International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(1): 1076-1083
© 2019 IJCS
Received: 11-11-2018
Accepted: 15-12-2018

PP Kale
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

ER Vaidya
Associate Professor, Post Graduate Institute, Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Sangita U Fatak
Junior research assistant (Oilseeds Research Unit), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

SS Nichal
Associate Professor, (Regional Research Centre, Dr. P.D.K.V., Amaravati, Maharashtra, India

Aditi R Rajane
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Correspondence
PP Kale
M.Sc. Scholar, Department of Agricultural Botany (Genetics and Plant Breeding), Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India

Heterotic studies for yield and its component traits in sunflower (*Helianthus annuus* L.)

PP Kale, ER Vaidya, Sangita U Fatak, SS Nichal and Aditi R Rajane

Abstract
Fifty four hybrids were obtained by crossing six cytoplasmic male sterile lines and nine testers in Line x Tester fashion during *rabi* 2016-17. These fifty four hybrids along with their parents and two standard checks DRSH-1 and PDKVSH-952 were evaluated in randomized block design with three replications at Oilseeds Research Unit, Dr. PDKV, Akola during *kharif* 2017. The highest desirable significant average heterosis for seed yield per plant was exhibited by cross HA-303A x AK-1R (134.91%) followed by AKSF-14-2A x AK-1R (117.75%). The highest significant heterobeltiosis for seed yield per plant was recorded by AKSF-14-2A x AK-1R (90.32%) followed by HA-303A x AK-1R (77.64%). The highest standard heterosis for seed yield per plant over best check i.e. PDKVSH-952 (seed yield – 36.18g) was recorded by the cross HA-303A x AK-1R (22.46%) followed by HA-303A x RHA-138-2R (20.54%), HA-303A x EC-512687 (20.22%) and HA-249A x 856R (18.62%). The highest standard heterosis for oil content over best check i.e. DRSH-1 (oil content – 38.51%), was recorded by cross HA-228A x EC-601951 (3.36) followed by HA-303A x GMU-116 (3.15) and HA-228A x EC-512687 (2.93).

Keywords: cytoplasmic male sterile, line x tester, randomized block design, average heterosis

Introduction
Sunflower (*Helianthus annuus* L.) is an important oilseed crop. As regards taxonomic category, sunflower belongs to, division Angiosperm, sub-division Tubiflorae, tribe Heliantheae, family Compositeae or Asteraceae sub-family Asteroideae, genus Helianthus and species *annuus* (Panero and Funck, 2002) [11]. The basic chromosome number for the genus Helianthus is 17. *Helianthus annuus* L. (2n=2x=34) which belongs to Helianthinae subtribe, Asteroideae subfamily and Compositae family (Seiler and Riseberg, 1997) [17]. *Helianthus tuberoses* L. (2n=6x=102) provides potential sources of desirable genes in breeding for resistance to pathogens as well as high protein and oleic acid content (Atlagic, 1996) [1]. In sunflower poor seed set and high percentage of empty seeds are the major constraints, to overcome these constraints breeders have to focus their attention towards production of hybrids through heterosis breeding, which became possible due to the discovery of cytoplasmic male sterility by (Leclercq, 1969) [9] and fertility restoration system by (Kinman, 1970)[8]. Sunflower oil is considered as premium oil as compared to most other vegetable oils because of its light yellow colour, pleasant flavour, high level of linoleic acid (55-60%) low oleic acid (25-30%), fairly high oil content of poly unsaturated fatty acids (PUFA) and absence of linolenic acid. The oil extracted from seeds contributes about 80% of value of crop (Baydar and Erbas, 2005) [3]. Sunflower is popular among the farmers due to its various features viz. drought tolerance ability, photo insensitivity, production of high oil per unit area, lower seed rate, high seed multiplication ratio, can thrive well in variety of soils and serve as an ideal contigent crop.

Materials and Methods
The present investigation was carried out at the research farm of Oilseeds Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. During the *rabi* season of 2016, all the F_1 were obtained by crossing the six cytoplasmic male sterile lines viz., AKSF-14-2A, AKSF-15-1-2A, AKSF-15-1-3A, HA-228A, HA-249A and HA-303A along with nine restorer lines viz., AK-1R, RHA-138-2R, 856R, EC-601951, PKV-105R, GMU-1116, EC-6022011, EC-512687 and TSG-187. During *kharif* 2017, all the 71 genotypes which comprised of the 54 hybrids, nine restorer lines, six maintainer (B) lines and two standard checks DRSH-1 & PDKVSH-952

were sown in randomized block design (RBD) with three replications. Each entry was sown in one row of 4.5 m length in each replication. The inter and intra-row spacing was 60 cm and 30 cm respectively. The crop was raised under rainfed condition. The crop stand and the crop growth were satisfactory. All the recommended practices were followed for raising successful crop. The observations for days to 50 per cent flowering and days to maturity were recorded on plot basis and the remaining observations viz., plant height at harvest (cm), head diameter (cm), hundred seed weight (g), volume weight (g/100ml), seed filling percentage, hull content (%), oil content (%) and seed yield per plant (g) were recorded on plant basis. The significance was determined at 0.05 and 0.01 level using the t-test (Singh and Choudhary, 1977) [14].

Results and Discussion

The analysis of variance carried out for the seed yield, its component characters and oil content is presented in Table 1. The mean sum of square due to treatments (genotypes) were highly significant for all the characters, indicating the presence of substantial genetic variability among the genotypes for all the characters under study. The mean sum of square due to parents, crosses and parents vs crosses were also found highly significant for all the characters studied. Character wise results of average heterosis (H1), heterobeltiosis (H2) and standard heterosis (H3) observed in the 54 crosses is given in Table 2.

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	0.75	5.91	209.71	1.15	0.35	18.89	3.79	3.97	2.15	11.67
Treatments	68	21.33**	25.30**	1935.70**	17.63**	2.52**	43.50**	192.13**	99.10**	10.22**	105.19**
Parents	14	33.19**	30.85**	1324.86**	13.18**	1.77**	50.43**	250.32**	110.58**	13.63**	92.08**
Parents vs Crosses	1	31.41**	43.86**	45742.27**	568.75**	28.95**	938.22**	4710.82**	21.76**	256.30**	2171.33**
Crosses	53	18.00**	23.49**	1270.52**	8.40**	2.22**	24.79**	91.50**	97.52**	4.68**	69.67**
Error	136	2.08	2.18	85.13	1.17	0.21	6.33	3.26	3.23	1.59	6.78

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

For days to 50 percent flowering heterosis over standard best check PDKVSH-952 was negative in direction for most of the hybrids indicating earliness of hybrids. The cross HA-249A x PKV-105R (-10.61%) and HA-228A x RHA-138-2R (-10.54%) had the highest significant negative mid parent heterotic value. The cross HA-228A x RHA-138-2R (-10.24%) followed by cross HA-228A x GMU-1116 (-8.15%) and HA-228A x PKV-105R (-6.90%) recorded highest negative significant better parent heterosis. The crosses HA-249A x PKV-105R (-13.13%) followed by HA-249A x 856R (-11.25%) and HA-249A x TSG-187 (-8.75%) recorded highest significant negative heterosis over best check PDKVSH-952 for days to 50% flowering.

