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Original Research Article

COMBINING ABILITY ANALYSIS FOR VARIOUS MORPHOLOGICAL TRAITS IN SUNFLOWER (*HELIANTHUS ANNUUS* L.)

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Abstract: *The present research was conducted in the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Six lines and four testers were sown, and 24 crosses were generated. The seeds of these crosses were sown in a randomized complete block design (RCBD) with three replications and data for several morphological traits, including the number of days to flowering, plant height, number of whorls per head, head diameter, number of seeds per head, number of leaves per plant, achene yield per plant, 100-seed weight, oil content and protein content were recorded. Data were analyzed using analysis of variance and line × tester analysis. General combining ability (GCA) and specific combining ability (SCA) for traits mentioned above were evaluated. Lines with crosses showing high values of GCA and SCA were selected for further breeding programs. The recorded data were further subjected to analysis of variance, GCA and SCA to determine genetic variability and association among the characters. The results showed that the parental lines A-1, A-2, A-7 and A-8 showed good potential for most of the traits so that they could be taken to further breeding programs. The crosses A-5×A-10 and A-2×A-7 could be used for hybrid development.*

Keywords: *Helianthus annuus,* SCA, GCA, line × tester analysis, hybrid

Introduction

The sunflower is an important oilseed crop. After canola, palm, and soybean, it is the fourth most significant oilseed crop (Farrokhi et al., 2011). In 2019-20, despite a minor decline in cottonseed and sunflower seed production, global oilseed production was virtually unchanged at 610.42 million tonnes (Sheikh et al., 2021). It includes between 40 and 50 percent oil and 23 percent protein, which is a substantial amount. Its yellow oil is regarded as being of the highest quality. Numerous experts have already proven sunflower oil's amount and quality. It is rich in fat-soluble vitamins A, B, E, and K and has a pleasant flavor. This crop produces a range of commodities, including human food and animal feed. The dried plant stem is used as fuel. It was reportedly utilized as an ornamental plant. It was utilized in numerous ancient rituals. A few sunflower parts are also used to create body paint, textile colors, and other ornaments. Cooking, salad dressings and the production of margarine and shortening all utilize sunflower oil. Sunflower oil is also utilized in numerous cosmetics. It is a common component in the paint industry (Encheva & Shindrova, 2011). Sunflower's shorter duration, high yield potential, and broad adaptability help close the gap between national edible oil output and consumption. Early maturing cultivars reach maturity between 90 to 120 days after planting, while late maturing cultivars reach maturity between 120 to 160 days after planting. Although sunflower oil has a high production potential, it costs a significant amount of foreign currency to import annually. Pakistan produces negligible sunflower seeds compared to other nations despite its favorable terrain, enough water resources, expansive stretches of deep soil, and agreeable climate (Riaz et al., 2017).

To increase edible oil production, local hybrids and genotypes with high yields and resistance to biotic and abiotic stress can be introduced (Memon et al., 2015). The Pervenetz variety of sunflower is the first genotype to possess a significant proportion of oleic acid. It was produced in the former Soviet Union by treating sunflower seeds with dimethyl sulphonate (Baloch et al., 2018). The increased self-fertility, improved stability, and more uniform maturity of sunflower hybrids contribute to their great yield potential. Since sunflowers are a cross-pollinated

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crop, breeding for heterosis enabled the creation of superior and unique hybrids. Increased heterosis in sunflower hybrids results from the capacity of female and male inbred lines to mate. Most earlier research concerned the significant heterotic effects on several critical traits and yield (Habib et al., 2021). In recent years, line tester analysis has been a popular method for combining aptitude testing. According to a report, line tester analysis is recognized as a leading cross-technique extension that includes several testers (SAEED et al., 2022). Two testers were deemed sufficient for testing the GCA of inbred. It allows us to assess many genotypes to determine their compatibility. A "tester" is a variety or line with a varied genetic background and exceptional combination potential (Jan et al., 2017). Good combining abilities of the likely parents and desirable characteristics result in a viable hybrid with desirable characteristics. Demand for higher-quality, higher-yielding sunflower hybrids is increasing in both domestic and international markets, necessitating a swift shift to superior, more productive, and more stable hybrids.

