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CODEN: IAASCA **ORIGINAL ARTICLE**

Combining Ability Analysis for Yield and Yield Components in Sunflower (*Helianthus annus* L.)

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ABSTRACT
Thirteen inbred lines viz A-23, A-24, A-25, A-27, A-29, A-30, A-31, A-32, A-34, A-35, A-37, A-39 and A-40 were sown. Experiment was conducted in the field during winter season 2013. Ten females and three males were crossed by using line × tester design to develop 30 F_1 crosses during spring 2013. Parents and F_1 hybrids were grown in field during autumn 2013 and data for yield related traits viz. plant height (cm), stem girth (cm), leaves per plant, leaf area (cm^3), leaf color, leaf shape, intermodal length (cm), days to 50% flowering, days to maturity, head diameter (cm), achene yield per head (g), number of whorls per head and 100 achene weight was recorded. Significant differences among the entries for all the characters were observed. Results indicated significant differences of hybrids with parents for all the traits indicating the presence of heterosis for these traits. Crosses A30×A23, A31×A27, A30×A27, A31×A37, A30×A23, A25×A27, A32×A37, A34×A23, A31×A27, A24×A27 and A35×A23 showed significant and positive SCA effects for achene yield related traits, respectively.
Key words*: Achene, Agronomic traits, Hybrids, Linolenic acid.*

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INTRODUCTION

Pakistan is deficient in edible oils. The edible oil production does not meet the necessities of the country. An enormous amount of foreign exchange is used up on imports. Edible oil is the most important part of our food but Pakistan is deficient in its production. More than 70% of edible oil requirements are met through imports. Due to restricted production of our traditional oilseed crops like cotton seed, mustard and rape seed, efforts are being done to raise non-traditional oilseed crops cultivation such as safflower, sunflower, and soybean. Sunflower has great prospective under Pakistan's agro-ecological circumstances. It is second oilseed crop after soybean and is extensively grown for edible oil in different countries in the world.

Sunflower can play a vital role in enhancing our local oil production because it has high yield potential, salt tolerance and drought resistance in the current cropping pattern. It takes less time to grow and its cultivation can be done two times annually under irrigated as well as rain fed environments. Sunflower has an extreme potential in non-conventional oilseed crop and has potential for satisfying the gap of demand and production of edible oil in our country. Sunflower seeds are chief source of edible oil. Its seed contain high oil contents ranging from 40 to 45% (28). Its seed contains 40-50% oil contents that contain oleic acid and linolenic acid (33, 24, 25, 26). It is also wealthy in protein which is 23% (32). Its oil is thought to be the best oil due to its mild taste, less amount of saturated fatty acids and light colour (7).

For agronomically main characters, expression of heterosis is essential for discovering useful hybrids (29). For No. of days taken to maturity, plant stature, heterobeltosis for seed yield and no. of days taken to 50% flowering, standard heterosis can be exploited successfully (12). To get high seed production, heterosis is important and it has significance for cultivated sunflower in hybrid seed producing industry (6). For superior genotype selection, exploitation of genetic variability is done by identifying better parent for hybridization in the breeding procedures (9). In plant breeding, general as well as specific combining abilities are main parameters. To find the best selection plan for evolving high yielding hybrids, breeding programs can take benefit from such facts on combining ability (1, 4, 5, 6, 29). Line × tester analysis is utilized for estimating large number of inbred lines and it also gives knowledge on the comparative status of GCA and SCA effects to assume the genetic origin of leading plant characters (2, 3, 31). The present study is being attempted to develop new hybrids of sunflower and to evaluate newly developed hybrids for yield characters.

MATERIALS AND METHODS

The present research was conducted to do genetic variability analysis for yield related traits in sunflower (*Helianthus annus* L.). The six traits *viz.* plant height (cm), stem girth (cm), days to 50 % flowering, days to maturity, head diameter (cm) and achene yield per head (g) were taken. Present research was conducted in the research area of Plant Breeding and Genetics, University of Agriculture, Faisalabad during the years 2012 and 2013. Experiment was completed in two seasons. Six parents were used which consisted of 10 female (lines) and 3 male (testers) of sunflower. Controlled cross pollination was done using line × tester design and 30 crosses were attempted during spring 2013. Seeds of the crosses were harvested individually. Standard cultural and agronomic practices were performed from sowing till harvest. Parents and crosses were sown in randomized complete block design with 3 replications each having 49 rows and plant to plant distance was 25cm and row to row 75cm.

