanka x Aligator) to 193 cm (Banaćanka x Valeska). Having studied several quantitative and qualitative traits of rapeseed lines, cultivars and hybrids, KUDLA (1997) reported different values of plant height. The shortest were "0" type cultivars with the mean height of 138 cm, the highest inbred lines and F1 hybrids (145 and 152 cm, respectively). In our study, positive heterosis in the inheritance of plant height was expressed in five combinations, dominance of better parent in three combinations. Positive GCA values for plant height were found in three cultivars, negative in two cultivars (Table 2). The lowest GCA value, which was significantly different from the other values, was registered in the cultivar Banaćanka. Hybrid combinations Banaćanka x Orkan, Orkan x Valeska and Orkan x Alaska had highest SCA values, which were highly significant in relation to the SCA values of the other hybrid combinations (Table 3). It had been observed before that crossing a parent with high GCA values with a parent with low GCA values may produce a hybrid combination with high SCA values (KRALJEVIĆ-BALALIĆ, 1978; MARINKOVIĆ, 2004).

Height to the first lateral branch is a rarely studied quantitative trait of rapeseed. If set too low (about 20 cm), the first lateral branch may cause significant loss during combine harvesting, so it is necessary to pay due attention to it in breeding work. It is desirable to know the mode of inheritance and gene effect for this trait in the F_1 generation. In the study of MARJANOVIĆ-JEROMELA and MARINKOVIĆ (1998) on inheritance of the first lateral branch in the F_1 generation, heterosis, intermediacy and partial dominance of better parent were expressed. Using the analysis of variance for combining abilities, the authors found that the inheritance of the height to the first lateral branch was predominantly controlled by additive genes. In this study, the height to the first branch ranged from 52 cm (Banaćanka) to 56.5 cm (Valeska) in the cultivars and from 44 cm (Banaćanka x Alaska) to 67.3 cm (Valeska x Aligator) in the hybrids. These values are much higher than those reported by other authors (KUDLA, 1997). Our results could be explained by differences in stand density. Similar conclusions had been reported in papers on soybean, which established the dependence of the height of the first pod on stand density (WILLOX, 1974; HRUSTIĆ, 1983). Positive heterosis in the inheritance of the first lateral branch was exhibited by a single combination in our study. Only that cross (Valeska x Aligator) had a significantly higher value for that trait than the better parent (Table 1).

Table 1. Analysis of results of diallel crossing for plant height, height of the first lateral branch, number of lateral branches and seed yield per plant

Parent/cross	Generation	Trait			
		Plant height	Height of 1st lateral branch	No. of lateral branches	Seed yield per plant
Banaćanka	P1	121.7	52	5.1	5.6
Banaćanka x Orkan	F1	140.3^{h}	52	8.0^{h+}	13^{h+}
Banaćanka x Valeska	F1	193.0^{h}	52.3	7.6^{i}	12.7^{h+}
Banaćanka x Aligator	F1	132.0^{i}	54.7	7.8^{d+}	14.9^{d+}
Banaćanka x Alaska	F1	134.7^{d+}	44^{h-}	8.0^{d+}	15.8^{h+}
Orkan	P2	125.6	54.5	6.8	8.7
Orkan x Valeska	F1	145.0^{h}	63	8.1^{d+}	11.9
Orkan x Aligator	F1	141.0^{h}	54.2	7.5	10.1
Orkan x Alaska	F1	149.7^{h}	61^{i}	7.2	11.8
Valeska	P3	127.0	56.5	8.4	8.7
Valeska x Aligator	F1	141.0^{d+}	67.3^{h+}	7	7.8
Valeska x Alaska	F1	137.3^{d+}	55.8^{d-}	8	10.8
Aligator	P4	140.3	53.8	7.9	11
Aligator x Alaska	F1	142.2	50.2^{d-}	8.1	9.4
Alaska	P5	136.0	65	7.0	7.2
$LSD_{0.05}$		**7.83**	**8.80**	**1.27**	**4.44**
$LSD_{0.01}$		**10.56**	**11.87**	**1.71**	**5.99**

Negative heterosis was expressed in one case. Dominance of poorer parent was registered in two combinations, intermediacy in one combination. Regarding the height to the first lateral branch, three cultivars had a positive GCA value, two cultivars a negative value (Table 2). The lowest GCA value, which was significantly different from the other values, was registered in the cultivar Banaćanka. The hybrid combination Banaćanka x Alaska had a significant negative SCA value and the combination Valeska x Aligotor a highly significant positive SCA value in relation to the other combinations (Table 3). The combinations with a significant SCA were considered prospective for development of F_1 hybrids.