Material and Methods

The research was conducted in the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, during two growing seasons. Ten accessions of *H. annuus* L. were collected from the department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The parents, 6 lines A-1, A-2, A-3, A-4, A-5 and A-6 and 4 testers A-7, A-8, A-9 and A-10 were planted in the field in the last week of March 2019. Row to row distance of 2.5ft and plant to plant distance of 9 inches was maintained. All agronomic and cultural methods were performed, from sowing to harvesting. Lines were crossed with testers, and 24 crosses were generated. The seed of the crosses was harvested separately. Hand emasculation was done by removing the anthers from the florets with the help of forceps. This was done in the morning from about 7 am to 9 am. Ovary remains receptive for 2-3 days. The pollens from the desirable tester were collected by tapping the flower and collecting the pollens in petri dish. These pollens were then dusted on the emasculated head. Pollination was done in the morning from 8 am to 9 am. Pollens remain viable for 12 hours. The pollinated sunflower heads were harvested and sundried when the seed was developed. After that seed was knocked out of heads by hand and collected in separate packets for resowing. The seed of the crosses and parental lines was sown in the last week of August 2019 under RCBD with 3 replications. All cultural and agronomic practices, from sowing to harvesting, were also carried out. Data for DF (Days to flowering), NOWH (No. of whorls per head), NLP (No. of leaves per plant), HD (Head diameter), PH (Plant height), NSH (No. of seeds per head), SW (100-seed weight), AYP (Achene yield per plant), OC (Oil content), PC (Protein content) were recorded. The recorded data was then analyzed through line × tester analysis [22] to estimate general and specific combining ability.

Table 1 Lines and Testers Exploited in Experiment

Sr. No.	Testers	Sr. No.	Lines
1	A-7	1	A-1
2	A-8	2	A-2
3	A-9	3	A-3
4	A-10	4	A-4
		5	A-5
		6	A-6

Statistical Analysis

Recorded data from both experiments were evaluated using the statistical software STATISTIX 8.1, combining ability effects determined by DOSBox.

Results and Discussions

The results showed significant differences among the accessions for DF, NOWH, NLP, HD, PH, NSH, SW, AYP, OC and PC. Female lines exhibited significant GCA effects for all the traits except oil and PC. Male parental lines showed significant results for all the traits other than DF, AYP, OC and PC. The crosses showed significant SCA effects for all the traits except DF. Crosses vs parents exhibited significant differences for all the traits studied. Line × tester interaction was significant for all plant traits. The significance of GCA and SCA for most of the traits exhibited the importance of both additive and non-additive (dominance and/or epistasis) gene action. Significant SCA effects for these traits indicated the contribution of non-additive gene action among the hybrids under study. Mean values analysis showed that all the accessions had a variable range for different traits. As early flowering is a desirable trait, the lowest DF were exhibited by parental lines A-4 and A-7, but these were not significant. The cross A-4 × A-10 exhibited the lowest DF (Jan et al., 2017). The line A-5 and the tester A-8 showed the maximum NLP. The maximum NLP was shown by the cross A-5 × A-9 (Binodh et al., 2008). A-1, A-7 and A-8 showed the maximum NOWH. The crosses A-1 × A-8, A-2 × A-7, A-2 × A-10 and A-6 × A-9 possessed the maximum NOWH (Mehmood, 2021). The largest HD was shown by A-6, A-9 and A-6 × A-7 (Khan et al., 2009). The highest PH was shown by A-5 and A-7, and A-6 × A-9 (Dhanalakshmi et al., 2022). A-5, A-9 and A-5 × A-10 showed the maximum NSH. The maximum value for SW was shown by A-2, A-7 and A-1 × A-10 (Hladni et al., 2014). A-6, A-7 and A-5 × A-9 showed the maximum value of AYP. The maximum OC was possessed by the parental lines A-1 and A-7 (Hammadi et al., 2021). The cross A-2 × A-7 exhibited the highest percentage of OC (ANDARKHOR et al., 2014). The maximum PC was shown by the parental lines A-5 and A-8. The cross A-1 × A-10 exhibited the highest percentage of PC (Laureti & Del Gatto, 2001).