From the Table 2, it is quite evident that most of the crosses recorded heterosis and standard checks in negative direction, indicating early maturity in crosses. The crosses HA-249A x PKV-105R (-9.66%) and HA-249A x TSG-187 (-7.93%) exhibited highest negative heterosis over best check PDKVSH-952. In general, the crosses derived with HA-249A as the female parent had highest negative heterosis over check hybrid. Neelima and Rafi (2013) [10] and Venkata and Nadaf (2013) [19] have also reported earliness in hybrids.

For plant height maximum heterobeltiosis is shown by the cross AKSF-14-2A x GMU-1116 (90.00%). Maximum negative standard heterosis found in HA-249A x TSG-187 (-22.82%) over best check PDKVSH-952. Sujatha and Reddy (2009) [18] and Neelima and Rafi (2013) [10] reported both positive and negative heterosis values for plant height.

The next important yield contributing character in sunflower is head diameter. Among the 54 crosses HA-303A x AK-1R (106.58%), HA-303A x AK-1R (94.30%) followed by HA-303A x RHA-138-2R (4.05%) recorded highest significant positive heterosis over mid parent, better parent and standard best check DRSH-1 respectively. Both positive and negative heterotic effects have been reported by a most of workers for this trait. Sawargaonkar and Ghodke (2008) [16], Sapkale *et al.*(2016) [15], Janjal *et al.* (2016) [5] and Rathi *et al.* (2016) [13] reported significant positive heterosis.

In the present investigation, for 100 seed weight most of the hybrids recorded positive heterosis over mid parent and better parent. Among 54 hybrids AKSF-15-1-3A x AK-1R (20.93%), HA-303A x AK-1R (18.60%), HA-249A x 856R (18.60%) recorded maximum significant positive heterosis over standard best check DRSH-1. In general, the hybrid combinations with AKSF-14-2A as female parents recorded the highest positive average heterosis. These observations are in conformity with the report of Alone *et al.* (2003) [2], Sawargaonkar and Ghodke (2008) [16], Venkata and Nadaf (2013) [19] and Neelima and Rafi (2013) [10].

For the trait volume weight, total of 38 hybrids recorded significant positive heterosis over the mid parent and three hybrids had significant positive heterosis over the best check DRSH-1. The crosses HA-303A x RHA-138-2R (15.00%) and AKSF-14-2A x EC-6022011 (11.82%) recorded highest standard heterosis percentage for this trait. These observations were comparable with the reports of Radhika *et al*. (2001) [12], Sawargaonkar and Ghodke (2008) [16] and Chandra *et al*. (2013) [4].

The crosses HA-303A x EC-512687 (43.82%, 43.02%, 6.59%), HA-303A x AK-1R (34.24%, 25.27%, 6.57%) and HA-228A x 856R (11.84%, 9.20%, 6.02%) has recorded highly significant heterosis over mid, better parent and standard best check DRSH-1 respectively for seed filling percentage. Similar reports on significant positive heterosis have also been reported by Alone *et al*. (2003) [2], Janjal *et al.* (2016) [5] and Rathi *et al.* (2016) [13].

Sunflower exhibits negative association between hull content and oil content. Out of 54, 29 crosses exhibited negative heterosis over the mid parent for hull content. The highest negative significant mid parent heterosis of -46.11 per cent was recorded by the hybrid AKSF 15-1-2A x EC-512687. The highest negative standard heterosis over best check DRSH-1 recorded by the cross HA-249A x AK-1R (-37.78%). Comparable result was reported by Volotovich *et al.* (2008) [20].

For oil content considerable amount of heterosis is observed in the present investigation, total of 4 hybrids exhibited significant positive average heterosis. The highest average heterosis recorded by the cross HA-228A x TSG-187 (7.56%) followed by HA-249A x TSG-187 (6.66%) and HA-303A x TSG-187 (6.46%). Several workers reported similar result viz., Volotovich *et al.* (2008) [20], Chandra *et al*. (2013) [4].

For the trait seed yield per plant the values of heterosis over mid parent indicated presence of heterosis to an extent of 134.91 per cent and majority of the crosses were observed to be positive and significant in their expression. The cross HA-303A x AK-1R recorded the highest mid parent heterosis of 134.91 per cent which is followed by AKSF 14-2A x AK-1R with 117.75 per cent and AKSF-15-1-3A x AK-1R with 100.83 per cent.

The cross AKSF 14-2A x AK-1R (90.32%) recorded highest significant positive heterosis over better parent, followed by HA-303A x AK-1R (77.64%). The cross HA-303A x AK-1R (22.46%) recorded the highest significant positive heterosis over standard best check PDKVSH-952, followed by HA-303A x RHA-138-2R (20.54%) and HA-303A x EC-512687 (20.22%).

The standard heterosis involving AK-1R, RHA-138-2R, and EC-512687 as male parents was appreciably high than those involving other tester parents. Among female parents, crosses involving HA-303A recorded higher heterosis over the checks followed by HA-249A. The cross HA-303A x AK-1R (22.46) had registered the highest standard heterosis over best check PDKVSH-952 for seed yield. Higher standard heterosis for seed yield per plant also reported by Kalpande *et al*. (2004) [6], Karasu and Turan (2010) [7], Chandra *et al.* (2013) [4].

