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Determination of Combining Ability in Sunflower Parents According to Line X Tester Analysis Method

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ABSTRACT

In this research, which including two cytoplasmic male sterile female (CMS) lines and six recessives branching male tester parent (RfRf), 12 hybrids (F_1) were obtained by crossing the female and male lines in the Plant Breeding Greenhouse of Field Crops Department in 2018-19 winter period. Field trial was carried out in 2019 as four replications. Plant height (cm), head diameter (cm), 100 seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) were investigated. Multiple sequence variance analysis, general and specific combining abilities, proportional relationships of some genetic parameters, heterosis and heterobeltiosis values, narrow and broad heritability were calculated. In conclusion, in this research; some of their agricultural characteristics and heritability were determined upon obtaining high yield sunflower lines. Considering the general combination abilities of parents for F1 generation, R31 was identified as appropriate parents for plant height; R02 for head diameter; R02 for 100 seed weight; R61 and R80 for yield seed yield and oil yield; and R61 for yield content. Considering the special combination abilities of hybrids in F1 generation, all hybrids were found to be significant and positive for plant height, 100 seed weight and oil content. RAM-1 X R80, RAM-19 X R61, RAM-1 X R31, RAM-19 X R71 and RAM-19 X R02 hybrids were found to be significant and positive for yield seed yield and oil yield.

1. Introduction

In Turkey, hybrid seeds are used in sunflower oil production, and hybrid varieties are preferred by producers due their features such as high yield performance, superior quality characteristics, uniform appearance, resistance to certain diseases and orobanche (Kaya et al., 2009). Therefore, breeding programs in sunflower in the world are generally directed towards hybrid breeding (Khan et al. 2004; Dagustu et al. 2012). In these breeding programs, the target is to obtain, to develop inbred lines with properties such as high seed yield and oil content, hence high oil yield, earliness, resistance to diseases and pests and so on, and to obtain hybrids with desired performance through them taking advantage of hybrid overgrowth (Vear, 2016). However, it is also very important that these bred lines maintain their superior performance under different environmental conditions. Therefore, knowing the factors affecting the oil yield, yield elements that play a decisive role and the relationships between, in the sunflower, which is an oil crop plant, will provide great benefit to the breeders in achieving the desired goals (Todorova, 1984; Kaya et al., 2009; Gontcharov, 2012).

By using heterosis effect in hybrid breeding, seed and oil yield is increased (Vranceanu 1998). In addition, hybrid sunflower is more stable than open pollinated varieties, highly auto-fertile and quite uniform in ripening. The high performance of hybrid combinations depends on the ability of the parents to combine. Breeders have been working on combining ability for many reasons. Some of these are: development of superior synthetics or hybrids, and planning of breeding programs by determining gene effects in terms of some properties of the material studied (Tan, 1993).

The Line x Tester analysis method provides breeders with a systematic approach to selection of parents for crossbreeding and enables them to crossbreed between superior parents to achieve the desired properties. At the same time, it can help breeders choose the most effective breeding method that can be used since it allows the estimation of different genetic parameters (Bozbek, 2006). It has been modified from the top crosses method proposed

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by Kempthorne (1957) by Line x tester analysis and this method can be used as a suitable method in hybrid breeding where particularly cytoplasmic vicious and restorer lines play a role as parents (Singh and Chaudhary, 1977; Yildirim and Büyükbaykal, 1980; Yildirim and Cakir, 1986; Tan, 1993).

In the line x tester analysis, hybridizations are performed in all possible combinations with a group of tester parents which are used as males and parents which are used as female. The F_1 hybrid generations obtained are repeatedly assayed (Turgut, 2003). Singh and Chaudhary (1977) stated that this method could be applied in a trial plan including and excluding parents.

This study was carried out to determine the parent (broodstock) and hybrids having superior general and special combination ability in two main lines and six male testers and their 12 F_1 hybrids.

2. Materials and Methods

The research was carried out in Experimental Field of Selcuk University Faculty of Agriculture in Konya in 2019. 12 hybrids (F_1) to be used in the study were obtained using two cytoplasmic male sterile (CMS) main lines developed by Assoc. Prof. Dr. Rahim ADA (RAM-1 and RAM-19) and six recessives branching male (RfRf) testers (R02, R06, R31, R61, R71 and R80) by hybridization of female (CMS) and male (Restorer) lines in the Plant Breeding Greenhouse of Field Crops Department in 2018-19 winter period. The hybrids obtained were RAM-1xR02, RAM-1xR06, RAM-1xR31, RAM-1xR61, RAM-1xR71, RAM-1xR80, RAM-19xR02, RAM-19xR06, RAM-19xR31, RAM-19xR61, RAM19xR71 and RAM19xR80.

