LINE *X* TESTER ANALYSIS FOR PLANT HEIGHT AND HEAD DIAMETER IN SUNFLOWER (*HELIANTHUS ANNUUS*)

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Abstract

One of the prime tasks of sunflower breeding is the development of inbred lines by interspecific hybridization in order to obtain high-yielding and stable hybrids. This study used seven new divergent (A) CMS inbreds obtained 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. A two-year trial with three replicates was set up at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops using the line x tester method (Singh and Chouduary, 1976). Significant differences were found between the A-lines and Rf testers and their F1 hybrids in plant height and head diameter. Highly significant positive values of GCA for plant height and head diameter were found in the inbred lines NS-GS-4 and NS-GS-5, whereas the inbred line NS-GS-1 had a highly significant negative GCA value. The greatest highly significant positive SCA value was found in NS-GS-6 x RHA-R-PL-2/1 for plant height and in NS-GS-5 x RHA-R-PL-2/1 for head diameter. The nonadditive component of genetic variance played the main role in the inheritance of both plant height and head diameter, as shown by the ANOVA of variance of combining abilities and analysis of genetic variance components. This is supported by the GCA/SCA ratio for plant height (0.57) and head diameter (0.08) in the F1 generation, which was below the value of one for both traits and in both years of study. The largest average contribution in the expression of plant height (79.98%) and head diameter (55.56%) was that of the female A-lines. These results may be of importance for the development of new high-yielding sunflower genotypes based on interspecific hybridization.

Introduction

The sunflower is the main plant used for edible oil production in many countries of the world, including Serbia and Montenegro. Plant height, head size, form and position on the stem, and leaf number, duration and distribution on the plant all play important roles in defining the optimal architecture of sunflower hybrids (Škorić, 1975, 1989, 2002). One of the primary tasks of sunflower breeding is the development of inbred lines by interspecific hybridization in order to obtain high-yielding and stable hybrids. The optimal average height of a sunflower hybrid is 160 to 180 cm (Shabbana, 1974, Škorić, 1975). The development of hybrids with plant height reduced to 120 to 150 cm would result in better resistance to lodging and easier cultivation and harvesting (Scheneiter, 1988). Shorter hybrids have a similar yield potential to standard-height hybrids (Schneiter 1992, Velasco et al., 2003). Semidwarf (SD) hybrids with a plant height of 120 to 150 cm are much more tolerant of a higher plant number per hectare than the standard hybrids (SH), as reported by Schneiter (1988), Stanojević (1989), and Suzer and Atakisi (1993). Furthermore, reduced-height genotypes may be better adapted to high-yield environments (Miller and Hammond, 1991). One of the more recent directions in sunflower breeding involves increasing the harvest index and resistance to lodging via reduced plant height. (Marinković and Dozet, 1997).

Head size, expressed as head diameter (cm), is one of the sunflower yield components that directly influence hybrid model changes. A sunflower head should be of medium size, 20 to 25 cm in diameter, thin, and should have a firm epidermis (Škorić, 1980). Increasing head size above the optimal value reduces kernel yield (g/head) and seed oil content and increases hull percentage and number of empty seeds (Škorić, 1989). Head size is affected by genetic as well as environmental factors (moisture, fertility, and number of plants per unit area) and growing season length (Marinković et al., 2003). Fick (1978) determined that the contribution of genetic factors is smaller in the inheritance of head diameter than with most other agronomic traits. Increased row-to-row spacing increases head diameter, as reported by Esendal and Kandemir (1996).

The objective of this study was to investigate the effects of the general combining ability (GCA) of inbred lines and the special combining ability (SCA) of F1 hybrids as well as gene effects, components of genetic variance and average percentage contribution of lines, testers and their interactions in the expression of sunflower plant height and head diameter.

Materials and Methods

This study used seven new divergent (A) cms inbreds, 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, and NS-GS-7) had been obtained by interspecific hybridization. The male restorer inbreds (RHA-R-PL-2/1, RHA-N-49, and 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 line. A two-year trial with three replicates was set up at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops using the experimental design required by the line x tester method. The lines and hybrids were sown manually on optimal dates in a well prepared soil. The basic plot had four rows with 12 plants each. The row-to-row spacing was 70 cm and plant-to-plant spacing of 25 cm. The basic sample used for trait analysis included 30 plants (10 per replicate) taken from the rows in the middle of each block. Plant height and head diameter were measured at physiological maturity. The analysis of combining abilities was performed according to the line x tester method. (Singh and Choudhary, 1976).

