Heterosis for agronomically important traits in sunflower (*Helianthus annuus* L.)

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Abstract

Significant manifestation of heterosis for agronomically important traits is the main precondition for obtaining productive sunflower hybrids (Škorić et al., 2006). The development of new high-yielding and stable sunflower hybrids based on interspecific hybridization requires knowledge of the heterotic effect in the F1 generation. Heterosis for seed yield per plant, total seed number per head and 1,000-seed mass was studied in interspecific hybrids obtained by the line x tester method. The seven female inbred lines used in the study had been developed by interspecific hybridization, while the three male restorer inbreds with good combining abilities were used as testers in the form of fertility restorers. Twenty one F1 hybrids were obtained by crossing each tester with each female inbred line. A trial with the lines and F1 hybrids was set up at the Rimski Šančevi. Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad using a randomized block design with three replications. Our study found significant differences in the mean values of all the traits under investigation. Heterosis values for seed yield were positive and highly significant relative to parental average (98.4-274.1%) as well as better parent (55.8-223.2%). Considerably less heterosis was found for total seed number per head (69.6-203.7%) relative to parental average and better parent (47.6-183.3%). With 1,000-seed mass, the values ranged between 26.5% and 48.8% relative to parental average and from –42.4% to 30.9% relative to better parent. This study could prove useful in the development of new high-yielding sunflower hybrids based on interspecific hybridization.
Key words: sunflower, seed yield, total seed number per head, 1,000-seed mass, heterosis

Introduction

The sunflower is one of the most important oil crops in the world and the most important cuiltivated oil crop in Serbia, where it was grown on 200,000 ha in 2005. Sunflower breeding is directed at developing new, more productive, adaptable and resistant hybrids for different agroecological conditions that will outyield the existing hybrids when used in commercial production. The Institute of Field and Vegetable Crops in Novi Sad can conduct such efforts thanks to its sunflower breeding center and the genetic resources and variability of the materials used in it (Škorić et al., 2006)

Interspecific hybridization, or the discovery of desirable genes in the wild species of the genus *Helianthus* and their incorporation into cultivated sunflower genotypes, holds a special place in sunflower breeding (Škorić et al., 2002).

Manifestation of heterosis for agronomically important traits is an important prerequisite for obtaining productive hybrids (Škorić et al., 2002). The occurrence of heterosis in sunflower hybrids is highly correlated with genetic distance between the parental lines. Heterosis does not appear in all hybrid combinations of the F1 generation. Heterotic effects are different for different traits. Heterotic effects for seed yield per plant, total seed number per head, and 1,000-seed mass in the F1 generation have been the subject of study by sunflower geneticists and researchers (Škorić, Marinković, Jocić…).

Sunflower seed yield is a complex trait with a polygenic basis and is influenced greatly by the environment (Jocić, 2003). Direct components of seed yield in sunflower include: seed number per head (>1,500), 1,000-seed mass (>80 g), test weight (45-50 kg), plant number per hectare (55,000-60,000), low hull content (20-24%), and high seed oil content (>50%), Škorić et al., (1989, 2002). Based on the findings of several researchers (Vranceanu and Stoenescu, 1969; Škorić, 1975; Marinković, 1984; Kumar et al., 1999), Marinković (2003) reported that heterosis for seed yield relative to parental average or better parent was 25-60%. Heterosis for seed yield relative to parental average ranged between 43.3% and 92.3% (Hladni et al., 2003), while that relative to better parent was 22,0-118,4% (Joksimović and Atlagić, 2001), 278.0% (Singh et al., 2002), 35.0-85.7% (Hladni et al., 2003), and 129.3-412.0% (Jocić, 2003).

Seed number per sunflower head is one of the most important components of yield. This number is determined by the number of disk flowers formed, the level of self-compatibility, attractiveness to pollinators, and environmental factors at flowering and pollination (Škorić and Dozet, 1992). Many researchers have found a highly positive correlation between total seed number per head and seed yield. (Patil et al., 1996; Tahir et al., 2002; Dagustu, 2002). Škorić (1974), Marinković (1987) and Dušanić (1998) found positive direct effects of seed number per head on seed yield.