Table 1. Various crosses developed for Sunflower genotypes

Sr. No.	Hybrids/Crosses	Sr. No.	Hybrids/Crosses
1.	A-30 × A-27	16.	A-31 × A-23
2.	A-29 × A-27	17.	A-35 × A-23
3.	A-25 × A-27	18.	A-32 × A-23
4.	A-24 × A-27	19.	A-40 × A-23
5.	A-34 × A-27	20	A-39 × A-23
6.	A-31 × A-27	21.	A-30 × A-37
7.	A-35 × A-27	22.	A-29 × A-37
8.	A-32 × A-27	23.	A-25 × A-37
9.	A-40 × A-27	24.	A-24 × A-37
10.	A-39 × A-27	25.	A-34 × A-37
11.	A-30 × A-23	26.	A-31 × A-37
12.	A-29 × A-23	27.	A-35 × A-37
13.	A-25 × A-23	28.	A-32 × A-37
14.	A-24 × A-23	29.	A-40 × A-37
15.	A-34 × A-23	30.	A-39 × A-37

Biometrical analysis. Data was recorded and analyzed using analysis of variance technique (30) for determination of differences among entries. To estimate general and specific combining ability effects, line × tester analysis was performed (16). Procedure of was used to calculate heritability and heterosis (8).

RESULTS AND DISCUSSION

Estimation of variability. The idea of general and specific combining ability has become increasingly important to plant breeders because of the extensive use of hybrid cultivars and many crop plants. Mean square values from analysis of variance of eleven traits of sunflower are elaborated in Table 2. It was showed high significant differences among sunflower genotypes for the traits studied. The sums of squares of sunflower genotypes for these characters were further divided into parents, crosses and parent *vs* crosses. Parents and crosses revealed highly significant differences among themselves and parent *vs* cross, days to flowering, days to maturity, plant height, leaf area, head diameter, stem girth and achene yield per plant had significant differences among themselves. The sum of squares calculated for sunflower crosses were further partitioned into lines, testers and line × tester components. High significant differences were displayed by line × tester interaction for all indicated traits. Significant differences among genotypes with respect to all characters indicated that the breeding material had genetic variability and its variability may be used in future breeding program for the improvement of achene yield and its related characters in sunflower.

Table 2. Mean square values from ANOVA of yield and its components in sunflower

S.O.V	DF	PH	SG	D50%F	DM	HD	AWPH
Replication	2	1185.90	0.32	11.96	114.58	3.47	52.72
Genotypes	42	2069.87	3.08	29.66	107.58	35.74	111.93
Parents	12	1916.56	3.83	31.47	7.79	20.85	95.23
Crosses	29	1933.93	2.17	29.93	137.98	36.19	106.08
P. vs Crosses	1	7851.75	20.47	0.02	423.52	201.34	481.93
Lines	9	2086.20	0.95	34.99	120.34	25.70	78.65
Testers	2	4460.71	0.84	27.51	120.21	83.99	78.92
L x T	18	1577.04	2.93	27.67	148.77	36.12	122.81
Error	84	294.19	0.83	1.22	88.21	9.23	61.15
Total	128	890.77	1.56	10.72	94.98	17.84	77.69

PH = plant height, SG = stem girth, D50%F = days to50% flowering, DM = days to maturity, HD = head diameter, AYPH = achene yield per head

Plant height (cm).

Table 3 showed range of plant height in testers from141.67cm to 156cm. Among sunflower testers, A-27 was observed as tall followed by A-23 which had significant difference with each other and also from all other testers. Tester A-37 had minimum height. Range of plant height in lines was observed from 96 cm to 190.67 cm. The maximum plant height observed by line A-31 followed by A-30 that was significantly different from each other and also from all other lines. Among sunflower lines A-24 was observed as dwarf followed by A-25 which revealed significant estimates from all other lines. Among the crosses, plant height ranged from 90.60 cm to 212.67 cm. The cross A31×A27 showed maximum height followed by A40×A23 which was 208.83 cm. The minimum plan height showed by cross A29×A27 followed by A24 × A27 which was 140.67 cm which had significant difference with each other and also from all other crosses. Plant height ranged from 96-212.67 cm. Further improvement in the material in terms of plant height is required to meet the standards reported in literature could be possible through targeted breeding (34, 35).

Stem girth (cm). It was observed from Table 3 that stems girth for sunflower testers ranged between 5.45cm to 6.45cm. Maximum and minimum stem girth was shown by A-37 and A-23, respectively. Both the testers A-37 and A-23 had significant difference from other testers under study. Stem girth for sunflower lines ranged from 3.87 cm to 8.17 cm. The sunflower lines A-39 followed by A-40 and had maximum stem girth respectively, which had significant difference with all other lines but non-significant differences with each other. On the other hand Line A-24 had smallest stem girth which had significant difference from all other lines. Among the crosses, stem girth ranged from 6.06 cm to 10.34 cm. The cross A29×A37 showed maximum stem girth followed by A29×A23 which was valued 8.39 cm. The minimum plan height showed by cross A39×A27 followed by A24×A37 which was 6.12 cm which had non-significant difference with each other but significantly differ from all other crosses as shown in Table 3. Stem girth ranged from 3.87 cm to 10.34 cm (22). It was reported stem girth from 4.17 cm to 6.27 cm. Further improvement in the material in terms of stem girth is required to meet the standards reported in literature could be possible through targeted breeding.