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Line A-4 (-3.90) showed negative GCA effects for DF, which is desirable, whereas the testers revealed non-significant GCA effects for this trait (Darvishzadeh, 2012). Line A-5 (2.76) showed significantly positive GCA effects for the NOWH, which is desirable. The tester A-7 (1.63) showed significant positive effects for NOWH. Line A-2 (1.53) exhibited significantly positive GCA effects for the NLP, which is desirable. The tester A-9 (0.92) showed significant and positive effects for the NLP. Line A-4 (2.50) showed significantly positive GCA effects for HD, which is desirable in this case. The tester A-9 (2.31) showed significantly positive GCA effects, which is desirable for HD (Hammadi et al., 2021). Line A-2 (-1.37) showed significantly negative GCA effects, which is desirable for PH. The tester A-10 (-1.07) exhibited significantly negative GCA effects, which is desirable for PH (Ghodekar et al., 2021). Line A-5 (5.17) exhibited significantly positive GCA effects for the NSH, which is desirable as it enhances the yield. The tester A-9 (3.03) showed significantly positive GCA effects for the NSH, which is desirable (Karande et al., 2020). Line A-5 (120.85) showed highly significant positive GCA effects, which is desirable for SW. The tester A-7 (13.82) showed the significant positive GCA effects for SW which is desirable (Rizwan et al., 2020). Line A-1 (0.31) exhibited significantly positive GCA effects for AYP, which is desirable. The tester A-7 (0.16) showed significantly positive GCA effects, a desirable trait for AYP (Shinde et al., 2016). Line A-6 (3.337) exhibited highly significant positive GCA effects, which is desirable for OC. The tester A-8 (0.862) exhibited significantly positive GCA effects for OC (Cvejić et al., 2017). Line A-4 (1.238) exhibited significantly positive GCA effects for the desirable PC. The tester A-10 (2.638) showed significantly positive GCA effects PC (Kholghi et al., 2014).

The estimates of specific combining ability effects showed that the crosses exhibited non-significant SCA effects for all DF. The cross A-4 × A-8 (5.15) showed the maximum positive and significant SCA effects, which is desirable for the NOWH [14]. The cross A-6 × A-9 (3.58) showed positive and significant SCA effects for the NLP, which is desirable (Rabia et al., 2015). The cross A-5 × A-9 (2.53) showed significantly positive SCA effects, which is desirable for HD (Nooryazdan et al., 2011). The maximum negative and significant SCA effects for PH were shown by A-6 × A-8 (-1.32), which is desirable as short-statured plants are required to overcome lodging (Rauf et al., 2012). The cross A-6 × A-9 (10.55) showed significantly positive SCA effects for NSH which is a desirable trait as it enhances yield (Kanwal et al., 2015). The cross A-5 × A-10 (164.26) showed desirable SCA effects for SW (Ashraf et al., 2015). The cross A-5 × A-10 (0.571) showed the maximum positive and significant SCA effects for AYP, which is desirable (Muhammad et al., 2015). The cross A-2 × A-7 (5.99) showed significantly positive SCA effects, which is desirable for OC (Tavade et al., 2009). The cross A-3 × A-7 (6.796) showed significantly positive SCA effects for PC, which is desirable (Hristova-Cherbadzi, 2009).

