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Heterotic Performance of F_1 Hybrids for Yield, its Components and Oil Content of Sunflower (*Helianthus annuus* L.)

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ABSTRACT: The experimental material was developed by crossing five lines and twelve testers in L x T fashion. Parents and their 60 hybrids were evaluated in randomized block design with three replications at Oilseeds Research Unit, Dr. PDKV, Akola during kharif 2017. The highest standard heterosis over best check DRSH-1 for yield per plant was recorded by HA228A x AKSFI-16-4 (27.91 %) followed by HA208A x AKSFI-16-4 (17.71), HA208A × AKSFI-16-1 (15.67 %) and HA208A × AKSFI-16-2 (13.59 %). Cross HA303A x AKSFI-16-12 (5.94 %) exhibited highest useful heterosis for oil content followed by HA302A × AKSFI-16-1(4.77 %) and HA302A × AKSFI-16-12 (4.08 %) over the check DRSH-1. On the basis of mean performance, average heterosis, heterobetiosis and standard heterosis, the crosses HA228A × AKSFI-16-4, HA208A × AKSFI-16-4, HA208A × AKSFI-16-1, HA208 × AKSFI-16-2 and HA303A × AKSFI-16-12 were identified as promising crosses.

Keywords: Heterosis, heterobeltiosis, standard heterosis, Randomized block design and line × tester design.

INTRODUCTION

Sunflower is one of the most important oilseed crops grown for edible purposes in the world. Per capita consumption and requirements for edible oil is increasing. So the local production of hybrid seed with increased seed and oil yield is one of basic step to achieve the goal. An important direction of research work on sunflower is heterosis breeding. Heterosis or hybrid vigour is the increased or decreased vigour growth, fitness or yield of a hybrid over the parental value, resulting from the crossing of genetically unlike organisms (Shull 1908).

In sunflower poor seed set and high percentage of empty seeds are the major constrains. To overcome these constrains breeders have focused their attention towards production of hybrids through heterosis breeding which become possible due to discovery of cytoplasmic male sterility by Leclercq (1969) and fertility restoration by Kinnman (1970).

Expression of high heterotic effects in sunflower made it to emerge as one of the important oilseed crops in the world (Ahmad *et al.*, 2005). The present investigation revealed extent of heterosis (average heterosis, heterobeltiosis and standard heterosis) observed within the available genetic variability of crosses for various characters studied. The main purpose of this study is to identify superior cross combination for seed yield as well as for oil content, which would be certainly helpful for evolving superior hybrids in future.

MATERIAL AND METHODS

Present research was conducted at Oilseeds Research Unit, Dr. PDKV, Akola. The parent material for the study consisted of five CMS lines *viz.*, HA2228A, HA249A, HA302A, HA208A and HA303A and twelve restorer lines *viz.*, AKSFI-16-1, AKSFI-16-2 AKSFI-16-3, AKSFI-16-4, AKSFI-16-5, AKSFI-16-6, AKSFI-16-7, AKSFI-16-8, AKSFI-16-9, AKSFI-16-10, AKSFI-16-11 and AKSFI-16-12. Crossing work was done in *rabi* 2016 and evaluation was done in *kharif* 2017, resultant 60 crosses and two checks (PDKVSH-952 and DRSH-1) were sown in RBD design with three replications for evaluation in line x tester fashion. Each entry was sown in one row of 4.5 m length in each replication. Inter and intra-row spacing was 60 cm and 30 cm, respectively. All the standard agronomic and plant protection measures were followed. The data was recorded on plant basis and plot basis, from each genotype in each replication on 5 randomly selected plants and their average values were computed for ten quantitative traits *viz.*, days to 50% flowering, days to maturity, plant height at harvest (cm), head diameter (cm), hundred seed weight (g), volume weight (g/100ml), seed filling percentage, hull content (%), seed yield per plant (g) and oil content (%). Oil content of all genotypes was determined by using Bench top Pulse Nuclear Magnetic Resonance (NMR) Spectrometer (Model MQC OXFORD). Heterosis was calculated over mid parent, better parent and standard checks (PDKVSH-952 and DRSH-1) for seed yield, its components traits and oil content.

RESULTS AND DISCUSSION

The Analysis of Variance carried out for the seed yield, its component characters and oil content are presented in Table 1. The mean sum of squares due to treatments (genotypes) were highly significant for all characters *viz.*, days to 50 per cent flowering, days to maturity, plant height, head diameter, seed filling per cent, 100 seed weight, volume weight, hull content, seed yield and oil content. The mean sum of squares due to parents (lines & testers), Male (testers) × Female (lines), crosses and parents vs crosses were also found highly significant for all the characters studied. This indicated the presence of substantial genetic variability among the genotypes for all the characters studied.

The percentage of average heterosis (H_1), heterobeltiosis (H_2) and standard heterosis [(H_3) and (H_4)] for all the characters under study are given in the Table 2. In sunflower, positive heterosis is desirable for all characters studied except days to 50% flowering, days to maturity, plant height and hull content, for which negative heterosis is desirable.

Standard heterosis for days to 50% flowering, days to maturity and plant height was calculated over the check PDKVSH-952 and for head diameter, 100 seed weight, volume weight, seed filling percentage, hull content, oil content, seed yield per plant was calculated over the checks DRSH-1.

In sunflower, early flowering is generally considered as desirable character. The range of average heterosis was recorded from -9.81 to 6.29 per cent. Out of 60 crosses, 21 crosses, showed significant negative heterosis for this character and highest significant negative heterosis was recorded bycross HA228A × AKSFI-16-7 (-14.03%) followed by HA228A × AKSFI-16-2 (-13.27%) and HA228A × AKSFI-16-3 (-12.35%). Heterobeltiosis was ranged from -18.18 to 6.92 per cent. Out of 60 crosses, eight crosses showed significant heterobeltiosis in negative direction and among eight crosses, highest significant negative heterobeltiosis was recorded by cross HA228A × AKSFI-16-2 (-9.81%) followed by HA228A × AKSFI-16-7 (-9.43%) and HA228A × AKSFI-16-3 (-9.15%). For days to 50% flowering, the standard heterosis ranged from -11.66% to 4.29%. Out of 60 crosses, 14 crosses showed significant negative standard heterosis for the trait over standard check PDKVSH-952.Among fourteen crosses, highest significant negative standard heterosis was recorded by cross HA228A x AKSFI-16-7 (-11.66%) followed by HA228A × AKSFI-16-2 (-9.82%), HA303A × AKSFI-16-12 (-9.20%) and HA228A × AKSFI-16-3 (-8.59%).

Similarly early maturity is desired trait in sunflower. For mid parental heterosis 19 crosses were showing significant negative heterosis. The average heterosis ranged from -8.18 to 5.47 and highest significant negative heterosis was recorded by HA302A × AKSFI-16-5 (-8.18 per cent) followed by HA302A × AKSFI-16-4 (-8.01 per cent) and H228A × AKSFI-16-3 (-7.32 per cent). For heterobeltiosis, out of 60 crosses, six crosses were showing significant negative heterosis and highest negative heterobeltiosis was recorded HA302A × AKSFI-16-5 (-8.18 per cent) followed by HA302A × AKSFI-16-4 (-7.83 per cent), HA302A × AKSFI-16-4 (-8.18 per cent) and HA228A × AKSFI-16-3 (-4.51 per cent). Range of standard heterosis for days to maturity was recorded from -10.83 per cent to 4.33 per cent over the standard check PDKVSH-952. Out of 60 crosses, 33 crosses showed significant negative standard heterosis for this trait and highest significant negative heterosis was registered by cross HA302A × AKSFI-16-4 (-10.83 per cent) followed by HA302A × AKSFI-16-5 (-10.83 per cent) and HA228A × AKSFI-16-3 (-8.30 per cent).

Average heterosis for plant height ranged from 0.57 to 65.77 per cent (Table 3). None of the crosses exhibited negative heterosis for plant height. Heterobeltiosis ranged from 5.68 to 78.63 per cent. The cross HA228A x AKSFI-16-10 (5.68 per cent) exhibited highest heterobeltiosis followed by HA303A × AKSFI-16-6 (15.37 per cent) and HA228A×AKSFI-16-2 (15.90 per cent).For the plant height, standard heterosis ranged from -36.12 to 4.56 per cent over check PDKVSH-952. 49 crosses were negatively significant for this character. Maximum negative heterosis was exhibited by crosses HA249A × AKSFI-16-2 (-36.12 per cent) followed by HA302A × AKSFI-16-1 (-29.13 per cent) and HA228A × AKSFI-16-2 (-28.78 per cent).