Table 2. GCA values

Trait / Parent	Plant height	Rank	Height of 1st lateral branch	Rank	No. of lateral branches	Rank	Seed yield per plant	Rank
Banaćanka	-5.434*	5	-3.943*	5	-0.486*	5	0.551	1
Orkan	1.475	3	0.676	3	-0.090	4	0.061	3
Valeska	-1.577	4	2.414	1	0.362	1	-0.460	5
Aligator	2.851	1	-0.086	4	0.176	2	0.074	2
Alaska	2.685	2	0.938	2	0.038	3	-0.226	4
$LSD_{0.05}$	**3.991**		**4.485**		**0.648**		**2.265**	
$LSD_{0.01}$	**2.985**		**3.324**		**0.480**		**1.679**	

Number of branches is a component of seed yield in rapeseed. New cultivars with a modern plant habit have more branches than the old cultivars (POSPIŠIL and MUSTAPIĆ, 1995). The cultivars from this study had a relatively varied average number of branches per plant, from 5.1 (Banaćanka) to 8.4 (Valeska). In the crosses, the value of this trait ranged from 7 (Valeska x Aligator) to 8.1 (Orkan x Valeska and Aligator x Alaska). The results of this study are in agreement with those of POSPIŠIL and MUSTAPIĆ (1995), while ZHUJUN (1994) and KUDLA (1997) report larger values of the number of branches per plant. Positive heterosis in the inheritance of the number of lateral branches was exhibited by one cross combination (Table 1). Dominance of better parent in the inheritance of this trait was expressed in three crosses, intermediacy in a single cross. High values of branching (6.6-15.4) were found by SCHUSTER et al. (1985) in an analysis of different generations of winter and spring rapeseeds and white mustards. Heterotic effects in the F_1 generations were higher in their study than in ours. Considering the GCA values for the number of lateral branches, the cultivar Banaćanka could be distinguished for its significantly different value. The cultivar Orkan too had a negative GCA value, but it was not significantly different from the positive GCA values in the other three cultivars. The hybrid combination Banaćanka x Orkan had a high DCA value. Although that value was not significantly different, this combination could be used in breeding for the number of lateral branches.

Seed yield per plant is a highly variable trait, mainly because it depends on all other yield components. This complex trait is controlled by a large number of genes, whose expression is strongly affected by environmental conditions. In this study, different values of seed yield per plant were registered, from 5.6 g in Banaćanka to 11g in Aligator. The hybrids had somewhat increased value compared with their parents, from 7.8 g in Valeska x Aligator to 15.8 g in Banaćanka x Alaska. Similar results were reported by SINGH (1985), SCHUSTER et al. (1985), POSPIŠIL and MUSTAPIĆ (1995) and SCHÖNBERGEr (1998).

Table 3. SCA values

Parent	Trait	Orkan	Valeska	Aligator	Alaska	LSD 0.05	LSD 0.01
Banaćanka	Plant height	8.119**	-0.495	-1.590	1.243	6.614	8.924
	Height of 1st lateral branch	-0.500	-1.905	2.929	-8.762*	7.433	10.028
	No. of lateral branches	1.043	0.224	0.610	0.981	1.074	1.449
	Seed yield per plant	1.768	1.956	3.638	4.808*	3.754	5.064
Orkan	Plant height		8.929**	0.667	9.333**	6.614	8.924
	Height of 1st lateral branch		4.143	-2.190	3.786	7.433	10.028
	No. of lateral branches		0.362	-0.086	-0.281	1.074	1.449
	Seed yield per plant		1.676	-0.628	1.375	3.754	5.064
Valeska	Plant height			3.552	0.052	6.614	8.924
	Height of 1st lateral branch			9.238*	-3.286	7.433	10.028
	No. of lateral branches			-0.971	0.100	1.074	1.449
	Seed yield per plant			-2.447	0.887	3.754	5.064
Aligator	Plant height				0.457	6.614	8.924
	Height of 1st lateral branch				-6.452	7.433	10.028
	No. of lateral branches				0.419	1.074	1.449
	Seed yield per plant				-1.088	3.754	5.064

Significantly higher seed yields per plant were reported by SINGH and GUPTA (1983, cited by KUDLA, 1997) and ROECKEL et al. (1998). The reasons for the difference should be sought in genotype structure as well as in the method and conditions of growing. Positive heterosis in the inheritance of seed yield per plant was expressed in three combinations (Table 1), dominance of better parent in one combination. Positive heterosis and its utilization in commercial hybrids of other species from the genus *Brassica* were also reported by TEKLEWOLD and BECKER, 2005. In this study, the cultivars showed no significant difference in GCA values for yield per plant. The cross between the cultivar Banaćanka, which had the highest GCA value, and the cultivar Alaska, which had a negative GCA value, exhibited a positive SCA value which was significantly different from the values of the other cross combinations.