Days to 50% flowering. Days to 50% flowering for sunflower testers showed ranges between 60 to 65.33 days. Maximum and minimum days to 50% flowering were shown by tester A-27 and A-37, respectively observed from the Table 3. Sunflower lines depicted the ranges from 60.67 to 70.33 days taken to 50% flowering. The sunflower lines A-24 had maximum days to 50% flowering followed by line A-31. Line A-40 had minimum days to 50% flowering which had significant difference from all other lines. Among the sunflower crosses, days to 50% flowering ranged between 59 days to 70 days. The cross A39×A23 showed maximum days to 50% flowering followed by the cross A29×A37, A30× A23, A32×A23 which was valued 69 days, respectively. The minimum days to 50% flowering showed by cross A31×A37 followed by the cross A40×A37 which was valued 59.67 days. Days to 50% flowering ranged from 59–70 days in present study(12). Further improvement in the material in terms of days to 50% flowering is required to meet the standards reported in literature could be possible through targeted breeding.

Days to maturity. Days to maturity for sunflower means how many days a crop take for its full maturity. Days to maturity for studied testers ranged from 105.67 to 111 days. Maximum days to maturity were shown by A-37 tester and minimum days to maturity were shown by tester A-27 concluded from the Table 3. Sunflower lines took 107 days to 111.33 days for to take their full maturity. The sunflower line A-25 had maximum Days to maturity followed by line A-32 that were 110 days. Line A-34 had minimum Days to maturity which had significant difference from all other lines. Parent crosses of sunflower showed days to maturity ranged from 102.33 days to 110.33 days. The cross A29×A27 showed maximum days to maturity followed by the cross A39×A23 which were 109.67 days. The minimum days to 50% flowering showed by cross A31×A37 followed by the cross A31×A27, A35×A27 and A40×A37 which was valued 103 days days. Days to maturity ranged from 102.33-111.33 days in present study. Mean values for days to maturity ranged between 90.48 to 103.22 days had been reported (19). The present breeding material meets the standards reported in literature for days to maturity. The material may also be improved to get early matured hybrids.