For head diameter, out of 60 hybrids, 51 hybrids recorded significant average heterosis in positive direction. The least heterosis of -3.65 per cent has been recorded by the hybrid HA303A × AKSFI-16-3, while highest heterosis of 222.32 per cent was recorded by the hybrid HA208A × AKSFI-16-1 followed by HA208A × AKSFI-16-8 (194.57 per cent) and HA208A × AKSFI-16-12 (134.70). The heterosis over better parent ranged from -10.91 per cent to 177.49 per cent. Out of 60 hybrids, 39 hybrids recorded significant heterobeltiosis in positive direction. The cross HA208A ×AKSFI-16-1 (177.49 per cent) exhibited highest positive heterobeltiosis followed by HA208A × AKSFI-16-8 (170.48 per cent) and HA208 × AKSFI-16-12 (66.60 per cent). For the head diameter, range of standard heterosis over the check DRSH-1 was -30.15 per cent (HA228A × AKSFI-16-10) to 13.24 per cent (HA303A × AKSFI-16-12) and cross, HA303A × AKSFI-16-12 (13.24%) exhibited maximum positive standard heterosis followed by cross HA302A × AKSFI-16-4 (12.38%) and HA208A × AKSFI-16-2 (11.40%).

Average heterosis for 100 seed weight ranged from -15.22 to 81.33 per cent. Most of the crosses exhibited significant positive average heterosis, the cross HA228A × AKSFI-16-3 (81.33%) exhibited maximum positive average heterosis followed by the cross HA228A × AKSFI-16-4 (63.64%) and HA249A × AKSFI-16-8 (60.00%). Heterobeltiosis ranged from -18.00 to 61.90 per cent. The crosses HA228A × AKSFI-16-3 (61.90%) exhibited maximum significant positive heterobeltiosis followed by the cross HA249A × AKSFI-16-8 (60.00%) and HA208A × AKSFI-16-8 (59.00%). Standard heterosis over check DRSH-1 ranged from -22.00 to 36.00 per cent. The cross HA228A × AKSFI-16-3 (36.00%) recorded maximum standard heterosis, followed by the cross HA303A × AKSFI-16-12 (32.00%), HA228A × AKSFI-16-4 (26.00%) and HA228A × AKSFI-16-12 (26.00%) and the maximum negative heterosis recorded by HA249A × AKSFI-16-11 and HA302A × AKSFI-16-2 (-22.00%).

Range of heterosis for volume weight was from 2.56 per cent to 44.65 per cent. 55 crosses recorded significant positive volume weight. HA249A × AKSFI-16-2 (44.65%) recorded highest significant positive heterosis followed by HA208A × AKSFI-16-2 (43.07 %) and HA249A × AKSFI-16-8 (42.31 %). For heterobeltiosis (H_2), out of 60, 45 crosses recorded significant positive heterobeltiosis. Range of heterobeltiosis was from -9.66 per cent to 40.45 per cent. Highest heterobeltiosis was exhibited by HA249A × AKSFI-16-8 (40.45 %) followed by HA228A × AKSFI-16-12 (36.29 %) and HA303A × AKSFI-16-12 (36.29 per cent). Highest negative heterobeltiosis was exhibited by HA302A × AKSFI-16-5 (-9.66 %). For volume weight, standard heterosis ranged from -20.39 per cent to 13.38 per cent over the standard check DRSH-1. 7 crosses exhibited significant positive heterosis. HA208A × AKSFI-16-4 (13.38 %) recorded highest useful heterosis followed by HA303A × AKSFI-16-12 (11.18%) and HA228A × AKSFI-16-3 (9.87%). Highest negative heterosis was recorded by HA302A × AKSFI-16-6(-20.39 %).

For seed filling percentage, average heterosis ranged from -45.25 to 50.33 per cent (Table 2). Maximum significant positive average heterosis was recorded by HA228A × AKSFI-16-4 (50.33%) followed by HA303A × AKSFI-16-12 (46.69 %) and HA208A × AKSFI-16-12 (39.33 %). The heterobeltiosis ranged from -45.40 to 37.31 per cent. 14 crosses recorded significant positive heterobeltiosis. Maximum positive heterobeltiosis observed in cross HA228 × AKSFI-16-4 (37.31 %) followed by HA303A × AKSFI-16-12 (27.53 %) and HA228A × AKSFI-16-3 (25.09 %). Range of standard heterosis for percentage of filled seeds per head over DRSH-1 was observed from -47.21 to 32.04 per cent. Out of 60 crosses, 10 crosses exhibited positive and significant standard heterosis for this trait. The cross HA228A × AKSFI-16-4(32.04 %) exhibited maximum positive standard heterosis followed by cross HA303A × AKSFI-16-12 (25.92 %) and HA228A × AKSFI-16-3 (20.29 %)

Negative heterosis is desirable for hull content. Heterosis (H_1), *i.e*. average heterosis ranges from -64.06 per cent to 60.62 per cent. Forty-six crosses were showing highly significant negative heterosis andcross HA249A × AKSFI-16-5 (-64.06 %) showed highest negative heterosis followed by HA228A × AKSFI-16-5 (-58.35%) and HA208A × AKSFI-16-12 (-50.46%). Highest positive heterosis was recorded by HA208A × AKSFI-16-8 (60.62 %). Heterobeltiosis ranged from -67.08 per cent to 58.23 per cent. Out of sixty, forty-nine crosses showed highly significant negative heterosis. Cross HA228A × AKSFI-16-5 (-67.08%) and HA249A × AKSFI-16-5 (67.08 %) exhibited highest significant negative heterosis and followed by HA302A x AKSFI-16-10 (-60.44 %) and HA303A × AKSFI-16-5 (-51.98 %). Useful heterosis ranged from -44.61 per cent to 82.36 per cent. Thirty-three crosses recorded highly significant negative useful heterosis. Top ranking crosses for significant negative useful heterosis wereHA228A × AKSFI-16-5 (-44.61 %), HA249A × AKSFI-16-5 (-44.61 %), HA302A × AKSFI-16-10 (-44.61 %), HA302A × AKSFI-16-12 (-44.61 %), HA208A × AKSFI-16-4 (-44.61 %) and HA208A x AKSFI-16-12 (-44.61 %).

For oil content, mid parental heterosis was ranged from -5.44 per cent to 17.80 per cent. Forty-one crosses registered highly significant heterosis while five were significant. Cross HA208A × AKSFI-16-2(17.80 %) reported highest heterosis followed by HA208A × AKSFI-16-10 (17.50 %) and HA228A × AKSFI-16-12 (16.64 %). For heterobltiosis (H_2), seventeen crosses registered highly significant positive heterobeltiosis while one was significant. The range of heterobeltiosis was from -8.89 per cent to 13.12 per cent. HA208A × AKSFI-16-10 (13.12 %) exhibited highest positive significant heterobeltiosis followed by HA249A × AKSFI-16-10 (12.04 %) and HA228A × AKSFI-12 (10.37 %). Range of useful heterosis was from -9.22 percent to 5.94 per cent. Three crosses exhibited significant positive useful heterosis over the check DRSH-1. Cross HA303A × AKSFI-16-12 (5.94 %) exhibited highest useful heterosis followed by HA302A × AKSFI-16-1(4.77 %) and HA302A × AKSFI-16-12 (4.08 %). Cross HA249A × AKSFI-16-11 (-9.22 %) registered highest negative useful heterosis. Phad *et al*. (2002), Sujatha and Reddy (2009); Neelima and Rafi (2013); Venkata and Nadaf (2013); Qamar *et al.* (2015); Sapkale *et al.* (2016) have also reported high seed yielding hybrids having early maturity and good oil content.

Table 1: Analysis of variance.

Sources of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	100 seed weight (g)	Volume weight (g/100ml)	Seed filling (%)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
		1	2	3	4	5	6	7	8	9	10
Replications	2	3.76	6.17	45.99	2.33	0.23	0.07	17.54	0.08	1.10	25.97
Treatments	76	10.18**	19.12**	1379.41**	24.07**	1.18**	44.97**	416.85**	357.13**	11.35**	460.37**
Parents	16	15.24**	20.66**	1620.73**	31.13**	1.13**	30.22**	141.39**	202.70**	21.95**	80.98**
Parents vs Crosses	1	44.44**	68.79**	43176.27**	859.73**	10.13**	1169.05**	187.16**	2088.18**	153.69**	22474.52**
Crosses	59	8.23**	17.86**	605.56**	7.99**	1.04**	29.92**	495.44**	369.67**	6.07**	190.13**
Error	152	1.49	2.03	35.56	1.07	0.10	1.62	14.39	0.04	0.57	11.23

Note:* Significant at 5% level of significance ** Significant at 1% level of significance

Table 2: Heterosis (%) over mid-parent (MP), better-parent (BP) and standard checks [DRSH-1 (H_3) and PDKVSH-952 (H_4)] for different characters in sunflower.