Results and Discussion

Significant differences were found between the A-lines and Rf testers and their F1 hybrids in plant height and head diameter, indicating the presence of genetic differences among the genotypes studied. Of the A-lines, NS-GS-6 had the smallest (70.9 cm) and NS-GS-3 the greatest plant height (117.4 cm), while in the Rf-testers RHA-N-49 was the shortest (101.1 cm) and RUS-RF-OL-168 the tallest (120.6 cm). Among the F1 hybrids, NS-GS-6 x RUS-RF-OL-168 had the smallest (122.6 cm) and NS-GS-3 x RHA-N-49 the greatest average plant height (173.4 cm). The head diameter means ranged from 20.6 to 21.9 cm in the A-lines, 12.9 to 17.8 cm in the testers, and 22.0 to 29.6 cm in the F1 (Table 1).

Table1. Mean values of plant height (cm) and head diameter (cm) in sunflower.

No.	Parents and hybrids	Plant height	Head diameter
		$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$
1	NS-GS-1	94.1±0.62	21.9±0.20
2	NS-GS-2	105.8±0.74	21.3±0.19
3	NS-GS-3	117.4±0.93	20.6±0.15
4	NS-GS-4	107.9±0.73	21.9±0.20
5	NS-GS-5	89.6±0.73	21.1±0.18
6	NS-GS-6	70.9±0.65	21.8±0.21
7	NS-GS-7	89.3±0.74	21.5±0.23
8	RHA-R-PL-2/1	118.4±0.84	17.2±0.23
9	RHA-N-49	101.1±0.96	12.9±0.49
10	RUS-RF-OL-168	120.6±0.80	17.8±0.19
11	1x8	141.9±0.91	22.9±0.28
12	1x9	154.0±0.75	22.0±0.22
13	1x10	135.3±0.99	23.3±0.19
14	2x8	149.1±0.95	23.1±0.29
15	2x9	153.0±0.76	23.0±0.23
16	2x10	139.8±1.04	23.7±0.20
17	3x8	162.1±0.70	23.8±0.23
18	3x9	173.4±0.85	24.0±0.30
19	3x10	153.1±0.92	25.1±0.23
20	4x8	161.3±0.66	23.8±0.19
21	4x9	163.8±0.65	24.5±0.34
22	4x10	162.6±0.81	23.4±0.24
23	5x8	149.8±1.69	29.5±0.33
24	5x9	164.4±1.01	24.6±0.25
25	5x10	152.3±1.22	25.1±0.16
26	6x8	134.8±0.86	25.0±0.25
27	6x9	128.1±0.96	29.6±0.30
28	6x10	122.6±0.94	28.7±0.32
29	7x8	139.4±0.80	27.5±0.25
30	7x9	139.8±0.77	28.6±0.27
31	7x10	133.9±0.67	26.1±0.23

Analysis of combining abilities for plant height in the A-lines and Rf testers showed that there were significant differences in GCA in the female inbreds and tester lines. The lowest negative effect of plant height GCA was found in the A-lines NS-GS-6 and NS-GS-7, while the highest positive one was recorded in NS-GS-4. Among the Rf testers, the most pronounced negative and positive effects were observed in RUS-RF-OL-168 and RHA-N-49, respectively (Table 2).

With regards to plant height SCA, high positive values were found in six hybrids in both study years. A highly significant positive value for plant height in the F1 generation was found in the combinations NS-GS-1 x RHA-N-49 and NS-GS-4 x RUS-RF-OL-168, which had been obtained by crossing one parent with a poor plant height GCA to another one that had a highly positive GCA for this trait (Table 3). These results support those obtained by Škorić et al. (2000), who determined that crosses with a good plant height SCA usually involve one parent with high and one with low GCA values.

Table 2. GCA values for plant height and head diameter in sunflower inbreds.

No.	Parents	Plant height	Head diameter
1	NS-GS-1	-4.59**	-2.35**
2	NS-GS-2	-1.01	-1.84
3	NS-GS-3	14.55**	-0.83
4	NS-GS-4	162.58**	23.90**
5	NS-GS-5	7.219**	1.27**
6	NS-GS-6	-19.84**	2.65**
7	NS-GS-7	-10.62**	2.30**
8	RHA-R-PL-2/1	0.036	-0.01
9	RHA-N-49	5.48**	0.07
10	RUS-RF-OL-168	-5.51**	-0.06
SE GCA/line		0.67	0.16
SE (GCA_i-GCA_j)/line		1.01	0.26
SE GCA/tester		0.44	0.11
SE (GCA_i–GCA_j)/tester		0.62	0.15
LSD (1-7) 1%		1.330	0.34
LSD (1-7) 5%		1.995	0.51
LSD (8-10) 1%		0.874	0.48
LSD (8-10) 5%		1.311	0.31

Table 3. SCA values for plant height and head diameter in sunflower inbreds.