According to the Randomized Blocks Experimental Design, each row was accepted as one block in the field experiment established with four replications. The distance between blocks was 2 m, the width of rows was 25 cm and the length of the rows was 3 m; and each block is 2.1 m^2.

The soil of the trial area had a clay loam structure and its pH was slightly alkalic (7.70) and was low in organic matter (1.39%). These soils, having high lime content (691.5 kg ha^{-1}), had low phosphorus level (13.4 kg ha^{-1}) and no salinity problems.

The cultivation process for the trial was carried out on 24th April 2019. 400 kg ha^{-1} 15-15-15 compound fertilizer and 150 kg ha^{-1} urea (46% N), as top fertilizer, were given along with the cultivation. The field was hoed 3 times depending on the weed condition. Drip irrigation was done 4 times depending on the water needs of the plants. Harvesting was completed in the third week of September. Plant height (cm), head diameter (cm), 100-seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) were investigated.

The data obtained from observation, measurement and analysis on F_1 plants in the research were subjected to preliminary variance analysis according to the Randomized Blocks Experimental Pattern in the "MSTAT-C Statistical Software" on PC. Multiple sequence (line x tester) analysis was performed on traits with a variation of 1% and 5% significance level between hybrids (Kempthorne, 1957; Sing and Chaudhary, 1979). Griffing (1956) was referred to in determining the effect and variance power of general and specific combining ability; Stansfield (1969), in determining the degree of inheritance; Fonseca and Pattersan (1968), in calculating the percentage values of heterosis and heterobeltiosis; Yurtsever (1984), in determining the relationships between traits.

Weather data of the experimental area

The weather data of the experimental area in 2019 with growing seasons for the sunflower with the long-term climatic data were depicted in Table 1. Data showed that the average temperature was 11,1°C, 19,7°C, 23,0°C, 24,3°C, 24,8°C and 21,0°C; whereas, the total amount of rainfall was 26,4 mm, 5,4 mm, 31,8 mm, 8,2 mm, 2,0 mm and 10,2 mm during the month of April, May, June, July, August and September, 2019 respectively (Table 1).

3. Results and Discussion

According to the average of the squares, the genotypes had a variation of 1% significance level for all traits examined. Parents also had a variation of 1% significance level except the oil yield. Plant height, seed yield and oil yield characteristics of hybrids were at 1% significance level, while the head diameter and 100 seed weight characteristics had a variation of 5% significance level. Parent x Hybrid Interaction, plant height (cm), head diameter (cm), 100 seed weight (g), seed yield (kg ha^{-1}), oil content (%) and oil yield (kg ha^{-1}) characteristics had a variation of 1% significance level. The lines had 1% significance level for seed yield and oil yield. The testers had a variation at %1 significance level for plant height, seed yield and oil yield, while head diameter and 100 seed weight had a variation at 5% significance level. Line x Testers Interaction had a variation at 1% significance level for seed yield and oil yield (Table 2).

Table 1
Weather data of the experimental areas (Konya)

The long-term*	April	May	June	July	August	September
Max. T. (ºC)	26,56	29,75	33,98	37,16	36,18	33,76
Min. T. (ºC)	2,12	6,82	11,18	15,6	15,64	9,94
Avg. T. (ºC)	13,2	17,22	21,45	25,68	25,22	20,94
T. Rain. (mm)	24,31	44,62	42,53	3,11	8,08	15,48
Humd. (%)	49,28	50,73	46,04	33,9	35,16	39,1
2019	April	May	June	July	August	September
Max. T. (ºC)	25,6	34,5	34,4	37,7	36,3	32,8
Min. T. (ºC)	0,5	6,9	14,5	14,1	15,4	8,2
Avg. T. (ºC)	11,1	19,7	23,0	24,3	24,8	21,0
T. Rain. (mm)	26,4	5,4	31,8	8,2	2,0	10,2
Humd. (%)	58,5	39,8	47,2	39,7	40,7	41,3

Anonymous,2020. General Directorate of Meteorology-Ankara. * 2010-2018.

