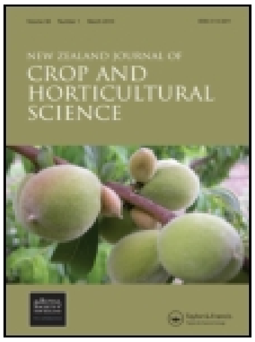

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Identification of inbred lines with superior combining ability for hybrid sunflower (*Helianthus annuus*) production in Turkey

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Abstract This research was conducted to estimate general and specific combining abilities for seed yield and certain yield components. Five female (CMS) lines and five male (restorer) lines were crossed resulting in 25 hybrids for determination of superior F1 sunflower (*Helianthus annuus*) hybrids using line × tester analysis. Based on the performance and gca, the parents CMS 11/2, CMS 47/1, RHA 68/4, and RHA 72/3 were found to be good general combiners. The crosses CMS11/2 × RHA68/4, CMS11/2 × RHA69/, CMS11/2 × RHA72/3, CMS46/2 × RHA72/3, and CMS47/1 × RHA71/1 gave the highest yields in the experiment, and in addition, CMS11/2 × RHA68/4 showed significant specific combining ability for seed yield. Three other crosses also revealed positive specific combining ability for other characters.

Keywords cross combinations; gca variances; gene interactions; seed yield

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INTRODUCTION

The selection of suitable parents for hybridisation is one of the most important steps in a hybridisation programme. Combining ability studies are frequently used by breeders to evaluate parents and their crosses for a number of objectives. Heterotic performance of a hybrid combination depends upon combining abilities of its parents (Kadkol et al. 1984). Thus, combining ability of parental lines is the ultimate factor determining future usefulness of the lines for hybrids and synthetics. The gca and sca provide an estimate for additive and non-additive gene actions, respectively (Sprague & Tatum 1942). Many breeders indicate that the variance of both gca and sca were significant for all characters in sunflower (*Helianthus annuus* L.) (Kadkol et al. 1984; Pathak et al. 1985). Kovacik & Skaloud (1972) and Setty & Sing (1977) suggested that parents for sunflower crosses should be chosen based on sca variances whereas Sindagi (1979) argued that gca variance was a more effective criterion than sca variance for producing high-yielding sunflower hybrids. Therefore several techniques have been developed for the evaluation of varieties or lines in their genetic makeup. Using a broad-based genotype as a tester, the general combining ability of lines is tested by the topcross method. Line × tester analysis is an extention of this method in which several testers are used (Kempthone 1957). This design thus provides information about the general and specific combining ability of parents and at the same time it is helpful in estimating various types of gene effects (Sing & Chaudhary 1977).

Turkey is one of the major areas for producing oil-type sunflowers. Sunflowers can be grown in various regions in Turkey and Bursa is one of the major production centres, with the Trakya-Marmara region having very suitable climatic conditions. Efforts have been made by sunflower breeders at Uludag University in Turkey to identify promising parents and high-yielding specific cross combinations to develop new F1 cultivars with the aims of increasing seed yield, oil content, and resistance to *Orobanche* species (Goksoy et al. 2001).

The aim of this study was to use line × tester analysis to estimate general and specific combining abilities of sunflower lines, improved by Uludag University, to determine superior F1 hybrids and to select parental lines having good combining abilities.

MATERIALS AND METHODS

Five cytoplasmic male sterile lines, CMS 11/2, CMS 12/1, CMS 12/2, CMS 46/2, CMS 47/1, and five fertility restorer lines, RHA 68/4, RHA 69/1, RHA 70/3, RHA 71/1 RHA 72/3, improved by Uludag University were crossed in 2000. Seed from each of the resulting 25 F1 populations were planted in a randomised complete block design with 3 replications at Bursa (Turkey) on 15 April 2001. Each replication was composed of two rows, 8 m in length with a spacing of 70 × 30 cm for parents and hybrids and plot area was 11.2 m^2. One hundred and twenty kg nitrogen (N) and 60 kg phosphate (P_2O_5) and potash (K_2O) per ha were applied. Trifluralin was sprayed for weed control. Sunflowers were grown without irrigation. Cultivation and other practices were done according to local agronomic practise (Turan & Goksoy 1998).