Table 3. Mean values for various morphological traits in sunflower

	PH	SG	LPP	LA	IL	DFF	DM	HD	NWPH	100-AW	AWPH
A23	32.3A	10.4A	40.0A	539.3A	5.1KL	70.3A	111.3A	29.2A	32.3A	5.6S	37.3CD
A27	31.3AB	9.0B	38.7AB	467.5AB	7.4ABCDEFG	70.0AB	111.0AB	28.5AB	31.3AB	5.9OPQR	5.4EFG
A37	31.0ABC	8.2BC	38.3AB	467.0AB	6.7BCDEFGHIJK	69.0ABC	110.3ABC	25.9BC	31.0ABC	6.9HIJ	42.0B
A24	27.3BCD	8.2BC	38.0AB	456.7ABC	6.3CDEFGHIJKL	69.0ABC	110.0ABCD	25.3ABCD	27.3BCD	8.1BC	36.9CDE
A25	27.0CDE	8.1BCD	37.0ABC	454.3ABC	7.1ABCDEFGH	69.0ABC	109.7ABCDE	24.5ABCDE	27.0CDE	6.0NOPQR	40.9B
A29	27.0CDE	8.0BCD	36.3ABC	443.2BCD	6.4CDEFGHIJKL	69.0ABC	109.7ABCDE	23.7BCDEF	27.0CDE	6.2LMNO	22.5RST
A30	27.0CDE	7.9BCDE	35.7ABC	422.9BCDE	6.3CDEFGHIJKL	68.3BCD	109.0ABCDEF	23.2CDEFG	27.0CDE	6.8IJ	21.8RST
A31	26.9CDEF	7.9BCDE	35.3ABCD	419.9BCDE	7.2ABCDEFGH	67.3CDE	109.0ABCDEF	23.0CDEFG	26.9CDEF	4.5U	32.6HIJ
A32	26.8CDEF	7.9BCDE	35.3ABCD	416.5BCDEF	7.5ABCDEF	67.0DEF	108.7BCDEFG	22.9CDEFG	26.8CDEF	5.7RS	19.8UV
A34	26.3DEFG	7.9BCDEF	35.3ABCD	409.1BCDEF	5.9FGHIJKL	67.0DEF	108.3CDEFGH	22.7CDEFG	26.3DEFG	6.1MNOPQR	23.6QR
A35	26.0DEFG	7.7BCDEFG	35.3ABCD	409.0BCDEF	5.4IJKL	66.7DEFG	108.3CDEFGH	22.7CDEFG	26.0DEFG	6.1MNOPQ	27.3MN
A39	24.7DEFGH	7.7BCDEFG	35.3ABCD	406.3BCDEF	79.0ABCD	66.7DEFG	108.3CDEFGH	22.5CDEFGH	24.7DEFGH	6.0MNOPQR	41.3B
A40	24.7DEFGH	7.7BCDEFG	34.3ABCD	398.0BCDEFG	5.0L	66.0EFGH	107.7DEFGHI	22.2CDEFGHI	24.7DEFGH	5.2T	31.7JK
A24×A23	23.7DEFGHI	7.7BCDEFG	34.3ABCD	396.8BCDEFG	6.5CDEFGHIJKL	65.7EFGH	107.7DEFGHI	22.0CDEFGHI	23.7DEFGHI	6.8J	22.9ST
A24×A27	23.3DEFGHIJ	7.6BCDEFGH	34.3ABCD	387.9BCDEFG	6.6CDEFGHIJK	65.3FGHI	107.7DEFGHI	21.7CDEFGHI	23.3DEFGHIJ	5.9PQR	32.0IJ
A24×A37	23.3DEFGHIJ	7.6BCDEFGHI	34.0ABCD	386.6BCDEFG	6.9ABCDEFGHI	65.3FGHI	107.7DEFGHI	21.5CDEFGHIJ	23.3DEFGHIJ	7.8DE	22.0RST
A25×A23	23.2DEFGHIJK	7.6BCDEFGHI	34.0ABCD	382.8BCDEFG	7.8ABCDE	65.0GHIJ	107.3EFGHIJ	21.2CDEFGHIJK	23.2DEFGHIJK	6.3LMN	24.8PQ
A25×A27	23.0EFGHIJK	7.4BCDEFGHIJ	33.3ABCDE	381.4BCDEFG	7.7ABCDE	65.0GHIJ	107.3EFGHIJ	21.2CDEFGHIJK	23.0EFGHIJK	7.3G	26.68NO
A25×A37	22.7FGHIJK	7.4BCDEFGHIJ	33.0ABCDE	380.3BCDEFG	6.8ABCDEFGHIJ	65.0GHIJ	107.0FGHIJK	21.2CDEFGHIJK	22.7FGHIJK	6.3LM	22.8RST
A29×A23	22.3GHIJKL	7.3BCDEFGHIJK	32.3ABCDEF	375.1BCDEFG	7.9ABC	64.7HIJK	107.0FGHIJK	21.0CDEFGHIJKL	22.3GHIJKL	3.9V	35.7EF
A29×A27	21.7HIJKLM	7.3BCDEFGHIJK	32.0ABCDEF	374.8BCDEFG	8.3A	64.7HIJK	106.7FGHIJKL	20.9DEFGHIJKL	21.7HIJKLM	8.0CD	30.0KL
A29×A37	21.3HIJKLMN	7.2BCDEFGHIJK	31.7ABCDEF	370.6CDEFG	6.6CDEFGHIJK	64.3HIJK	106.7FGHIJKL	20.9EFGHIJKL	21.3HIJKLMN	6.1LMNOPQ	33.1HIJ
A30× A23	21.3HIJKLMN	7.0BCDEFGHIJK	31.3ABCDEF	369.4CDEFG	7.7ABCDE	64.3HIJK	106.3GHIJKLM	20.4EFGHIJKL	21.3HIJKLMN	7.6EF	21.3TU
A30×A27	21.2HIJKLMNO	7.0BCDEFGHIJK	31.3ABCDEF	363.4CDEFG	6.2EFGHIJKL	64.3HIJK	106.0HIJKLM	20.3EFGHIJKL	21.2HIJKLMNO	7.2GH	34.0FGH
A30×A37	20.7HIJKLMNO	6.9BCDEFGHIJK	31.3ABCDEF	363.0CDEFG	7.5ABCDEF	64.0IJK	106.0HIJKLM	20.3EFGHIJKL	20.7HIJKLMNO	8.3AB	41.2B
A31×A27	20.7HIJKLMNO	6.9CDEFGHIJKL	31.0ABCDEF	356.1DEFGH	6.6CDEFGHIJK	64.0IJK	106.0HIJKLM	20.2EFGHIJKLM	20.7HIJKLMNO	4.2V	28.8LM
A31×A37	20.7HIJKLMNO	6.8CDEFGHIJKL	30.7ABCDEF	355.4DEFGH	7.6ABCDE	64.0IJK	105.7IJKLMN	20.0EFGHIJKLM	20.7HIJKLMNO	8.5A	41.9B
A32×A23	20.2IJKLMNO	6.8CDEFGHIJKL	30.3ABCDEF	345.9EFGHI	7.0ABCDEFGHI	63.7JKL	105.7IJKLMN	20.0EFGHIJKLM	20.2IJKLMNO	4.6U	5.4OP
A32×A27	19.9IJKLMNO	6.8CDEFGHIJKL	30.0ABCDEF	341.5EFGHI	5.8GHIJKL	63.7JKL	105.4IJKLMNO	19.9EFGHIJKLMN	19.9IJKLMNO	6.2LMNOPQ	21.3TU
A32×A37	19.3JKLMNOP	6.7DEFGHIJKL	30.0ABCDEF	339.9EFGHI	7.3ABCDEFGH	63.3KL	105.3IJKLMNO	19.8EFGHIJKLMN	19.3JKLMNOP	5.9PQR	29.9L
A34 ×A23	19.1JKLMNOP	6.6DEFGHIJKL	29.7ABCDEF	332.5EFGHI	5.7HIJKL	62.0LM	105.3IJKLMNO	19.7EFGHIJKLMN	19.1JKLMNOP	6.4KL	18.6VW
A34×A23	19.0KLMNOP	6.5EFGHIJKL	29.0ABCDEF	330.3EFGHI	6.9ABCDEFGHI	62.0LM	105.3IJKLMNO	19.6FGHIJKLMNO	19.0KLMNOP	5.9QR	38.1C
A34×A27	18.1LMNOPQ	6.5EFGHIJKL	29.0ABCDEF	329.5EFGHI	6.3DEFGHIJKL	61.3MN	105.3IJKLMNO	19.2FGHIJKLMNO	18.1LMNOPQ	6.2LMNO	21.8RST
A34×A37	18.0MNOPQ	6.4EFGHIJKL	28.7ABCDEF	329.3EFGHI	7.4ABCDEFG	61.3MN	105.0JKLMNO	18.4GHIJKLMNO	18.0MNOPQ	8.1BC	22.6RST
A35×A23	17.7MNOPQR	6.4FGHIJKL	28.0ABCDEF	327.7EFGHI	5.2JKL	60.7MNO	104.7KLMNOP	17.7HIJKLMNO	17.7MNOPQR	7.8CDE	17.9W
A35×A27	17.7MNOPQR	6.3GHIJKL	28.0ABCDEF	322.2FGHI	6.8ABCDEFGHI	60.3MNO	104.7KLMNOP	17.3IJKLMNO	17.7MNOPQR	7.3G	21.7ST
A35×A37	17.3NOPQR	6.2HIJKL	27.7ABCDEF	305.2GHIJ	7.5ABCDEF	60.3MNO	104.3LMNOP	16.6JKLMNOP	17.3NOPQR	6.6JK	33.1HIJ
A39×A23	17.3NOPQR	6.1IJKL	27.3BCDEF	61.1HIJK	7.09ABCDEFGH	60.0NO	104.0MNOP	16.3KLMNOP	17.3NOPQR	7.3FG	47.7A
A39×A27	17.0OPQR	6.1JKL	24.7CDEF	251.1IJK	6.7BCDEFGHIJK	60.0NO	103.3NOP	16.1LMNOP	17.0OPQR	5.8RS	23.4QRS
A39×A37	17.0OPQR	5.90KL	24.7CDEF	216.4JKL	6.5CDEFGHIJKL	60.0NO	103.0OP	15.3MNOP	17.0OPQR	5.9QR	42.6B
A40×A23	15.3PQR	5.9KL	23.0DEF	205.3KL	8.2AB	60.0NO	103.0OP	15.0NOP	15.3PQR	6.2LMNOP	38.3C
A40×A27	14.3QR	5.5L	21.3EF	96.3KL	7.3ABCDEFGH	59.7NO	103.0OP	14.7OP	14.3QR	7.1GHI	33.7GHI