Successful seed production requires knowledge of seed size, i.e. 1,000-seed mass, in the parental lines, because this trait affects the method of sowing, seeding rate, the hybrid seed quality, and seed yield per unit area (Škorić et al., 1988). It is considered very important that the seeds used for sowing have a large 1,000-seed mass, since such seeds have more reserve nutrients and a more developed embryo, and also because the plantlets developing from such seeds grow faster, which can often be very important under unfavorable climatic and edaphic conditions. Breeding for increased 1,000-seed mass can significantly increase sunflower seed yields. The 1,000-seed mass is a highly variable trait and is influenced by both genetic and environmental factors (Joksimović et al., 2004). The value of this character varies both among different genotypes in the same location and within a single genotype in different locations (Marinković et al., 1994). Besides being affected to a large extent by stand density, 1,000-seed mass is also greatly influenced by environmental factors, such as soil moisture, air temperature and humidity, soil status, and others (Marinković et al., 2003). Manifestation of heterosis in the inheritance of 1,000-seed mass was reported by Putt (1966), and Marinković and Škorić (1985). Joksimović et al. (2004) found heterosis and dominance of the better parent in the inheritance of this trait.

The objective of this paper was to investigate if and to what extent there was heterosis for seed yield per plant, total seed number per head and 1,000-seed mass in sunflower hybrids developed by crosses between seven cms inbred lines obtained by interspecific hybridization and three restorer lines used as testers.

Materials and methods

Used in the study were seven new divergent (A) cytoplasmically sterile inbreds developed by interspecific hybridization, three Rf-restorer lines used as testers, and 21 F1 hybrids developed at the Institute of Field and Vegetable Crops in Novi Sad. The female inbreds (NS-GS-1, NS-GS-2, NS-GS-3, NS-GS-4, NS-GS-5, NS-GS-6, NS-GS-7) were obtained by interspecific hybridization, while the restorer male inbreds (RHA-R-PL-2/1, RHA-N-49, RUS-RF-OL-168) with good combining abilities were used as testers in the form of fertility restorers. The F1 hybrids were obtained by crossing each tester with each female inbred. A trial was set up at the Rimski Šančevi Experiment Field using a randomized block design with three replicates. Row-to-row distance was 70 cm and plant-to-plant one 30 cm. The basic sample for the analysis of a given trait consisted of 30 plants (10 per replicate) taken from the rows in the middle of each block. The traits were analyzed in the laboratory. Seed yield per plant was measured in the laboratory after harvesting, removing all impurities, and reducing moisture down to 11% and expressed as g/per plant. Total seed number per head was determined by counting the number of full seeds per head, while 1,000-seed mass was determined on a random sample of absolutely pure air-dried seeds.

Data were analyzed by determining mean values and standard error of arithmetic mean (Hadživuković, 1991). Heterosis was assessed according to Jinks (1983).

Results and discussion

There were significant differences between the A-linija, Rf-testers and their F1 hybrids in the mean values of seed yield per plant, total seed number per head, and 1,000-seed mass (Tab. 1).

Tab. 1. Mean values of seed yield per plant (SY), total seed number per head (TSN), and 1,000-seed mass (1,000- S M) in sunflower

No.	Parents and hybrids	SY	TSN	1,000-S M
		(g)		(g)
1	NS-GS-1	35.6±1.46	1032.9±8.21	49.2±0.74
2	NS-GS-2	52.8±1.79	1081.0±18.79	54.2± 0.83
3	NS-GS-3	50.5±1.25	939.5±28.53	52.9±1.08
4	NS-GS-4	55.4±2.31	620.0±15.49	94.8±1.21
5	NS-GS-5	57.0±1.50	709.2±17.61	79.4±1.27
6	NS-GS-6	32.4±1.65	698.8±25.46	51.9±0.96
7	NS-GS-7	43.8±1.75	874.6±32.99	44.3±0.79
8	RHA-R-PL-2/1	30.1±1.19	614.0±21.00	49.8±0.57
9	RHA-N-49	23.7±1.08	806.0±29.51	27.6±0.50
10	RUS-RF-OL-168	25.5±0.86	968.5±23.68	29.4±0.38
11	1x8	79.6±2.42	1652.6±50.01	50.2±0.85
12	1x9	91.8±3.48	1995.5±61.98	45.8±0.82
13	1x10	96.6±2.71	1903.2±54.62	49.7±0.84
14	2x8	82.2±2.65	1595.5±38.18	51.7±0.93

