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Genetic Behavior of Sunflower for Achene Yield and Its Related Traits

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ABSTRACT

The sunflower is a remarkable oilseed crop due to better oil composition and short duration. In this experiment combining ability was computed for achene yield and its related trait. Fifteen genotypes of sunflower were crossed by using line × tester pattern. Out of 15 genotypes, A6, A7, A10, A11, A12, A17, A19, A20, A21 and A26 were taken as females (lines) and A8, A9, A16, A18 and A22 were taken as male (testers). The parental and 50 F1 crosses seed was sown in randomized complete block design in 3 replications in next growing season. The data was recorded for leaves/plant, leaf area, plant height, head angle, fresh head diameter, dry head diameter, number of achenes/head, average yield/plant, 100 achene weight and harvest index. The recorded data was used to estimate the genetic of descriptive traits among the genetic material. Heterosis study revealed that A19 × A22 was best hybrid for plant height. A21 × A8 performed well for number of achenes per head and directly involved in increasing yield. A7 × A8 hybrid combinations expressed positive and significant SCA values for average yield. The intermediate inheritance pattern was observed for all traits. It can be concluded that investigated material can be efficiently used for the development of high-yielding hybrids along with genetic improvement of sunflower accessions for different traits.

Key words: Genetic diversity, combining ability, sunflower

INTRODUCTION

Sunflower, being an essential oilseed crop, plays a crucial role in our daily diet as a cost-effective source of energy. However, Pakistan faces a deficit in the production of edible oil, highlighting the significance of addressing this shortage. Total oil requirement was 2.667 million tons but local production of edible oil was only 17.32% (0.462 million tons) of our requirement during 2021-22. Remaining 82.68% (2.205 million tons) at the cost of Rs 136.9 billion (US$ 1.392 billion) was met through imports (Govt. of Pakistan, 2021-22).

After soybean, sunflower is the second largest oilseed crop worldwide in terms of production and importance. Sunflower has maximum potential and a good source for filling the gap between local edible oil production and demand. It has short life span (90-120 days) and easily adjustable to our cropping system. It can be grown in rain fed and irrigated areas successfully twice a year due to its wider adaptability. It has more than 40% oil contents in its seed that can be used for cooking purposes. It also contains about 80% of unsaturated fatty acids. Sunflower has 30% carbohydrates, 18-20% protein (Aslam et al., 2010). Sunflower oil has unique properties like light in color, mild taste, high level of unsaturated fatty acids and low in saturated fatty acids. Sunflower oil is rich in essentials fatty acids such as oleic acid and their contribution is 85-95% in total fatty acids. The oil is of supreme quality and lowering heart diseases due to the presence of 20-25% essentials vitamins A, D, E and K (Evert et al., 1987). Margarine and vegetable ghee can also be manufactured from it. Its seeds are also feed to animals and birds. The seed cake meal is important source of protein and used in fattening of animals and birds. It has no side effect in animals (Robert et al. 1993). It can improve soil structure as have high amount of nitrogen (N), potassium (K) and calcium (Ca) (Pickett, 1936). Sunflower covers 214 thousand acres area with production of 92 thousand tons seed and 35 thousand tons oil (Govt. of Pakistan, 2021-22).

The gap between production and consumption of edible oil is increasing rapidly due to increasing population and change in life style. The gap can be compensated by developing high yielding hybrids. Production of edible oil will be increased by increasing the area under oilseed

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cultivation. Oil contents and seed quality improvement should be a main concern in development of the high yielding varieties and hybrids. Sunflower has potential for exploitation of heterosis for achene and oil yield. The combining ability of genotypes determined the strength of heterosis (Hilli et al., 2020). The hybrids said to be highly uniform, vigorous, higher in yield and resistant to diseases. Open pollinated varieties are less in production than hybrids. Plant breeders have improved edible oil and seed yield in sunflower by the exploitation of heterosis (Mumtaz et al., 2014). Plant breeding program required information about combining ability, genetic variability and mode of inheritance of desired plant traits for the development of stable and high yielding hybrids through inter-specific hybridization for future cultivation (Abdel-Aty et al., 2023, Mumtaz et al., 2016).