SOV = sources of variation, DF = degree of freedom, PH = plant height, SG = stem girth, LPP = leaves per plant, LA = leaf area, IL = internodal length, DFF = days to 50% flowering, DM = days to maturity, HD = head diameter, NWPH = number of whorls per head, AYPH = achene yield per head, 100 AW = 100-achene weight

Head diameter (cm*).* Head diameter for sunflower testers ranged from 15 cm to 17.67 cm. Maximum head diameter was shown by tester A-23 and minimum head diameter was shown by tester A-37 from the Table 3. Head diameter for sunflower lines ranged from 15.33 cm to 22.67 cm. The sunflower line A-32 had maximum head diameter followed by line A-40 that was 21.19 cm. Line A-31 had minimum Head diameter which had significant difference from all other lines. Head diameter for crosses made by parents showed ranges 12 cm to 29.20 cm. Head diameter of cross A34×A23 showed maximum followed by the cross A35×A27 which was 28.45 cm. The minimum head diameter showed by cross A29×A27 followed by the cross A30 × A23 which was valued 14.72 cm. Head diameter ranged from 12 cm to 29.20 cm in present study. In literature, It was reported minimum and maximum values for head diameter that ranged from 10.95 cm to 21.71 cm (10, 31).

Achene yield per head (g). Achene yield per head for sunflower testers ranged from 17.86 g to 37.29 g. Maximum Achene yield per head were shown by tester A-23 and minimum number of Achene yield per head shown by tester A-37 from the Table 3. Achene yield per head for sunflower lines ranged from 18.59 g to 42.55 g. The sunflower line A-40 had maximum Achene yield per head followed by line A-24 that was 35.42g. Line A-35 showed minimum Achene yield per head. Among the crosses, Achene yield per head ranged from 19.80 g to 42.04 g. The cross A24×A23 showed maximum Achene yield per head followed by the cross A34 ×A-23 which valued was 41.93 g. The minimum Achene yield per head showed by cross A25×A37 followed by the cross A32×A23 and A34×A27 which was valued 21.27 g yield per head. In literature achene yield per head ranged from 16.95 g to 85.90 g (20, 31). The studied material is poor in case of achene yield per head so further improvement in the material in terms of achene yield per plant is required to meet the standards reported in literature could be possible through targeted breeding.