Table 2
Sunflower F_1 hybrids examined for seed yield and some yield properties of the average number of squares calculated by multiple sequence analysis method

Source of Variations	DF	Plant Height	Head Diameter	100 Seed Weight
Replication	3	592.919	56.226	7.052
Genotypes	19	1098.474**	64.144**	16.152**
Parents	7	826.838**	11.468	5.990**
Crosses	11	255.547**	15.670*	3.221*
Parent x Cross Int.	1	12272.126**	966.084**	229.523**
Lines	1	83.240	0.043	5.434
Testers	5	457.888**	19.290*	5.014*
Line x Testers Int.	5	87.667	15.176	0.985
Error	57	94.386	6.663	1.535
Source of Variations	DF	Seed Yield	Oil Content	Oil Yield
Replication	3	1116.234	0.545	177.994
Genotypes	19	15050.549**	40.956**	2734.649**
Parents	7	3246.206**	32.233**	481.206*
Crosses	11	20108.185**	50.205**	3779.727**
Parent x Cross Int.	1	42046.955**	0.285	7012.890**
Lines	1	9600.920**	199.078**	5713.806**
Testers	5	9095.315**	39.401**	2200.790**
Line x Testers Int.	5	33222.508**	31.234**	4971.847**
Error	57	994.570	1.810	166.497

* : $p < 0.05$; ** : $p < 0.01$

Table 3
General combinations ability variance estimation (σ^2GKY), special combination ability variance estimation (σ^2ÖKY), additive variance (σ^2D), proportional relationships with dominance variance (σ^2H) for traits examined in Sunflower F1 hybrids

Specifications	□²GKY	□²ÖKY	□²GKY/ □²ÖKY	□²D	□²H	$(H/D)^{1/2}$
Plant Height	4.809	25.597	0.188	9.618	-1.680	0.418
Head Diameter	0.014	1.200	0.012	0.028	2.128	8.668
100 Seed Weight	0.064	0.526	0.122	0.128	-0.138	1.037
Yield	-375.671	4328.366	----	-751.341	8056.984	3.275
Oil Content	0.543	21.661	0.025	1.087	7.356	2.602
Oil Yield	-34.149	1055.012	----	-68.299	1201.337	4.194

3.1. Plant Height (cm)

In the research, it was observed that the average plant height of the parents ranged between 60.86 cm (R61) and 99.21 cm (R06), and the length of F_1 hybrids ranged between 87.74 cm (RAM-1 X R61) and 117 cm (RAM-1 X R31) (Table 4). It was found that the GCA variance for plant height was 4,809 and the SCA variance was 25,597 in F_1 hybrids (Head 2). In the study, when the plant height was examined for the plant height, RAM-1, RAM-19 and R61 varieties showed significant and negative ($p < 0.01$) GCA, R31 ($p<0.01$) varieties showed significant and positive, R80 ($p<0.05$) showed significant and positive GCA (Table 4). When the SCA effects of hybrids were examined in the F_1 generation, it was observed that all hybrids (p

<0.01) were genotypes with positive and significant SCA effect (Table 4). When Table 4 was analyzed, the average heterosis value determined in F_1 generation was 37.4% and the heterobeltiosis value was 24.40%. While none of the hybrids had statistically significant heterosis value in terms of this investigated feature, heterobeltiosis values of RAM-1 X R31, RAM-1 X R61, RAM-1 X R80, RAM-19 X R31, RAM-19 X R61 and RAM-19 X-R80 were statistically significant ($p<0.01$) and positive; and the values of RAM-1 X R02, RAM-19 X R02 and RAM-19 X R71 hybrids were significant ($p<0.05$) and positive (Table 4). Heterosis values ranged between 18.69% (RAM-19 X R06) and 62.41% (RAM-1 X R80), and heterobeltiosis values ranged between 5.84% (RAM-19 X R06) and 39.76% (RAM-19 X R80). In F_1 generation, the heritability level in the broad sense was 63.07 and the heritability level in the narrow sense was 30.50 for plant height. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. It is in agreement with the findings of some researchers (Goksoy et al., 1999; Tan, 1993).