Observations were recorded on 20 plants randomly selected in each replication for plant height, head diameter, seed weight per head, 1000-seed weight, and seed yield per ha. Plot means were used for the statistical analysis for all characters. Line × tester analysis was used to estimate combining abilities and estimate general and specific combining abilities of parental lines and crosses (Singh & Chaudhary 1977).

RESULTS

Combining ability variances

Analysis of variance for combining ability revealed that the differences among the parents were highly significant for all of the characters, except head diameter and 1000-seed weight for the lines (Table 1). Interactions between lines and testers were highly significant for all the traits with the exception of plant height and 1000-seed weight (Table 1). High gca variances for plant height (Table 2) and high sca variances for seed yield, seed weight per plant, head diameter, and 1000-seed weight (Table 3) were observed in this study.

Table 1 Analysis of variance for combining ability (mean squares).

Source	d.f.	Plant height (cm)	Head diam. (cm)	Seed weight/plant (g)	Seed yield (kg/ha)	1000-seed weight (g)
Lines	4	237.2 $P \leq 0.05$	4.55	432.4 $P \leq 0.01$	5592.0 $P \leq 0.01$	153.5
Testers	4	317.6 $P \leq 0.01$	13.90 $P \leq 0.01$	464.4 $P \leq 0.01$	2093.4	704.2 $P \leq 0.01$
Lines × Testers	16	63.8	4.97 $P \leq 0.01$	159.5 $P \leq 0.01$	2641.8 $P \leq 0.05$	75.2
Error	48	42.2	2.25	83.9	1283.3	66.0

Table 2 Estimate of general combining ability effects of the parents.

Parent	Plant height (cm)	Head diam. (cm)	Seed weight/plant (g)	Seed yield/ha	1000-seed weight (g)
Line					
CMS 11/2	3.27	0.13	–0.76	23.32 $P \leq 0.05$	–1.49
CMS 12/1	–0.82	0.68	–2.03	–20.87 $P \leq 0.05$	3.35
CMS 12/2	–5.22 $P \leq 0.01$	0.30	9.37 $P \leq 0.01$	–12.41	3.47
CMS 46/2	–1.84	–0.40	–2.56	–7.43	–3.39
CMS 47/1	4.61 $P \leq 0.01$	–0.70	–2.60	17.39	–1.94
Tester					
RHA 68/4	5.59 $P \leq 0.01$	–0.39	6.71 $P \leq 0.01$	6.09	11.74 $P \leq 0.01$
RHA 69/1	–6.45 $P \leq 0.01$	–0.29	–0.49	–14.12	–5.79 $P \leq 0.01$
RHA 70/3	0.01	–0.80 $P \leq 0.05$	–3.49	1.84	–2.99
RHA 71/1	–1.96	–0.19	–6.96 $P \leq 0.01$	–9.14	–2.68
RHA 72/3	2.81	–1.67	4.23	15.33	–0.28

Table 3 Estimates of specific combining ability (sca) effects of the crosses and mean values (M).