Sr. No.	Crosses	Days to 50% Flowering				Days to Maturity			
		1				2			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1.	HA228A × AKSFI-16-1	-8.66**	-3.77*	-10.53**	-6.13**	-1.1	1.12	-7.56**	-2.89*
2.	HA228A × AKSFI-16-2	-13.27**	-9.81**	-14.04**	-9.82**	-4.25**	-2.64*	-11.00**	-6.50**
3.	HA228A × AKSFI-16-3	-12.35**	-9.15**	-12.87**	-8.59**	-6.27**	-4.51**	-12.71**	-8.30**
4.	HA228A × AKSFI-16-4	-6.27**	-1.26	-8.19**	-3.68*	-1.12	-0.76	-9.28**	-4.69**
5.	HA228A × AKSFI-16-5	-5.17**	1.96	-8.77**	-4.29*	1.31	1.88	-6.87**	-2.17
6.	HA228A × AKSFI-16-6	-4.45**	-0.01	-5.85**	-1.23	1.88	1.88	-6.87**	-2.17
7.	HA228A × AKSFI-16-7	-14.03**	-9.43**	-15.79**	-11.66**	-3.56**	-3.39*	-11.68**	-7.22**
8.	HA228A × AKSFI-16-8	-6.86**	-6.32**	-4.68**	0	-1.43	3.38*	-5.50**	-0.72
9.	HA228A × AKSFI-16-9	-4.99**	-1.82	-5.26**	-0.61	1.68	2.63*	-6.19**	-1.44
10.	HA228A ×AKSFI-16-10	-7.25**	-5.32*	-6.43**	-1.84	-0.18	2.63*	-6.19**	-1.44
11.	HA228A × AKSFI-16-11	-7.47**	-6.39**	-5.85**	-1.23	-2.17*	1.50	-7.22**	-2.53*
12.	HA228A × AKSFI-16-12	-4.22**	1.92	-7.02**	-2.45	0.75	1.50	-7.22**	-2.53*
13.	HA249A × AKSFI-16-1	-0.64	0.64	-8.77**	-4.29*	-3.33**	-0.38	-10.31**	-5.78**
14.	HA249A × AKSFI-16-2	-1.89	0.64	-8.77**	-4.29*	-2.42*	0.00	-9.97**	-5.42**
15.	HA249A × AKSFI-16-3	-0.31	2.57	-7.02**	-2.45	-3.72**	-1.14	-11.00**	-6.50**
16.	HA249A × AKSFI-16-4	1.91	3.22	-6.43**	-1.84	2.26*	3.44*	-6.87**	-2.17
17.	HA249A × AKSFI-16-5	1.95	2.61	-8.19**	-3.68*	-2.07	-0.76	-10.65**	-6.14**
18.	HA249A × AKSFI-16-6	1.9	3.86*	-5.85**	-1.23	1.14	1.91	-8.25**	-3.61**
19.	HA249A × AKSFI-16-7	0	1.28	-8.19**	-3.68*	-1.7	-0.76	-10.65**	-6.14**
20.	HA249A × AKSFI-16-8	-5.78**	-0.01	-9.36**	-4.91**	-4.33**	1.15	-8.93**	-4.33**
21.	HA249A × AKSFI-16-9	0.63	3.86*	-5.85**	-1.23	2.44*	4.20**	-6.19**	-1.44
22.	HA249A × AKSFI-16-10	-4.32**	-0.01	-9.36**	-4.91**	-1.66	1.91	-8.25**	-3.61**
23.	HA249A × AKSFI-16-11	-3.36*	1.93	-7.60**	-3.07	-1.46	3.06*	-7.22**	-2.53*
24.	HA249A × AKSFI-16-12	-0.96	-0.65	-9.94**	-5.52**	-0.38	1.15	-8.93**	-4.33**
25.	HA302A × AKSFI-16-1	0.63	1.28	-7.02**	-2.45	-0.55	1.11	-6.53**	-1.81
26.	HA302A × AKSFI-16-2	1.25	3.19	-5.26**	-0.61	-2.21*	-1.12	-8.59**	-3.97**
27.	HA302A × AKSFI-16-3	0.93	3.19	-5.26**	-0.61	0.55	1.85	-5.84**	-1.08
28.	HA302A × AKSFI-16-4	-2.53	-1.90	-9.94**	-5.52**	-8.01**	-7.83**	-15.12**	-10.83**
29.	HA302A × AKSFI-16-5	1.94	3.27	-7.60**	-3.07	-8.18**	-8.18**	-15.12**	-10.83**
30.	HA302A × AKSFI-16-6	1.26	2.55	-5.85**	-1.23	2.43*	3.00*	-5.84**	-1.08
31.	HA302A × AKSFI-16-7	3.80*	4.47*	-4.09*	0.61	2.24*	2.62*	-5.84 **	-1.08
32.	HA302A × AKSFI-16-8	-2.11	3.19	-5.26**	-0.61	-5.53**	-1.49	-8.93**	-4.33**
33.	HA302A × AKSFI-16-9	0.62	3.19	-5.26**	-0.61	1.11	1.48	-6.19**	-1.44
34.	HA302A × AKSFI-16-10	-3.07	0.64	-7.60**	-3.07	-5.09**	-2.98*	-10.31**	-5.78**
35.	HA302A × AKSFI-16-11	-1.52	3.19	-5.26**	-0.61	-2.70*	0.37	-7.22**	-2.53*
36.	HA302A × AKSFI-16-12	2.24	2.56	-6.43**	-1.84	0.19	0.37	-7.22**	-2.53*
37.	HA208A × AKSFI-16-1	0	1.89	-5.26**	-0.61	-2.39*	-0.37	-8.59**	-3.97**
38.	HA208A × AKSFI-16-2	-3.05	-2.45	-7.02**	-2.45	-2.95**	-1.50	-9.62**	-5.05**
39.	HA208A × AKSFI-16-3	-2.74	-2.44	-6.43**	-1.84	-0.55	1.12	-7.22**	-2.53*
40.	HA208A × AKSFI-16-4	-1.85	0.00	-7.02**	-2.45	0.93	1.12	-7.22**	-2.53*
41.	HA208A × AKSFI-16-5	0.63	4.58*	-6.43**	-1.84	1.12	1.50	-6.87**	-2.17
42.	HA208A × AKSFI-16-6	0.61	1.86	-4.09*	0.61	2.44*	2.63*	-6.19**	-1.44
43.	HA208A × AKSFI-16-7	-1.85	0.00	-7.02**	-2.45	-1.5	-1.50	-9.62**	-5.05**
44.	HA208A × AKSFI-16-8	-3.83*	-1.21	-4.68**	0	-1.97	2.62*	-5.84**	-1.08
45.	HA208A × AKSFI-16-9	-1.82	-1.82	-5.26**	-0.61	2.97**	3.75**	-4.81**	0
46.	HA208A × AKSFI-16-10	1.8	3.03	-0.58	4.29*	5.47**	8.24**	-0.69	4.33**
47.	HA208A × AKSFI-16-11	-5.64**	-3.64	-7.02**	-2.45	0.9	4.49**	-4.12**	0.72
48.	HA208A × AKSFI-16-12	0.31	3.21	-5.85**	-1.23	2.05	2.62*	-5.84**	-1.08
49.	HA303A × AKSFI-16-1	5.66**	5.66**	-1.75	3.07	0.73	1.83	-4.81**	0
50.	HA303A × AKSFI-16-2	1.86	3.14	-4.09*	0.61	0.91	1.47	-5.15**	-0.36
51.	HA303A × AKSFI-16-3	0.93	2.52	-4.68**	0	0	0.00	-5.84**	-1.08
52.	HA303A × AKSFI-16-4	6.92**	6.92**	-0.58	4.29*	1.48	2.24	-5.84**	-1.08

53.	HA303A × AKSFI-16-5	5.13**	7.19**	-4.09*	0.61	0.92	1.48	-6.19**	-1.44
54.	HA303A × AKSFI-16-6	3.75*	4.40*	-2.92	1.84	3.35**	4.51**	-4.47**	0.36
55.	HA303A × AKSFI-16-7	6.29**	6.29**	-1.17	3.68*	0.56	1.50	-6.87**	-2.17
56.	HA303A × AKSFI-16-8	-3.90*	0.63	-6.43**	-1.84	-4.61**	-1.11	-7.56**	-2.89*
57.	HA303A × AKSFI-16-9	-1.23	0.63	-6.43**	-1.84	-0.55	-0.37	-7.22**	-2.53*
58.	HA303A × AKSFI-16-10	-3.66*	-0.63	-7.60**	-3.07	-2.71*	-1.11	-7.56**	-2.89*
59.	HA303A × AKSFI-16-11	-3.93*	0.00	-7.02**	-2.45	-2.15*	0.36	-6.19**	-1.44
60.	HA303A × AKSFI-16-12	-6.03**	-5.13*	-13.45**	-9.20**	-0.37	0.00	-7.22**	-2.53*
	Range	-14.03 to 6.92	-9.81 to 6.92	-15.79 to -0.58	-11.66 to 4.29	-8.18 to 5.47	-8.18 to 8.24	-15.12 to -0.69	-10.83 to 4.33
	SE(D)±	0.86	0.99	0.99	0.99	1.008	1.16	1.16	1.16
	CD 5%	1.70	1.97	1.97	1.97	1.99	2.30	2.30	2.30
	CD 1%	2.25	2.60	2.60	2.60	2.63	3.04	3.04	3.04

Table 2: Heterosis (%) over mid-parent (MP), better-parent (BP) and standard checks [DRSH-1 (H_3) and PDKVSH-952 (H_4)] for different characters in sunflower.