Table 4
Sunflower Parent and F_1 Hybrids of plant height, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (cm)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	65.05	-27.635**			
RAM-19	77.72	-25.660**			
R02	86.56	-3.714			
R06	99.21	-1.077			
R31	88.57	9.253**			
R61	60.86	-12.408**			
R71	98.54	3.786			
R80	73.95	4.161*			
Hybrids					
RAM-1 X R02	101.63		33.942**	34.06	17.40*
RAM-1 X R06	106.03		37.171**	29.09	6.87
RAM-1 X R31	117.00		41.471**	52.32	32.10**
RAM-1 X R61	87.74		24.119**	39.36	34.87**
RAM-1 X R71	106.38		32.775**	30.05	7.95
RAM-1 X R80	112.88		41.067**	62.41	52.64**
RAM-19 X R02	104.13		34.641**	26.76	20.29*
RAM-19 X R06	105.00		33.171**	18.69	5.84
RAM-19 X R31	114.69		35.757**	37.94	29.50**
RAM-19 X R61	100.63		38.669**	45.22	29.47**
RAM-19 X R71	114.38		40.808**	29.78	16.07*
RAM-19 X R80	108.63		32.766**	43.24	39.76**
LSD %1 : 18.342	mean Hs % : 37.41	h^2 :	30.50	Lines	3.435
LSD %5 : 13.808	mean Hb % : 24.40	H^2 :	63.07	SH Testers	1.983
				SH (SCA)	4.858

3.2. Head Diameter (cm)

In the research, it was observed that the average head diameter ranged between 8.03 cm (R61) and 12.97 cm (RAM-1) in the parents, and between 14.08 (RAM-1 X R61) and 19.68 cm (RAM-1 X R02) in F_1 hybrids (Table 5). It was found that the GCA variance for plant height was 4,809 and the SCA variance was 25,597 in F_1 hybrids (Table 3). The fact that υ2GCA/υ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for head diameter showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3). In the experiment, when the GCA was examined for the head diameter, RAM-1, RAM-19 and R06 varieties showed significant and negative ($p<0.01$), R31 ($p<0.05$) varieties showed significant and negative, R02 ($p<0.01$) varieties showed significant and positive GCA (Table 5). When the SCA effects of the hybrids were examined, RAM-19 X R06 and RAM-19 X R31 ($p<0.05$) had positive and significant SCA, and all other hybrids except for the RAM-1 X R61 hybrid were genotypes that had significant ($p<0.01$) and positive SCA effect. (Table 5). When Table 5 was analyzed, the average heterosis value determined in F_1 generation was 58.16% and the heterobeltiosis value was 38.65%.

In terms of this characteristic examined, the heterosis values of RAM-1 X R02, RAM-19 X R02 and RAM-19 X R61 hybrids were significant ($p<0.01$) and positive; those of RAM-1 X R06, RAM-1 X R31, RAM-1 X R80, RAM-19 X R71 and RAM-19 X R80 hybrids are significant ($p<0.05$) and positive, the heterobeltiosis values of RAM-1 X R02, RAM-1 X R31, RAM-19 X R02, RAM-19 X R61, RAM-19 X R71 and RAM-19 X R80 hybrids were statistically significant ($p<0.01$) and positive, and those of RAM-1 X R06, RAM-1 X R71 and RAM-1 X R80 hybrids

were significant ($p<0.05$) and positive (Table 5). Heterosis values ranged between 32.25% (RAM-19 X R06) and 84.51% (RAM-19 X R61), and heterobeltiosis values, between 8.52% (RAM-1 X R61) and 63.02% (RAM-19 X R02). In F_1 generation, the heritability in the broad sense was 57.48 and the heritability in the narrow sense was 0.74 for head diameter. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. These results contradict the findings of some other researchers working on the same subject (Hussain et al., 2017; Tan, 1993). These different results may be due to different genetic conditions and environmental conditions used.

Table 5
Sunflower Parent and F_1 Hybrids head diameter, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (cm)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	12.97	-4.322**			
RAM-19	11.89	-4.277**			
R02	10.29	2.328**			
R06	9.67	-1.653**			
R31	8.68	-1.287*			
R61	8.03	-0.972			
R71	10.58	0.948			
R80	8.72	0.636			
Hybrids					
RAM-1 X R02	19.68		6.738**	69.17**	51,70**
RAM-1 X R06	16.84		6.936**	48.77*	29,82*
RAM-1 X R31	17.50		7.453**	61.64*	34,93**
RAM-1 X R61	14.08		2.571	34.03	8,52
RAM-1 X R71	17.42		5.105**	47.88	34,27*
RAM-1 X R80	17.50		5.531**	61.36*	34,93*
RAM-19 X R02	19.38		6.279**	74.75**	63,02**
RAM-19 X R06	14.25		3.426*	32.25	19,90
RAM-19 X R31	14.32		3.154*	39.25	20,49
RAM-19 X R61	18.38		8.245**	84.51**	54,61**
RAM-19 X R71	18.88		6.992**	68.02*	58,81**
RAM-19 X R80	18.17		6.358**	76.32*	52,84**

