GENERAL (GCA) AND SPECIFIC (SCA) COMBINING ABILITIES IN SUNFLOWER

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SUMMARY

Used in this study were 20 new Rf-lines, five A-tester lines and their 100 hybrid combinations. A large number of agronomically important traits of these genotypes have been studied. The present paper reports the results for plant height, seed yield (kg/ha), seed oil content (%), oil yield (kg/ha), and resistance to *Sclerotinia* head rot.

In most of the hybrid combinations significant heterosis of various intensity levels was found for all the above traits.

Analysis of the combining abilities for the traits concerned has shown that there are significant differences among the Rf-lines and A-tester lines regarding the values of the general combining ability (GCA). In some of the lines highly significant positive and negative GCA effects were observed. Analysis of the components of genetic variance has shown both additive and nonadditive gene action to be responsible for the inheritance of the traits. Still, the contribution of the nonadditive component was more significant. This is supported by the GCA/SCA ratio values, which were lower than 1 and as such indicative of the higher importance of nonadditive genes in the expression of the traits.

The largest contribution to the traits' expression was that of the A-testers. The contributions of the Rf-lines and tester/line interactions were smaller.

Based on the study's results, it can be concluded that the following lines have the largest practical value in breeding terms: PR-ST-3A, Ha-26A, RHA-N-92, and RUS-RF-100.

KEY WORDS: Combining abilities — GCA and SCA, plant height, seed and oil yields, *Sclerotinia* head rot.

INTRODUCTION

The first extensive studies on inbreeding, heterosis, and combining abilities in sunflower were carried out in Russia in the 1920s (Morozov, 1947). Inbreeding depression in different generations of self-pollination, the manifestation of heterosis for different traits, and studies on the GCA and SCA were covered in detail by Schuster (1964).

A large number of authors have studied the GCA and SCA for the major agronomic traits (Škorić, 1975; Joksimović, 1992; and many others). Sunflower yields depend on a number of traits as well as on environmental conditions. Because of the importance of environmental factors, the heritability of seed yield is relatively low compared with other agronomic traits (Miller and Fick, 1997). Putt (1966) concluded that the SCA for seed yield is more important than the GCA for the same trait, suggesting that nonadditive genetic variance has more importance than the additive one when it comes to yield fluctuations.

Schuster (1964), Škorić (1975), and Joksimović (1992) all found significant heterotic effects for seed yield content. Schuster (1964) also found a significant positive correlation between the seed oil content of the F1 hybrids and that of the female parents. Kovačik and Škalaud (1972) reported that the inheritance of seed oil content is controlled by incomplete dominance.

Many authors have reported very frequent and high heterosis for plant height. Joksimović (1992) found significant and highly significant differences in the GCA for plant height among the inbred lines he studied.

The inheritance of resistance to *S. sclerotiorum* is complex, especially bearing in mind that there are three types of this disease in sunflower (root, stem, and head forms). Results found in the literature are often contradictory (Pirvu et al., 1985). Nevertheless, the development of hybrids highly tolerant to all three forms of this disease is possible, as evidenced by the existence of such hybrids in commercial production.

The objectives of this study were: i) to investigate the GCA and SCA of 20 new Rf-inbreds and five known tester A-lines for plant height, seed yield, seed oil content, oil yield, and resistance to *Sclerotinia* head rot; ii) to determine the components of genetic variance and the ratio of GCA-indicators of additive genetic variance to SCA-indicators of nonadditive genetic variance; and iii) to determine the percentage contribution of the Rf-lines, testers, and their interactions to the expression of the traits under study.

MATERIALS AND METHODS

Used in this study were the following 20 new Rf-lines and five A-tester lines with different values of the agronomically important traits — <u>Rf-lines</u>: RHA-N-6, RHA-N-13, RHA-N-49, RHA-N-62, RHA-N-55, RHA-N-92, RHA-N-147, RHA-N-155, RHA-N-187, RF-KV-2, RF-KV-4, RF-KV-5, RUS-RF-6, RUS-RF-78, RUS-RF-94, RUS-RF-168, RUS-RF-51, RUS-RF-100, RUS-RF-16, RUS-RF-156; <u>A-tester lines</u>: Ha-26A, Ha-48A, PR-ST-3A, PH-BC-1-40A, and VL-A-8A.

Hybrid combinations among the A-sterile testers and the Rf-lines were produced in cages as genetically pure.

