Studies on general and specific combining abilities in sunflower

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ABSTRACT

Understanding the genetic basis and mode of gene(s) action for grain yield and important agronomic traits of sunflower would facilitate the improvement of sunflower production in Iran. The objectives of this study were to determine the mode of gene action, the general combining ability (GCA) and specific combining ability (SCA) for seed yield and important agronomic traits in the F_1 generation of Iranian sunflower hybrids. An experiment with four male sterile testers, four Rf-lines, and their 16 F_1 hybrids were carried out at the Experimental Field of Seed and Plant Improvement Institute (SPII) at Karaj, Iran in 2007. The trials were arranged in a randomized complete block design with two replicates. Results showed that variance due to the GCA of the males was significant for plant height, 1000 seed weight, oil content and vegetation period characteristics. Variance due to the general combining ability of the females was significant for vegetation period, plant height, oil content and seed yield. Highly significant positive or negative effects were recorded for agronomic characters in several hybrid combinations. The GCA/SCA ratio in the F_1 generation was lower than 1, indicating that the non-additive component of genetic variance (dominance and epistasis) made a larger contribution to total genetic variance for seed yield than the additive one. The contribution of the non-additive component of genetic variance in the expression of seed oil content was higher than that of the additive one. Understanding the genetic control of traits in newly released hybrids with good agronomic characteristics would facilitate the efficiency of sunflower breeding programs.

Key words: GCA – gene effect – inheritance – SCA – sunflower.

INTRODUCTION

A sunflower breeding program was started during late 1970's at the Oil Crops Research Department of Seed and Plant improvement Institute (SPII), with the cooperation of the Field and Vegetable Crops Institute at Novi Sad, Serbia. Some sunflower hybrids have been introduced by the Oil Crops Research Department at SPII during the last forty years. Now, we are going to release the new generation of Iranian sunflower hybrids. A large number of researchers have studied the general (GCA) and specific combining abilities (SCA) of agronomic traits, mode of gene action and the inheritance of important traits, as reviewed and summarized by Škorić et al. (2007).

MATERIALS AND METHODS

Plant materials consisted of four new Rf-lines (RF81-154/2, RF81-R27/2, RF81-R125/1 and RF81-R131/1) and and four male sterile A-lines (AF81-48, AF81-166, AF81-226 and AF81-222). Hybrid combinations of the A-sterile lines and the Rf testers were produced under cages to obtain genetically pure material.

Comparative trials with four A-sterile lines, four Rf testers, and their 16 F_1 hybrids were carried out at the Experimental Field of the Seed and Plant Improvement Institute (SPII) at Karaj, Iran in 2007. The trials were arranged with a randomized complete block design in two replicates with a net plot of 40 plants. All observations and measurements were made during the growing season of 2007.

Analysis of variance for grain yield of parents and F_1 hybrids was performed according to the analysis of the combining abilities using the line x tester method suggested by Singh and Chaudhary (1976).

RESULTS AND DISCUSSION

Analysis of variance showed that the genotypes differed significantly for all the characters (P<0.01) (Table 1). The mean squares due to parents also differed significantly (P<0.01), indicating a great deal of diversity among them. Highly significant differences (P<0.01) were also observed for the variance components, viz. parents vs. crosses for all characters. These results showed the expression of heterosis for above mentioned characters. The variance due to the GCA of the males was highly significant for growing period, plant height, 1000 seed weight and oil content. Variance due to the GCA of females was highly significant (P<0.01) for vegetation period, plant height and oil content. Lines x testers effects were non significant for all of the characters except for oil content, which was significantly different (P<0.05).

Table 1. Analysis of variance for combining ability on different traits

Sources of variation	df	Mean squares				
		Growing period	Plant height	1000 seed weight	Seed yield	Oil content
Replications	1	3.056ns	91.230ns	117.480 *	0.840ns	0.565 ns
Genotypes	23	159.827**	1151.569**	314.448 **	2.158 **	15.498 **
Parents	7	137.252**	1129.110**	651.422 **	1.978 **	17.314 **
Parents vs. crosses	1	153.495**	8497.568**	1321.837 **	26.131 **	48.741 **
Crosses	15	170.785**	672.317**	90.035 **	0.644*	12.434 **
Lines	3	68.886**	1845.128**	282.759 **	0.608 ns	23.607 **
Testers	3	742.382**	980.135**	76.123 **	0.916 ns	29.511 **
Lines x Testers	9	14.219ns	178.775ns	30.430ns	0.565 ns	3.017 *
Error	23	15.109	200.875	27.207	0.274	1.118

ns,*, ** Nonsignificant, significant at 5% and 1 % level, respectively

Among the A lines (females), the shortest plant height was observed in AF81-166 (131.18 cm) and the tallest in AF81-266 (165.29 cm). Of the Rf testers (males), RF81-27.2 was the shortest (131.50 cm) and RF81-154/2 the tallest one (156.49 cm). Regarding seed yield, the lowest-yielding A-line was AF81-166 with 2.656 t/ha, while the high-yielding one was AF81-48 with 3.255 t/ha. Among the Rf testers, RF81-R27/2 had the lowest and RF81-125/1 the highest seed yield (2.700 and 3.503 t/ha, respectively). The lowest seed oil content among the A lines was found in AF81-226 (39.88%) and the highest in AF81-222 (43.63%). Among the Rf testers, the lowest value was recorded in RF81-27/2 (40.42%) and the highest in RF81- R131/1 (44.11%).