LSD %1 :	4.874	mean Hs % :	58.16	h^2:	0,74	SH (Lines) :	0,913
LSD %5 :	3.669	Mean Hb %	38.65	H^2:	57,48	SH (Testers)	0,527
						SH (SCA) :	1,291

3.3. 100 Seed Weight (g)

In this study, values of 100 seed weights of parents and F_1 hybrids are given in Table 6. In the study, the average weight of 100 seeds of the parents ranged from 2.15 g (R31) to 5.36 g (RAM-1), whereas the values in F_1 hybrids ranged from 5.51 g (RAM-1 X R31) to 8.02 g (RAM-19 X R02) (Table 6). It is seen that the variance of the GCA is 0.064 and the variance of SCA is 0.526 for 100 seed weights of F_1 hybrids (Table 3). The fact that υ2GCA/υ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for 100 seed weight showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3).

In the experiment, when the GCA was examined for the 100 seed weight, RAM-1, RAM-19 and R31 varieties among testers were significant ($p<0.01$) and negative GCA, R02 variety showed significant ($p<0.05$) and negative GCA (Table 6). When the SCA effects of the hybrids were examined, RAM-1 X R61 and RAM-19 X R31 hybrids were positive and significant ($p<0.05$), and all other hybrids were significant ($p<0.01$) and positive in F_1 generation (Table 6). When Table 6 was analyzed, the average heterosis value determined in F_1 generation is 70.22% and the heterobeltiosis value was 29.07%. In terms of this characteristic examined, the heterosis value of RAM-1 X R31 was significant ($p<0.05$) and positive; all the other hybrids were significant ($p<0.01$) and positive, the heterobeltiosis values of RAM-1 X R02, RAM-1 X R31, RAM-19 X R02 and RAM-19 X R71 were significant ($p<0.01$) and positive; and the heterobeltiosis values of RAM-19 X R06 and RAM-19 X R61 were significant ($p<0.05$) and positive (Table 6). Heterosis values were between 45.97% (RAM-1 X R71) and 101.57% (RAM-19 X R02), and heterobeltiosis values were between 2.75% (RAM-1 X R31) and 53.98% (RAM-19 X R02). In F_1 generation, the heritability in the broad sense was 52.33 and the heritability in the narrow sense was 34.22 for 100 seed weight. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was

high. It is in agreement with the findings of some researchers (Chandra et al., 2011; Göksoy et al., 1999; Tan, 1993).

Table 6
Sunflower Parent and F_1 Hybrids 100 seed weight averages, general combining ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents			Averages (cm)	GCA		SCA	Hs (%)	Hb (%)
RAM-1			5.36	-1.957**				
RAM-19			5.21	-1.452**				
R02			2.75	1.134**				
R06			2.79	0.287				
R31			2.15	-1.301**				
R61			2.59	-0.161				
R71			3.17	0.172				
R80			2.85	-0.132				
Hybrids								
RAM-1 X R02			7.88			2.892**	94.27**	46.95**
RAM-1 X R06			6.95			2.503**	70.51**	29.65
RAM-1 X R31			5.51			2.167**	46.69*	2.75**
RAM-1 X R61			5.80			1.417*	45.97**	8.21
RAM-1 X R71			6.30			1.744**	47.57**	17.44
RAM-1 X R80			6.44			2.238**	56.83**	20.09
RAM-19 X R02			8.02			2.409**	101.57**	53.98**
RAM-19 X R06			7.26			2.233**	81.32**	39.25*
RAM-19 X R31			5.52			1.511*	50.07**	6.00
RAM-19 X R61			7.51			3.021**	92.63**	44.15*
RAM-19 X R71			7.68			2.915**	83.24**	47.41**
RAM-19 X R80			6.93			2.219**	71.96**	33.01
LSD %1 :	2.339	*mean* Hs % :	70.22	h^2	34.22	SH (*Lines)*	0.438	
LSD %5 :	1.761	*Mean* Hb % :	29.07	H^2	52.33	SH (Testers)	0.253	
						SH (SCA)	0.620	