Comparative trials with the five A-sterile testers, 20 Rf-lines, and their 100 F1 hybrids were carried out at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad. The trials were set up in three replications with a net plot of 40 plants. All observations and measurements were made during the growing season.

Weather conditions during the growing season were optimal for the development of *Sclerotinia* head rot (over 200 mm in July) — in point of fact they could not have been made better even if the disease had been introduced by inoculation. The severity of attack by *S. sclerotiorum* was estimated based on the percentage of healthy plants per basic plot.

Analysis of variance for the parents and F1 hybrids was performed according to Suab (1973) and analysis of the combining abilities using the line x tester method by Singh and Choudhary (1976). The results concerning the SCA will not be shown in tables due to their volume, instead, they will only be commented upon.

RESULTS AND DISCUSSION

Significant differences were found among the Rf- and A-tester lines and their F1 hybrids regarding plant height, seed yield (ha), seed oil content, oil yield (kg/ha), and severity of attack by *Sclerotinia* head rot, indicating the existence of genetic differences among the genotypes.

Among the Rf-lines, the smallest plant height was observed in RHA-N-147 (101.6 cm) and the largest in RUS-RF-168 (176.6 cm). Of the A-testers, PH-BC-1-40A was the shortest (124 cm) and Ha-48A the tallest (201 cm). As regards seed yield, the lowest-yielding Rf-line was RHA-N-49 with 100.6 kg/ha, while the highest-yielding one RUS-RF-168 with 696 kga/ha. Among the A-testers, PH-BC-1-40 A had the lowest and Ha-26A the highest seed yield (735 and 2,027 kg/ha, respectively). The lowest seed oil content among the Rf-lines was found in RHA-N-62 (37%) and the highest in RUS-RF-6 (52.8%), while among the A-testers the lowest value was recorded in PR-ST-3A (36.5%) and the highest in Ha-48A (45%). In the case of oil yield, the highest value was observed in RUS-RF-168 (335 kg/ha) and the lowest in RHA-N-49 (39.8 kg/ha). Finally, the two Rf-lines most resistant to *Sclerotinia* head rot were RHA-N-92 (100%) and RUS-RF-168 (99.3%). Among the A-testers, the highest resistance was recorded in VL-A-8A (100%) and the lowest in PH-BC-1-40A.

Heterosis for plant height manifested itself in all the hybrid combinations.

Analysis of the combining abilities for plant height has shown that there are significant differences between the Rf-lines and A-testers with respect to the GCA. .

The most prominent negative effect of the GCA for plant height was found in the Rf-lines RF-KV-4 and RF-KV-5, while the most prominent positive effect was observed in RHA-N-6. In the A-testers, the most prominent negative and positive effects of the GCA for this trait were recorded in VL-A-8A and Ha-48A, respectively (Table 1).

In studying the SCA for plant height, highly significant positive effects were recorded in several hybrid combinations, most notably in Ha-26A x RUS-RF-168 and Ha-48A x RUS-RF-156. These results support an earlier observation made by a number of authors, namely that the highest SCA values for plant height will, as a rule, be found in hybrid combinations that include one parent with a poor and one with a good GCA for this trait.

Highly significant negative values of the SCA for plant height were also found in several combinations, most notably in PR-ST-3A x RHA-N-49 and PH-BC-1-40A x RUS-RF-156.

The GCA/SCA ratio for plant height was less than 1, namely 0.08 (Table 3). Our analysis of genetic variance components showed that additive and nonadditive gene action played a significant role in the inheritance of plant height. The study's results indicate that the nonadditive component had a more significant role in the inheritance of plant height in the F1 hybrid combinations (Table 2).

On average, the A-tester female parent lines made the largest contribution (55.8%) to the expression of plant height in the F1 hybrids. The contributions of the Rf-lines and line/tester interactions were less significant (Table 3). These results are in agreement with those of Joksimović (1992), who also found that tester lines played the dominant role.

Heterosis for seed yield (ha) was manifested in most of the hybrid combinations. The exceptions were combinations that suffered significant *Sclerotinia* head rot attacks, which decimated their yields.

The mean squares of all sources of variation in the variance analysis for seed yield (kg/ha) were highly significant.

Highly significant positive effects of the GCA for seed yield (kg/ha) were observed in the Rf-lines RUS-RF-100 and RHA-N-92 and the A-lines PR-ST-3A and Ha-26A. Highly significant negative effects effects for seed yield were found in RF-KV-4, RF-KV-2, and PH-BC-1-40A (Table 1).

