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HETEROSIS FOR AGRONOMICALLY IMPORTANT TRAITS IN SUNFLOWER (*Helianthus annuus* L.)

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SUMMARY

Significant manifestation of heterosis for agronomically important traits is the main precondition for obtaining productive sunflower hybrids (Škorić *et al.*, 2006). Development of high-yielding and stable sunflower hybrids based on interspecific hybridization requires knowledge of heterotic effects occurring in the F_1 generation. Heterosis for seed yield per plant, total seed number per head and 1,000-seed weight was studied in interspecific hybrids obtained by the line × 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 F_1 hybrids were obtained by crossing each tester with each female inbred line. A trial with the lines and F_1 hybrids was set up at Rimski Šančevi. Experiment Field of 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 weight, heterosis**

INTRODUCTION

The sunflower is one of the most important oil crops in the world and the most important cultivated oil crop in Serbia, where it was grown at 200,000 ha in 2005.

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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. 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 discovery of desirable genes in 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 F_1 generation. Heterotic effects are different for different traits. Heterotic effects for seed yield per plant, total seed number per head, and 1,000-seed weight in the F_1 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 weight (>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, 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 weight, in the parental lines, because this trait affects the method of sowing, seeding rate, 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 weight, 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 important under unfavorable climatic and edaphic conditions. Breeding for increased 1,000-seed weight can significantly increase sunflower seed yields. The 1,000-seed weight is a highly variable trait which 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 weight 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 weight 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 monitor the occurrence of heterosis for seed yield per plant, total seed number per head and 1,000-seed weight in sunflower hybrids developed by crossing the seven cms inbred lines obtained by interspecific hybridization and the three restorer lines used as testers.

MATERIALS AND METHODS

Seven new divergent (A) cytoplasmically sterile inbreds, three *Rf*-restorer lines and 21 F_1 hybrids made at Institute of Field and Vegetable Crops in Novi Sad were used in this study. 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 F_1 hybrids were obtained by crossing each tester with each female inbred. A trial was set up at Rimski Šančevi Experiment Field using a randomized block design with three replicates. The planting scheme was 70 $\times$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 removing all impurities and reducing moisture down to 11%. It was 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 weight was determined in 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 F_1 hybrids in the mean values of seed yield per plant, total seed number per head, and 1,000-seed mass (Table 1).

Table 1: Mean values of seed yield per plant (SY), total seed number per head (TSN), and 1,000-seed weight (1,000-S W) in sunflower

No.	Parent or hybrid	SY (g)	TSN	1,000-SW (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	1 × 8	79.6±2.42	1652.6±50.01	50.2±0.85
12	1 × 9	91.8±3.48	1995.5±61.98	45.8±0.82
13	1 × 10	96.6±2.71	1903.2±54.62	49.7±0.84
14	2 × 8	82.2±2.65	1595.5±38.18	51.7±0.93
15	2 × 9	96.9±2.54	2089.6±59.58	47.4±0.71
16	2 × 10	81.7±2.49	1737.9±47.23	48.0±1.09
17	3 × 8	89.9±1.39	1597.7±27.02	58.0±0.80
18	3 × 9	106.2±2.65	2120.7±50.89	50.8±1.17
19	3 × 10	102.0±2.74	1791.7±36.67	54.6±1.10
20	4 × 8	111.1±2.67	1559.2±64.03	78.6±1.11
21	4 × 9	94.4±2.68	1695.5±38.67	54.6±0.76
22	4 × 10	103.3±1.81	1521.4±37.50	65.5±1.22
23	5 × 8	162.9±3.28	2009.0±44.26	85.7±1.85
24	5 × 9	117.0±3.71	2025.7±72.78	64.7±1.08
25	5 × 10	112.4±2.40	1519.3±38.78	68.8±1.16
26	6 × 8	79.0±3.18	1390.0±61.82	51.8±1.19
27	6 × 9	104.7±2.49	2262.6±69.83	50.8±0.98
28	6 × 10	87.4±2.45	1715.7±54.71	52.9±0.93
29	7 × 8	93.0±2.09	1699.5±39.55	53.3±0.93
30	7 × 9	100.4±2.23	2071.1±69.06	53.5±0.96
31	7 × 10	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 yield 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-6 × RHA-N-49. The restorer in this combination had the lowest mean value of seed yield per plant in the experiment (Table 2).