3.4. Seed Yield (kg ha^{-1})

In this study, values of yield seed yield of parents and F_1 hybrids are given in Table 7. In the research, it was observed that the average yield seed yield of the parents ranged between 1714.1 45 kg ha^{-1} (R31) and 2616.1 45 kg ha^{-1} (R06), and seed yield of F_1 hybrids ranged between 1684.5 kg ha^{-1} (RAM-1 X R71) and 4292.9 45 kg ha^{-1} (RAM-1 X R80) (Table 7). It was found that the GCA variance was -375.671 and the SCA variance was 4328.366 in F_1 hybrids for yield seed yield. The fact that υ2GCA/υ2SCA ratios were negative in F_1 hybrids examined for yield seed yield showed that the additive genes, i.e. dominant genes were effective on the heredity of this trait. (Table 3). In the experiment, when the GCA was examined for yield seed yield, RAM-1, RAM-19 and R31 varieties among testers showed significant ($p<0.01$) and negative GCA; R61 and R80 varieties showed significant ($p<0.01$) and negative GCA; and R31 variety showed significant ($p<0.05$) and negative GCA (Table 7). When the SCA effects of the hybrids were examined, it was found that all other hybrids except for RAM-1 X R61, RAM-1 X R71, RAM-19 X R31 and RAM-19 X R80 hybrids were genotypes that had significant ($p<0.01$) and positive SCA effect. (Table 7). When Table 7 was examined, it was found the average heterosis value determined in F_1 generation was 20.62%; the heterobeltiosis value was 13.99%. In terms of this trait, none of the hybrids had statistically significant heterosis values, whereas the heterobeltiosis values of RAM-1 X R31, RAM-1 X R80 and RAM-19 X R61 hybrids were positive and ($p<0.01$) significant, the value of RAM-1 X R71 hybrid was negative and significant ($p<0.01$); the value of RAM-19 X R02 was positive, and the value of RAM-19 X R31 was negative and significant ($p<0.05$). Heterosis values ranged between -28.25% (RAM-1 X R71) and 91.11% (RAM-1 X R80), and heterobeltiosis values, between -32.78% (RAM-1 X R71) and 74.05% (RAM-1 X R80). In F_1 generation, the heritability in the broad sense was 95.05 and the heritability in the narrow sense was 9.95 for yield seed yield (Table 7). The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. It is in agreement with the findings of some researchers (Gouri Shankar et al., 2007; Kang et al., 2013; Göksoy et al., 1999; Radić et al., 1977).

Table 7
Sunflower parent and F_1 hybrids Average seed yield, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (kg ha^{-1})	GCA	SCA	Hs (%)	Hb (%)
RAM-1	2222	-58.124**			
RAM-19	2407	-79.338**			
R02	2171	4.962			
R06	2616	-3.513			
R31	1714	-16.075*			
R61	2147	22.206**			
R71	2506	-53.122**			
R80	2466	45.543**			
Hybrids					
RAM-1 X R02	2633		56.974**	19.84	18.45
RAM-1 X R06	2931		105.180**	21.13	12.02
RAM-1 X R31	3269		162.824**	66.06	47.07**
RAM-1 X R61	2535		26.729	16.04	14.06
RAM-1 X R71	1685		-11.352	-28.75	-32.78**
RAM-1 X R80	4293		237.781**	83.11	74.05**
RAM-19 X R02	2965		129.617**	29.53	23.16*
RAM-19 X R06	2498		75.761**	-0.56	-4.52
RAM-19 X R31	1908		9.743	-7.40	-20.73*
RAM-19 X R61	3408		171.358**	49.64	41.54**
RAM-19 X R71	3669		159.221**	12.01	9.81
RAM-19 X R80	2822		-24.136	-13.15	-14.19
LSD %1 59.541	mean Hs %	20.62	h^2	9.95	SH (Lines)	11.150
LSD %5 44.823	Mean Hb %	13.99	H^2	95.05	SH (Testers)	6.437
					SH (SCA)	15.768

3.5. Oil Content (%)

In this study, values of oil content of parents and F_1 hybrids are given in Table 8. In the research, it was observed that the average oil content of the parents ranged between 3518% (R06) and 42.20% (R80), and oil content of F_1 hybrids ranged between 36.07% (RAM-19 X R06) and 48.11%(RAM-1 X R61) (Table 8). It was found that the GCA variance for oil content was 0.543 and the SCA variance was 21.661 in F_1 hybrids (Table 3). The fact that υ2GCA/υ2SCA ratios were below 1 and (H/D) 1/2 ratios were over 1 in F_1 hybrids examined for oil content showed that the non-additive dominant gene was effective on the heredity of this trait (Table 3).