F_1 hybrids		Plant height	Head diameter
1	1x8	-1.84	0.23
2	2x8	1.74	-0.13
3	3x8	-0.81	-0.50
4	4x8	-1.29	-0.12
5	5x8	-5.73**	3.15**
6	6x8	6.24**	-2.73**
7	7x8	1.69	0.10
8	1x9	4.80**	-0.88
9	2 x9	0.22	-0.33
10	3 x9	5.08**	-0.36
11	4 x9	-4.23**	0.53
12	5 x9	3.41**	-1.90**
13	6 x9	-5.87**	1.78**
14	7 x9	-3.42	1.16**
15	1x10	-2.96	0.65*
16	2 x10	-1.96	0.46
17	3 x10	-4.27**	0.86*
18	4 x10	5.51**	-0.41
19	5 x10	2.32*	-1.25**
20	6 x10	-0.38	0.96**
21	7 x10	1.74	-1.26**
SE SCA		1.16	0.28
SE(S_{ij} –S_{kj})		1.63	0.39
LSD 0.01		2.30	0.51
LSD 0.05		3.46	0.76

The lowest negative GCA for head diameter was found in the A-line NS-GS-1 and the highest positive one in NS-GS-4 (Table 2). A highly significant positive effect of SCA for head diameter was found in the hybrids NS-GS-5 x RHA-R-PL-2/1 and NS-GS-6 x RHA-N, while a negative one was recorded in NS-GS-6 x RHA-R-PL-2/1, NS-GS-5 x RHA-N-49 and NS-GS-7 x RUS-RF-OL-168 (Table 3). The nonadditive component of genetic variance played the main role in the inheritance of both plant height and head diameter, as shown by the analysis of variance of combining abilities and analysis of genetic variance components. This is supported by the GCA/SCA ratio for plant height (0.57) and head diameter (0.08) in the F1 generation, which was below the value of one (Table 4).

Table 4. Components of genetic variance for plant height and head diameter.

Komponente	Plant height	Head diameter
GCA	13.92	0.30
F=0 V_A	53.70	1.12
F=1 V_A	26.34	0.56
F=0 V_D/V_A	1.81	17.97
F=0 V_D/V_A	0.93	8.90
SCA	24.30	4.51
F=0 V_D	97.19	18.08
F=1 V_D	24.30	4.51
GCA/SCA	0.57	0.08

A higher contribution of nonadditive genetic variance has been reported by Marinković (1982), Škorić (2000) and Joksimović (2000) for the inheritance of plant height and by Marinković (1984), Joksimović et al. (2000) and Hladni et al. (2003) for the inheritance of head diameter. By contrast, Bhat et al. (2000), Shekar et al. (2000), Ashok et al. (2000) and Hladni et al. (2000) found the additive component to be have been more significant in the inheritance of plant height, while Dua et al. (1985) and El-Hity (1992) did the same in the case of head diameter. Equal significance of the two components in plant height inheritance has been established by Tyagi (1988) and Gangappa et al. (1997). The largest average contribution in the expression of plant height (79.98%) and head diameter (55.56%) was that of the female A-lines, while the contributions of Rf testers and line x tester interactions were less significant (Table 5).

Table 5. Average percentage contribution of female lines and tester lines and their interactions to expression of plant height and head diameter.

Average contribution	Plant height	Head diameter
	%	%
Female line	79.98	55.56
Tester line	12.07	1.84
Line x tester	7.95	42.61

These results are in disagreement with those of Joksimović et al. (2000), who found the contribution of Rf testers to have been more significant in the expression of plant height (62.5%) and head diameter (54.51%).

Conclusions

Based on the study results, the following conclusions can be made. Significant differences were found among the genotypes studied (inbreds and hybrids) in the mean values of plant height and head diameter. The nonadditive component of genetic variance played the main role in the inheritance of both plant height and head diameter, as shown by the analysis of variance of combining abilities and analysis of genetic variance components. This is supported by the GCA/SCA ratio in the F1 generation, which was below the value of one for both traits and in both years of study. The largest average contribution in the expression of plant height (79.98%) and head diameter (55.56%) was that of the female A-lines, while the contributions of Rf testers and line x tester interactions were less significant.

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