Sr. No.	Crosses	Plant Height (cm)				Head diameter (cm)			
		3				4			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1.	HA228A × AKSFI-16-1	25.67**	54.91**	-23.99**	-15.22**	101.97**	60.36**	0.80	5.14
2.	HA228A × AKSFI-16-2	0.57	15.90**	-36.15**	-28.78**	57.89**	43.85**	9.99*	14.71**
3.	HA228A × AKSFI-16-3	20.60**	31.63**	-20.00**	-10.76**	53.33**	36.72**	9.71*	14.43*
4.	HA228A × AKSFI-16-4	16.30**	21.44**	-12.69**	-2.61	61.30**	48.22**	11.20*	15.98**
5.	HA228A × AKSFI-16-5	28.13**	52.89**	-20.72**	-11.57**	69.05**	66.99**	7.59	12.22*
6.	HA228A × AKSFI-16-6	11.62**	12.47**	-20.35**	-11.16**	32.57**	19.65**	-6.57	-2.56
7.	HA228A × AKSFI-16-7	24.48**	26.05**	-11.62**	-1.41	43.76**	31.18**	-0.04	4.26
8.	HA228A × AKSFI-16-8	32.58**	58.48**	-18.08**	-8.62**	100.25**	50.94**	-5.12	-1.04
9.	HA228A × AKSFI-16-9	12.11**	18.38**	-14.90**	-5.07	26.00**	9.40	-6.63	-2.62
10.	HA228A × AKSFI-16-10	4.60	5.68	-24.03**	-15.25**	-1.11	-10.91	-30.15**	-27.15**
11.	HA228A × AKSFI-16-11	16.18**	23.60**	-11.14**	-0.88	18.72**	0.83	-9.28	-5.38
12.	HA228A × AKSFI-16-12	30.90**	45.68**	-14.56**	-4.70	49.72**	48.89**	-5.36	-1.29
13.	HA249A × AKSFI-16-1	32.34**	37.81**	-32.38**	-24.58**	98.43**	55.41**	1.41	5.77
14.	HA249A × AKSFI-16-2	5.84	7.80*	-42.74**	-36.12**	50.41**	39.39**	6.57	11.15*
15.	HA249A × AKSFI-16-3	44.19**	54.58**	-17.89**	-8.40**	29.02**	16.97**	-6.14	-2.11
16.	HA249A × AKSFI-16-4	25.49**	55.18**	-17.57**	-8.05**	39.52**	30.44**	-2.14	2.07
17.	HA249A × AKSFI-16-5	32.21**	33.82**	-30.61**	-22.60**	38.70**	37.82**	-10.06*	-6.20
18.	HA249A × AKSFI-16-6	30.88**	52.68**	-18.90**	-9.53**	17.00**	7.39	-16.15**	-12.54*
19.	HA249A × AKSFI-16-7	32.75**	53.99**	-18.20**	-8.76**	35.15**	25.44**	-4.41	-0.31
20.	HA249A × AKSFI-16-8	48.17**	50.21**	-22.35**	-13.38**	97.58**	47.08**	-4.02	0.10
21.	HA249A × AKSFI-16-9	13.87**	42.61**	-24.25**	-15.50**	12.92*	-0.37	-14.97**	-11.32*
22.	HA249A × AKSFI-16-10	28.76**	53.31**	-18.56**	-9.16**	28.38**	17.62**	-7.79	-3.83
23.	HA249A × AKSFI-16-11	12.01**	41.35**	-24.85**	-16.17**	7.43	-7.33	-16.62**	-13.03*
24.	HA249A × AKSFI-16-12	34.71**	41.71**	-24.72**	-16.03**	39.99**	38.18**	-9.83*	-5.95
25.	HA302A × AKSFI-16-1	18.76**	29.49**	-36.47**	-29.13**	77.88**	35.77**	-4.69	-0.59
26.	HA302A × AKSFI-16-2	33.16**	36.59**	-24.75**	-16.07**	24.84**	19.73**	-8.46	-4.52
27.	HA302A × AKSFI-16-3	32.27**	35.52**	-21.49**	-12.43**	7.41	0.68	-19.21**	-15.74**
28.	HA302A × AKSFI-16-4	21.71**	43.05**	-17.13**	-7.56**	54.77**	49.79**	12.38**	17.21**
29.	HA302A × AKSFI-16-5	40.72**	48.96**	-22.76**	-13.84**	41.13**	35.33**	-5.00	-0.92
30.	HA302A × AKSFI-16-6	18.00**	31.12**	-24.04**	-15.27**	15.00*	9.20	-14.73**	-11.07*
31.	HA302A × AKSFI-16-7	28.60**	42.13**	-17.66**	-8.16**	26.83**	21.83**	-7.16	-3.17
32.	HA302A × AKSFI-16-8	40.57**	49.05**	-22.95**	-14.05**	68.79**	22.75**	-13.83**	-10.13*
33.	HA302A × AKSFI-16-9	5.90*	26.01**	-27.00**	-18.57**	7.06	-2.44	-16.74**	-13.16*
34.	HA302A × AKSFI-16-10	24.11**	40.66**	-18.52**	-9.11**	22.79**	16.37*	-8.77	-4.85
35.	HA302A × AKSFI-16-11	16.72**	40.04**	-18.88**	-9.51**	11.61*	-0.65	-10.61*	-6.77
36.	HA302A × AKSFI-16-12	28.66**	29.4 5**	-25.01**	-16.35**	58.23**	50.75**	5.83	10.37*
37.	HA208A × AKSFI-16-1	43.44**	47.62**	-27.57**	-19.21**	222.32**	177.49**	2.57	6.98
38.	HA208A × AKSFI-16-2	39.68**	43.94**	-25.26**	-16.63**	116.02**	45.70**	11.40*	16.19**
39.	HA208A × AKSFI-16-3	44.48**	56.81**	-18.58**	-9.18**	59.93**	6.55	-14.50**	-10.82*
40.	HA208A × AKSFI-16-4	21.83**	52.72**	-20.70**	-11.55**	117.13**	47.18**	10.42*	15.16**
41.	HA208A × AKSFI-16-5	56.79**	56.90**	-18.65**	-9.25**	120.84**	56.15**	0.61	4.93
42.	HA208A × AKSFI-16-6	32.83**	56.99**	-18.49**	-9.07**	64.57**	10.4	-13.79**	-10.09*
43.	HA208A × AKSFI-16-7	45.00**	70.40**	-11.52**	-1.31	76.89**	19.41**	-9.01	-5.10
44.	HA208A × AKSFI-16-8	65.77**	66.13**	-14.12**	-4.20	194.57**	170.48**	-13.71**	-10.01
45.	HA208A × AKSFI-16-9	20.28**	52.72**	-20.70**	-11.55**	55.10**	1.79	-13.13**	-9.39
46.	HA208A × AKSFI-16-10	48.05**	78.63**	-7.25**	3.46	70.05**	13.96*	-10.65*	-6.81
47.	HA208A × AKSFI-16-11	23.92**	58.70**	-17.60**	-8.09**	57.82**	2.31	-7.95	-3.99
48.	HA208A × AKSFI-16-12	51.34**	61.13**	-16.33**	-6.67*	134.70**	66.60**	5.91	10.46*
49.	HA303A × AKSFI-16-1	20.27**	44.78**	-28.96**	-20.76**	66.13**	18.17**	3.35	7.80
50.	HA303A × AKSFI-16-2	24.48**	40.26**	-22.73**	-13.81**	15.91**	8.61	-5.00	-0.92
51.	HA303A × AKSFI-16-3	12.93**	20.63**	-26.69**	-18.22**	-3.65	-7.63	-19.21**	-15.74**
52.	HA303A × AKSFI-16-4	13.33**	20.87**	-16.52**	-6.89**	32.29**	22.88**	7.47	12.09*
53.	HA303A × AKSFI-16-5	40.79**	64.16**	-14.88**	-5.05	40.58**	22.07**	6.77	11.36*