In the experiment, when the GCA was examined for the oil content, RAM-1, RAM-19 and R06 varieties showed significant ($p < 0.01$) and negative GCA, R02 and R61 varieties showed significant ($p<0.01$) and negative GCA (Table 8). When the SCA effects of hybrids were examined in the F_1 generation, it was observed that all hybrids were genotypes with positive and significant ($p < 0.01$) SCA effect (Table 8). When Table 8 was analyzed, the average heterosis value determined in F_1 generation was 2.10% and the heterobeltiosis value was -2.31%. In terms of this characteristic examined, the heterosis values of AM-1 X R02, RAM-1 X R61 and RAM-1 X R80 hybrids were significant ($p<0.01$) and negative; those of RAM-19 X R02 and RAM-19 X R06 hybrids were significant ($p<0.05$) and negative, the heterobeltiosis values of RAM-19 X R06, RAM-19 X R61, RAM-19 X R71 and RAM-19 X R80 hybrids were significant ($p<0.01$) and negative, those of RAM-1 X R31 and RAM-19 X R02 hybrids were significant ($p<0.05$) and negative, that of RAM-1 X R61 was significant ($p<0.01$) and positive; and that of RAM-1 X R71 hybrid was significant ($p<0.05$) and positive (Table 8). Heterosis values were between -11.66% (RAM-19 X R80) and 24.90% (RAM-1 X R61), and heterobeltiosis values were -%13.43 (RAM-19 X R80) and 15.52% (RAM-1 X R61). In F_1 generation, the heritability in the broad sense was 96.39 and the heritability in the narrow sense was 12.22 for oil content. The high heritability level in a broad sense and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high. These results were also reported by Chandra et al., (2011) and Tan, (1993).

Table 8
Sunflower Parent and F_1 Hybrids average oil content, general combining ability (GCA), special combining ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (%)	GCA	SCA	Hs (%)	Hb (%)
RAM-1	35.40	-8.443**			
RAM-19	40.50	-11.498**			
R02	41.28	0.793**			
R06	35.18	-3.722**			
R31	41.73	-0.126			
R61	41.65	3.167**			
R71	40.16	0.163			
R80	42.20	-0.275			
Hybrids					
RAM-1 X R02	42.35		13.747**	10.45**	2.58
RAM-1 X R06	36.26		10.142**	2.74	2.43
RAM-1 X R31	39.53		10.918**	2.52	-5.26*
RAM-1 X R61	48.11		19.064**	24.90**	15.52**
RAM-1 X R71	42.58		14.693**	12.72	6.03*
RAM-1 X R80	42.69		15.275**	10.04**	1.17
RAM-19 X R02	39.01		13.370**	-4.61*	-5.51*
RAM-19 X R06	36.07		13.966**	-4.69*	-10.95**
RAM-19 X R31	39.98		15.588**	-2.76	-4.18
RAM-19 X R61	37.99		9.636**	-7.52**	-8.79**
RAM-19 X R71	37.51		12.004**	-6.99**	-7.39**
RAM-19 X R80	36.53		11.131**	-11.66**	-13.43**
LSD %1 2.540	mean Hs %	2.10	h^2	12.22	SH (Lines)	0.476
LSD %5 1.912	mean Hb %	-2.31	H^2	96.39	SH (Testers)	0.275
					SH (SCA)	0.673