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

No.	Parents and hybrids	SY		TSN		1,000-SW	
		h1	h2	h1	h2	h1	h2
1	NS-GS-1						
1 × 8	NS-GS-1 × RHA-R-PL-2/1	142.38**	123.66**	100.70**	60.00**	1.41	0.80
1 ×9	NS-GS-1 × RHA-N-49	209.61**	157.86**	117.03**	93.19**	19.27	-6.91
1 ×10	NS-GS-1 × RUS-RF-OL-168	216.37**	171.49**	90.19**	84.26**	26.46**	1.02
2	NS-GS-2						
2 ×8	NS-GS-2 × RHA-R-PL-2/1	98.39**	55.74**	88.26**	47.59**	-0.58	-4.61
2 ×9	NS-GS-2 × RHA-N-49	153.44**	83.60**	121.47**	93.30**	15.89	-12.55
2 ×10	NS-GS-2 × RUS-RF-OL-168	108.79**	54.81**	69.59**	60.77**	14.83	-11.44
2 ×10	NS-GS-2 × RUS-RF-OL-168	108.79**	54.81**	69.59**	60.77**	14.83	-11.44
3	NS-GS-3						
3 ×8	NS-GS-3 × RHA-R-PL-2/1	122.98**	77.94**	105.69**	70.06**	12.95	9.64
3 ×9	NS-GS-3 × RHA-N-49	186.15**	110.22**	142.99**	125.73**	26.21	-3.97
3 ×10	NS-GS-3 × RUS-RF-OL-168	168.40**	101.97**	87.81**	85.00**	32.69*	3.21
4	NS-GS-4						
4 ×8	NS-GS-4 × RHA-R-PL-2/1	159.99**	100.62**	152.71**	151.48**	8.71	-17.09**
4 ×9	NS-GS-4 × RHA-N-49	138.56**	70.31**	137.80**	110.36**	-10.78	-42.41**
4 ×10	NS-GS-4 × RUS-RF-OL-168	155.37**	86.46**	91.55**	57.09**	5.48	30.91**
5	NS-GS-5						
5 ×8	NS-GS-5 × RHA-R-PL-2/1	274.10**	185.83**	203.72**	183.33**	32.66**	7.94
5 ×9	NS-GS-5 × RHA-N-49	189.98**	105.27**	167.38**	151.33**	20.93	-18.51*
5 ×10	NS-GS-5 × RUS-RF-OL-168	172.42**	97.14**	81.12**	56.87**	26.47*	-13.35
6	NS-GS-6						
6 ×8	NS-GS-6 × RHA-R-PL-2/1	152.87**	143.89**	111.76**	98.91**	1.87	-0.19**
6 ×9	NS-GS-6 × RHA-N-49	273.29**	223.17**	200.72**	180.72**	27.80	-2.12**
6 ×10	NS-GS-6 × RUS-RF-OL-168	202.04**	169.88**	106.17**	77.46**	30.14*	1.93
7	NS-GS-7						
7 ×8	NS-GS-7 × RHA-R-PL-2/1	151.65**	112.29**	128.34**	94.32**	13.28	7.03
7 ×9	NS-GS-7 × RHA-N-49	171.82**	129.31**	146.47**	136.81**	48.82**	20.77
7 ×10	NS-GS-7 × RUS-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						

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-5 × RHA-R-PL-2/1 - H1=203.7% and H2=183.3%, respectively

(Table 2). With 1,000-seed weight, 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 weight per head, 1,000-seed weight varied according to both, trait and 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-5 × RHA-R-PL-2/1 and NS-GS-7 × RHA-N-49 had highly significant heterotic effects relative to parental average for all three traits (Table 2).

CONCLUSION

The following can be concluded based on the study results.

- There were significant differences among the studied genotypes (inbred lines and hybrids) in the mean values of yield per plant, total seed number per head, and 1,000-seed weight.
- 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 F_1 generation. The findings of this study may be of significance in the development of new high-yielding sunflower genotypes.