An analysis of the SCA effects of the inbred lines in the F1 hybrids showed that the highest positive values for seed yield were achieved by the following combinations: Ha-48A x RUS-RF-156, PR-ST-3A x RF-KV-4, Ha-48A x RF-KV-4, and Ha-26A x RHA-N-92. The highest negative values of the SCA for seed yield were recorded in VL-A-8A x RF-KV-4, Ha-48A x RF-KV-2, and HA-48A x RHA-N-62. Interestingly, Ha-48A and RF-KV-4 appear with great frequency in both hybrid combinations with positive and those with negative SCA effects for seed yield.

The GCA/SCA ratio in the F1 generation was lower than 1 (0.07), indicating that the nonadditive component of genetic variance (dominance and epistasis) made a larger contribution to total genetic variance for seed yield than the additive one (Table 2).

The average contribution of the testers to the expression of seed yield was 51.4%, followed by that of Rf-lines (23.9%) and tester/lines (24.6%) (Table 3).

Heterosis for seed oil content manifested itself in most of the F1 hybrid combinations.

Our results showed that the highest positive GCA value for seed oil content was achieved by the lines RUS-RF-6 and PH-BC-1-40A. The highest negative values were those of RF-KV-2 and PR-ST-3A (Table 3).

The highest positive SCA values for seed oil content were recorded in Ha-48A x RF-KV-5 and Ha-48A x RUS-RF-156, while the highest negative ones were found in the combinations Ha-26A x RHA-N-187 and Ha-48A x RF-KV-2.

The GCA/SCA ratio for seed oil content was less than 1, namely 0.18 (Table 2). Also, the other components of genetic variance showed that the contribution of the nonadditive component of genetic variance in the expression of this trait was higher than that of the additive one.

The average contribution of the tester lines to the expression of seed oil content was 58.2% (Table 3).

Heterosis for oil yield (kg/ha) was very pronounced in this study.

The highest positive value of the GCA for oil yield was found in those lines that had positive GCA values for both seed yield and seed oil content. Significant negative GCA values for this trait were found in lines that had either negative GCA values for both seed yield and seed oil content or a very high negative GCA value for seed yield (Table 1). The combination Ha-48A x RUS-RF-156 had the highest positive and VL-A-8A x RF-KV-4 the highest negative value of the SCA for this trait.

The GCA/SCA ratio for oil yield was lower than 1, meaning that nonadditive gene action (dominance and epistasis) played a considerably more important role in the inheritance of oil yield than additive gene action (Table 2). These results are in agreement with the findings of a number of other authors.

The average contributions to the expression of oil yield were as follows: tester female lines — 38.6%, Rf-lines — 29.9%, and tester/line interactions — 31.4% (Table 3). These results differ from the results of Joksimović (1992), where it was the interactions that made the largest contribution (55.4%).

The highest positive values of the GCA for resistance to *Sclerotinia* head rot were observed in RHA-N-92, RF-KV-2, and PR-ST-3A, whereas the highest negative ones were found in RF-KV-4, RUS-RF-6, and PH-BC-1-40A (Table 1).

Notably, the highest positive SCA value for this trait was recorded in the hybrid combination Ha-48A x RF-KV-4 and the highest negative one in PH-BC-1-40A x RF-KV-4, meaning that the most resistant combination was composed of a line with a positive GCA value and the line with the highest negative GCA value for this trait. This supports the results of other authors, which indicate that the SCA is very important in developing hybrids with high tolerance to *Sclerotinia* head rot (Pirvu et al., 1985).

Overall, the average contribution of the A-tester lines to the expression of tolerance to *Sclerotinia* head rot was much more significant than those of the Rf-lines and interactions (Table 3).

CONCLUSIONS

The study’s results have lead us to conclude that :

- There are significant differences among the sunflower genotypes (inbred lines and F1 hybrids) we tested with regard to the mean values of all the traits involved;
- The nonadditive component of genetic variance plays the main role in the inheritance of the traits concerned, as shown by the analysis of variance of combining abilities and the analysis of genetic variance components. This conclusion is also supported by the fact that values of the GCA/SCA ratio for all the traits were lower than one;
- For each of the traits, highly significant positive and negative SCA values were recorded in some of the hybrid combinations;
- The largest average contribution to the expression of the studied traits was that of the A-tester female lines.