Combining ability analysis. Effects of General Combining Ability (GCA) for lines and testers in experimented sunflower genotypes were estimated for eleven plant characters to identify the best parents for subsequent hybrid development program. The results obtained from this study regarding the effects of the general combining ability for lines and testers are presented in Table 4.

Table 4. Estimation of General Combining Ability effects of sunflower lines and testers for yield and related traits.

LINES

Parents	PH	S G	DF F	D M	HD	AYPH
A24	16.17	-0.09	2.06	-9.53	-1.13	2.97
A25	-7.72	-0.14	-0.28	1.02	2.52	1.98
A29	12.61	-0.38	2.61	3.24	1.98	2.08
A30	10.28	0.10	2.61	2.13	-0.25	3.41
A31	6.39	0.84	1.39	1.13	-0.31	0.56
A32	12.72	-0.13	-2.06	-0.42	-1.04	1.61
A34	-12.83	0.05	-1.39	0.13	-0.09	-2.04
A35	2.22	0.15	0.71	-2.31	0.19	1.87
A39	-13.15	0.03	-1.09	1.12	-1.76	-0.94
A40	10.93	-0.18	0.38	1.19	1.57	-0.94

Testers

Parents	PH	SG	D50%F	DM	HD	AYPH
A23	-31.22	-0.20	-1.28	3.36	-3.27	-5.22
A27	-11.50	-0.04	-1.28	-0.64	0.08	-3.51
A37	5.11	0.01	-2.39	-0.42	1.50	-1.85

PH = plant height, SG = stem girth, D50%F = days to50% flowering, DM= days to maturity, HD= head diameter, AYPH = achene yield per head

Plant height. For plant height direction and variable magnitude of GCA effects was observed. The line A-24 (16.24) followed by lines A-32, A-29, A-40 and A-30 depicted significant and highest positive general combining ability effects for plant height. On the other hand among the lines A-39, A-34 and A-25 performed highest negative general combining ability effects for plant height. Among the testers GCA estimates were variable. Tester A-37 showed significant and positive GCA effects and A-23 followed by A-27 performed highest negative GCA effects for plant height.Significant and positive values of GCA are desirable for high yield so A-24 is best general combiner among lines and A-37 among testers (17, 18).

Stem girth. General combining ability effects were estimated for stem girth and concluded results were presented in Table 4.14. The line A-31 (0.84) followed by A-31, A-30, A-31 and A-34 showed significant and positive GCA effects for Stem girth. While among the lines A-40, A-32, A-24 and A-25 performed negative GCA effects for plant height. GCA estimates among the testes were also variable. Tester A-37 showed significant and positive GCA effects and A-27 followed by A-23 performed highest negative GCA effects for plant height, respectively.Significant and positive values of GCA are desirable for high yield so A-35 is best general combiner among lines and A-37 among testers (17,3,4).

Days to 50% flowering. Days to 50% flowering refers when a plant completes its 50% flowering. Thegeneral combining abilityeffects for days to 50% were observed for both lines and testers and data regarding trait was presented in Table 3. The lines A-29 and A-30 followed by A-24, A-31 and A-35 performed highly significant and highest positive general combining ability effects for days to 50% flowering. While among the lines A-25 followed by A-39 and A-34 performed negative GCA effects for Days to 50% flowering. Among the testers general combining ability estimates were variable. Tester A-27, A-23 followed by A-37 showed significant and negative GCA effects for Days to 50% flowering, respectively. Significant and positive values of GCA are desirable for high yield so A-29 is best general combiner among lines and A-27 and A-23 among testers(13, 18).

Days to maturity. The direction and variable magnitude of GCA effects was observed for days to maturity. Among the lines A-29 followed by A-30, A-40, A-31 and A-39 showed highly significant and highest positive general combining ability effects for days to maturity. While among the lines A-32 followed by A-35 and A-24 performed negative general combining ability effects for days to maturity. Among the testers general combining ability estimates were variable. Tester A-37 and A-27 showed negative general combining ability effects and A-23 performed highest positive general combining ability effects for days to maturity. Significant and positive values of general combining ability are desirable for high yield so A-29 is best general combiner among lines and A-23 among testers (13, 15, 18).

Head diameter. Magnitude of GCA effects was observed for head diameter for studied sunflower genotypes. Among the lines A-25 followed by A-29, A-40 and A-35 showed highly significant and highest positive general combining ability effects for head diameter as presented in Table 4.14. While on the other hand among the lines A-34 followed by A-30, A-24 and A-39 performed negative GCA effects for head diameter. Tester A-37 followed by A-27 showed significant and positive GCA effects and A-23 performed highest negative GCA effects for head diameter, respectively. Regarding head diameter significant and positive values of GCA are desirable for high yield so from the data printed in the Table A-25 is best general combiner among lines and A-37 among testers (10, 31).