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

Sr. No	Crosses	Days to 50% Flowering				Days to Maturity				Plant Height (cm)			
		1				2				3			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_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	AKSF-14-2A X AK -1R	4.70*	8.33**	-10.34**	-2.5	2.72*	5.60**	-8.71**	-2.41	26.51**	61.64**	8.71*	16.41**
2	AKSF-14-2A X RHA -138-2R	1.21	8.46**	-4.02	4.38	0.17	3.54**	-5.48**	1.03	21.81**	56.59**	5.31	12.77**
3	AKSF-14-2A X 856 R	7.94**	10.40**	-2.3	6.25**	2.43*	4.24**	-4.84**	1.72	21.40**	65.45**	11.27**	19.16**
4	AKSF-14-2A X EC-601951	8.63**	10.40**	-2.3	6.25**	4.07**	4.26**	-5.16**	1.38	26.26**	61.45**	8.58*	16.28**
5	AKSF-14-2A X PKV-105 R	5.63**	9.74**	-2.87	5.63*	2.46*	3.18*	-5.81**	0.69	19.01**	67.40**	12.58**	20.56**
6	AKSF-14-2A X GMU -1116	5.20**	11.69**	-1.15	7.50**	1.2	3.89**	-5.16**	1.38	34.97**	90.00**	27.78**	36.84**
7	AKSF-14-2A X EC -6022011	3.82	5.84*	-6.32**	1.88	1.76	2.12	-6.77**	-0.34	23.02**	63.56**	10.00*	17.80**
8	AKSF-14-2A X EC-512687	7.79**	7.79**	-4.60*	3.75	3.73**	4.29**	-5.81**	0.69	19.52**	60.04**	7.64	15.26**
9	AKSF-14-2A X TSG187	3.25	3.25	-8.62**	-0.63	1.94	2.12	-6.77**	-0.34	14.35**	42.31**	-4.29	2.49
10	HA-249-A X AK -1R	10.03**	10.42**	-8.62**	-0.63	8.72**	9.34**	-5.48**	1.03	38.36**	43.17**	-9.96*	-3.58
11	HA-249-A X RHA 138-2R	-2.8	7.59**	-10.34**	-2.5	-1.22	4.43**	-8.71**	-2.41	26.66**	32.12**	-16.91**	-11.02*
12	HA-249-A X 856-R	-7.19**	-2.07	-18.39**	-11.25**	-4.96**	-1.11	-13.55**	-7.59**	22.21**	37.58**	-13.47**	-7.34
13	HA-249-A X EC-601951	-2.63	2.07	-14.94**	-7.50**	-2.35*	-0.37	-12.90**	-6.90**	32.29**	37.03**	-13.82**	-7.71
14	HA-249-A X PKV-105-R	-10.61**	-4.14*	-20.11**	-13.13**	-6.09**	-3.32*	-15.48**	-9.66**	14.05**	33.74**	-15.89**	-9.93*
15	HA-249-A X GMU-1116	-1.89	7.59**	-10.34**	-2.5	-0.18	4.80**	-8.39**	-2.07	14.24**	34.08**	-15.67**	-9.70*
16	HA-249-A X EC-6022011	-0.98	4.14*	-13.22**	-5.63*	-1.44	1.11	-11.61**	-5.52**	23.52**	34.67**	-15.31**	-9.31*
17	HA-249-A X EC- 512687	7.69**	11.05**	-7.47**	0.63	3.81**	5.54**	-7.74**	-1.38	29.53**	42.52**	-10.36*	-4.01
18	HA-249-A X TSG-187	-2.34	0.70	-16.09**	-8.75**	-3.78**	-1.47	-13.87**	-7.93**	14.68*	14.80**	-27.93**	-22.82**
19	AKSF 15-1-3A X AK 1R	-5.13*	2.77	-14.94**	-7.50**	-3.07**	0.00	-13.55**	-7.59**	26.86**	43.39**	-3.56	3.27
20	AKSF 15-1-3A X RHA138-2R	-5.23**	-2.98	-6.32**	1.88	-1.19	1.76	-6.45**	0	29.36**	44.99**	-0.98	6.04
21	AKSF 15-1-3A X 856-R	-1.52	0.56	-6.90**	1.25	2.08	3.51**	-4.84**	1.72	28.43**	33.38**	4.98	12.42**
22	AKSF 15-1-3A X EC-601951	0.31	3.15	-5.75**	2.5	0.88	1.41	-7.74**	-1.38	40.07**	58.22**	6.58	14.14**
23	AKSF 15-1-3AX PKV-105 R	1.8	2.05	-2.3	6.25**	3.15**	3.51**	-4.84**	1.72	30.14**	30.30**	10.21*	18.03**
24	AKSF 15-1-3A X GMU-1116	-3.81*	-2.38	-5.75**	2.5	1.2	3.51**	-4.84**	1.72	30.85**	30.90**	10.91**	18.77**
25	AKSF 15-1-3A X EC-6022011	-1.22	1.26	-6.90**	1.25	1.75	1.76	-6.45**	0	37.25**	47.00**	9.13*	16.86**
26	AKSF 15-1-3A X EC- 512687	0.62	5.20*	-6.90**	1.25	1.24	2.14	-7.74**	-1.38	30.90**	38.97**	4.91	12.34**
27	AKSF 15-1-3A X TSG-187	-5.59**	-1.29	-12.64**	-5.00*	-1.58	-1.42	-9.68**	-3.45**	20.64**	41.79**	-10.98**	-4.67
28	AKSF 15-1 -2A X AK 1R	-1.32	3.48	-14.37**	-6.88**	-1.26	2.62	-11.29**	-5.17**	17.25**	34.69**	-9.42*	-3
29	AKSF 15-1 -2A X RHA138-2R	-6.59**	-1.27	-10.34**	-2.5	-5.25**	-3.11*	-9.68**	-3.45**	32.21**	50.58**	2.84	10.12*
30	AKSF 15-1 -2A X 856-R	-1.57	-0.65	-9.77**	-1.88	-2.75*	-2.08	-8.71**	-2.41	20.95**	27.51**	0.36	7.48
31	AKSF 15-1 -2A X EC-601951	-0.95	-0.65	-9.77**	-1.88	-1.58	-0.35	-9.35**	-3.10*	27.63**	46.50**	-1.31	5.69
32	AKSF 15-1 -2A X PKV-105 R	0	2.53	-6.90**	1.25	-1.04	-0.70	-8.06**	-1.72	19.17**	21.04**	2.4	9.66*
33	AKSF 15-1 -2A X GMU-1116	-2.11	2.53	-6.90**	1.25	-2.56*	-1.04	-7.74**	-1.38	9.77*	11.44*	-5.6	1.09

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

Sr. No	Crosses	Days to 50% flowering				Days to maturity				Plant Height (cm)			
		1				2				3			
		MP(H_1)	BP(H_2)	Check(H_3)	Check(H_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)
34	AKSF 15-1 -2A X EC-6022011	-1.26	-0.65	-9.77**	-1.88	-2.79*	-2.11	-10.00**	-3.79**	26.82**	37.94**	2.4	9.66*
35	AKSF 15-1 -2A X EC- 512687	1.92	3.31	-8.62**	-0.63	-0.53	1.07	-8.71**	-2.41	24.08**	33.76**	0.98	8.14
36	AKSF 15-1 -2A X TSG-187	-0.64	0.72	-10.92**	-3.13	-1.22	-0.36	-8.71**	-2.41	12.44**	34.38**	-15.64**	-9.66*
37	HA-303 A X AK 1R	-1.01	2.08	-15.52**	-8.13**	-1.28	1.12	-12.58**	-6.55**	27.85**	28.27**	-14.29**	-8.22
38	HA-303 A X RHA138-2R	-6.99**	0.00	-12.07**	-4.38	-4.97**	-1.43	-10.65**	-4.48**	26.96**	28.38**	-14.22**	-8.14
39	HA-303 AX 856-R	-1.27	1.31	-10.92**	-3.13	-2.79*	-0.72	-10.00**	-3.79**	20.59**	31.32**	-12.25**	-6.04
40	HA-303 A X EC-601951	-5.77**	-3.92*	-15.52**	-8.13**	-2.66*	-2.50	-11.61**	-5.52**	23.54**	24.08**	-17.09**	-11.21*