No.	Parents and hybrids	SY	TSN	1,000-S M
15	2x9	96.9±2.54	2089.6±59.58	47.4±0.71
16	2x10	81.7±2.49	1737.9±47.23	48.0±1.09
17	3x8	89.9±1.39	1597.7±27.02	58.0±0.80
18	3x9	106.2±2.65	2120.7±50.89	50.8±1.17
19	3x10	102.0±2.74	1791.7±36.67	54.6±1.10
20	4x8	111.1±2.67	1559.2±64.03	78.6±1.11
21	4x9	94.4±2.68	1695.5±38.67	54.6±0.76
22	4x10	103.3±1.81	1521.4±37.50	65.5±1.22
23	5x8	162.9±3.28	2009.0±44.26	85.7±1.85
24	5x9	117.0±3.71	2025.7±72.78	64.7±1.08
25	5x10	112.4±2.40	1519.3±38.78	68.8±1.16
26	6x8	79.0±3.18	1390.0±61.82	51.8±1.19
27	6x9	104.7±2.49	2262.6±69.83	50.8±0.98
28	6x10	87.4±2.45	1715.7±54.71	52.9±0.93
29	7x8	93.0±2.09	1699.5±39.55	53.3±0.93
30	7x9	100.4±2.23	2071.1±69.06	53.5±0.96
31	7x10	94.9±1.65	1676.4±43.97	53.1±1.01
	LSD 0.05	3.16	99.72	5.92
	LSD 0.01	4.74	149.58	8.88

In all the hybrid combinations, heterosis values for seed yierld per plant were highly significant both relative to parental average (98.4-274.1%) and relative to better parent (55.8-223.2%). These results are in agreement with those of Limbore et al. (1998) 114.8%, Singh et al. (2002) 278.0%, and Jocić (2003) 129.3-412.0%. There were high positive heterotic effects ((H1=273%, H2=223%)) in the hybrid combination NS-GS-6xRHA-N-49 which is a cross between the inbred line and restorer with the smallest mean value of seed yield per plant (Tab.2). Heterosis effects for total seed number per head were highly significant and positive, ranging from 69.6 to 203.7% relative to parental average and from 47.6 to 183.3% relative to better parent. The highest and highly significant heterotic effect for total seed number per head relative to parental average and better parent was found in NS-GS-5xRHA-R-PL-2/1 (H1=203.7%, H2=183.3%), tab. 2. With 1,000-seed mass, heterosis was 26.5-48.8% relative to parental average and -42.4-30.9% relative to better parent.

Heterosis for seed yield, total seed mass per head, 1,000-seed mass varied both according to trait and according to hybrid combination. Heterosis values relative to better parent differed significantly from those relative to parental average for all the traits. The hybrid combinations NS-GS-5xRHA-R-PL-2/1 and NS-GS-7xRHA-N-49 had highly significant heterotic effects relative to parental average for all three traits (Tab.2).

Table 2. Heterosis for seed yield per plant (SY) total seed number per head (TSN), and 1,000-seed mass (1.000-SM) relative to parental mean (H1) and better parent (H2)

No.	Parents and hybrids	SY		TSN		1,000-S M	
		H1	H2	H1	H2	H1	H2
1	NS-GS-1						
1x8	NS-GS-1xRHA-R-PL-2/1	142,38**	123,66**	100,70**	60,00**	1,41	0,80
1x9	NS-GS-1xRHA-N-49	209,61**	157,86**	117,03**	93,19**	19,27	-6,91
1x10	NS-GS-1xRUS-RF-OL-168	216,37**	171,49**	90,19**	84,26**	26,46**	1,02
2	NS-GS-2						
2x8	NS-GS-2xRHA-R-PL-2/1	98,39**	55,74**	88,26**	47,59**	-0,58	-4,61
2x9	NS-GS-2xRHA-N-49	153,44**	83,60**	121,47**	93,30**	15,89	-12,55
2x10	NS-GS-2xRUS-RF-OL-168	108,79**	54,81**	69,59**	60,77**	14,83	-11,44