54.	HA303A × AKSFI-16-6	13.92**	15.37**	-20.32**	-11.12**	0.55	-4.85	-16.77**	-13.20*
55.	HA303A × AKSFI-16-7	27.14**	28.11**	-11.52**	-1.31	22.13**	14.27*	-0.06	4.24
56.	HA303A × AKSFI-16-8	40.30**	63.87**	-15.29**	-5.51*	51.81**	3.59	-9.40	-5.50
57.	HA303A × AKSFI-16-9	10.48**	19.17**	-17.70**	-8.19**	6.95	5.65	-7.59	-3.62
58.	HA303A × AKSFI-16-10	18.21**	21.90**	-15.81**	-6.09*	8.11	2.51	-10.34	-6.49
59.	HA303A × AKSFI-16-11	24.86**	35.72**	-6.27**	4.56	-2.61	-3.97	-13.60	-9.88
60.	HA303A × AKSFI-16-12	22.94**	33.86**	-21.49**	-12.43**	49.96**	29.48**	13.24**	18.11**
	Range	0.57 to 65.77	5.68 to 78.63	-42.74 to -6.27	-36.12 to 4.56	-3.65 to 222.32	-10.91to 177.49	-30.15 to 13.24	-27.15 to 18.11
	SE(D)±	4.22	4.87	4.87	4.87	0.73	0.84	0.84	0.84
	CD 5%	8.35	9.64	9.64	9.64	1.45	1.67	1.67	1.67
	CD 1%	11.04	12.75	12.75	12.75	1.91	2.21	2.21	2.21

Table 2: Heterosis (%) over mid-parent (MP), better-parent (BP) and standard checks [DRSH-1 (H_3) and PDKVSH-952 (H_4)] for different characters in sunflower.

Sr. No.	Crosses	100 seed weight (g)				Volume weight (g/100ml)			
		5				6			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1.	HA228A × AKSFI-16-1	40.74**	18.75**	14.00*	14.00*	36.52**	29.03**	5.26	6.43*
2.	HA228A × AKSFI-16-2	29.11**	10.87	2	2	26.87**	21.15**	-3.29	-2.22
3.	HA228A × AKSFI-16-3	81.33**	61.90**	36.00**	36.00**	38.36**	27.48**	9.87**	11.09**
4.	HA228A × AKSFI-16-4	63.64**	43.18**	26.00**	26.00**	29.95**	15.49**	7.89**	9.09**
5.	HA228A × AKSFI-16-5	39.13**	33.33**	-4.00	-4.00	19.16**	7.25*	-2.63	-1.55
6.	HA228A × AKSFI-16-6	20.00**	2.13	-4.00	-4.00	22.81**	13.95**	-3.29	-2.22
7.	HA228A × AKSFI-16-7	52.00**	35.71**	14.00*	14.00*	32.83**	24.60**	3.29	4.43
8.	HA228A × AKSFI-16-8	26.98**	21.21*	-20.00**	-20.00**	31.53**	27.72**	-7.24**	-6.21*
9.	HA228A × AKSFI-16-9	22.22**	12.82	-12.00	-12.00	22.93**	18.49**	-7.24**	-6.21*
10.	HA228A × AKSFI-16-10	1.20	-16.00*	-16.00*	-16.00*	8.77**	-1.47	-11.84**	-10.86**
11.	HA228A × AKSFI-16-11	23.08**	6.67	-4.00	-4.00	20.14**	17.24**	-10.53**	-9.53**
12.	HA228A × AKSFI-16-12	48.24**	21.15**	26.00**	26.00**	40.05**	36.29**	4.61	5.76*
13.	HA249A × AKSFI-16-1	30.77**	6.25	2.00	2.00	32.58**	23.39**	0.66	1.77
14.	HA249A × AKSFI-16-2	50.00**	23.91**	14.00*	14.00*	44.65**	35.99**	8.55**	9.76**
15.	HA249A × AKSFI-16-3	41.67**	21.43**	2.00	2.00	6.81*	-3.05	-16.45**	-15.52**
16.	HA249A × AKSFI-16-4	54.05 **	29.55**	14.00*	14.00*	4.5	-8.45**	-14.47**	-13.53**
17.	HA249A × AKSFI-16-5	36.36**	25.00**	-10.00	-10.00	17.65**	4.35	-5.26	-4.21
18.	HA249A × AKSFI-16-6	16.88*	-4.26	-10.00	-10.00	13.66**	3.88	-11.84**	-10.86**
19.	HA249A × AKSFI-16-7	33.33**	14.29	-4.00	-4.00	12.54**	3.97	-13.82**	-12.86**
20.	HA249A × AKSFI-16-8	60.00**	60.00**	-4.00	-4.00	42.31**	40.45**	-1.32	-0.22
21.	HA249A × AKSFI-16-9	39.13**	23.08**	-4.00	-4.00	17.80**	11.76**	-12.50**	-11.53**
22.	HA249A × AKSFI-16-10	2.50	-18.00**	-18.00**	-18.00**	9.56**	-2.21	-12.50**	-11.53**
23.	HA249A × AKSFI-16-11	4.00	-13.33	-22.00**	-22.00**	14.30**	9.77**	-16.23**	-15.30**
24.	HA249A × AKSFI-16-12	31.71**	3.85	8.00	8.00	17.24**	12.29**	-13.82**	-12.86**
25.	HA302A × AKSFI-16-1	4.58	0	-4.00	-4.00	28.57**	16.13**	-5.26	-4.21
26.	HA302A × AKSFI-16-2	-13.14*	-15.22*	-22.00**	-22.00**	27.41**	16.21**	-7.24**	-6.21*
27.	HA302A × AKSFI-16-3	-2.10	-4.11	-16.00*	-16.00*	10.25**	-2.80	-16.23**	-15.30**
28.	HA302A × AKSFI-16-4	16.17**	15.91*	2.00	2.00	22.31**	4.23	-2.63	-1.55
29.	HA302A × AKSFI-16-5	12.78	2.74	-10.00	-10.00	4.76	-9.66**	-17.98**	-17.07**
30.	HA302A × AKSFI-16-6	-11.89*	-14.89*	-20.00**	-20.00**	5.68	-6.20	-20.39**	-19.51**
31.	HA302A × AKSFI-16-7	4.90	2.74	-10.00	-10.00	15.04**	3.17	-14.47**	-13.53**
32.	HA302A × AKSFI-16-8	8.40	-8.68	-20.00**	-20.00**	27.45**	25.00**	-14.47**	-13.53**
33.	HA302A × AKSFI-16-9	-0.97	-6.39	-18.00**	-18.00**	28.46**	18.21**	-7.46**	-6.43*
34.	HA302A × AKSFI-16-10	-10.45	-16.00*	-16.00*	-16.00*	22.60**	6.37*	-4.82	-3.77
35.	HA302A × AKSFI-16-11	-9.91	-11.11	-20.00**	-20.00**	26.85**	18.10**	-9.87**	-8.87**
36.	HA302A × AKSFI-16-12	12.73*	3.85	8.00	8.00	38.15**	28.29**	-1.54	-0.44
37.	HA208A × AKSFI-16-1	36.84**	8.33	4.00	4.00	38.45**	26.61**	3.29	4.43
38.	HA208A × AKSFI-16-2	35.14**	8.7	0	0	43.07**	32.14**	5.48*	6.65*
39.	HA208A × AKSFI-16-3	28.57**	7.14	-10.00	-10.00	4.65	-6.62*	-19.52**	-18.63**
40.	HA208A × AKSFI-16-4	50.00**	22.73**	8.00	8.00	40.80**	21.36**	13.38**	14.63**
41.	HA208A × AKSFI-16-5	37.50**	22.22*	-12	-12.00	17.66**	2.66	-6.80*	-5.76*
42.	HA208A × AKSFI-16-6	12	-10.64	-16.00*	-16.00*	13.03**	1.55	-13.82**	-12.86**
43.	HA208A × AKSFI-16-7	37.14**	14.29	-4.00	-4.00	20.63**	9.52**	-9.21**	-8.20**
44.	HA208A × AKSFI-16-8	55.17**	50.00**	-10.00	-10.00	21.93**	21.23**	-17.05**	-16.13**
45.	HA208A × AKSFI-16-9	19.40*	2.56	-20.00**	-20.00**	19.93**	11.76**	-12.50**	-11.53**
46.	HA208A × AKSFI-16-10	5.13	-18.00**	-18.00**	-18.00**	16.97**	2.7	-8.11**	-7.10*
47.	HA208A × AKSFI-16-11	9.59	-11.11	-20.00**	-20.00**	16.70**	10.06**	-16.01**	-15.08**
48.	HA208A × AKSFI-16-12	32.50**	1.92	6.00	6.00	38.82**	30.57**	0.22	1.33
49.	HA303A × AKSFI-16-1	7.53	4.17	0	0	30.65**	30.65**	6.58*	7.76**
50.	HA303A × AKSFI-16-2	-1.10	-2.17	-10.0	-10.0	16.30**	15.05**	-6.14*	-5.10
51.	HA303A × AKSFI-16-3	-5.75	-8.89	-18.00**	-18.00**	14.25**	11.20**	-4.17	-3.10

