

HETEROSIS FOR YIELD AND ITS COMPONENT TRAITS IN SAFFLOWER (*Carthamus tinctorious* L.)

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ABSTRACT

In the present investigation, a complete set of 36 genotypes (eight parents and their 28 crosses developed through half diallel mating design) were planted in randomized complete block design replicated thrice at the College Farm, N. M. College of Agriculture, NAU, Navsari during rabi 2013-14 to estimate heterosis in safflower. Among the parents, PBNS-12, A-1 and SSF-906 were the best performing parents for seed yield per plant and its component attributes. Significant and positive heterosis was observed for majority of the yield attributing characters. High expression of heterosis for seed yield per plant was associated with high heterotic effects for yield attributing components, viz., number of seeds per capitulum and 100 seeds weight. The crosses A-1 x PBNS-12, PBNS-12 x SSF-906, PBNS-12 x SSF-902, Phule x PBNS-12 and Tara x PBNS-12 appeared most promising, as they registered high per se performance with significant relative heterosis, heterobeltiosis as well as standard heterosis for seed yield per plant, indicated that these crosses could be exploited for commercial cultivation in respect of safflower.

KEY WORDS: Heterosis, heterobeltiosis, safflower.

INTRODUCTION

Safflower (*Carthamus tinctorious* L.) belongs to *Asteraceae* family commonly known as “Kusum”. Safflower is one of the important *rabi* oilseed crop of India, cultivated in vertisols under residual moisture in Karnataka, Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Bihar and Gujarat. Safflower is known for its cultivation since time immemorial, either for orange red dye extracted from its florets and for its much valued oil. Latha and Prakash (1984) reported that the seed contains 27.5 per cent oil, 15 per cent protein, 41 per cent crude fiber and 2.3 per cent ash. Safflower oil, which on average contains 75 per cent linoleic acid, also contains tocopherols, known to have antioxidant effect and high vitamin E content. For this reason, safflower

oil is used in the diets of patients with cardiovascular disease and bears great importance for its anti-cholesterol effect. Safflower oil cake is a valuable animal feed (Weiss, 2000). In India, safflower is grown in 2.29 lakh hectares with a production of 1.43 lakh metric tonnes (2012-13) and ranked first in area and second in production accounting for 60 per cent and 45 per cent of global area and production, respectively (Anonymous, 2013). Safflower is a often cross pollinated crop; as it has some out crossing depending on genotype and insect activity (Knowels, 1969). Bundles of young plants are commonly sold as a green vegetable in markets in India and some neighboring countries (Nimbkar, 2002). Safflower can be grazed or stored as hay or silage. Safflower forage is palatable, and its

feed value and yields are similar to or better than those for oats or alfalfa. However, interest in this crop has been rekindled in the last few years due to huge shortfall in oilseed production in countries having a sizable area with scanty rainfall; preference of consumers for healthy oil with less amounts of saturated fats; medicinal uses of flowers in China and extraction of edible dyes from flowers have become more widely known. In recent years, efforts are being made to improve the productivity of this crop through the use of high yielding varieties and improved crop production technology. However, in general, varietal improvement programme has not made any dent in testing the yield potential in safflower.

MATERIALS AND METHODS

The present investigation was carried out on Heterosis in safflower (*Carthamus tinctorius* L.) at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari during the *rabi* season of 2013-14 in randomized block design replicated thrice. The experimental material for present investigation comprising 28 F_1 s developed through diallel mating design of 8 parents excluding reciprocals. The genotypes were obtained from ANGRAU, Hyderabad and PDKV, Akola. The crossing technique consisted of hand emasculation of selected proper size flower buds from new flush, in the evening during 4.00 pm to 6.00 pm. The emasculated flowers were covered by red colored butter paper packet for easy identification. The emasculated flowers were pollinated in the next day morning during 7.30 am to 10.30 am by brushing the pollen from selected male plant on the stigmatic surface of the female plant. Seeds were extracted from dried fruits for evaluation. All recommended practices were followed and timely plant protection measures were taken to avoid damage through insect-pests and diseases. For each experimental unit, five plants were randomly selected and tagged excluding border plants to record the observation for various quantitative characters, except days to flowering and days

to maturity, they were recorded on population bases. Total 14 traits were recorded in the field and laboratory and mean values were subjected to statistical analysis as Panse and Sukhtme (1985) and Griffing (1956).