41	HA-303 A X PKV-105 R	-0.94	3.27	-9.20**	-1.25	0	1.07	-8.39**	-2.07	19.55**	35.45**	-9.49*	-3.08
42	HA-303 A X GMU-1116	-3.07	3.27	-9.20**	-1.25	-2.94**	0.00	-9.35**	-3.10*	32.15**	49.88**	0.15	7.24
43	HA-303 A X EC-6022011	-3.51	-1.31	-13.22**	-5.63*	-3.18**	-2.50	-11.61**	-5.52**	18.74**	25.33**	-16.25**	-10.32*
44	HA-303 A X EC-512687	-2.28	-1.96	-13.79**	-6.25**	-2.32*	-2.14	-11.61**	-5.52**	17.32**	24.96**	-16.51**	-10.59*
45	HA-303 AX TSG-187	-2.93	-2.61	-14.37**	-6.88**	-3.72**	-3.20	-12.26**	-6.21**	23.16**	27.13**	-20.18**	-14.52**
46	HA 228-A X AK 1R	-4.70*	5.56*	-12.64**	-5.00*	-3.52**	2.24	-11.61**	-5.52**	28.78**	41.66**	-4.73	2.02
47	HA 228-A X RHA138-2R	-10.54**	-10.24**	-9.77**	-1.88	-5.65**	-5.33**	-8.39**	-2.07	36.60**	49.04**	1.78	9.00*
48	HA 228-A X 856-R	-7.74**	-3.78*	-10.92**	-3.13	-6.91**	-5.81**	-10.97**	-4.83**	28.38**	30.01**	2.33	9.58*
49	HA 228-A X EC-601951	-4.19*	0.62	-8.05**	0	-1.72	1.41	-7.74**	-1.38	35.97**	49.47**	0.69	7.83
50	HA 228-A X PKV-105 R	-4.99**	-6.90**	-6.90**	1.25	-0.17	-2.33	-5.48**	1.03	27.98**	31.03**	5.78	13.28**
51	HA 228-A X GMU-1116	-8.62**	-8.15**	-8.62**	-0.63	-4.01**	-3.68*	-7.42**	-1.03	19.82**	22.79**	-0.87	6.15
52	HA 228-A X EC-6022011	-5.67**	-1.18	-9.20**	-1.25	-3.25**	-0.71	-8.71**	-2.41	28.23**	33.82**	-0.65	6.39
53	HA 228-A X EC-512687	-4.56*	2.01	-9.77**	-1.88	-2.76*	0.72	-9.03**	-2.76*	10.47*	14.31**	-13.71**	-7.59
54	HA 228-A X TSG-187	-10.03**	-3.84*	-14.94**	-7.50**	-5.14**	-2.47	-10.65**	-4.48**	6.78	22.04**	-23.38**	-17.95**
	RANGE	-10.61 to 10.03	-10.24 to 11.69	-20.11 to -2.3	-13.13 to 7.50	-6.91 to 8.72	-5.81 to 9.34	-15.48 to -4.84	-9.66 to 1.72	6.78 to 40.07	11.44 to 90.00	-27.93 to 27.78	-22.82 to 36.84
	SE(m)±	1.20	1.17	1.17	1.17	1.04	1.20	1.20	1.20	6.5	7.5	7.5	7.5
	CD 5%	2.02	2.33	2.33	2.33	2.07	2.39	2.39	2.39	12.93	14.93	14.93	14.93
	CD 1%	2.67	3.09	3.09	3.09	2.74	3.16	3.16	3.16	17.11	19.76	19.76	19.76

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

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

Sr. No	Crosses	Head diameter (cm)				100 seed weight (g)				Volume weight (g/100ml)			
		4				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)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
1	AKSF-14-2A X AK -1R	33.29**	7.6	-18.61**	-15.01**	14.63*	-8.74	-12.56*	-6	15.65**	15.34*	-0.91	0.46
2	AKSF-14-2A X RHA -138-2R	6.23	3.76	-17.69**	-14.05**	21.79**	0	-11.63*	-5	-0.37	-2.25	-13.18*	-11.98*
3	AKSF-14-2A X 856 R	25.45**	17.90**	1.38	5.87	52.63**	27.47**	7.91	16.00**	25.39**	23.71**	8.64	10.14
4	AKSF-14-2A X EC-601951	24.02**	10.33	-16.55**	-12.86*	17.26**	-2.7	-16.28**	-10	18.16**	9.04	-6.82	-5.53
5	AKSF-14-2A X PKV-105 R	19.10**	7.26	-18.87**	-15.28**	22.92**	3.35	-13.95**	-7.5	5.26	0.39	-5.45	-4.15
6	AKSF-14-2A X GMU -1116	15.11*	9.36	-17.29**	-13.63**	32.90**	10.27	-5.12	2	1.56	-0.51	-11.36*	-10.14
7	AKSF-14-2A X EC -6022011	35.01**	29.39**	-2.14	2.19	45.96**	17.50**	9.3	17.50**	36.67**	30.85**	11.82*	13.36*
8	AKSF-14-2A X EC-512687	14.61*	11.79	-15.44**	-11.70*	30.29**	8.11	-6.98	0	2.77	-2.39	-7.27	-5.99
9	AKSF-14-2A X TSG187	20.26**	10.77	-16.22**	-12.51*	33.52**	2.17	9.3	17.50**	-2.87	-11.74*	-7.73	-6.45
10	HA-249-A X AK -1R	64.29**	54.43**	-18.43**	-14.82**	-8.87	-10.19	-13.95**	-7.5	8.77	3.33	-1.36	0
11	HA-249-A X RHA 138-2R	33.44**	11.15	-11.83*	-7.93	12.82*	10	2.33	10	8.04	4.29	-0.45	0.92
12	HA-249-A X 856-R	46.79**	18.47**	1.88	6.39	33.51**	27.50**	18.60**	27.50**	15.08**	10.48	5.45	6.91
13	HA-249-A X EC-601951	53.69**	45.72**	-14.12**	-10.32*	16.88**	12.50*	4.65	12.50*	27.91**	12.38*	7.27	8.76
14	HA-249-A X PKV-105-R	71.60**	60.58**	-2.69	1.62	21.37**	15.00**	6.98	15.00**	14.57**	13.81*	8.64	10.14
15	HA-249-A X GMU-1116	8.63	-3.55	-34.33**	-31.43**	-21.04**	-24.00**	-29.30**	-24.00**	0	-3.33	-7.73	-6.45
16	HA-249-A X EC-6022011	49.61**	31.79**	-8.63	-4.58	2.5	2.5	-4.65	2.5	20.94**	10	5	6.45
17	HA-249-A X EC- 512687	41.43**	22.66**	-11.80*	-7.89	19.48**	15.00**	6.98	15.00**	13.60**	13.33*	8.18	9.68
18	HA-249-A X TSG-187	38.82**	26.97**	-19.13**	-15.55**	4.65	-2.17	4.65	12.50*	0.45	-3.91	0.45	1.84
19	AKSF 15-1-3A X AK 1R	100.00**	81.94**	3.21	7.78	40.16**	26.21**	20.93**	30.00**	30.58**	25.40**	7.73	9.22
20	AKSF 15-1-3A X RHA138-2R	21.76**	4.41	-17.18**	-13.51**	12.68*	5.26	-6.98	0	14.78*	8.5	-3.64	-2.3
21	AKSF 15-1-3A X 856-R	33.88**	11.1	-4.46	-0.23	27.38**	21.43**	2.79	10.5	20.92**	14.91*	0.91	2.3
22	AKSF 15-1-3A X EC-601951	77.95**	74.61**	2.91	7.47	34.29**	27.03**	9.3	17.50**	30.33**	24.71**	-1.36	0
23	AKSF 15-1-3AX PKV-105 R	43.51**	38.93**	-15.81**	-12.09*	19.19**	14.53*	-4.65	2.5	21.72**	11.97*	5.45	6.91
24	AKSF 15-1-3A X GMU-1116	29.06**	18.30*	-19.46**	-15.90**	0	-5.41	-18.60**	-12.50*	22.16**	15.31*	2.73	4.15
25	AKSF 15-1-3A X EC-6022011	61.46**	46.78**	1.77	6.27	28.77**	17.50**	9.3	17.50**	28.90**	28.16**	1.36	2.76
26	AKSF 15-1-3A X EC- 512687	60.63**	43.67**	3.32	7.89	31.43**	24.32**	6.98	15.00**	9.14	0	-5	-3.69
27	AKSF 15-1-3A X TSG-187	40.99**	33.28**	-15.11**	-11.35*	4.81	-10.00*	-3.72	3.5	14.85**	0.87	5.45	6.91
28	AKSF 15-1 -2A X AK 1R	36.08**	7.33	-13.60**	-9.78	-4.19	-11.17*	-14.88**	-8.5	35.14**	19.05**	2.27	3.69
29	AKSF 15-1 -2A X RHA138-2R	27.81**	26.88**	2.14	6.66	25.68**	21.05**	6.98	15.00**	37.30**	19.24**	5.91	7.37
30	AKSF 15-1 -2A X 856-R	8.97	5.49	-9.29	-5.27	21.79**	19.78**	1.4	9	36.42**	19.05**	4.55	5.99
31	AKSF 15-1 -2A X EC-601951	31.75**	14.10*	-8.15	-4.08	21.33**	18.38**	1.86	9.5	40.59**	33.96**	-3.18	-1.84