No.	Parents and hybrids	SY		TSN		1,000-S M	
		H1	H2	H1	H2	H1	H2
2x10	NS-GS-2xRUS-RF-OL-168	108,79**	54,81**	69,59**	60,77**	14,83	-11,44
3	NS-GS-3						
3x8	NS-GS-3xRHA-R-PL-2/1	122,98**	77,94**	105,69**	70,06**	12,95	9,64
3x9	NS-GS-3xRHA-N-49	186,15**	110,22**	142,99**	125,73**	26,21	-3,97
3x10	NS-GS-3xRUS-RF-OL-168	168,40**	101,97**	87,81**	85,00**	32,69*	3,21
4	NS-GS-4						
4x8	NS-GS-4xRHA-R-PL-2/1	159,99**	100,62**	152,71**	151,48**	8,71	-17,09**
4x9	NS-GS-4xRHA-N-49	138,56**	70,31**	137,80**	110,36**	-10,78	-42,41**
4x10	NS-GS-4xRUS-RF-OL-168	155,37**	86,46**	91,55**	57,09**	5,48	30,91**
5	NS-GS-5						
5x8	NS-GS-5xRHA-R-PL-2/1	274,10**	185,83**	203,72**	183,33**	32,66**	7,94
5x9	NS-GS-5xRHA-N-49	189,98**	105,27**	167,38**	151,33**	20,93	-18,51*
5x10	NS-GS-5xRUS-RF-OL-168	172,42**	97,14**	81,12**	56,87**	26,47*	-13,35
6	NS-GS-6						
6x8	NS-GS-6xRHA-R-PL-2/1	152,87**	143,89**	111,76**	98,91**	1,87	-0,19**
6x9	NS-GS-6xRHA-N-49	273,29**	223,17**	200,72**	180,72**	27,80	-2,12**
6x10	NS-GS-6xRUS-RF-OL-168	202,04**	169,88**	106,17**	77,46**	30,14*	1,93
7	NS-GS-7						
7x8	NS-GS-7xRHA-R-PL-2/1	151,65**	112,29**	128,34**	94,32**	13,28	7,03
7x9	NS-GS-7xRHA-N-49	171,82**	129,31**	146,47**	136,81**	48,82**	20,77
7x10	NS-GS-7xRUS-RF-OL-168	181,29**	116,75**	81,91**	73,09**	44,10**	19,87
8	RHA-R-PL-2/1						
9	RHA-N-49						
10	RUS-RF-OL-168						

Conclusion

The following can be concluded based on our study's results:

There were significant differences among the genotypes (inbred lines and hybrids) studied in the mean values of yield per plant, total seed number per head, and 1,000-seed mass.

In all the hybrid combinations, heterosis values for the traits under study were highly significant both relative to parental average and relative to beter parent. Heterosis values relative to better parent (H1) differed significantly from those relative to parental average (H2) for all the traits.

The development of hybrids with a high genetic potential for seed yield requires information on the manifestation of heterosis for agronomically important traits in the F1 generation. The findings of this study may be of significance in the development of new high-yielding sunflower genotypes.

Literatura

Dagustu N. 2002. Correlations and path coefficient analysis of seed yield components in sunflower (*Helianthus annuus* L.). Turkish J. Field Crops, 7, 1, 15-19.

Dušanić N. 1998. Uticaj gustine useva na dinamiku rastenja i prinos hibrida suncokreta, kao i neke mikroklimatske činioce. Doktorska disertacija, Poljoprivredni fakultet, Univerzitet u Novom Sadu.

Hadživuković S. 1991. Statistički metodi. Drugo prošireno izdanje. Poljoprivredni fakultet, Novi Sad.

Hladni N., Škorić D., Kraljević-Balalić M. 2003. Efekat heterozisa za komponente prinosa suncokreta (*Helianthus annuus* L.). Zbornik radova sa 44 Savetovanja industrije ulja, Budva, 35-41.

Jinks J. L. 1983. Biometrical genetic of heterosis. Monograph on theoretical and applied genetics. Vol. G. Heterosis, ed. By R. Frankel Springel –Verlag, Berlin, Heidelberg

Jocić S. 2003: Nasleđivnje komponenti prinosa kod suncokreta (*Helianthus annuus* L.). Doktorska disertacija,