RESULTS AND DISCUSSION

The results revealed highly significant differences among parents for all the characters except days to flower initiation, days maturity, head diameter, leaf area at flowering, number of seeds per capitulum and seed yield per plant, which suggested that sufficient variability was present among the parents for most of the characters (Table 1). Significant variability exhibited by hybrids for all the traits studied. Parents vs. hybrids comparison indicated that means of hybrids were significantly different from means of parents as a group for days to flower initiation, days to 50 per cent flowering, stem diameter, leaf area at flowering and number of filled seeds per capitulum.

The estimates of heterosis over mid parent (MP) and better parent (BP) for different characters in safflower are presented in Table 2. Heterosis was measured as per cent increase or decrease over mid parent (relative heterosis) and over better parent (heterobeltiosis). For calculation of relative heterosis and heterobeltiosis for days to 50 per cent flowering, plant height, flower initiation, unfilled seed per capitulum and days to maturity, parents with less values were considered as better parent and crosses with lower values were considered as heterotic crosses. The magnitude of heterotic effects observed in different characters varied from cross to cross.

For days to flower initiation, negative values are desired for earliness. The heterotic effects for this trait ranged from -11.00 per cent to 5.49 per cent for relative heterosis, and from -13.80 per cent to 2.16 per cent for heterobeltiosis. Total of six and seven hybrids manifested heterotic effects in desired direction for relative heterosis and

heterobeltiosis, respectively. Ramachandram and Goud (1982) and Jhajharia *et al.* (2013) reported similar results for days to flower initiation.

None of the hybrids manifested the significant negative relative heterosis for this trait. The hybrids, Tara x PBNS-12, Phule x PBNS-12, PBNS-12 x SSF-902 and A-1 x Tara manifested significant negative heterobeltiosis for days to 50 per cent flowering (Table 2). The results are in accordance with the finding of Narkhede and Patil (1987), Pandya *et al.* (1988) and Shivani *et al.* (2012).

Out of 28 hybrids, none of the hybrids showed significant negative relative heterosis, while single hybrid (SMVT x PBNS-12) depicted significance negative heterobeltiosis for days to maturity (Table 2). The similar results were also reported by Pandya *et al.* (1988), Sarode *et al.* (2008) and Shivani *et al.* (2012).

For plant height, four hybrids A-1 x PBNS-12, SSF-906 x SSF-902, Phule x PBNS-12 and Tara x PBNS-12 depicted significant negative relative heterosis, while A-1 x PBNS-12, SSF-906 x SSF-902, Phule x PBNS-12, Tara x PBNS-12 and AKS-311 x SSF 902 manifested significant negative heterobeltiosis. The similar results were also reported by Deokar and Patil (1979), Narkhede *et al.* (1986) and Raghunatham *et al.* (1989).

With regards to head diameter, the range of relative heterosis was from -12.49 per cent to 3.25 per cent and for heterobeltiosis, it was from -16.52 per cent to 0.14 per cent. None of the hybrids possessed significant and positive relative heterosis as well as heterobeltiosis. Similar results were also reported by Reddy (1983) and Deokar *et al.* (1984).

Low to high heterosis was observed for stem diameter. Out of 28 crosses, 8 and 7 crosses manifested heterotic effects in desired direction for relative heterosis and heterobeltiosis, respectively, for this trait. A-1 x PBNS-12, Phule x PBNS-12, Tara x PBNS-12, PBNS-12 x SSF-902 and PBNS-

12 x SSF-906 were the common hybrids registered the significant positive relative heterosis as well as heterobeltiosis. The results are in agreement with reports of Reddy (1983) and Deokar *et al.* (1984).