This research is an effort for understanding the genetic behaviour of sunflower accessions for yield and its related traits and to identify the superior crosses for oil percentage and achene yield. The acquired knowledge will be helpful in development of high yielding hybrids in future breeding program in sunflower. The basic purpose of this experiment was to improve sunflower germplasm for edible oil yield, achene yield and quality of oil.

MATERIALS AND METHODS

Current research was conducted at the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture Faisalabad. Research was completed in spring season and summer season in 2013. Faisalabad is situated in the rolling flat plains of North East Punjab. It is situated between longitude 73º-06º east, latitude 30º-26º North and altitude is 184.4 m (above the sea level). It possesses the arid climate. It can touch both extremes, with a summer with maximum temperature 50ºC and winter temperature of −2ºC. The mean maximum and minimum temperatures in summer of this area are 39ºC and 27ºC respectively. In winter (December to February) its peaks at around 17ºC and 6ºC respectively.

Planting material for research was developed through crossing of 10 lines (female) and 5 testers (male). Female lines were A6, A7, A10, A11, A12, A17, A19, A20, A21 and A26. Tester or male lines were A8, A9, A16, A18 and A22. During the whole experiment the recommended agronomic practices for Sunflower growing were performed uniformly from sowing till harvesting.

The parental lines (15) were planted in the field during March 2013 to develop 50 hybrids by hand emasculation and pollination in line × tester mating design. These F1 seeds and their parents were sown in the field in randomized complete block design with three replications during September 2013. Plant to plant and row to row distance were maintained 25 cm and 75 cm, respectively. Dibbler was used to maintain plant to plant and uniform depth of 1.5 cm for seed sowing.

Ten plants from each entry in each replication were taken and data were recorded on the descriptive (Leaf color, Leaf Shape, Head angle, Head shape, Stem color, Stem Pubescence) and

quantitative (Number of Leaves, Leaf area, Plant height, Fresh Head diameter, Dry Head diameter, No of Achenes per Head, Average yield, 100 achene weight, Harvest index) traits.

Biometrical Approach

Descriptive traits inheritance was estimated according to Mendelian genetics. The calculation of percent heterosis over mid parent, better parent (Heterobeltiosis), and commercial heterosis was performed by utilizing formulas based on the amount of heterosis. Heterosis is expressed as the disparity between the F1 value and the mid parent value, as proposed by Falconer and Mackay in 1996.

RESULTS AND DISCUSSION

Descriptive Traits in Sunflower

1) Leaf color

All the accessions were investigated for leaf color attributes. It was found that studied genotypes had variable response in leaf color. Leaf color can be light green, green and dark green as mentioned in the Table 1. Most of the accessions responded by producing green and dark green color in leaf. It was also revealed that inheritance of leaf color was of intermediate behavior. The cross of dark green and light green (A11 × A8, A17 × A8) produces green leaves. Mumtaz et al., 2017 also found descriptive traits inheritance in *Brassica rapa*.

2) Head angle

All the planted material was observed for head angle with stem. It can be 45^o, 90^o, 135^o, 180^o and 235^o with respect to plant stem as listed in Table 1. It was found that maximum accessions showed 90^o and 135^o head angle. Among female lines, A21 responded by producing 45^o head angle.

3) Head shape

All the accessions were observed for head shapes. It can be concave, round, convex, flat and misshapes according to Table 1. Mostly the female lines exhibited flat head shape except A26 which revealed convex head shape. Among testers A9 and A22 showed flat shape while A16 exhibited convex head shape. Among crosses maximum cross combinations revealed flat and concave shapes while only two accessions showed convex and A21 × A8 with misshape head was observed. The inheritance of head shape is also of intermediate behavior.

4) Stem Color

All the lines were observed for stem greenness. It can be light green, slightly light green, intermediate, slightly dark and dark green according to Table 1. The inheritance of stem colour is also of intermediate behavior.