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

Sr. No	Crosses	Head diameter (cm)				100 seed weight (g)				Volume weight (g/100ml)			
		4				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)	MP(H_1)	BP(H_2)	Check(H_3)	Check(H_4)
32	AKSF 15-1 -2A X PKV-105 R	16.04**	1.69	-18.13**	-14.51**	-1.41	-2.23	-18.60**	-12.50*	21.30**	2.8	-3.18	-1.84
33	AKSF 15-1 -2A X GMU-1116	14.41*	5.59	-15.00**	-11.24*	16.34**	13.51*	-2.33	5	27.65**	10.71	-1.36	0
34	AKSF 15-1 -2A X EC-6022011	8.24	0.73	-18.91**	-15.32**	6.38	0	-6.98	0	37.97**	26.74**	-0.91	0.46
35	AKSF 15-1 -2A X EC- 512687	2.68	-2.79	-21.75**	-18.28**	22.99**	20.00**	3.26	11	13.31*	-4.31	-9.09	-7.83
36	AKSF 15-1 -2A X TSG-187	24.08**	11.13	-10.54*	-6.58	15.76**	2.17	9.3	17.50**	28.88**	4.78	9.55	11.06
37	HA-303 A X AK 1R	106.58**	94.30**	2.49	7.02	28.79**	23.79**	18.60**	27.50**	23.12**	17.22**	11.36*	12.90*
38	HA-303 A X RHA138-2R	57.58**	31.18**	4.05	8.66	31.58**	31.58**	16.28**	25.00**	25.12**	21.05**	15.00**	16.59**
39	HA-303 AX 856-R	21.52**	-1.97	-15.70**	-11.97*	10.22	7.89	-4.65	2.5	10.39	6.22	0.91	2.3
40	HA-303 A X EC-601951	45.08**	37.46**	-18.98**	-15.40**	-9.87	-11.05	-21.40**	-15.50**	7.61	-5.26	-10	-8.76
41	HA-303 A X PKV-105 R	36.59**	27.74**	-22.59**	-19.17**	-10.03	-12.63*	-22.79**	-17.00**	8.12	7.66	2.27	3.69
42	HA-303 A X GMU-1116	56.80**	39.14**	-5.27	-1.08	1.33	0	-11.63*	-5	2.72	-0.48	-5.45	-4.15
43	HA-303 A X EC-6022011	30.80**	15.15*	-20.16**	-16.63**	-2.05	-4.5	-11.16*	-4.5	11.81*	1.91	-3.18	-1.84
44	HA-303 A X EC-512687	63.69**	41.88**	2.03	6.54	30.67**	28.95**	13.95**	22.50**	16.75**	16.75**	10.91	12.44*
45	HA-303 AX TSG-187	49.16**	36.34**	-13.16**	-9.31	16.67**	6.52	13.95**	22.50**	2.51	-2.17	2.27	3.69
46	HA 228-A X AK 1R	61.02**	31.61**	-3.61	0.65	20.20**	14.08*	9.3	17.50**	27.60**	13.76*	-2.27	-0.92
47	HA 228-A X RHA138-2R	5.77	1.72	-19.31**	-15.74**	18.93**	17.37**	3.72	11.50*	29.30**	13.61*	0.91	2.3
48	HA 228-A X 856-R	27.96**	18.47**	1.88	6.39	22.62**	21.62**	4.65	12.50*	37.16**	21.12**	6.36	7.83
49	HA 228-A X EC-601951	21.58**	9.71	-19.65**	-16.09**	10.81*	10.81	-4.65	2.5	16.61*	12.58	-18.64**	-17.51**
50	HA 228-A X PKV-105 R	27.51**	16.51*	-14.67**	-10.89*	20.88**	18.92**	2.33	10	17.12**	0.39	-5.45	-4.15
51	HA 228-A X GMU-1116	45.02**	39.91**	2.47	7.01	19.46**	19.46**	2.79	10.5	18.60**	4.08	-7.27	-5.99
52	HA 228-A X EC-6022011	14.58*	11.52	-18.32**	-14.70**	-0.78	-4.5	-11.16*	-4.5	29.38**	20.35**	-5.91	-4.61
53	HA 228-A X EC-512687	7.67	6.69	-21.86**	-18.40**	-10.81*	-10.81	-23.26**	-17.50**	-8.68	-22.01**	-25.91**	-24.88**
54	HA 228-A X TSG-187	17.47**	9.81	-19.57**	-16.01**	15.66**	4.35	11.63*	20.00**	20.63**	-0.87	3.64	5.07
	RANGE	2.68 to 106.58	-2.79 to 94.30	-34.33 to 4.05	-31.43 to - 8.66	-21.04 to 52.63	-12.63 to 31.58	-29.30 to 20.93	-24.00 to 30.00	-8.68 to 40.59	-22.01 to 33.96	-25.91 to 15.00	-24.88 to 16.59
	SE(m)±	0.76	0.88	0.88	0.88	0.32	0.37	0.37	0.37	1.77	2.05	2.05	2.05
	CD 5%	1.52	1.75	1.75	1.75	0.64	0.74	0.74	0.74	3.52	4.07	4.07	4.07
	CD 1%	2.01	2.32	2.32	2.32	0.85	0.98	0.98	0.98	4.66	5.38	5.38	5.38

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

Cont….Table 2: Heterosis (%) over mid-parent (MP), better parent (BP) and standard checks DRSH-1(H_3), & 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	AKSF-14-2A X AK -1R	23.07**	12.29**	-4.48*	7.68**	30.35**	48.20**	4.34	-4.86
2	AKSF-14-2A X RHA -138-2R	24.77**	9.86**	1.28	14.18**	13.32**	19.41**	7.08	-2.36
3	AKSF-14-2A X 856 R	19.11**	2.6	-0.39	12.29**	-1.05	4.30	-6.48	-14.72**
4	AKSF-14-2A X EC-601951	36.33**	32.32**	-7.16**	4.66	34.19**	52.82**	7.28	-2.18
5	AKSF-14-2A X PKV-105 R	24.05**	9.68**	0.17	12.93**	8.32	12.51**	0.9	-7.99
6	AKSF-14-2A X GMU -1116	20.94**	18.88**	-16.58**	-5.97*	-38.47**	-23.86**	-31.71**	-37.73**
7	AKSF-14-2A X EC -6022011	50.63**	43.57**	0.74	13.56**	-0.52	5.62	-5.27	-13.62**
8	AKSF-14-2A X EC-512687	26.35**	22.66**	-8.59**	3.05	15.08**	43.65**	28.83**	17.48**
9	AKSF-14-2A X TSG187	38.75**	28.64**	-9.74**	1.75	5	22.80**	10.13*	0.42
10	HA-249-A X AK -1R	36.12**	10.63**	-5.89**	6.09*	-11.39	-11.15**	-37.78**	-43.27**
11	HA-249-A X RHA 138-2R	23.11**	-2.92	-10.50**	0.89	25.77**	52.03**	6.48	-2.91