Analysis of the combining abilities for plant height revealed significant differences (P<0.05) between the Rf-lines (males) and A lines (females) with respect to GCA. The most prominent negative effect of the GCA for plant height was found in the Rf-lines RF81-R27/2, while the most prominent positive effect was observed in RF81-154/2. In the A lines, the most prominent negative and positive effects of the GCA for this trait were recorded in AF81-166 and AF81-226, respectively (Table 2).

Table 2. Value and general combining ability effects of the parents on different traits

	Growing period		Plant height		1000 seed weight		Seed yield		Oil content	
	Days	GCA	cm	GCA	gr	GCA	t/ha	GCA	%	GCA
Lines										
A F81-48	106.35	4.320	139.81	-7.902	56.77	-4.505	3.255	0.189	43.31	0.898
A F81-166	101.37	-0.653	131.18	-16.537	57.61	-3.664	2.656	-0.409	42.81	0.406
A F81-226	100.09	-1.941	165.29	17.575	69.77	8.498	3.164	0.099	39.88	-2.527
A F81-222	100.30	-1.725	154.58	6.864	60.95	-0.329	3.187	0.122	43.63	1.223
Testers										
RF81-154/2	106.16	4.135	156.49	8.772	64.37	3.097	3.118	0.053	41.10	-1.305
RF81-R27/2	87.62	-14.408	131.50	-16.214	63.48	2.206	2.700	-0.365	40.42	-1.986
RF81-R125/1	106.47	4.447	151.32	3.604	58.73	-2.550	3.503	0.438	44.11	1.698
RF81- R131/1	107.85	5.825	151.55	3.837	58.52	-2.753	2.940	-0.125	44.00	1.593
SE GCA / lines and testers		1.374		5.011		1.844		0.185		0.374
SE (Gi-Gj) / lines and testers		1.943		7.087		2.608		0.262		0.529

As the number of testers and lines were equal, SE for GCA and (Gi-Gj) were the same for both lines and testers.

Regarding the SCA for plant height, highly significant (P<0.01) positive effects were recorded in several hybrid combinations, most notably in AF81-48 x RF81-125/1 and AF81-222 x RF81-27/2. Highly significant (P<0.01) negative values of the SCA for plant height were also found in several combinations, most notably in AF81-226 x RF81-27/2 and AF81-48 x RF81-125/1. The GCA/SCA ratio for plant height was less than 1, namely 0.328 (Table 4). These results were in agreement with those of Škorić et al. (2000), although not in full agreement with Tiagi (1988), Mihaljevic (1988) and Ortegon et al. (1992), who reported an equal effect for GCA and SCA in plant height. On average, the female parents made the largest contribution (54.89.8%) to the expression of plant height in the F_l hybrids. The contributions of the Rf-lines and line x tester interactions were less significant (Table 5).

Table 3. Mean value and specific combining ability effects of the crosses on different traits

	Testers	RF81-154/2		RF81-R27/2		RF81-R125/1		RF81- R131/1	
	lines	value	SCA	value	SCA	value	SCA	value	SCA
Growing period (Days)	A F81-48	113	2.40	93	1.04	109	-1.7	110	-1.74
	A F81-166	106	0.10	88	0.75	104	-1.86	108	1.02
	A F81-226	100	-3.98	86	-0.09	105	0.82	109	3.25
	A F81-222	106	1.49	84	-1.71	108	2.74	104	-2.53
	SE for SCA				2.749				
	SE(Sgi-Sgj)				3.887				
Plant height (cm)	AF81-48	139.64	-8.94	125.51	1.91	157.79	14.38	136.31	-7.34
	AF81-166	144.22	4.27	113.01	-1.96	129.95	-4.84	137.54	2.52
	AF81-226	181.64	7.58	138.46	-10.62	169.55	0.66	171.51	2.38
	AF81-222	160.44	-2.91	149.03	10.67	147.99	-10.19	160.86	2.44
	SE for SCA				10.022				
	SE(Sgi-Sgj)				14.173				
1000 seed weight (gr)	AF81-48	59.68	-0.18	59.14	0.17	56.56	2.34	51.70	-2.32
	AF81-166	55.85	-4.86	60.11	0.29	59.63	4.57	54.86	0.00
	AF81-226	75.80	2.92	71.53	-0.45	66.91	-0.32	64.87	-2.15
	AF81-222	66.17	2.12	63.15	-0.01	51.81	-6.59	62.67	4.47
	SE for SCA				3.688				
	SE(Sgi-Sgj)				5.216				
Seed yield (t/ha)	AF81-48	3.334	0.03	2.254	-0.64	4.524	0.83	2.907	-0.22
	AF81-166	2.370	-0.34	2.318	0.03	2.846	-0.25	3.090	0.56
	AF81-226	3.493	0.28	2.695	-0.10	3.422	-0.18	3.045	0.01
	AF81-222	3.275	0.04	3.534	0.71	3.222	-0.40	2.717	-0.34
	SE for SCA				0.370				
	SE(Sgi-Sgj)				0.523				
Oil content (%)	AF81-48	40.83	-1.17	42.12	0.80	45.09	0.09	45.18	1.08
	AF81-166	40.99	-0.52	42.37	1.54	43.48	-1.03	44.42	0.58
	AF81-226	38.37	-0.20	37.14	-0.76	42.57	1.00	41.44	-2.54
	AF81-222	44.22	1.89	40.06	-1.59	45.27	-0.05	44.97	0.88
	SE for SCA				0.748				
	SE(Sgi-Sgj)				1.057				