5) Stem Pubescence

Observations were made at the surface of 5 cm below the flower head just before the flowering. Pubescence can be absent, almost none, little, intermediate, much and very much according to Table 1. The inheritance of stem pubescence is also of intermediate behavior.

Heterosis Manifestation

Heterosis or hybrid vigor is referring to the superiority of F_1 hybrid over its parents in any desired character, particularly in yield; for example, heterosis in crop plants can be measured as an increase in achene yield.

Table 1: Sunflower Accessions

Sr. No.	Accessions	Leaf Color	Head Shape	Head Angle	Head Shape	Stem Colour	Stem pubescence
1	A6	Green	Triangular	90°	Flat	Slightly Green	Little
2	A7	Green	Cordate	90°	Flat	Light Green	Little
3	A10	Light Green	Lanceolate	180°	Flat	Slightly Dark Grean	Very Much
4	A11	Dark Green	Cordate	90°	Flat	Intermediate	Little
5	A12	Dark Green	Lanceolate	90°	Flat	Slightly Green	Intermediate
6	A17	Dark Green	Lanceolate	135°	Flat	Slightly Light Green	Much
7	A19	Light Green	Cordate	90°	Flat	Intermediate	Intermediate
8	A20	Green	Cordate	135°	Flat	Light Green	Intermediate
9	A21	Green	Cordate	45°	Flat	Light Green	Much
10	A26	Green	Cordate	90°	Convex	Dark Green	Much
11	A8	Light Green	Round	90°	Convex	Slightly light Green	Very Much
12	A9	Green	Lanceolate	135°	Flat	Light Green	Little
13	A16	Light Green	Cordate	135°	Concave	Light Green	Much
14	A18	Dark Green	Cordate	90°	Concave	Intermediate	Much
15	A22	Light Green	Cordate	90°	Flat	Slightly Light Green	Little
16	A6 × A8	Green	Cordate	90°	Flat	Intermediate	Much
17	A7 × A8	Dark Green	Cordate	90°	Concave	Light Green	Little
18	A10 × A8	Green	Cordate	135°	Flat	Slightly Light Green	Very Much
19	A11 × A8	Light Green	Cordate	90°	Concave	Light Green	Intermediate
20	A12 × A8	Light Green	Cordate	90°	Concave	light Green	Very Much
21	A17 × A8	Green	Cordate	135°	Flat	Light Green	Much
22	A19 × A8	Dark Green	Cordate	90°	Concave	Slightly Light Green	Intermediate
23	A20 × A8	Green	Cordate	135°	Flat	Light Green	Little
24	A21 × A8	Green	Cordate	135°	Flat	Slightly Light Green	Much
25	A26 × A8	Green	Cordate	180°	Concave	Intermediate	Much
26	A6 × A9	Light Green	Cordate	135°	Flat	Light Green	Much
27	A7 × A9	Green	Cordate	135°	Flat	Light Green	Very Much
28	A10 × A9	Green	Cordate	90°	Flat	Slightly Light Green	Little
29	A11 × A9	Light Green	Cordate	135°	Flat	Light Green	Little
30	A12 × A9	Light Green	Cordate	135°	Flat	light Green	Little
31	A17 × A9	Green	Cordate	90°	Convex	Light Green	Very Much
32	A19 × A9	Dark Green	Cordate	90°	Flat	Slightly Light Green	Little
33	A20 × A9	Dark Green	Lanceolate	135°	Concave	Slightly Light Green	Intermediate
34	A21 × A9	Dark Green	Cordate	135°	Flat	Slightly Green	Little
35	A26 × A9	Green	Round	135°	Convex	Light Green	Little
36	A6 × A16	Green	Cordate	135°	Concave	Slightly Dark Grean	Very Much
37	A7 × A16	Dark Green	Cordate	90°	Flat	Intermediate	Little
38	A10 × A16	Dark Green	Cordate	90°	Flat	Slightly Green	Intermediate
39	A11 × A16	Green	Cordate	90°	Flat	Slightly Light Green	Much
40	A12 × A16	Green	Cordate	135°	Flat	Light Green	Intermediate
41	A17 × A16	Green	Round	135°	Concave	Light Green	Intermediate
42	A19 × A16	Dark Green	Cordate	135°	Flat	Slightly Dark Grean	Much
43	A20 × A16	Dark Green	Cordate	135°	Concave	Intermediate	Much
44	A21 × A16	Light Green	Lanceolate	90°	Flat	Slightly Green	Very Much
45	A26 × A16	Green	Cordate	135°	Flat	Slightly Light Green	Little
46	A6 × A18	Green	Cordate	90°	Concave	Intermediate	Much
47	A7 × A18	Light Green	Round	90°	Concave	Light Green	Much
48	A10 × A18	Green	Cordate	135°	Flat	Light Green	Little
49	A11 × A18	Light Green	Cordate	135°	Flat	Dark Green	Much
50	A12 × A18	Light Green	Cordate	135°	Flat	light Green	Little
51	A17 × A18	Light Green	Cordate	90°	Concave	Light Green	Very Much
52	A19 × A18	Green	Cordate	90°	Concave	Light Green	Intermediate
53	A20 × A18	Dark Green	Cordate	135°	Flat	Intermediate	Very Much
54	A21 × A18	Light Green	Cordate	90°	Concave	Slightly Light Green	Much
55	A26 × A18	Light Green	Cordate	135°	Concave	Intermediate	Intermediate
56	A6 × A22	Green	Round	135°	Mis shape	Light Green	Little
57	A7 × A22	Green	Cordate	135°	Flat	Slightly Light Green	Much
58	A10 × A22	Dark Green	Cordate	135°	Concave	Light Green	Much
59	A11 × A22	Green	Cordate	90°	Concave	light Green	Much
60	A12 × A22	Light Green	Cordate	90°	Concave	Light Green	Little
61	A17 × A22	Light Green	Round	135°	Flat	Slightly Light Green	Little
62	A19 × A22	Green	Cordate	135°	Flat	Slightly Light Green	Very Much
63	A20 × A22	Green	Cordate	135°	Concave	Slightly Light Green	Little
64	A21 × A22	Green	Cordate	90°	Concave	Intermediate	Intermediate
65	A26 × A22	Light Green	Cordate	135°	Concave	Light Green	Much