12	HA-249-A X 856-R	40.38**	8.66**	5.49*	18.92**	-16.61**	0.82	-29.39**	-35.61**
13	HA-249-A X EC-601951	46.97**	32.69**	-12.37**	-1.22	23.21**	23.36**	-13.61**	-21.23**
14	HA-249-A X PKV-105-R	30.62**	3.36	-5.60*	6.42**	-13.55**	2.85	-27.97**	-34.32**
15	HA-249-A X GMU-1116	35.03**	20.52**	-18.31**	-7.92**	-2.74	40.49**	-1.61	-10.28*
16	HA-249-A X EC-6022011	73.53**	59.37**	1.33	14.23**	-18.35**	-0.43	-30.28**	-36.42**
17	HA-249-A X EC- 512687	46.46**	25.51**	-6.46**	5.45*	-6.09	36.92**	-4.1	-12.56**
18	HA-249-A X TSG-187	45.97**	37.77**	-17.41**	-6.90**	14.32**	55.16**	8.68	-0.9
19	AKSF 15-1-3A X AK 1R	27.14**	24.37**	5.80**	19.27**	14.02**	32.31**	-6.85	-15.06**
20	AKSF 15-1-3A X RHA138-2R	6.05**	-0.18	-7.97**	3.74	8.87*	12.54**	4.66	-4.56
21	AKSF 15-1-3A X 856-R	12.39**	3.29	0.29	13.05**	-12.60**	-9.63*	-15.95**	-23.36**
22	AKSF 15-1-3A X EC-601951	22.18**	10.67**	-9.95**	1.51	-6.52	8.62*	-23.73**	-30.45**
23	AKSF 15-1-3AX PKV-105 R	5.07*	-0.66	-9.27**	2.28	-26.90**	-25.48**	-30.69**	-36.80**
24	AKSF 15-1-3A X GMU-1116	12.23**	2.86	-16.31**	-5.65*	-5.95	48.20**	5.94	-3.4
25	AKSF 15-1-3A X EC-6022011	30.83**	16.53**	-5.18*	6.89**	-10.73*	19.41**	-13.52**	-21.14**
26	AKSF 15-1-3A X EC- 512687	28.24**	22.85**	-0.04	12.69**	-36.89**	4.30	-28.30**	-34.62**
27	AKSF 15-1-3A X TSG-187	35.74**	17.87**	-4.1	8.11**	38.30**	52.82**	47.35**	34.36**
28	AKSF 15-1 -2A X AK 1R	5.62*	1.65	-13.53**	-2.52	40.00**	12.51**	33.49**	21.72**
29	AKSF 15-1 -2A X RHA138-2R	21.92**	12.99**	4.17	17.43**	-11.34**	-23.86**	-2.66	-11.24*

Cont….Table 2: Heterosis (%) over mid-parent (MP), better parent (BP) and standard checks DRSH-1(H_3), & 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)
30	AKSF 15-1 -2A X 856-R	8.03**	-2.21	-5.06*	7.03**	-3.69	13.92**	5.76	-3.57
31	AKSF 15-1 -2A X EC-601951	29.97**	19.53**	-5.96**	6.02*	-20.24**	-7.02	-24.03**	-30.73**
32	AKSF 15-1 -2A X PKV-105 R	-4.11	-10.75**	-18.48**	-8.11**	-27.41**	-22.90**	-21.27**	-28.21**
33	AKSF 15-1 -2A X GMU-1116	31.06**	21.98**	-4.03	8.19**	-43.03**	58.45**	-28.05**	-34.39**
34	AKSF 15-1 -2A X EC-6022011	19.70**	8.22**	-14.85**	-4.02	-12.27**	89.58**	-3.04	-11.59*
35	AKSF 15-1 -2A X EC-512687	26.12**	22.79**	-3.39	8.91**	-46.11**	-1.94	-31.43**	-37.47**
36	AKSF 15-1 -2A X TSG-187	48.08**	30.45**	2.64	15.70**	-6.57	6.46	12.29*	2.39
37	HA-303 A X AK 1R	34.24**	25.27**	6.57**	20.13**	-13.59**	8.18*	-28.14**	-34.47**
38	HA-303 A X RHA138-2R	27.51**	14.72**	5.77**	19.23**	-7.51	-18.51*	-9.72	-17.68**
39	HA-303 AX 856-R	3.28	-9.16**	-11.81**	-0.58	3.82	-40.20**	1.36	-7.57
40	HA-303 A X EC-601951	28.67**	21.98**	-10.10**	1.34	22.44**	-3.79	1.7	-7.26
41	HA-303 A X PKV-105 R	-0.3	-9.92**	-17.73**	-7.26**	34.81**	-42.99**	29.79**	18.35**
42	HA-303 A X GMU-1116	33.51**	28.14**	-5.56*	6.46**	-14.25**	-6.50	-2.15	-10.78*
43	HA-303 A X EC-6022011	14.00**	6.18*	-21.75**	-11.78**	7.15	2.06	5.37	-3.91
44	HA-303 A X EC- 512687	43.82**	43.02**	6.59**	20.15**	-29.00**	-5.88	-18.30**	-25.50**
45	HA-303 AX TSG-187	30.93**	18.72**	-12.51**	-1.37	29.74**	5.67	40.14**	27.78**
46	HA 228-A X AK 1R	13.74**	9.16**	0.99	13.85**	17.96**	44.87**	-2.88	-11.45*
47	HA 228-A X RHA138-2R	3.79	3.61	-4.14	8.06**	4.45	35.31**	1.08	-7.83
48	HA 228-A X 856-R	11.84**	9.20**	6.02**	19.52**	-4.64	2.01	-7.7	-15.83**
49	HA 228-A X EC-601951	7.48**	-7.90**	-14.79**	-3.94	30.18**	9.83*	7.04	-2.39
50	HA 228-A X PKV-105 R	-9.42**	-9.99**	-16.73**	-6.13*	8.16	-14.83**	3.22	-5.88
51	HA 228-A X GMU-1116	8.48**	-6.02*	-13.06**	-1.99	-24.26**	46.09**	-14.21**	-21.77**
52	HA 228-A X EC-6022011	11.56**	-5.89*	-12.93**	-1.85	6.34	37.93**	3.68	-5.46
53	HA 228-A X EC- 512687	16.50**	5.17*	-2.7	9.69**	7.93*	7.25	23.29**	12.42**
54	HA 228-A X TSG-187	-1.01	-18.44**	-24.54**	-14.94**	1.14	-2.04	8.39	-1.16
	RANGE	-4.11 to 73.53	-10.75 to 59.37	-24.54 to 6.57	-14.94 to 20.15	-46.11 to 40.00	-42.99 to 89.58	-37.78 to 47.35	-43.27 to 34.36
	SE(m)±	1.27	1.47	1.47	1.47	1.27	1.46	1.46	1.46
	CD 5%	2.53	2.92	2.92	2.92	2.52	2.91	2.91	2.91
	CD 1%	3.35	3.86	3.86	3.86	3.33	3.85	3.85	3.85