The mean squares of treatments, parents, parents vs. crosses in the variance analysis for seed yield were highly significant (P<0.01) and for crosses they were significant (P<0.05). Highly significant (P<0.01) positive effects of the GCA for seed yield (t/ha) were observed in the A line AF81-48 and the Rf line RF81-125/1. Highly negative (P<0.01) effects for seed yield were found in lines AF81-166 and RF81-27/2 (Table 2). Results of analysis of the SCA effects of the inbred lines in the F_l hybrids showed that the highest positive values for seed yield were achieved by the following combinations: AF81-48 x RF81-125/1 and AF81-222 x RF81-27/2 (Table 3). The highest negative values of the SCA for seed yield were recorded in the combination AF81-48 x RF81-27/2. The GCA/SCA ratio for this trait in the F_l generation was lower than 1 (0.01), indicating that the non additive component of genetic variance (dominance and epistasis) made a larger contribution to total genetic variance for seed yield than the additive one (Table 4). A similar relationship was established in the studies of Škorić et al. (2000), Sindagi et al. (1996) and Farrokhi (2003). The average contribution of the testers, lines and lines x testers was 16.91%, 62.81%, and 20.28%, respectively (Table 5).

The highest positive GCA value for seed oil content was achieved by the lines RF51-125/1 and RF81-131/1. The highest negative values were those of AF81-226 and RF81-27/2 (Table 2). The highest positive SCA values for seed oil content were recorded in AF81-222 x RF81-154/2 and AF81-166 x RF81-27/2, while the highest negative ones were found in the combinations RF81-131/1 x AF81-226 and RF81-27/2 x AF81-228. The GCA/SCA ratio for seed oil content was less than 1, namely 0.2 (Table 4). Also, the other components of genetic variance showed that the contribution of the non additive 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 28.46% (Table 5). The same results were reported in oil content by Škorić et al. (2000), but the results of Farrokhi (2003) showed additive gene effects.

Table 4. Components of genetic variance for different traits

		VA	VD	VD/VA	GCA	SCA	GCA/SCA
Growing period	F = 0	32.618	6.664	0.204	8.154	6.664	1.224
	F = 1	16.309	13.328	0.817			
Plant height	F = 0	102.821	78.337	0.762	25.705	78.337	0.328
	F = 1	51.411	156.674	3.047			
1000 seed weight	F = 0	12.418	16.827	1.355	3.104	16.827	0.184
	F = 1	6.209	33.654	5.420			
Seed yield	F = 0	0.016	0.428	26.750	0.004	0.428	0.010
	F = 1	0.008	0.857	107.125			
Oil content	F = 0	1.962	2.458	1.253	0.490	2.458	0.200
	F = 1	0.981	4.917	5.012			

The highest positive value of the GCA for vegetation period was found in RF81-131/1 and AF81-48. Significant ($P<0.05$) negative GCA values for this trait were found in RF81-27/2 (Table 2). The combination AF81-226 x RF81-131/1 had the highest positive and AF81-226 x RF81-154/2 the highest negative value of the SCA for this trait (Table 3). The GCA/SCA ratio for vegetation period was higher than 1, meaning that additive gene action played a considerably more important role in the inheritance of vegetation period than non additive gene action (Table 4). The average contributions to the expression of the vegetation period were as follows: tester lines 86.94%, A lines 8.07%, and tester x lines 5% (Table 5).

Table 5. Average contributions (%) of the lines, testers, and their interactions to the expression of different traits

Average Contribution	Growing period	Plant height	1000 seed weight	Seed yield	Oil content
Lines	8.07	54.89	22.84	62.81	18.88
Testers	86.94	29.16	12.93	16.91	28.46
Lines x testers	5.00	15.95	64.23	20.28	52.67

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