Number of Leaves

Demonstration of heterosis for number of leaves in cross combinations was variable in direction and strength as average performance and heterotic effects reflected by F_1 hybrids shown in Table 2. Positive heterosis was required for number of leaves because these are the most important part of plant body for light harvesting and photosynthetic activity. Significant positive heterosis in both mid and better parents was revealed by 16 crosses. Cross A12 × A16 showed highest significant positive heterosis in mid parental heterosis and A17 × A22 showed highest significant positive heterosis in better parent heterosis for number of leaves. Crosses A7 × A9 lowest significant positive heterosis in mid parental heterosis and A10 × A9 showed lowest significant positive heterosis in better parent heterosis for number of leaves. They were found significantly different from all other investigated crosses. These findings had resemblance with previous findings of researcher for number of leaves Iqbal et al. (2009) and Nasreen et al. (2011).

Leaf Area (cm^2)

Direction and strength of heterosis for leaf area in cross combinations was variable in range Table 2 revealed average performance and heterosis for F_1 hybrids. Positive heterosis was needed for leaf area because these are the most important part for light harvesting and produce photosynthetic products in plants. Cross A10 × A9 showed highest significant positive heterosis in mid parental heterosis and A26 × A9 showed highest significant positive heterosis in better parent heterosis for leaf area. Crosses A10 × A18 lowest significant positive heterosis in mid parental heterosis and A19 × A16 exhibited lowest heterotic effects for leaf area. These were significantly different from all others under study crosses. These results were resembled with previous findings of scientist for leaf area Nasreen et al. (2011) and Khan et al. (2008).