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

Cont….Table 2: Heterosis (%) over mid-parent (MP), better parent (BP) and standard checks DRSH-1(H_3), & 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	AKSF-14-2A X AK -1R	1.52	0.09	-1.54	5.01	117.75**	90.32**	-9.05	-10.13
2	AKSF-14-2A X RHA -138-2R	-3.13	-6.49*	-8.02**	-1.89	48.06**	17.96*	-5.01	-6.14
3	AKSF-14-2A X 856 R	-6.80**	-9.08**	-10.56**	-4.61	58.01**	21.26**	8.36	7.07
4	AKSF-14-2A X EC-601951	-4.2	-4.23	-5.79*	0.48	44.56**	20.39*	-13.56*	-14.59*
5	AKSF-14-2A X PKV-105 R	-2.67	-2.94	-3.98	2.41	39.83**	11.73	-10.71	-11.78*
6	AKSF-14-2A X GMU -1116	-8.48**	-10.07**	-8.34**	-2.24	46.59**	27.94**	-18.01**	-18.98**
7	AKSF-14-2A X EC -6022011	-0.42	-0.74	-1.72	4.82	71.44**	36.80**	9.72	8.41
8	AKSF-14-2A X EC-512687	-6.23**	-7.71**	-6.25*	-0.01	47.40**	16.41*	-4	-5.14
9	AKSF-14-2A X TSG187	5.06*	-2.03	-3.63	2.79	54.92**	33.47**	-11.79	-12.84*
10	HA-249-A X AK -1R	2.09	-1.14	0.89	7.61**	54.45**	17.95*	-20.04**	-20.99**
11	HA-249-A X RHA 138-2R	0.04	-5.11*	-3.17	3.28	26.46**	16.45*	-6.22	-7.33
12	HA-249-A X 856-R	-3.05	-7.08**	-5.18*	1.14	52.78**	34.34**	20.05**	18.62**
13	HA-249-A X EC-601951	0.72	-1.13	0.9	7.62**	49.58**	45.40**	4.4	3.16
14	HA-249-A X PKV-105-R	0.15	-1.38	0.64	7.34**	44.49**	33.54**	6.71	5.45
15	HA-249-A X GMU-1116	-7.49**	-7.55**	-5.65*	0.63	14.13	11.02	-24.74**	-25.63**
16	HA-249-A X EC-6022011	-6.77**	-8.16**	-6.28*	-0.04	44.20**	33.04**	6.7	5.44
17	HA-249-A X EC- 512687	-2.57	-2.79	-0.8	5.81*	30.62**	19.00**	-1.86	-3.03
18	HA-249-A X TSG-187	6.66**	-2.21	-0.2	6.44*	21.58**	20.06*	-18.61**	-19.58**
19	AKSF 15-1-3A X AK 1R	-6.10**	-8.85**	-7.44**	-1.28	100.83**	45.75**	15.41*	14.04*
20	AKSF 15-1-3A X RHA138-2R	1.26	-3.73	-2.24	4.27	11.91	10.98	-10.63	-11.69*
21	AKSF 15-1-3A X 856-R	-0.27	-4.19	-2.71	3.77	28.58**	21.26**	8.36	7.07
22	AKSF 15-1-3A X EC-601951	-3.24	-4.78*	-3.32	3.12	48.78**	41.84**	12.32*	10.98
23	AKSF 15-1-3AX PKV-105 R	-2.78	-4.03	-2.55	3.93	12.89*	12.38	-10.19	-11.26
24	AKSF 15-1-3A X GMU-1116	-2.62	-2.8	-0.93	5.66*	16.32*	5.3	-16.65**	-17.64**
25	AKSF 15-1-3A X EC-6022011	1.74	0.48	2.03	8.82**	36.42**	35.55**	8.72	7.43
26	AKSF 15-1-3A X EC- 512687	-5.04*	-5.06*	-3.56	2.86	33.70**	31.04**	8.07	6.78
27	AKSF 15-1-3A X TSG-187	-0.37	-8.44**	-7.03**	-0.84	18.18*	8.41	-14.16*	-15.18*
28	AKSF 15-1 -2A X AK 1R	-5.72**	-8.20**	-7.37**	-1.2	44.16**	6.23	-19.82**	-20.78**
29	AKSF 15-1 -2A X RHA138-2R	-1.72	-6.29*	-5.44*	0.86	44.74**	40.19**	12.90*	11.55
30	AKSF 15-1 -2A X 856-R	0.08	-3.56	-2.68	3.79	16.77*	7.70	-3.77	-4.91
31	AKSF 15-1 -2A X EC-601951	-1.27	-2.54	-1.65	4.89	22.58**	19.61*	-9.73	-10.8

Cont….Table 2: Heterosis (%) over mid-parent (MP), better parent (BP) and standard checks DRSH-1(H_3), & 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)
32	AKSF 15-1 -2A X PKV-105 R	-8.99**	-9.89**	-9.07**	-3.02	3.19	2.41	-22.70**	-23.62**
33	AKSF 15-1 -2A X GMU-1116	-3.66	-4.14	-2.29	4.21	34.34**	24.20**	-6.26	-7.37
34	AKSF 15-1 -2A X EC-6022011	-2.22	-3.14	-2.26	4.25	12.60	9.28	-12.35*	-13.39*
35	AKSF 15-1 -2A X EC- 512687	-4.47*	-4.79*	-3.28	3.16	8.54	3.93	-14.30*	-15.31*
36	AKSF 15-1 -2A X TSG-187	3.23	-4.86*	-3.99	2.4	55.86**	46.18**	10.32	9.01
37	HA-303 A X AK 1R	-2.72	-6.34**	-3.28	3.16	134.91**	77.64**	23.94**	22.46**
38	HA-303 A X RHA138-2R	0.39	-5.31*	-2.22	4.28	62.33**	51.48**	21.99**	20.54**
39	HA-303 AX 856-R	-1.5	-6.12*	-3.06	3.4	31.10**	16.73*	4.31	3.07
40	HA-303 A X EC-601951	-0.4	-2.78	0.39	7.07**	18.11*	16.44*	-16.39**	-17.39**
41	HA-303 A X PKV-105 R	-2.8	-4.84*	-1.74	4.8	5.14	1.92	-24.24**	-25.14**
42	HA-303 A X GMU-1116	0.54	-0.11	3.15	10.02**	37.14**	20.54**	10.97	9.65
43	HA-303 A X EC-6022011	-4.23*	-6.20**	-3.14	3.31	23.76**	15.71*	-7.2	-8.3
44	HA-303 A X EC- 512687	-3.86	-4.64	-1.53	5.02	59.83**	47.52**	21.66**	20.22**
45	HA-303 AX TSG-187	6.46**	-2.91	0.26	6.93**	39.74**	36.06**	-5.07	-6.2
46	HA 228-A X AK 1R	0.56	-2.56	-0.68	5.93*	67.58**	8.04	-4.12	-5.26
47	HA 228-A X RHA138-2R	2.53	-2.7	-0.82	5.78*	5.75	7.01	-15.83**	-16.83**
48	HA 228-A X 856-R	3.97	-0.3	1.63	8.39**	35.60**	27.49**	13.92*	12.57*
49	HA 228-A X EC-601951	3.23	1.4	3.36	10.24**	20.77	2.40	-9.13	-10.21
50	HA 228-A X PKV-105 R	-0.35	-1.82	0.08	6.74*	12.22	0.28	-11.02	-12.08*
51	HA 228-A X GMU-1116	-0.63	-0.64	1.28	8.02**	49.99**	16.29*	7.06	5.79
52	HA 228-A X EC-6022011	-0.08	-1.51	0.39	7.07**	3.82	4.84	-17.53**	-18.51**
53	HA 228-A X EC- 512687	1.15	0.98	2.93	9.78**	-2.29	0.07	-21.27**	-22.21**
54	HA 228-A X TSG-187	7.56**	-1.32	0.58	7.27**	12.43	3.45	-18.63**	-19.59**
	RANGE	-8.99 to 7.56	-10.07 to 1.4	-10.56 to 3.36	-4.61 to 10.24	-2.29 to 134.91	0.07 to 90.32	-24.74 to 23.94	-25.63 to 22.46
	SE(m)±	0.81	0.93	0.93	0.93	1.84	2.12	2.12	2.12
	CD 5%	1.61	1.86	1.86	1.86	3.65	4.21	4.21	4.21
	CD 1%	7.56	2.46	2.46	2.46	4.83	5.57	5.57	5.57