Achene yield per head. Combining ability was observed for achene yield per head. Among the lines A-30, A-24, A-29, A-25 and A-35 showed highly significant and highest positive GCA effects for Achene yield per head. While among the lines, A-39, A-40 followed by A-34 performed negative general combining ability effects for Achene yield per head. Among the testers GCA estimates were variable. Tester A-37 followed by A-27 and A-23 showed negative GCA effects for Achene yield per head, respectively. Significant and positive values of GCA are desirable for high yield so A-20 is best general combiner among lines and A-37 among testers (10,13, 31).

Specific combining ability effects. Plant height. Specific Combining Ability (SCA) among crosses was recorded as Table 5 showed. It was observed that highly significant SCA was obtained for a crossA30×A23 followed by the crosses A30×A23, A25×A27, A32×A37, A40×A37, A34×A27 and A29×A37, respectively.High value of specific combining ability (SCA) indicated the additive effect of gene that may be useful for hybrid development program. So according to data obtained from field experiment these crosses can help for yield improvement in future breeding program. Cross A31×A37 showed highest negative value of SCA, so this needs further improvement to improve yield (14, 15, 16).

Table 5. Estimation of Specific Combining Ability effects of 36 sunflower crosses for yield and related traits

Crosses	PH	SG	DFF	DM	HD	AYPH
A30×A27	-0.53	15.67	-1.73	-1.07	60.86	0.49
A29×A27	-3.70	-41.96	-4.41	0.67	-136.53	-0.19
A25×A27	4.23	26.29	6.14	0.40	75.67	-0.30
A24×A27	-3.76	-27.05	-2.15	-0.48	-61.91	1.61
A34×A27	3.41	-9.18	2.24	0.71	35.11	0.03
A31×A27	0.34	36.23	-0.09	-0.23	26.81	-1.64
A35×A27	0.36	-8.99	5.33	-0.30	19.01	-1.05
A32×A27	-3.14	-1.79	-2.00	0.49	-0.69	0.26
A40×A27	2.79	10.79	-3.33	-0.19	-18.33	0.79
A39×A27	-3.20	-22.05	2.04	-1.37	-29.60	-0.16
A30×A23	4.97	24.32	-3.83	0.08	22.37	0.66
A29×A23	-1.77	-2.27	1.79	1.30	7.22	-0.50
A25×A23	-0.76	-20.99	-1.48	0.24	-68.90	0.28
A24×A23	1.08	20.87	-2.20	0.31	-58.43	0.72
A34×A23	-0.32	0.12	3.67	-0.54	127.32	-1.00
A34×A23	1.13	10.34	0.92	0.53	-16.84	0.74
A35×A23	0.30	1.87	3.68	-0.34	88.35	-1.54
A32×A23	-1.43	-12.21	-4.61	-0.19	-71.50	0.80
A40×A23	1.02	19.34	-0.21	0.06	52.56	-0.93
A39×A23	1.52	9.04	2.10	-0.60	41.31	-0.14
A30×A37	-2.54	-28.38	-1.89	0.55	-93.87	1.07
A29×A37	4.24	16.23	-1.12	1.97	29.73	0.15
A25×A37	-3.92	-2.74	0.97	-0.06	-10.74	-0.49
A24×A37	-0.32	-13.49	0.16	-1.92	-19.00	0.34
A34×A37	2.80	6.23	-0.92	0.27	0.00	-1.87
A31×A37	-5.74	-1.10	-2.24	-3.01	3.03	-1.46

A35×A37	-0.49	0.83	0.96	-0.74	-2.11	-0.41
A32×A37	11.28	0.15	1.62	3.53	-0.68	6.26
A40×A37	5.32	-0.16	-2.24	-2.90	0.41	-3.53
A39×A37	-16.60	0.01	0.62	-0.63	0.26	-2.72

PH = plant height, SG = stem girth, D50%F = days to50% flowering, DM days to maturity, HD= head diameter, AYPH = achene yield per head

Stem girth. Among the crosses, amount of SCA estimates were variable.With regards to cob girth, high value for specific combining ability was obtained from a cross A31×A27 followed by A31×A27, A25×A27, A30×A23, A24×A23, A40×A23, A29×A37 and A30×A27, respectively. These crosses can help for yield improvement in future breeding programme, while poorest value of combining ability was recorded from the cross A29×A27. This showed highest negative value of SCA, so this needs further improvement to improve yield (27).