Table 4. Components of genetic variability

Component	Trait			
	Plant height	Height of 1st lateral branch	No. of lateral branches	Seed yield per plant
D	52.827	16.660	1.374	1.658
H_1	160.635	140.206	2.157	35.010
H_2	124.720	98.684	1.513	25.165
F	34.857	26.971	1.935	10.025
E	7.301	9.221	0.193	2.351
$H_2/4H_1$	0.194	0.176	0.175	0.180
u	0.736	0.772	0.773	0.765
v	0.264	0.228	0.227	0.235
$\sqrt{H_1/D}$	1.744	2.901	1.253	4.596
K_D/K_R	1.467	1.774	3.565	4.847

Further analysis of components of genetic variability showed that the additive gene effect was less important than the dominant effect in the inheritance of the studied traits, which was in agreement with the combining ability analysis. Superdominance was expressed in the inheritance of all traits since the value of $\sqrt{H_1/D}$ was larger than unity. Dominant genes (u) prevailed over recessive ones (v) in all parents, which was in agreement with the calculated value of the formula K_D/K_R (Table 4). Other authors too emphasized the importance of the knowledge of genetic parameters in the breeding of adaptable and stable rapeseed cultivars (ENGQVIST and BECKER, 1991; SHEN et al., 2005).

The knowledge of yield components helps breeders to select genotypes and methods suitable for achieving specific objectives in rapeseed breeding. It is also desirable to know other traits and the genetic rules regulating their inheritance since these traits are associated with yield components. DEGENHART and KONDORA (1984) pointed out the distinct negative correlations between plant height and yield in all five rapeseed genotypes and all three years of study. Similar results were reported by GILANI et al. (1993) who found a negative correlation between yield per plant on one side and plant height and the number of primary branches on the other. Conversely, THURLING (1974a and 1974b) claimed that the increase in plant size resulted in yield increase. MARINKOVIĆ and MARJANOVIĆ-JEROMELA (1996) found high positive genotypic correlations between plant height and height to the first lateral branch, height to the first lateral branch and the number of branches and the number of branches and 1000-seed weight in seven winter cultivars of rapeseed.

CONCLUSION

Highest GCA values were found in the cultivars Aligator (plant height), Valeska (height to first lateral branch and number of lateral branches) and Banaćanka (seed yield per plant).

The cultivars Banaćanka and Orkan had significant SCA values in most of the crosses.

The analysis of components of genetic variability showed that superdominance was expressed in the inheritance of all traits.

The results of this study allow the selection of parental pairs for crossing and of the method convenient for further breeding of rapeseed for yield and yield components.

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KOMBINIRAJUĆE SPOSOBNOSTI SORTI ULJANE REPICE (*Brassica napus* L.)

Ana MARJANOVIĆ-JEROMELA, Radovan MARINKOVIĆ
i Dragana MILADINOVIĆ

Naučni institut za ratarstvo i povrtarstvo, Novi Sad, Srbija

Izvod

Površine pod uljanom repicom u svetu su u stalnom porastu. Uljana repica se gaji za dobijanje ulja za humanu konzumaciju, za proizvodnju stočne hrane i biodizela. Za brži napredak u oplemenjivanju neophodno je poznavanje varijabilnosti i kombinacionih sposobnosti selekcionog materijala, odnosno načina nasleđivanja pojedinih svojstava.

U radu su analizirane opšte (OKS) i posebne (PKS) kombinacione sposobnosti pet sorti uljane repice i način nasleđivanja visine biljke, visine prve bočne grane, broja bočnih grana i prinosa semena po biljci. Pozitivni heterozis ispoljio se za visinu biljke kod pet, za visinu prve bočne grane kod dve, broj bočnih grana kod jedne i prinosa semena kod tri kombinacije ukrštanja.

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