3.6. Oil Yield (kg ha^{-1})

In this study, values of oil yield of parents and F_1 hybrids are given in Table 9. In the research, it was observed that the average oil yield of the parents ranged between 716.2 45 kg ha^{-1} (R31) and 1042.7 45 kg ha^{-1} (R80), and the oil yield of F_1 hybrids ranged between 714.1 45 kg ha^{-1} (RAM-1 X R71) and 129.68 kg/da (RAM-19 X R61) (Table 9). It was found that the GCA variance for oil yield was -34.149 and the SCA variance was 1055.012 in F_1 hybrids (Table 3). The fact that ²GCA/²SCA ratios were negative in F_1 hybrids examined for oil yield showed that the additive genes, i.e. dominant genes were effective on the heredity of this trait. (Table 3). In the experiment, when the GCA was examined for oil yield, RAM-1, RAM-19, R06 and R71 varieties among testers showed significant ($p<0.01$) and negative GCA; R61 and R80 varieties showed significant ($p<0.01$) and negative GCA; and R31 variety showed significant ($p<0.05$) and negative GCA (Table 8). When the SCA effects of the hybrids were examined, it was found that RAM-19 x R80 had negative and significant ($p<0.05$) SCA effect, and all the other hybrids except for RAM-1 X R71 and RAM19 X R31 hybrids were genotypes that had significant ($p<0.01$) and positive SCA effect. (Table 9).

When Table 9 was examined, it was found the average heterosis value determined in F_1 generation was 23.48%; the heterobeltiosis value was 15.48%. In terms of this trait, none of the hybrids had statistically significant heterosis values, whereas the heterobeltiosis values of RAM-1 X R31, RAM-1 X R61, RAM-1 X R80 and RAM-19 X R61 hybrids were positive and ($p<0.01$) significant, the value of RAM-1 X R71 and RAM-19 X R80 hybrids were negative and significant ($p<0.01$); the value of RAM-1 X R02 was positive, and significant ($p<0.05$) and the value of RAM-19 X R31 was negative and significant ($p<0.05$). Heterosis values were between -23.21% (RAM-19 X R80) and 99.91% (RAM-1 X R80), and heterobeltiosis values were between -29.11% (RAM-1 X R71) and 75.40% (RAM-1 X R80). In F_1 generation, the heritability in the broad sense was 95.59 and the heritability in the narrow sense was 5.81 for oil yield (Table 9). The high heritability level in a broad sense and and the low heritability level in a narrow sense meant that the effect of environmental variance of this trait was high.

Table 9
Sunflower Parent and F_1 Hybrids average oil yield, general combination ability (GCA), special combination ability (SCA), heterosis (Hs), heterobeltiosis (Hb) and heritability

Parents	Averages (kg ha^{-1})	GCA	SCA	Hs (%)	Hb (%)
RAM-1	787.0	-19.218**			
RAM-19	973.6	-35.583**			
R02	896.1	3.805			
R06	922.0	-11.393**			
R31	716.2	-6.958*			
R61	894.1	16.259**			
R71	1007.4	-22.269**			
R80	1042.7	20.556**			
Hybrids					
RAM-1 X R02	1113.5		24.148**	32.31	24.26*
RAM-1 X R06	1061.9		32.470**	24.27	15.17
RAM-1 X R31	1291.8		58.684**	71.87	64.13**
RAM-1 X R61	1220.5		25.956**	45.19	36.50**
RAM-1 X R71	714.1		-3.029	-20.41	-29.11**
RAM-1 X R80	1829.0		102.795**	99.91	75.40**
RAM-19 X R02	1154.7		51.457**	23.51	18.59
RAM-19 X R06	902.3		33.003**	-4.81	-7.33
RAM-19 X R31	761.1		9.745	-9.92	-21.83*
RAM-19 X R61	1296.8		57.951**	38.86	33.19**
RAM-19 X R71	1032.5		61.250**	4.25	2.50
RAM-19 X R80	774.2		-16.024*	-23.21	-25.76**

LSD %1 :	24.361	mean Hs %	23.48	h^2	5.81	SH (Lines)	4.562
LSD %5 :	18.339	mean Hb %	15.48	H^2	95.59	SH (Testers)	2.634
						SH (SCA)	6.452

4. Conclusion

Considering the general combination abilities of parents for F_1 generation, R31 was identified as appropriate parents for plant height; R02 for head diameter; R02 for 100 seed weight; R61 and R80 for yield seed yield and oil yield; and R61 for yield content. Considering the special combination abilities of hybrids in F_1 generation, all hybrids were found to be significant and positive for plant height, 100 seed weight and oil content. All hybrids except for the RAM-1 X R61 were significant and positive for the head diameter. RAM-1 X R80, RAM-19 X R61, RAM-1 X R31, RAM-19 X R71 and RAM-19 X R02 hybrids were found to be significant and positive for yield seed yield and oil yield. As a result of the study, there is a sufficient genetic variation in the population addressed in terms of the agricultural features examined.

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