Days to 50% flowering. Regarding days to 50% flowering data were recorded from the field experiment and manipulated in Table 4. According to the data the direction and magnitude of SCA effects for days to 50% flowering varied among crosses. Crosses A25×A27 followed by A34×A27, A35×A27, A39×A27, A29×A23, A34×A23, A39×A23 and A34×A37 had highly significant and positive specific combining ability effects for days to flowering. These crosses can help for yield improvement in future breeding program. From all the crossesA32×A23 showed negative value of SCA, so this needs further improvement to improve yield (17, 18, 20, 27)

Days to maturity. Among the crosses, variable magnitude and direction of SCA effects was observed for days to maturity. According to the data regarded days to maturity from the Table 4 the crossA32×A37 followed by A29×A23, A34×A27, A29×A27, A25×A27, A29×A23, A29×A37 and A32×A37 had positive and highly significant SCA effects for days to maturity. These crosses are useful and can help for yield improvement in future breeding programme. Cross A31×A37 showed highest negative value of SCA, so this needs further improvement to improve yield (10, 31, 21, 23)

Head diameter. The direction and magnitude of SCA effects was observed for head diameter. Cross A34×A23 followed by A30×A27, A25×A27, A34×A27, A31×A27, A35×A27, A30×A23, A29×A23, A35×A23, A40×A23, A35×A23, A25×A27, A30×A27 and A40×A23 showed highest positive and significant SCA effects for head diameter. These crosses can help for yield improvement in future breeding programme. Cross A29×A27 showed highest negative value of SCA, so this needs further improvement to improve yield (10, 31, 24, 26)

Achene yield per head. The variable amount and direction of SCA effects were observed for achene yield per plant. Achene yield per plant (Table 4) single cross A24×A27exhibited the high and specific combining ability for achene yield per plant. These crosses can help for yield improvement in future breeding programme. Cross A40×A37 poor values of SCA, so this combination needs further improvement to improve yield. Regarding the achene yield per plant similar results were found by various scientists in past (10, 11, 12, 31)

Genetic variances. Variance due to general combining ability (δ^2GCA) and specific combining ability (δ^2SCA), ratio of GCA:SCA variances, additive variance (δ^2A), dominance variance (δ^2D) and degree of dominance [δ^2SCA/ δ^2GCA]½ for the traits in study for sunflower genotypes are shown in Table 6. Specific combining ability which is dominance variance was more important for most of the plant traits and is higher than general combining ability. Predominance of dominant gene action was declared by the GCA:SCA ratio and degree of dominance was greater than 1. Magnitude of GCA and SCA variances revealed that the non-additive effects of gene were higher than additive effects for all the characters studied. Non-additive gene action is also revealed by the degree of dominance which is greater than unity for all traits. Variance due to SCA was higher than variance due to GCA effects. So, it indicated that there is presence of dominant effects for traits. The degree of dominance showed preponderance of over dominance gene action. Non additive gene action has previously been reported for days to (2, 17, 28, 33) for days to maturity, for leaf area, intermodal length (10, 12, 14, 15) for 100-achene weight (5, 6, 7) for number of leaves per plant and achene yield per plant (8, 9, 10).

Table 6. Estimates of variance due to GCA, variance due to SCA, additive variance, dominance variance, ratio of SCA to GCA and degree of dominance of sunflower genotypes

Genetic components	PH	SG	DFF	DM	HD	AWPH
S.E(G.C.A)Lines	5.72	0.30	0.37	3.13	1.01	0.37
S.E(G.C.A)Testers	3.13	0.17	0.20	1.71	0.55	0.20
S.E(S.C.A)	9.90	0.53	0.64	5.42	1.75	0.63
S.E(G.C.A)Lines	8.09	0.43	0.52	4.43	1.43	0.52

S.E(G.C.A)Testers	4.43	0.24	0.29	2.43	0.78	0.28
S.E(S.C.A)	14.00	0.75	0.90	7.67	2.48	0.90
Co.V. H.S. lines	56.57	-0.22	0.81	-3.16	-1.16	-21.92
Co.V. H.S. tester	96.12	-0.07	-0.01	-0.95	1.60	-6.32
Co.V. H.S. average	-0.11	0.01	-0.13	-0.06	-0.10	-0.02
Co.V. Full sib	803.15	0.35	7.80	13.07	11.82	47.72
б gca =Co.V. H.S.av.	-0.11	0.01	-0.13	-0.06	-0.10	-0.02
б sca	427.62	0.70	8.82	20.18	8.96	90.97
Contribution of lines	239.13	41.92	129.345	255.73	114.89	306.69
Contribution of tester	113.62	8.17	225.972	56.77	83.44	75.01
Contribution of L×T	361.53	258.02	204.562	632.27	323.00	2188.65

PH = plant height, SG = stem girth, D50%F= days to50% flowering, DM= days to maturity, HD= head diameter, AYPH = achene yield per head

Additive type of gene action has been reported for days to flowering (22, 29, 34). The difference in the findings of different authors referenced in the present breeding material can be attributed to the divergence of the material used in their studies (11, 30).

CONCLUSIONS

It was concluded that significant differences of hybrids with parents for all the traits indicating the presence of heterosis for agronomic traits. Crosses A30×A23, A31×A27, A30×A27, A31×A37, A30×A23, A25×A27, A32×A37, A34×A23, A31×A27, A24×A27 and A35×A23 showed significant and positive SCA effects for achene yield related traits, respectively. Accession A-34 and A-29 was suggested the best general combiner among the female parents and A-37 among male parent for yield and yield components.

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