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HETEROSIS PARA LAS CARACTERÍSTICAS DE GIRASOL (*Helianthus annuus* L.) IMPORTANTES AGRONÓMICAMENTE

RESUMEN

La presentación del heterosis significante para las características importantes desde el punto de vista agronómico, es la condición principal para la obtención de híbridos de girasol productivos (Škorić y colaboradores, 2006). La creación de híbridos de girasol estables y de alto rendimiento sobre la base de hibridación de interespecies, requiere el conocimiento de los efectos heteróticos que se presentan en la generación F_1. El heterosis para el rendimiento de semilla por planta, el número total de semillas por capítulo y el peso de 1000 granos, ha sido investigadazo en los híbridos interespecies obtenidos por el método línea × testador. Siete líneas consanguíneas (inbred) de la madre, utilizadas en esta investigación, fueron creadas por la hibridación de interespecies, mientras que tres líneas masculinas restauradoras, con buena habilidad de combinación, fueron utilizadas como testadores en forma de restauradores de fertilidad masculina. Cruzando cada testador con cada línea materna, fue obtenido el híbrido 21 F_1. La investigación de las líneas y el híbrido F_1, fue realizada en tres repeticiones en el campo experimental del Instituto de Agricultura y Horticultura de Novi Sad, en Rimski Šanèevi. En la investigación fueron determinadas diferencias significantes en los valores medios de todas las características investigadas. Los valores heteróticos para el rendimiento de la semilla fueron positivos y altamente significantes en relación con el promedio de los progenitores (98,4-274,1%) tanto como del mejor progenitor (55,8-223,2%). Significativamente menor heterosis fue encontrado para el número total de semillas por capítulo (69,6-203,7%) en relación con el promedio de los progenitores y del mejor progenitor (47,6-183,3%). En cuanto al peso de 1000 granos, los valores oscilaban entre 26,5% y 48,8% en relación con el promedio de progenitores y desde -42,4% hasta 30.9% en relación con el mejor progenitor. Esta investigación podría demostrarse útil en creación de de híbridos de girasol de alto rendimiento, sobre la base de hibridación de interespecies.

HÉTÉROSIS POUR D'IMPORTANTES CARACTÉRISTIQUES AGRONOMIQUES DU TOURNESOL (*Helianthus annuus* L.)

RÉSUMÉ

La manifestation d'une hétérosis importante est la condition principale pour les caractéristiques agronomiques d'hybrides de tournesols productifs (Škorić *et al.*, 2006). Le développement d'hybrides de tournesol stables et à grand rendement basés sur l'hybridation interspécifique exige la connaissance des effets d'hétérosis apparaissant dans la génération F_1. L'hétérosis pour le rendement de graines par plante, le nombre total de graines par tête et le poids de 1,000 graines a été étudié dans les hybrides interspécifiques obtenus par la méthode lignée × testeur. Sept souches pures mères utilisées dans cette recherche ont été développées par hybridation interspécifique tandis que trois souches de restauration mâles ayant de bonnes aptitudes de combinaison ont été utilisées comme testeurs sous forme de restaurateurs de fertilité mâe. Vingt-un hybrides F_1 ont été obtenus par croisement de chaque testeur avec chaque source pure femelle. Un essai avec les lignées et les hybrides F_1 a été fait en trois fois dans le champ expérimental de l'Institut d'Agriculture et d'Horticulture de Novi Sad. L'étude a constaté des différences importantes dans les valeurs moyennes de toutes les caractéristiques étudiées. Les valeurs d'hétérosis pour le rendement en graines étaient positives et très significatives par rapport à la moyenne parentale (98,4-274,1%) aussi bien que par rapport à celle du meilleur parent (47,6-183,3%). Pour le nombre total de graines par tête une hérétosis beaucoup moindre a été constatée par rapport à la moyenne du parent (69,6-203,7%) et du meilleur parent (47,6-183,3%). Pour ce qui est du poids de 1000 graines, les valeurs variaient de 26,5% et 48,8% relativement à la moyenne du parent et de -42,4% à 30,9% par rapport au meilleur parent. Cette étude pourrait se montrer utile lors de la création d'hybrides de tournesol à grand rendement basés sur l'hybridation interspécifique.