Conclusion

It was concluded from the results that the parental lines A-1, A-2, A-7 and A-8 showed good potential for most of the traits so that they could be used in further breeding programs. The hybrid A-5×A-10 and A-2×A-7 performed well for many of the traits used for hybrid development.

Table 2 Mean Square for Analysis of Variance for Plant-related Traits

SOV	DF	DF	NOWH	NLP	HD	PH	NSH	SW	AYH	OC	PC
Replication	2	4.397	0.657	11.92**	0.069	0.006	0.527	1.598	0.008	0.0091	0.25*
Genotypes(G)	33	71.4**	52.99**	21.69**	31.17**	7.294**	684**	719.4**	1.549**	51.899 **	34.701**
Crosses(C)	23	73.1**	60.59**	18.69**	22.12**	6.709**	397.9**	655.3**	0.755**	55.933 **	25.748**
Lines(L)	5	263**	60.41**	12.09**	47.5**	15.98**	1251**	175.6**	0.751**	39.601	9.596
Tester(T)	3	7.524	62.72**	8.306**	47.8**	11.01**	221**	286.8**	0.332**	10.82	58.054
L×T	15	22.92	60.23**	21.04**	8.53**	2.758**	148.9**	413.6**	0.841**	70.399**	24.674**
Parents(P)	9	67.5**	20.39**	29.87**	46.18**	9.151**	1279**	603.1**	2.701**	45.192**	14.647**
L vs T	1	86.31*	5*	58.94**	128.4**	32.83**	712.6**	413.9**	16.45**	24.252**	32.143**
P vs C	1	67.48*	171.7*	16.94**	104.1**	4.037**	1908**	325**	9.427**	19.482**	91.104**
Error	66	13.14	0.808	0.417	0.725	0.02	0.334	2.992	0.071	0.05	0.026

Table 3 General Combining Ability Effects of Sunflower Lines for Morphological Traits

	DF	NOWH	NLP	HD	PH	NSH	SW	AYH	OC	PC
Lines										
A-1	-0.22	1.26 **	0.69 **	-0.50 *	0.74 **	2.01 **	20.60 **	0.31 **	-0.504 **	-0.521 *
A-2	-3.84 **	0.76 **	1.53 **	-3.08 **	-1.37 **	-10.61 **	-128.4 **	-0.18 *	0.271 *	0.596 **
A-3	-3.46 **	0.43	-0.22	-0.83 **	-0.72 **	-10.37 **	-80.65 **	-0.11	-2.113 *	-0.929 **
A-4	-3.90 **	-3.49 **	-1.39 **	2.50 **	-0.93 **	-2.46 **	-72.24 **	-0.34 **	-0.696 **	1.238 **
A-5	6.79 **	2.76 **	-0.14	1.75 **	0.81 **	5.17 **	120.85 **	0.20 *	-0.296 *	0.479 *

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A-6	4.63 **	-1.74 **	-0.47 **	0.17	1.48 **	16.26 **	57.85 **	0.12	3.337 **	-0.862 *
Testers										
A-7	0.1	1.63 **	0.36 **	-0.97 **	0.74 **	-3.30 **	13.82 **	0.16 *	0.386 **	-0.896 **
A-8	0.22	1.35 **	0.14	-0.03	-0.06 *	3.02 **	-7.57 **	-0.17 *	0.862 **	-1.318 *
A-9	-0.92	-0.60 **	0.92 **	2.31 **	0.39 **	3.03 **	7.10 **	-0.04	-0.904 **	-0.424 *
A-10	0.59	-2.38 **	-1.42 **	-1.31 **	-1.07 **	-2.76**	-13.35 **	0.05	-0.326 *	2.638 **

Table 4 Specific Combining Ability Effects of 24 Crosses for Morphological Traits in Sunflower