Poljoprivredni fakultet, Novi Sad.
Joksimović J., Atlagić J. 2001. Pojava heterozisa za neke osobine suncokreta. Zbornik radova 42. Savetovanja industrije ulja, Herceg Novi, Yugoslavia, 59-63.
Joksimović J., Atlagić, J., Jovanović D., Marinković R., Dušanić N., Miklič V. 2004. Path coefficient analysis of some head and seed characteristics in sunflower. Proc. of 16th Inter. Sunf. Conf., Fargo, North Dakota, USA, II, 525-530.
Kumar A., Genesh M., Kumar S., Reddy A. 1999. Heterosis in sunflower (*Helianthus annuus* L.). Annals of agric. Res., 4, 20, 478-480.
Limbore A., Weginwar D., Lande S., Gizte B., Ghodke K. 1998. Heterosis in sunflower (*Helianthus annuus* L.). Annals of Plant Phy., 1, 12, 38-42.
Marinković R. 1984. Način nasleđivanja prinosa semena i nekih komponenti prinosa ukrštanjem raznih inbred linija. Doktorska disertacija, Univerzitet u Novom Sadu, Poljoprivredni fakultet.
Marinković R., Škorić D. 1985. Nasleđivanje mase 1000 semena i hektolitarske mase kod suncokreta u F1 generaciji i komponente genetske varijabilnosti. Zbornik radova Instituta za ratarstvo i povrtarstvo, Novi Sad, 14/15, 62-71.
Marinković R. 1987. Analiza komponenti prinosa semena suncokreta (*Helianthus annuus* L.) koeficientom putanje I. Abstr. III Kongres genetičara Jugoslavije sa međunarodnim učešćem, Ljubljana, Yugoslavija, 95.
Marinković R., Škorić D., Nenadić N., Jovanović D., Miklič V., Joksimović J., Stanojević D., Nedeljković S. 1994. Uticaj položaja semena u glavi na prinos i neke komponente prinosa semena kod suncokreta (*H. annuus* L.). Zbornik radova Instituta za ratarstvo i povrtarstvo, Novi Sad, 22, 379-389.
Marinković R., Dozet B., Vasić D. 2003. Oplemenjivanje suncokreta (Monografija), Školska knjiga, Novi sad, 368 str.
Patil B. R., Rudraradhya M., Vijayakumar C. H. M., Basappa H., Kulkarni R. S. 1996. Correlation and path analysis in sunflower. J. of Oilseeds Res. 13, 2, 162-166.
Putt E. D. 1966. Heterosis, combininig ability, and predicted synthetics from a diallel cross in sunflowers (*Helianthus annuus* L.). Can. J. Plant. Sci., 46, 59-67.
Singh R., Sing S.B., Rahaeja R. K., 2002. Heterosis for fatty acid composition over enviromnents in sunflower (*Helianthus annuus* L.). J. of Res., Punjab Agric. University, 39, 1, 1-5.
Škorić D. 1974. Correlation among the most important characters of sunflower in F1 generation. Proc. of 6th Inter. Sunf. Conf., Bucharest, Romania, 283-289.
Škorić D. 1975. Mogućnost korišćenja heterozisa na bazi muške sterilnosti kod suncokreta. Doktorska disertacija, Univerzitet u Novom Sadu, Poljoprivredni fakultet.
Škorić D., Atlagić Jovanka, Dozet B 1988. A collection of wild sunflower species and its use in a breeding program. Proc. of 12th Inter. Sunfl. Conf., Novi Sad, II, 267-269.
Škorić D., Vrebalov T., Ćupina T., Turkulov J., Marinković R., Maširević S., Atlagić J., Tadić L., Sekulić R., Stanojević D., Kovačević M., Jančić V., Sakač Z. 1989. Suncokret (monografija), Nolit, 1-635.
Škorić D., Dozet B. 1992. Use of wild *Helianthus* species in sunflower breeding for resistance to disease. 13th EUCARPIA Congres, Angeres, France, 735-737.
Škorić D., Marinković R., Jocić S. Jovanović D., Hladni N. 2002. Dostignuća i dalji pravci u oplemenjivanju suncokreta i izbor hibrida za setvu u 2002 godini. Zbornik radova Naučnog instituta za ratarsvo i povrtarstvo, 36, 147-160.
Škorić D., Jocić, S., Jovanović D., Hladni N., Marinković R., Atlagić J., Panković D., Vasić D., Miladinović, F., Gvozdenović S., Terzić, S., Sakač, Z. 2006. Dostignuća u oplemenjvanju suncokreta. Zbornik radova Naučnog instituta za ratarsvo i povrtarstvo, 42, 131-171.
Tahir M. H. N., Sadaqat H. A., Sajid Bashir 2002. Correlation and path coefficient analysis of morphological traits in sunflower (*Helianthus annuus* L.) populations. Int. J. Agric. Biol., 4, 3, 341-343.
Vranceanu V., Stoenescu F. 1969. Hibrizii simpli de floreasporelui o perspecitiva apropiata pentru producties. Probleme agricole, Bucharest, 10, 21-32.