Crosses	Plant height (cm) M	Plant height (cm) sca	Head diam. (cm) M	Head diam. (cm) sca	Seed weight/head (g) M	Seed weight/head (g) sca	Seed yield (kg/ha) M	Seed yield (kg/ha) sca	1000-seed weight (g) M	1000-seed weight (g) sca
CMS 11/2 × RHA 68/4	166.9ad	–1.15	17.9ei	–0.38	60.3ad	4.56	2765a	48.83 $P \leq 0.05$	72.9ab	3.32
CMS 11/2 × RHA 69/1	158.1af	5.09	18.4ci	–0.02	50.0cj	1.43	2392ab	31.77	54.2ei	2.12
CMS 11/2 × RHA 70/3	161.7ae	2.27	17.8fi	–0.07	40.1gj	–5.50	2094bg	–14.06 $P \leq 0.05$	50.7fi	–4.12
CMS 11/2 × RHA 71/1	155.7bg	–1.70	17.4gi	–1.11	37.3 ij	–4.77	1592eh	–53.28 $P \leq 0.05$	49.9gi	–5.28
CMS 11/2 × RHA 72/3	157.7af	–4.51	21.9a	1.56	57.0 bf	3.69	2236ad	–13.26	61.5bh	3.96
CMS 12/1 × RHA 68/4	155.2cg	–5.76	20.3ae	1.41	66.0 a-b	11.49	1378h $P \leq 0.05$	–45.73 $P \leq 0.05$	78.8a	4.39
CMS 12/1 × RHA 69/1	147.7fi	–1.18	17.6gi	–1.37	39.0 hj	–8.30	159.3eh	–4.00	48.5hi	–8.42
CMS 12/1 × RHA 70/3	159.9ae	4.59	17.3gi	–1.18	45.0 ej	0.69	2033bg	24.10	65.9ae	6.27
CMS 12/1 × RHA 71/1	158.6af	5.19	20.4ad	1.38	36.0 j	–4.84	1751dh	6.87	63.3bf	3.29
CMS 12/1 × RHA 72/3	155.3bg	–2.85	20.7ac	–0.25	53.0 bh	0.96	2115bf	18.76	56.9di	–5.52
CMS 12/2 × RHA 68/4	161.9ae	5.44	17.1hi	–1.35	53.3 bh	–12.57	2003bg $P \leq 0.05$	8.32	71.2ac	–3.33
CMS 12/2 × RHA 69/1	144.1hi	0.41	20.2af	1.66	73.0a	14.29	1565fh $P \leq 0.01$	–15.25	58.7ci	1.66
CMS 12/2 × RHA 70/3	151.7ei	0.79	18.3ci	0.21	58.3ae	2.63	2031bg	15.38	62.3bg	2.48
CMS 12/2 × RHA 71/1	145.7gi	–3.24	19.0bh	0.34	50.0cj	–2.24	189bh	12.85	58.3ci	–1.85
CMS 12/2 × RHA 72/3	151.2ae	–2.58	19.7ag	–0.82	61.3ac	–2.11	179.8ch	–21.63	63.6bf	1.05
CMS 46/2 × RHA 68/4	159.5ae	–0.44	17.5gi	–0.25	51.3bi	–2.64	1973bg	0.36	63.1bg	–4.56
CMS 46/2 × RHA 69/1	142.i	–5.86	17.9ei	0.02	41.0gj	–5.77	1512gh	–25.47	53.6ei	3.46
CMS 46/2 × RHA 70/3	153.1dh	–1.25	16.3i	–1.04	44.7ej	0.89	1710dh	–21.63	47.9i	–4.97
CMS 46/2 × RHA 71/1	152.6ei	0.28	18.1di	0.12	44.7 e-j	4.36	1969bg	15.24	53.7ei	0.41
CMS 46/2 × RHA 72/3	164.4ac	7.27	20.9ab	–1.04	54.7bg	3.16	2376ac	31.50	61.3bg	5.65
CMS 47/1 × RHA 68/4	168a	1.91	18.0di	0.56	51.7bi	–0.84	2099bf	–11.81	69.3ad	0.16
CMS 47/1 × RHA 69/1	156.7bf	2.36	17.3gi	–0.29	43.7ej	–1.64	2145bf	12.94	52.8ei	1.20
CMS 47/1 × RHA 70/3	154.4 ch	–6.40	19.1bh	2.06 $P \leq 0.05$	43.0fj	0.69	2137bf	–3.79	54.7ei	0.33
CMS 47/1 × RHA 71/1	158.3 af	–0.52	16.9hi	–0.71	46.3dj	7.49	2248ad	18.28	58.1ci	3.42
CMS 47/1 × RHA 72/3	166.2 ab	2.66	17.9ei	–1.61	44.3ej	–5.70	2154be	–15.59	51.9fi	–5.15
Mean of hybrids	156.1		18.5		49.8		1982		59.3	
SE		3.75		0.87		5.29		20.68		4.69