Plant Height (cm)

Heterosis for plant height in crosses was found variable in direction and magnitude as mean performance and heterotic expression for crosses showed in Table 2. Negative heterosis was required for plant height. Significant and negative heterosis over mid and better parents was found in crosses A19 × A22 and A7 × A8. 12 crosses showed over mid parent and 22 crosses exhibited over better parent negative heterosis for plant height. The cross showed A17 × A8 lowest negative heterosis value for plant height. They were significantly different from all other cross combinations but did not significantly differ themselves. The present study findings had similarity with following researcher findings for plant height Jocković et al. (2018) and Rukmini et al. (2005).

Fresh Head Diameter (cm)

Magnitude over mid and better parent heterosis was observed in the cross combinations for head diameter. In Table 2 results indicated that head diameter revealed significant and positive heterosis in cross combinations A12 × A8 and A12 × A9. These crosses also showed maximum and significant positive heterobeltiosis for this character. Fresh head diameter heterosis reported by different researcher their results were comparable with present study results i.e., Bhoite et al., (2018) and Ahmad *et al.* (2013)

Dry Head Diameter (cm)

Magnitude over mid and better parent heterosis was observed in the cross combinations for head diameter. In Table 2 results indicated that head diameter revealed significant and positive heterosis in cross combinations A12 × A8 and A12 × A9. These crosses also showed maximum and significant positive heterobeltiosis for this character. Dry head diameter heterosis reported by different researcher their results were comparable with present study results i.e., Khair et al. (1992), Goksoy (2002), Sujatha et al. (2002), Devi et al. (2005), Hladni *et al*. (2006), Habib *et al.* (2006), Athoni and Nandini (2012) and Ahmad et al. (2013).

No of Achenes/ Head

The results of mean performance and heterosis manifestation were observed in the crosses for no of achene yield per head. Results in Table 2 revealed that no of achene per head showed significant and positive heterosis for 50 crosses over mid parent and better parent. Cross A26 × A9 followed by A6 × A9 showed significant and positive maximum heterosis over mid parent and over better parent. These crosses showed significant difference from each other and from all other crosses under study and had significant and positive maximum heterosis over mid and better parent. No of achene yield per head heterosis reported by different researcher their results were comparable with present study results i.e. Devi et al. (2005), Hladni et al. (2006), Lakshman et al. (2019) and Ghaffari et al. (2011).

Average yield (g)

Heterosis varied in manifestation and magnitude for average yield over mid and better parents in crosses. It was evident from the Table 2 that 22 crosses expressed mid parent and 17 crosses explicit better parent heterosis for average yield. A7 × A16 expressed the maximum heterosis value while A17 × A9 minimum value for this trait. Cross combination A7 × A9 exhibited largest heterobeltiosis value and varied significantly from other crosses. The results of this traits were resembled with previous research. Khan et al. (2008), Hilli et al. (2020) and Ahmad et al. (2013) had reported similar results for average yield.

100-Achene Weight (g)

Table 2 indicated the results of heterosis manifestation over mid and better parents for 100-achene weight. It was evident from the results that 10 crosses showed mid parent heterosis 15 crosses expressed better parent heterosis manifestation for 100-achene weight. Cross A12 × A18 expressed the highest heterosis value while A10 × A16 lower one for in this attribute. Cross combination A19 × A22 exhibited highest negative value and significantly varied from other ones. Khan et al. (2008) and Kang et al. (2013) had reported similar results for 100-achene weight.