52.	HA303A × AKSFI-16-4	-5.62	-6.67	-16.00*	-16.00*	10.53**	3.52	-3.29	-2.22
53.	HA303A × AKSFI-16-5	1.23	-8.89	-18.00**	-18.00**	12.98**	7.25*	-2.63	-1.55
54.	HA303A × AKSFI-16-6	-15.22*	-17.02*	-22.00**	-22.00**	8.30**	6.20	-9.87**	-8.87**
55.	HA303A × AKSFI-16-7	10.34	6.67	-4.00	-4.00	9.87**	8.99**	-9.65**	-8.65**
56.	HA303A × AKSFI-16-8	20.00**	0	-10.00	-10.00	16.37**	6.99*	-12.72**	-11.75**
57.	HA303A × AKSFI-16-9	-4.76	-11.11	-20.00**	-20.00**	11.66**	9.41**	-10.75**	-9.76**
58.	HA303A × AKSFI-16-10	-3.16	-8.00	-8.00	-8.00	2.56	-1.96	-12.28**	-11.31**
59.	HA303A × AKSFI-16-11	-11.11	-11.11	-20.00**	-20.00**	14.44**	10.75**	-9.65**	-8.65**
60.	HA303A × AKSFI-16-12	36.08**	26.92**	32.00**	32.00**	40.44**	36.29**	11.18**	12.42**
	Range	-15.22 to 81.33	-18.00 to 61.90	-22.00 to 36.00	-22.00 to 36.00	2.56 to 44.65	-9.66 to 40.45	-20.39 to 13.38	-19.51 to 14.63
	SE(D)±	0.22	0.26	0.26	0.26	0.90	1.04	1.04	1.04
	CD 5%	0.44	0.51	0.51	0.51	1.78	2.06	2.06	2.06
	CD 1%	0.58	0.67	0.67	0.67	2.35	2.72	2.72	2.72

Table 2: Heterosis (%) over mid-parent (MP), better-parent (BP) and standard checks [DRSH-1 (H_3) and PDKVSH-952 (H_4)] for different characters in sunflower.

Sr. No.	Crosses	Seed filling (%)				Hull content (%)			
		7				8			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1.	HA228A × AKSFI-16-1	18.36**	6.61	2.51	3.61	-9.43**	-15.14**	-5.11**	-15.14**
2.	HA228A × AKSFI-16-2	37.42**	18.20**	13.66**	14.87**	-9.43**	-15.14**	-5.11**	-15.14**
3.	HA228A × AKSFI-16-3	37.78**	25.09**	20.29**	21.57**	-26.52**	-41.92**	-2.29**	-12.62**
4.	HA228A × AKSFI-16-4	50.33**	37.31**	32.04**	33.44**	-14.44**	-14.44**	-16.39**	-25.23**
5.	HA228A × AKSFI-16-5	18.80**	10.79*	6.54	7.67	-58.35**	-67.08**	-44.61**	-50.46**
6.	HA228A × AKSFI-16-6	-10.04	-22.13**	-25.12**	-24.32**	53.40**	30.22**	82.36**	63.08**
7.	HA228A × AKSFI-16-7	27.03**	16.73**	12.24*	13.44**	-14.44**	-14.44**	-16.39**	-25.23**
8.	HA228A × AKSFI-16-8	-27.29**	-27.97**	-29.42**	-28.67**	18.27**	9.27**	25.93**	12.62**
9.	HA228A × AKSFI-16-9	-13.82**	-14.29**	-16.67**	-15.79**	6.73**	0	11.82**	0
10.	HA228A × AKSFI-16-10	12.40**	5.44	1.39	2.47	29.67**	10.07**	54.14**	37.85**
11.	HA228A × AKSFI-16-11	-45.25**	-45.40**	-47.21**	-46.64**	-5.93**	-20.15**	11.82**	0
12.	HA228A × AKSFI-16-12	20.97**	6.37	2.28	3.38	-6.73**	-12.62**	-2.29**	-12.62**
13.	HA249A × AKSFI-16-1	14.54**	2.32	0.26	1.33	-33.61**	-40.30**	-16.39**	-25.23**
14.	HA249A × AKSFI-16-2	25.38**	7.00	4.84	5.96	-27.16**	-34.50**	-8.28**	-17.97**
15.	HA249A × AKSFI-16-3	17.69**	5.96	3.83	4.93	-45.76 **	-50.31**	-16.39**	-25.23**
16.	HA249A × AKSFI-16-4	18.57**	7.38	5.22	6.35	-29.67**	-40.30**	-16.39**	-25.23**
17.	HA249A × AKSFI-16-5	-36.75**	-41.52**	-42.70**	-42.09**	-64.06**	-67.08**	-44.61**	-50.46**
18.	HA249A × AKSFI-16-6	-36.30**	-45.29**	-46.39**	-45.82**	-18.17**	-18.17**	14.60**	2.48**
19.	HA249A × AKSFI-16-7	-29.91**	-36.14**	-37.42**	-36.76**	-29.67**	-40.30**	-16.39**	-25.23**
20.	HA249A × AKSFI-16-8	16.21**	16.21**	13.88**	15.09**	-34.50**	-40.30**	-16.39**	-25.23**
21.	HA249A × AKSFI-16-9	-38.05**	-38.29**	-39.53**	-38.89**	-11.20**	-20.15**	11.82**	0
22.	HA249A × AKSFI-16-10	2.04	-5.11	-7.02	-6.03	-20.15**	-20.15**	11.82**	0
23.	HA249A × AKSFI-16-11	-29.50**	-29.97**	-31.38**	-30.64**	-20.15**	-20.15**	11.82**	0
24.	HA249A × AKSFI-16-12	19.46**	4.20	2.11	3.19	-33.61**	-40.30**	-16.39**	-25.23**
25.	HA302A × AKSFI-16-1	25.40**	12.82*	8.77	9.93*	-22.89**	-27.75**	-19.21**	-27.75**
26.	HA302A × AKSFI-16-2	-10.59*	-23.18**	-25.94**	-25.15**	6.73**	0	11.82**	0
27.	HA302A × AKSFI-16-3	2.61	-6.95	-10.29*	-9.33	-15.91**	-33.54**	11.82**	0
28.	HA302A × AKSFI-16-4	15.04**	4.95	1.18	2.26	-17.32**	-17.32**	-19.21**	-27.75**
29.	HA302A × AKSFI-16-5	-26.40**	-31.44**	-33.91**	-33.20**	-37.13**	-50.31**	-16.39**	-25.23**
30.	HA302A × AKSFI-16-6	-20.21**	-31.01**	-33.49**	-32.78**	-5.93**	-20.15**	11.82**	0
31.	HA302A × AKSFI-16-7	-1.4000	-9.50	-12.75*	-11.82*	-14.44**	-14.44**	-16.39**	-25.23**
32.	HA302A × AKSFI-16-8	-31.57**	-32.12**	-33.49**	-32.78**	5.02**	-2.97**	11.82**	0
33.	HA302A × AKSFI-16-9	-32.06**	-32.35**	-34.23**	-33.53**	47.13**	37.85**	54.14**	37.85**
34.	HA302A × AKSFI-16-10	-23.85**	-28.65**	-31.22**	-30.48**	-53.40**	-60.44**	-44.61**	-50.46**
35.	HA302A × AKSFI-16-11	-30.01**	-30.12**	-32.43**	-31.71**	53.40**	30.22**	82.36**	63.08**
36.	HA302A × AKSFI-16-12	26.23**	10.87*	6.89	8.03	-47.13**	-50.46**	-44.61**	-50.46**
37.	HA208A × AKSFI-16-1	28.93**	16.86**	10.81*	11.99*	-12.62**	-12.62**	-2.29**	-12.62**
38.	HA208A × AKSFI-16-2	37.39**	18.87**	12.72*	13.92**	-25.23**	-25.23**	-16.39**	-25.23**
39.	HA208A × AKSFI-16-3	-20.06**	-26.96**	-30.74**	-30.00**	-20.15**	-33.54**	11.82**	0
40.	HA208A × AKSFI-16-4	22.32**	12.44*	6.62	7.75	-47.13**	-50.46**	-44.61**	-50.46**
41.	HA208A × AKSFI-16-5	25.68**	17.97**	11.87*	13.06**	-40.30**	-50.31**	-16.39**	-25.23**
42.	HA208A × AKSFI-16-6	-16.76**	-27.52**	-31.27**	-30.54**	-11.20**	-20.15**	11.82**	0