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

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

Crosses	Mean Seed yield /plant	Heterosis (%) for seed yield				Oil content (%)	Significant GCA effects of parents for other characters
		H_1	H_2	H_3	Significant H_3 for other characters		
HA-303A x AK-1R	44.30**	134.91**	77.64**	22.46**	1,2,3,4,5,6,7,8	37.25	$P_{1\,–\,1,2.3.6.8.9}$ $P_{2\,-\,1,2,4,7}$
HA-303A x RHA-138-2R	43.61**	62.33**	51.48**	20.54**	1,2,3,4,5,6,7,8	37.65	$P_{1\,–\,1,2,3,6,8,9}$ $P_{2\,–\,7}$
HA-303A x EC-512687	43.49**	59.83**	47.52**	20.22**	1,2,3,4,5,7,8	37.92	$P_{1\,–\,1,2,3,6,8,9}$ $P_{2\,–\,7}$
HA-249A x 856R	42.91**	52.78**	34.34**	18.62**	1,2,3,4,5,7,8	36.52	$P_{1\,–\,1,2,3,6,8}$ $P_{2\,–\,4,5,6,7,8}$

H_1 - Average heterosis H_2 - Heterobeltiosis H_3 - Standard heterosis over PDKVSH-952

1) Days to 50% flowering 2) days to Maturity 3) Plant height
4) Head diameter 5) 100 seed weight 6) Volume weight
7) Seed filling percentage 8) Hull content 9) Oil content.

Conclusion

In this study fifty four F1 hybrids obtained from crossing of six cytoplasmic male sterile lines and nine restorers were evaluated using line x tester design. Observations were recorded on yield and its contributing characters, and data was analysed for estimation of heterosis, heterobeltiosis and standard heterosis of F1 hybrids. The extent of standard heterosis observed for seed yield over the best check PDKVSH-952 was up to 22.46 per cent. The highest significant standard heterosis was recorded by the cross HA-303A x AK-1R (22.46%) followed by HA-303A x RHA-138-2R (20.54%), HA-303A x EC-512687 (20.22%) and HA-249A x 856R (18.62%). For oil content, cross HA-228A X EC-601951 (3.36) followed by HA-303A x GMU-116 (3.15), HA-228A x EC-512687 (2.93) has recorded highest standard heterosis over best check DRSH-1. On the basis of mean performance, heterosis, heterobeltiosis and standard heterosis, four crosses *viz.*, HA-303A x AK-1R, HA-303A x RHA-138-2R, HA-303A x EC-512687, HA-249A x 856R are identified as promising crosses for seed yield and as well as oil content and thus, these crosses may be evaluated in preliminary or multilocation hybrid trials for further commercial exploitation.

References

1. Atlagic J. Cytological studies in hexaploid Helianthus species and there F_1 Hybrid with cultivated sunflower, (*Helianthus annuus* L.). Plant breed. 1996; 15:257-260.
2. Alone RK, Mate SN, Gagare KC, Manjare MR. Heterosis in sunflower (*Helianthus annuus* L.). Indian Journal of Agricultural Sciences. 2003; 37:56-59.
3. Baydar H, Erbas S. Influence of seed development and seed position on oil, fatty acids and total tocopherol contents in sunflower (*Helianthus annuus* L.). Turk J. Agric. 2005; 29:179 -186.
4. Chandra BS, Ranganatha ARG, Kumar SS. Heterosis studies for seed yield and its components in sunflower hybrids over locations. Madras Agricultural Journal. 2013; 100(1, 3):23-29.
5. Janjal SM, Vaidya ER, Nichal SS, Ratnaparkhi RD, Rathi SR. Heterosis Studies In Sunflower (*Helianthus annuus* L.). Advances in life sciences. 2016; 5(21)10049-10055.
6. Kalpande VV, Lande SS, Weginwar DG, Dudhe MY. Heterosis studies in single and TWC hybrid in sunflower. PKV Res. J. 2004; 28(1):73.
7. Karasu A, Turan ZM. Combining ability and heterosis for yield component in sunflower. Agrobot. Cluj. 2010; 38(3):259-264.
8. Kinman ML. New development in the USDA and state experiment station, sunflower breeding programme. In: Proc. of the 4th International Sunflower Conference, Memphis, Tenness, USA. 1970, 181-183.
9. Leclercq P. Une sterilite male cytoplasmique chez le tournesol. Annales del Ameloation des Plantes. 1969; 19:99-106
10. Neelima S, Rafi SM. Estimation of standard heterosis in sunflower hybrids. Karnataka Journal of Agricultural Sciences. 2013; 26(3):415-416.
11. Panero JL, Funk VA. Toward a phylogenetic subfamilial classification for the Compositae. Proc. Biol. Soc. Wash. 2002; 115:909-922.
12. Radhika PK, Jagadeshwar R, Khan HA. Heterosis and combining ability through line x tester analysis in sunflower (*Helianthus annuus* L.). J. Res. ANGRAU. 2001; 29(2-3):35-43.
13. Rathi SR, Nichal SS, Vaidya ER, Wandhare MR, Janjal SM. Heterosis for yield, its component and oil content in sunflower (*Helianthus annuus* L.). International Journal of Tropical Agriculture. 2016; 34(4):1063-1072.
14. Singh RB, Choudhary BD. Biometrical methods in quantitative genetic analysis. Line x Tester analysis, Kalyani Publishers. New Delhi, 1997,
15. Sapkale RB, Shinde SR, Pawar RM. Heterosis studies in sunflower (*Helianthus annuus* L.). International. J Plant sci. 2016; 11(1):22-27.
16. Sawargaonkar SL, Ghodke MK. Heterosis in relation to combining ability studies in restorer lines of sunflower. Helia. 2008; 31:95-100.
17. Seiler GJ, Rieseberg LH. Systematics, origin and germplasm resources of the wild and domesticated sunflower. 1997, 21-66.
18. Sujatha M, Reddy AV. Heterosis and combining ability for seed yield and other yield contributing characters in sunflower (*Helianthus annuus* L.). J. Oilseeds Res. 2009; 26(1):21-31.
19. Venkata RP, Nadaf HL. Exploitation of Heterosis in sunflower (*Helianthus annuus* L.). Trends in Bioscience. 2013; 6(6):662-669.
20. Volotovich AA, Silkova TA, Fomchenko NS, Davydenko OG. Combining ability and heterosis effects in sunflower of byelorussian origin. Helia. 2008; 31(48):111-118.