Conclusion

The inheritance behavior of descriptive traits was of intermediate. In leaf color most of the accessions responded by producing green and dark green color in leaf. The most

Table 2: Heterotic expression in hybrids for number of leaves

		Number of Leaves		Plant Height		Head Diameter		Dry Head Diameter		No of Achenes/ Head		Average Yield		100-Achene Weight	
Sr. No.	Accessions	Ht	HBt	Ht	HBt	Ht	HBt	Ht	HBt	Ht	HBt	Ht	HBt	Ht	HBt
1	A6 × A8	-11.76*	3.03*	12.33*	2.14*	33.89*	23.26*	33.40*	22.90*	-34.30*	-38.10*	-36.92*	-51.27*	-23.99*	-29.20*
2	A7 × A8	-15.63*	6.67*	-12.85*	-20.15*	-1.83*	-11.79*	-1.62*	-11.51*	-27.92*	-30.14*	22.57*	0.75*	26.74*	11.69*
3	A10 × A8	17.29*	-8.90*	-10.85*	-17.96*	13.24*	3.83*	12.99*	3.12*	-21.79*	-24.00*	-55.31*	-59.45*	4.94*	2.05*
4	A11 × A8	23.44*	6.67*	37.06*	29.94*	34.16*	30.19*	33.56*	28.87*	-3.47*	-4.99*	-46.58*	-53.33*	-36.17*	-39.83*
5	A12 × A8	16.13*	3.33*	47.75*	19.55*	91.79*	61.03*	89.79*	58.03*	6.47*	1.85^{ns}	-36.60*	-40.19*	13.28*	10.07*
6	A17 × A8	>0.01^{ns}	-10.61*	-0.25*	-6.70*	0.07*	-8.67*	0.03*	-6.67*	-21.51*	-26.22*	-8.94*	-16.10*	12.24*	8.99*
7	A19 × A8	37.50*	5.66*	22.73*	15.70*	7.25*	-4.45*	6.15*	-3.32*	-24.53*	-33.73*	45.90*	45.60*	4.86*	-3.92*
8	A20 × A8	5.60*	-14.38*	4.89*	-0.67*	16.97*	6.33*	14.57*	5.32*	16.40*	8.12*	-13.84*	-34.22*	27.31*	25.36*
9	A21 × A8	34.48*	11.54*	27.84*	24.85*	-13.30*	-15.08*	-12.25*	-11.08*	19.69*	16.93*	-9.27*	-15.37*	25.20*	23.10*
10	A26 × A8	31.48^{ns}	3.85^{ns}	63.65*	29.38*	61.36*	36.54*	59.36*	30.44*	11.40*	3.14*	57.31*	36.04*	6.58*	-0.67*
11	A6 × A9	-3.39*	-10.61*	-6.18*	-16.00*	25.93^{ns}	7.94^{ns}	23.24^{ns}	8.14^{ns}	33.13*	30.63*	20.76*	17.82*	-4.74*	-13.19*
12	A7 × A9	3.45*	9.43*	11.38*	0.47*	7.62*	-9.77*	6.32*	-8.34*	-13.78*	-22.46*	105.68*	85.65*	-7.96*	-11.14*
13	A10 × A9	-18.92*	1.37*	14.07*	3.34*	61.36*	37.79*	60.15*	36.46*	-10.91*	-15.27*	-20.94*	-43.76*	-33.31*	-41.60*
14	A11 × A9	48.94*	-9.62*	32.42*	23.52*	55.10*	47.53*	54.17*	46.30*	14.51*	7.56*	102.95*	71.90*	19.28*	7.47*
15	A12 × A9	26.79^{ns}	7.69^{ns}	53.52*	25.88*	87.65*	68.89*	85.95*	67.52*	19.15*	15.10*	52.36*	20.75*	-9.83*	-24.73*
16	A17 × A9	25.45^{ns}	-16.67^{ns}	36.89*	5.12*	3.52*	-2.96*	3.01*	-2.63*	-10.13*	-11.61*	6.64*	3.81*	22.88*	17.99*
17	A19 × A9	10.34*	9.43*	53.46*	18.54*	4.42*	-4.51*	4.35*	-4.15*	18.00*	11.43*	76.42*	67.06*	-2.22*	8.99*