43.	HA208A × AKSFI-16-7	-9.70*	-16.49**	-20.82**	-19.97**	-47.13**	-50.46**	-44.61**	-50.46**
44.	HA208A × AKSFI-16-8	-1.20	-2.79	-4.75	-3.73	60.62**	58.23**	82.36**	63.08**
45.	HA208A × AKSFI-16-9	-30.62**	-31.47**	-33.38**	-32.67**	0	0	11.82**	0
46.	HA208A × AKSFI-16-10	-13.92**	-18.72**	-22.93**	-22.11**	-11.20**	-20.15**	11.82**	0
47.	HA208A × AKSFI-16-11	-20.28**	-21.04**	-23.66**	-22.85**	33.61**	20.15**	68.25**	50.46**
48.	HA208A × AKSFI-16-12	39.33**	23.26**	16.88**	18.13**	-50.46**	-50.46**	-44.61**	-50.46**
49.	HA303A × AKSFI-16-1	27.69**	13.68**	12.24*	13.43**	-15.14**	-15.14**	-5.11**	-15.14**
50.	HA303A × AKSFI-16-2	19.05**	1.28	0	1.07	-25.23**	-25.23**	-16.39**	-25.23**
51.	HA303A × AKSFI-16-3	-22.42**	-30.39**	-31.27**	-30.54**	-10.07**	-25.15**	25.93**	12.62**
52.	HA303A × AKSFI-16-4	11.24*	0.41	-0.86	0.20	-22.08**	-27.00**	-18.37**	-27.00**
53.	HA303A × AKSFI-16-5	14.21**	5.22	3.89	5.00	-42.31**	-51.98**	-19.21**	-27.75**
54.	HA303A × AKSFI-16-6	-8.82	-21.94**	-22.93**	-22.11**	-11.20**	-20.15**	11.82**	0
55.	HA303A × AKSFI-16-7	11.55*	1.28	0	1.07	-20.20**	-25.23**	-16.39**	-25.23**
56.	HA303A × AKSFI-16-8	2.30	1.92	0.63	1.70	-1.51**	-2.97**	11.82**	0
57.	HA303A × AKSFI-16-9	0.84	0.06	-1.2	-0.15	37.85**	37.85**	54.14**	37.85**
58.	HA303A × AKSFI-16-10	-16.56**	-22.68**	-23.66**	-22.85**	0.65*	-9.49**	26.75**	13.35**
59.	HA303A × AKSFI-16-11	-19.71**	-20.54**	-21.55**	-20.71**	-11.20**	-20.15**	11.82**	0
60.	HA303A × AKSFI-16-12	46.69**	27.53**	25.92**	27.26**	-28.60**	-28.60**	-20.15**	-28.60**
	Range	-45.25 to 50.33	-45.40 to 37.31	-47.21 to 32.04	-46.64 to 33.44	-64.06 to 60.62	-67.08 to 58.23	-44.61 to 82.36	-50.46 to 63.08
	SE(D)±	2.68	3.10	3.10	3.10	0.14	0.16	0.16	0.16
	CD 5%	5.31	6.13	6.13	6.13	0.27	0.31	0.31	0.31
	CD 1%	7.02	8.11	8.11	8.11	0.36	0.41	0.41	0.41

Table 2: Heterosis (%) over mid-parent (MP), better-parent (BP) and standard checks [DRSH-1 (H_3) and PDKVSH-952 (H_4)] for different characters in sunflower.

Sr. No.	Crosses	Oil content (%)				Seed Yield / plant			
		9				10			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1.	HA228A × AKSFI-16-1	13.44**	2.89	2.92	4.90**	323.98**	294.64**	3.30	6.16
2.	HA228A × AKSFI-16-2	15.58**	7.79**	1.44	3.39*	319.24**	293.72**	3.05	5.92
3.	HA228A × AKSFI-16-3	11.17**	2.83	-1.49	0.40	288.27**	256.39**	11.61	14.71*
4.	HA228A × AKSFI-16-4	15.49**	7.33**	1.77	3.73*	351.72**	319.95**	27.91**	31.47**
5.	HA228A × AKSFI-16-5	10.53**	2.55	-2.40	-0.52	257.25**	209.96**	10.35	13.41*
6.	HA228A × AKSFI-16-6	10.66**	3.18	-2.85	-0.98	117.27**	72.69**	-23.35**	-21.22**
7.	HA228A × AKSFI-16-7	13.55**	4.89**	0.77	2.71	294.50**	266.75**	11.71	14.81*
8.	HA228A × AKSFI-16-8	4.73**	-2.69	-7.68**	-5.91**	151.33**	126.46**	-40.73**	-39.08**
9.	HA228A × AKSFI-16-9	3.90*	-5.03**	-6.63**	-4.84**	172.35**	119.67**	-6.22	-3.62
10.	HA228A × AKSFI-16-10	10.30**	9.09**	-9.19**	-7.44**	98.32**	61.75**	-32.93**	-31.06**
11.	HA228A × AKSFI-16-11	5.62**	-2.11	-6.63**	-4.84**	121.27**	62.48**	-9.25	-6.73
12.	HA228A × AKSFI-16-12	16.64**	10.37**	0.69	2.63	298.12**	277.98**	-1.07	1.68
13.	HA249A × AKSFI-16-1	8.76**	-1.54	-1.52	0.38	372.33**	348.67**	1.18	4.00
14.	HA249A × AKSFI-16-2	13.33**	5.48**	-0.73	1.18	370.88**	343.27**	1.90	4.73
15.	HA249A × AKSFI-16-3	9.75**	1.31	-2.95	-1.08	239.92**	180.10**	-12.28	-9.85
16.	HA249A × AKSFI-16-4	9.93**	1.95	-3.33*	-1.47	234.92**	179.03**	-15.01*	-12.65
17.	HA249A × AKSFI-16-5	9.57**	1.45	-3.45*	-1.59	133.45**	83.26**	-34.76**	-32.95**
18.	HA249A ×AKSFI-16-6	7.58**	0.10	-5.74**	-3.93*	94.85**	41.96**	-36.99**	-35.24**
19.	HA249A × AKSFI-16-7	9.11**	0.60	-3.36*	-1.5	167.38**	122.76**	-32.15**	-30.26**
20.	HA249A × AKSFI-16-8	4.01*	-3.55*	-8.50**	-6.74**	399.28**	390.95**	3.07	5.93
21.	HA249A × AKSFI-16-9	5.58**	-3.68*	-5.31**	-3.49*	84.66**	36.22*	-41.85**	-40.23**
22.	HA249A × AKSFI-16-10	13.52**	12.04**	-6.74**	-4.95**	123.84**	66.69**	-30.88**	-28.96**
23.	HA249A × AKSFI-16-11	2.9	-4.82**	-9.22**	-7.47**	37.86*	-6.03	-47.51**	-46.05**
24.	HA249A × AKSFI-16-12	12.13**	5.89**	-3.40*	-1.54	236.71**	213.58**	-26.23**	-24.18**
25.	HA302A × AKSFI-16-1	6.75**	4.74**	4.77**	6.79**	333.23**	316.96**	1.67	4.49
26.	HA302A × AKSFI-16-2	1.16	0.02	-3.71*	-1.85	212.78**	203.83**	-25.92**	-23.86**
27.	HA302A × AKSFI-16-3	-2.46	-2.7	-6.32**	-4.52**	175.27**	144.80**	-23.34**	-21.21**
28.	HA302A × AKSFI-16-4	7.93**	7.11**	3.12	5.11**	283.98**	245.68**	5.29	8.21
29.	HA302A × AKSFI-16-5	6.75**	6.14**	2.19	4.15*	197.40**	150.55**	-10.8	-8.33
30.	HA302A × AKSFI-16-6	-1.64	-2.72	-6.34**	-4.54**	101.34**	55.97**	-30.77**	-28.85**
31.	HA302A × AKSFI-16-7	7.13**	7.01**	3.03	5.01**	178.69**	150.90**	-23.58**	-21.46**
32.	HA302A × AKSFI-16-8	-1.24	-1.96	-5.61**	-3.79*	234.42**	211.18**	-24.13**	-22.02**
33.	HA302A × AKSFI-16-9	-0.75	-1.78	-3.44*	-1.58	58.42**	24.45	-46.87**	-45.40**
34.	HA302A × AKSFI-16-10	8.62**	1.26	-2.51	-0.63	134.24**	85.99**	-22.88**	-20.74**
35.	HA302A × AKSFI-16-11	2.18	1.70	-2.08	-0.20	100.58**	44.07**	-19.53**	-17.29**