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Table 1. The sunflower inbreds' GCA values for plant height, seed yield, seed oil content, oil yield, and resistance to *Sclerotinia*-head rot

No.	Inbred lines	Traits				
		Plant height	Seed Yield	Seed oil Content	Oil yield	*Sclerotinia* Head rot
1.	RHA-N-6	19.28	84.87	-0.21	37.68	-0.32
2.	RHA-N-13	-3.32	-152.72	-0.57	-83.64	-5.48
3.	RHA-N-49	3.48	-116.99	1.64	-23.53	-1.06
4.	RHA-N-62	4.28	86.01	-2.18	-6.21	7.67
5.	RHA-N-55	-12.12	-110.05	0.65	-38.55	-0.21
6.	RHA-N-92	0.81	367.07	0.32	179.66	10.21
7.	RHA-N-147	-11.18	196.14	-1.60	52.28	0.29
8.	RHA-N-155	-2.78	127.07	-0.11	61.48	3.35
9.	RHA-N-187	19.81	220.74	-1.99	53.48	7.89
10.	RF-KV-2	1.08	-433.59	-3.14	-248.50	10.38
11.	RF-KV-4	-15.72	-546.79	0.76	-248.13	-19.22
12.	RF-KV-5	-14.32	109.67	1.33	80.91	8.71
13.	RUS-RF-6	0.28	-267.12	2.82	-72.12	-14.19
14.	RUS-RF-78	0.34	79.47	-2.32	-15.11	-0.95
15.	RUS-RF-94	4.61	-213.72	0.95	-85.26	-12.09
16.	RUS-RF-168	9.81	151.01	0.30	75.77	3.41
17.	RUS-RF-51	3.81	-186.39	-0.06	-92.55	-9.71
18.	RUS-RF-100	-5.12	527.81	1.90	297.59	8.91
19.	RUS-RF-16	-1.65	276.61	0.71	149.97	7.05
20.	RUS-RF156	-1.38	-199.12	0.79	-75.21	-4.64
21.	Ha-26 A	-5.37	209.77	-1.21	75.54	-0.01
22.	Ha-48 A	22.53	-9.99	0.71	21.60	3.68
23.	PR-ST-3 A	8.16	474.97	-3.40	142.60	13.35
24.	PH-BC-1-40 A	-9.45	-685.85	2.58	-278.17	-21.73
25.	VL-A-8 A	-15.87	11.09	1.31	38.43	4.69
SE GCA / lines		1.315	76.284	0.199	36.109	2.241
SE (G_i-G_j) / lines		1.859	107.882	0.281	51.065	3.170
SE GCA / testers		0.657	38.142	0.099	18.054	1.121
SE (G_i-G_j) / testers		0.930	53.941	0.141	25.533	1.585
LSD (1-20)	5%	3.66	212.53	0.55	100.59	6.24
	1%	4.83	280.49	0.73	132.76	8.24
LSD (21-25)	5%	1.83	106.26	0.28	50.30	3.12
	1%	2.41	140.25	0.37	66.38	4.121

Table 2. Components of genetic variance for plant height, seed yield, seed oil content, oil yield, and resistance to *Sclerotinia*-head rot

Components	Plant height	Seed Yield	Seed oil content	Oil yield	*Sclerotinia* -head rot
GCA	6.308	4841.395	0.160	797.59	4.691
F=0 Va	25.235	19365.582	0.641	3190.37	18.767
F=1 Va	12.617	9682.791	0.320	1595.18	9.383
F=0 Vd/Va	12.021	13.311	5.499	20.04	12.513
F=1 Vd/Va	6.010	6.656	2.753	10.02	6.256
SCA	75.838	64447.591	0.881	15983.72	58.713
F=0 Vd	303.355	257790.367	3.525	63934.87	234.852
F=1 Vd	75.838	64447.591	0.881	15983.72	58.713
GCA/SCA	0.083	0.075	0.181	0.049	0.079

Table 3. Average contributions (%) of the lines, testers, and their interactions to the expression of plant height, seed yield, seed oil content, oil yield, and resistance to *Sclerotinia*-head rot

Average Contribution	Plant height	Seed Yield	Seed oil Content	Oil yield	*Sclerotinia* -head rot
Lines	25.17	23.90	30.81	29.90	26.20
Testers	55.84	51.41	58.29	38.69	50.40
Lines/Testers	18.98	24.68	10.88	31.40	23.39