18	A20 × A9	21.37*	-19.86*	35.43*	4.97*	8.82*	1.59*	8.04*	1.21*	3.21*	2.80*	3.10*	-24.27*	18.63*	18.18*
19	A21 × A9	48.89*	2.27*	30.81*	3.77*	19.25^{ns}	13.57^{ns}	18.45^{ns}	12.74^{ns}	7.54*	1.74*	6.12*	-6.07*	18.45*	15.14*
20	A26 × A9	57.45*	6.82*	16.25*	10.24*	32.94*	9.88*	31.12*	8.56*	35.61*	35.56*	-13.46*	-28.63*	21.05*	14.06*
21	A6 × A16	36.84*	-13.64*	6.14*	-6.51*	9.57*	-3.17*	8.12*	-2.09*	29.25*	28.10*	-5.32*	-9.17*	-8.74*	-10.26*
22	A7 × A16	12.73*	3.77*	15.69*	2.65*	19.41*	3.11^{ns}	17.87*	2.08^{ns}	2.66*	-5.31*	91.80*	84.26*	-9.49*	-16.07*
23	A10 × A16	25.62*	-17.12^{ns}	27.46*	13.56*	5.44*	-7.18*	5.22*	-6.18*	5.74*	3.33*	-6.45*	-30.61*	4.38*	1.48*
24	A11 × A16	12.00*	4.17*	13.85*	4.38*	32.37*	30.35*	29.27*	28.09*	7.34*	3.56*	24.43*	11.62*	26.80*	26.28*
25	A12 × A16	81.40*	-10.42*	76.27*	46.70*	41.24*	23.21*	39.20*	21.01*	-9.88*	-10.51*	-14.73*	-28.83*	45.62*	34.11*
26	A17 × A16	-2.94*	3.03*	1.57*	-0.84*	0.92*	-0.69*	0.67*	-0.45*	-16.49*	-17.43*	25.68*	-10.90*	32.13*	28.78*
27	A19 × A16	26.67^{ns}	13.21^{ns}	-9.85*	-11.26*	-5.88*	-9.77*	-4.44*	-8.51*	31.21*	20.72*	-34.91*	-51.38*	8.82*	0.06*
28	A20 × A16	13.04*	-21.23*	-1.88*	-2.96*	11.66*	9.40*	10.43*	8.20*	2.14*	-0.27*	-48.10*	-49.64*	-4.15*	-5.98*
29	A21 × A16	39.13*	9.52*	16.05*	13.67*	16.43*	5.81*	15.32*	4.56*	-18.42*	-20.71*	-52.22*	-62.43*	23.79*	22.17*
30	A26 × A16	75.00*	-4.76*	12.63*	-13.77*	20.71^{ns}	-4.03^{ns}	19.65^{ns}	-3.01^{ns}	20.90*	17.64*	-33.08*	-43.80*	30.78*	21.45*
31	A6 × A18	17.65*	3.03*	1.43*	0.36*	1.36*	-1.59*	1.29*	-1.43*	7.88*	3.83*	-39.56*	-50.99*	-0.92*	-5.02*
32	A7 × A18	14.53*	-8.59*	4.13*	2.19*	23.28^{ns}	16.64^{ns}	22.28^{ns}	14.42^{ns}	-10.62*	-21.02*	-44.49*	-51.86*	15.80*	4.83*
33	A10 × A18	-5.41*	1.37*	-15.90*	-17.85*	-10.39*	-13.37*	-9.29*	-12.31*	21.11*	13.05*	-52.57*	-59.34*	27.40*	27.12*
34	A11 × A18	35.85*	-17.19*	3.37*	-2.09*	25.58^{ns}	15.56^{ns}	24.41^{ns}	14.34^{ns}	-5.55*	-12.90*	-22.04*	-27.79*	14.30*	10.92*
35	A12 × A18	23.53^{ns}	-20.31^{ns}	30.82*	-2.19*	26.97*	2.00*	25.67*	1.93*	25.42*	18.87*	-42.21*	-42.53*	51.16*	42.66*
36	A17 × A18	22.22*	-13.70*	-9.15*	-11.89*	15.60*	>0.01^{ns}	14.46*	>0.001^{ns}	-8.23*	-11.47*	-16.21*	-24.92*	-39.18*	-39.78*
37	A19 × A18	16.13*	-15.07*	3.95*	>0.01^{ns}	-2.95*	-17.91*	-1.53*	-17.65*	13.61*	9.33*	-1.12*	-4.29*	-4.42*	-10.80*
38	A20 × A18	-2.56*	-8.90*	-14.35*	-17.98*	16.40*	0.32*	15.31*	0.29*	27.00*	24.04*	-8.30*	-28.44*	18.71*	14.64*