36.	HA302A × AKSFI-16-12	11.01**	8.10**	4.08*	6.08**	331.22**	323.64**	3.3	6.16
37.	HA208A × AKSFI-16-1	14.22**	1.09	1.12	3.07	494.44**	412.92**	15.67*	18.89**
38.	HA208A × AKSFI-16-2	17.80**	7.11**	0.80	2.74	477.24**	394.10**	13.59*	16.74*
39.	HA208A × AKSFI-16-3	8.84**	-1.81	-5.94**	-4.13*	251.25**	167.41**	-16.26*	-13.93*
40.	HA208A × AKSFI-16-4	14.15**	3.44*	-1.91	-0.03	402.78**	286.47**	17.71**	20.98**
41.	HA208A × AKSFI-16-5	12.94**	2.18	-2.75	-0.88	280.15**	177.46**	-1.22	1.52
42.	HA208A × AKSFI-16-6	11.12**	1.02	-4.88**	-3.05	103.36**	39.17**	-38.23**	-36.51**
43.	HA208A × AKSFI-16-7	13.02**	1.83	-2.18	-0.30	300.60**	207.93**	-6.21	-3.60
44.	HA208A × AKSFI-16-8	10.45**	0.07	-5.06**	-3.24	315.39**	269.61**	-22.40**	-20.25**
45.	HA208A × AKSFI-16-9	7.72**	-3.93*	-5.56**	-3.74*	154.50**	76.04**	-24.85**	-22.76**
46.	HA208A × AKSFI-16-10	17.50**	13.12**	-5.84**	-4.03*	161.05**	82.04**	-24.52**	-22.42**
47.	HA208A × AKSFI-16-11	10.12**	-0.47	-5.07**	-3.25	139.74**	54.99**	-13.43*	-11.02
48.	HA208A × AKSFI-16-12	15.69**	6.69**	-2.66	-0.79	423.49**	343.84**	4.42	7.32
49.	HA303A × AKSFI-16-1	0.93	0.22	1.68	3.63*	172.03**	90.75**	6.89	9.86
50.	HA303A × AKSFI-16-2	2.59	-1.12	0.32	2.25	141.92**	70.58**	-4.42	-1.76
51.	HA303A × AKSFI-16-3	-0.36	-3.14	-1.73	0.16	42.39**	10.98	-37.81**	-36.08**
52.	HA303A × AKSFI-16-4	3.51*	0.13	1.59	3.54*	146.24**	90.05**	6.49	9.45
53.	HA303A × AKSFI-16-5	3.31*	0.11	1.57	3.52*	140.81**	96.90**	10.33	13.39*
54.	HA303A × AKSFI-16-6	4.62**	0.86	2.33	4.30*	40.41**	25.82*	-29.50**	-27.54**
55.	HA303A × AKSFI-16-7	3.43*	0.68	2.14	4.11*	130.39**	77.81**	-0.37	2.40
56.	HA303A × AKSFI-16-8	-4.05**	-7.16**	-5.81**	-4.00*	99.01**	36.79**	-23.35**	-21.22**
57.	HA303A × AKSFI-16-9	-5.44**	-6.90**	-5.55**	-3.73*	43.30**	26.23*	-29.27**	-27.30**
58.	HA303A × AKSFI-16-10	0.03	-8.95**	-7.62**	-5.84**	85.04**	60.99**	-9.79	-7.29
59.	HA303A × AKSFI-16-11	-2.00	-4.94**	-3.56*	-1.70	57.91**	57.65**	-11.66	-9.21
60.	HA303A × AKSFI-16-12	9.96**	4.42**	5.94**	7.98**	183.76**	101.45**	12.88*	16.01*
	Range	-5.44 to 17.80	-8.95 to 13.12	-9.22 to 5.94	-7.47 to 7.98	37.86 to 494.44	-6.03to 412.92	-47.51 to 27.91	-46.05 to 31.47
	SE(D)±	0.53	0.62	0.62	0.62	2.37	2.73	2.73	2.73
	CD 5%	1.06	1.22	1.22	1.22	4.69	5.42	5.42	5.42
	CD 1%	1.40	1.62	1.62	1.62	6.20	7.16	7.16	7.16

Note : * Significant at 5% level of significance
** Significant at 1% level of significance

Table 3: Mean yield performance, heterosis, gca and sca effects in promising crosses.

Crosses	Mean seed yield /plant	Meanoil content (%)	Heterosis (%)			Significant H_3 for other characters	Significant GCA Effects of parents for other characters
			H1	H2	H3		
HA228A × AKSFI-16-4	54.73**	38.46	351.72**	319.95**	27.91**	1,2,5,6,7,8	P1-1,2,4,5,6,7,8 P2-2,4,5,6,7,8,9
HA208A × AKSFI-16-4	50.37**	37.06	402.78**	286.47**	17.71**	2,3,6,8	P1-1,2,4,5,6,7,8 P2-2,4,5,6,7,8,9
HA208A × AKSFI-16-1	49.50*	38.21	494.44**	412.92**	15.67*	2,3,7,8	P1-1,2,4,5,6,7,8 P2-3,4,5,6,7,8,9
HA208A × AKSFI-16-2	48.60*	38.09	477.24**	394.10**	13.59*	2,3,6,7,8	P1-1,2 P2-1,2,3,4,6,7,8,9
HA303A × AKSFI-16-12	48.30*	40.03**	183.76**	101.45**	12.88*	1,2,3,5,6,7,8,9	P1-6,7,9 P2-1,4,5,6,7,8,9

Note:* Significant at 5% level of significance ** Significant at 1% level of significance

For seed yield per plant, range of mid parental heterosis was from 37.86 per cent to 494.44 per cent. All crosses exhibited highly significant positive heterosis. Highest positive significant heterosis was recorded by HA208A × AKSFI-16-1 (494.44 %) followed by HA208A × AKSFI-16-2 (477.24 %), HA208A × AKSFI-16-12 (423.49 %) and HA208A × AKSFI-16-4 (402.78 %). Heterobeltiosis ranged from -6.03 per cent to 412.92 per cent. Fifty-seven crosses showed significant positive heterobeltiosis for seed yield per plant. For heterobeltiosis top ranking cross was HA208A × AKSFI-16-1 (412.92 %) followed by HA208A × AKSFI-16-2 (394.10 %) and HA249A × AKSFI-16-8 (390.95 %). Useful heterosis for seed yield ranged from -47.51 per cent to 27.91 per cent. Five crosses recorded significant positive useful heterosis for seed yield per plant. HA228A × AKSFI-16-4 (27.91 %) recorded highest useful heterosis followed by HA208A × AKSFI-16-4 (17.71), HA208A × AKSFI-16-1 (15.67 %) and HA208A × AKSFI-16-2 (13.59 %).Similar results were reported by Phad *et al.* (2002); Volotovich *et al.* (2008); Massod *et al*. (2009); Neelima and Parameshwarappa (2009); Dutta *et al*. (2011); Chandra *et al*. (2013); Thakare (2014); Depar *et al*. (2017).

CONCLUSION

In the present study, line × tester analysis was used as an appropriate method for the estimation of average heterosis, heterobeltiosis and standard heterosis.

Five crosses (Table 3) *viz.,* HA228A × AKSFI-16-4, HA208A × AKSFI-16-4, HA208A × AKSFI-16-1, HA208A × AKSFI-16-2 and HA303A × AKSFI-16-12 recorded significant standard heterosis for seed yield per plant over the check DRSH-1. Three crosses *viz.*,HA303A × AKSFI-16-12, HA302A × AKSFI-16-1 and HA302A × AKSFI-16-12 recorded significant standard heterosis for oil content. On the basis of mean seed yield performance, average heterosis, heterobeltiosis and standard heterosis, five crosses *viz.*, HA228A × AKSFI-16-4, HA208A × AKSFI-16-4, HA208A × AKSFI-16-1, HA208A × AKSFI-16-2 and HA303A × AKSFI-16-12 were identified as promising crosses for seed yield. Based on results obtained from present study, it is concluded that superior hybrids for seed yield and oil content can be utilized for development of elite sunflower varieties.

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