Effect of combining abilities of the parents and crosses

The comparative analysis of gca effects of the parents is shown in Table 2. In our breeding objectives, increased height was considered to be undesirable but increased head diameter, seed weight per plant, seed yield, and 1000-seed weight to be desirable. Given these objectives, two parents (CMS 11/2 and CMS 12/2) could be categorised as having "good gca" because their gca effects for each trait were desirable or insignificant. Four "poor gca" parents had only undesirable or insignificant gca effects—CMS 12/1, CMS 47/1, RHA 70/3, and RHA 71/1. "Mixed gca" parents (RHA 68/4 and RHA 69/1) had a combination of desirable and undesirable gca effects and "average gca" parents (CMS 56/2 and RHA 72/3) had only statistically insignificant effects.

Data on the specific combining ability effects of hybrids for all of the characters are presented in Table 3. The hybrid CMS 11/2 × RHA 68/4 produced the highest yield and also showed the only significant positive sca effects for seed yield. Other high yielding hybrids, including CMS 11/2 × RHA 69/1, CMS 46/2 × RHA 72/3 were found with high seed yield per plant, large head diameter, large numbers of seed, and high 1000-seed weight.

Three good gca crosses, CMS 11/2 × RHA 68/4 and CMS 12/2 × 'RHA 69/1 and CMS 47/1 × RHA 70/3, each had significant desirable sca effects for one yield-related trait. Three "poor sca" crosses, CMS 11/2 × RHA 70/3, CMS 11/2 × RHA 71/1, and CMS 12/2 × RHA 68/4, each had significant undesirable effects for one yield-related trait. One "mixed sca" cross, CMS 12/1 × RHA 68/4, had one significant undesirable and one significant desirable sca effect. The remaining "average sca" crosses had no significant sca effects.

DISCUSSION

The ratio of gca to sca variances were lower than 1 for all characters except plant height (data not shown). High sca variances were found for head diameter, seed weight per head, and seed yield. This is in accordance with the studies conducted by Pathak et al. (1985) and Kovacik & Skaloud (1972) that reported a significant sca effect for seed yield and certain plant characters.

Interestingly, none of the three good gca cross combinations, were produced by two good gca parents. Two came from crossing a good with a mixed gca parent, and the third from crossing a poor and an average gca parent. This indicates that all the types of gene interaction were involved in obtaining parental combinations with good specific combining ability.

The development of inbred lines with increased genetic value is a long-term process. To increase efficiency, breeders select among the available inbred lines before final test crossing. This selection is frequently made on the basis of gca. The data presented here show that variation in gca exists among the inbred sunflower lines developed by the sunflower breeding programme at Uludag University. Selection among lines based on gca should therefore be possible. This study and a previous study (Goksoy et al. 2000) identified lines with superior gca from among the inbred lines. Future inbred improvement efforts will focus on these superior lines. However, this study also reveals a limitation of selection based primarily on gca; some of the cross combinations with significant positive sca involved parents with average or mixed gca for traits of interest. Until heterotic groups are more clearly identified in this breeding population for this environment, it will be important to test as many combinations possible.

In Turkey, a short-term objective is making improved F1 cultivars available to farmers. We plan to use the cross combinations identified in the present study as having good sca to generate larger F1 populations for the testing necessary before the release of new F1 cultivars. These promising F1 cultivars will be compared with existing commercial cultivars for oil quality, resistance to *Orobanches*, and yield stability in multiple years and locations.

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