39	A21 × A18	54.90*	-30.14*	6.30*	-1.22*	28.40*	23.42*	26.23*	21.23*	-0.45^{ns}	-7.55*	18.26*	13.59*	22.28*	21.93*
40	A26 × A18	18.75*	-12.33*	24.29*	-8.30*	79.43*	50.14*	77.47*	49.04*	19.87*	17.49*	-22.39*	-31.07*	-3.06*	-11.29*
41	A6 × A22	11.86*	-10.61*	7.68*	4.28*	-5.34*	-1.59*	-4.30*	-1.53*	-0.87^{ns}	-4.28*	68.71*	39.16*	-14.38*	-16.30*
42	A7 × A22	-8.93*	5.66*	-8.62*	-10.79*	-6.32*	-7.35*	-5.22*	-6.28*	10.11*	4.10*	39.08*	22.92*	-8.98*	-16.07*
43	A10 × A22	20.00*	-14.38*	4.28*	2.29*	-2.71*	-5.88*	-1.62*	-4.67*	8.78*	8.43*	-21.74*	-34.11*	-8.74*	-10.74*
44	A11 × A22	40.43*	-9.62*	-1.96*	-3.18*	8.60*	-5.88*	7.54*	-4.81*	-14.47*	-15.31*	22.78*	16.06*	18.14*	16.94*
45	A12 × A22	60.00*	-13.46*	17.06*	-9.85*	5.77*	-19.12*	4.56*	-18.01*	-14.77*	-16.40*	-19.83*	-21.98*	3.85*	-3.83*
46	A17 × A22	-10.79*	15.83*	11.58*	6.05*	28.57*	14.29*	26.43*	12.12*	18.81*	14.46*	78.50*	73.33*	75.71*	45.16*
47	A19 × A22	4.76*	5.00*	-26.73*	-29.80*	26.06^{ns}	9.47^{ns}	24.02^{ns}	8.31^{ns}	18.19*	6.16*	14.86*	3.22*	-6.73*	-26.48*
48	A20 × A22	-19.74*	4.11*	6.38*	2.39*	47.47*	30.57*	42.21*	28.45*	18.97*	13.22*	20.43*	-14.58*	52.54*	30.75*
49	A21 × A22	4.35*	-4.17*	2.55*	1.83*	55.77*	54.41*	54.55*	55.26*	-1.20^{ns}	-1.42^{ns}	14.92*	-3.05*	24.06*	3.54*
50	A26 × A22	-11.71*	-7.50*	24.18*	-17.92*	37.64*	27.17*	36.44*	25.11*	0.72^{ns}	-4.47*	-14.04*	-12.56*	48.31*	33.58*

accession showed head angle of 90^0 and 135^0. Flat, concave, convex and misshape heads were observed in progeny. Intermediate, slightly light green and slightly dark green colors were observed in stem pubescence. Among investigated crosses A20 × A16 followed by A19 × A9 revealed significant negative heterosis values for plant. F_1 cross combination A12 × A22 revealed significant positive heterosis for number of leaves, leaf area, head diameter, 100-achene weight excluding average yield. A19 × A22 was best hybrid for plant height. A21 × A8 was best hybrid for No. of achenes per head and directly involved in increasing yield. A7 × A8 hybrid combinations expressed positive and significant SCA values for average yield. The above-mentioned findings revealed that investigated material can be efficiently used for the development of higher yielding hybrids along with genetic improvement of sunflower accessions for different traits.

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