Sr. No.	Crosses	DF	NOWH	NLP	HD	PH	NSH	SW	AYH	OC	PC
1	A-1 × A-7	-3.69	2.46**	-2.36**	-0.94	0.765*	-0.35**	2.82**	39.68**	-0.161**	-2.146**
2	A-1 × A-8	1.75	4.40**	2.86**	1.11*	1.638**	0.15*	-0.82**	154.4**	0.691**	-0.59*
3	A-1 × A-9	-0.76	-2.32**	-2.25**	-0.56	-2.062**	-1.16**	-2.08**	-103.6**	-0.014	-0.318*
4	A-1 × A-10	2.71	-4.54**	1.75**	0.39	-0.34*	1.35**	-5.59**	-90.49**	-0.516	3.054**
5	A-2 × A-7	4.43	-3.04**	1.47**	0.64	5.99**	1.01**	4.85**	126.35**	1.631**	-0.229**
6	A-2 × A-8	-1.99	-4.10**	-4.31**	-1.64**	-7.571**	-0.14*	8.66**	-42.26**	-0.229**	2.693**
7	A-2 × A-9	-2.78	2.18**	-0.42	-0.97*	-0.904**	-0.52**	-0.32	-42.60**	-1.07*	-0.435**
8	A-2 × A-10	0.35	4.29**	3.25**	1.97**	2.485**	0.34**	-6.57**	-41. 49**	-0.332**	-2.029**
9	A-3 × A-7	0.53	0.96	0.56	0.72	-6.86**	0.04	-1.77**	59.6**	-1.326**	6.796**
10	A-3 × A-8	-0.7	-3.76**	-1.56**	-0.89	-2.154**	0.86**	3.75**	-92.01**	0.29	-3.382**
11	A-3 × A-9	1.31	-1.49**	1.33**	-0.22	5.579**	-0.57**	1.75**	11.35**	0.169	-1.11*
12	A-3 × A-10	-1.14	4.96**	-0.33	0.39	3.435**	-0.25**	4.55**	21.10**	0.866**	-2.304**
13	A-4 × A-7	-0.37	1.54**	-1.61**	0.72	-5.243**	-0.42**	-0.95**	-87.50**	-1.35	-0.038
14	A-4 × A-8	0.6	5.15**	2.94**	0.44	0.829*	0.48**	-1.28**	93.57**	-1.095*	-0.449**
15	A-4 × A-9	0.73	-2.24**	-0.83*	-1.56**	1.163**	0.82**	-4.51**	-83.76**	2.032**	1.59*
16	A-4 × A-10	-0.96	-4.46**	-0.5	0.39	3.251**	-0.87**	4.43**	77.35**	0.413	-1.104**
17	A-5 × A-7	-4.1	-5.04**	0.47	-1.19*	3.49*	-1.03**	1.36**	-113.90**	0.926	-0.779*
18	A-5 × A-8	-0.76	-2.76**	1.36**	2.19**	4.896**	-0.03	-0.67*	-122.18**	-0.665**	2.143**
19	A-5 × A-9	3.62	2.85**	-1.42**	2.53**	-1.071*	1.46**	0.79**	71.82**	-0.832**	-1.651*
20	A-5 × A-10	1.23	4.96**	-0.42	-3.53**	-7.315**	-0.41**	-9.01**	164.26**	0.571**	0.287*
21	A-6 × A-7	3.2	3.13**	1.47**	0.06	1.857**	0.83**	13.28**	-24.57**	0.278	-3.604**
22	A-6 × A-8	1.11	1.07*	-1.31**	-1.22*	2.363**	-1.32**	-2.80**	8.49**	1.008**	-0.415*
23	A-6 × A-9	-2.12	1.01*	3.58**	0.78	-2.704**	-0.03	10.55**	146.82**	-0.284*	1.924**
24	A-6 × A-10	-2.19	-5.21**	-3.75**	0.39	1.515**	0.53**	5.53**	-130.74**	-1.002**	2.096**

Conflict of interest

The authors declared the absence of conflict of interest.

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