Three and two hybrids exhibited significant and positive heterosis over mid parent and better parent, respectively for number of leaves per plant. Crosses A-1 x PBNS-12 was the common in both heterosis and heterobeltiosis. Positive heterosis for number of leaves per plant was also reported by Manjare and Jambhale (1995) and Sarode *et al.* (2008).

With regards to leaf area at flowering, none of the hybrid manifested significant positive relative heterosis, while 5 crosses, A-1 x PBNS-12, Phule x PBNS- 12, Tara x PBNS-12, PBNS-12 x SSF-902 and PBNS-12 x SSF-906 exhibited significant positive heterobeltiosis. Similar results were found by Raghunatham *et al.* (1989).

The number of seeds per capitulum is the most valuable and economic character. For this character, none of the hybrid manifested significant positive relative heterosis, while 6 hybrids exhibited significant positive heterobeltiosis. Similar results have been reported by Sarode *et al.* (2008) and Shivani *et al.* (2012). For number filled seed per capitulum, the crosses exhibited significant positive relative heterosis were A-1 x AKS 311, A-1 x PBNS-12, Phule x PBNS-12, Tara x PBNS-12, PBNS-12 x SSF-902 and PBNS-12 x SSF-906, while crosses, A-1 x PBNS-12, A-1 x SSF-906, A-1 x SSF-902, PBNS-12 x SSF-902 and PBNS-12 x SSF-906 exhibited significant and positive heterobeltiosis. Similar results were also reported by Shivani *et al.* (2012). For number of unfilled seeds per capitulum, 14 and 12 crosses manifested significant positive relative heterosis and heterobeltiosis, respectively. Similar results were also reported Shivani *et al.* (2012).

The range of relative heterosis was in between -16.09 per cent to 22.77 per cent and for heterobeltiosis, it was in between -18.30 per cent to 18.82 per cent for 100

seeds weight. Out of 28 hybrids, 6 and 5 crosses manifested heterotic effects in desired direction for relative heterosis and heterobeltiosis, respectively, for this trait. The crosses, A-1 x PBNS-12, PBNS-12 x SSF-902, PBNS-12 x SSF-906 and Tara x PBNS-12 were the common crosses depicted significant positive heterosis over mid parent as well as heterobeltiosis. Similar results were also reported by Reddy (1983), Raghunatham *et al.* (1989) and Sarode *et al.* (2008).

Among 28 hybrids, five hybrids viz., A-1 x PBNS-12, PBNS-12 x SSF-902, PBNS-12 x SSF-906, Phule x PBNS-12 and Tara x PBNS-12 (Table 2) exhibited significant and positive estimates of both relative heterosis and heterobeltiosis for seed yield per plant. The results are in accordance with finding of Sarode *et al.* (2008) and Shivani *et al.* (2012).

For oil content, out of 28 hybrids, 6 and 5 crosses manifested heterotic effects in desired direction for relative heterosis and heterobeltiosis, respectively. The results are in agreement with finding of Kumar and Yadav (1989), Raghunatham *et al.* (1989), Sarode *et al.* (2008) and Shivani *et al.* (2012).

In the present investigation, variable degree of heterosis was observed for almost all the characters. Higher values of heterosis and heterobeltiosis for seed yield per plant were recorded by hybrids A-1 x PBNS-12, PBNS-12 x SSF-902, PBNS-12 x SSF-906, Phule x PBNS-12 and Tara x PBNS-12. Five best heterotic crosses and their performance for safflower seed yield per plant are depicted in Table 3. High heterotic hybrids had also high *per se* performance as well as high and significant heterosis for other yield attributing traits, therefore, selection of hybrids either on the basis of *per se* performance or on the basis of magnitude of heterotic effects would also be reliable.

CONCLUSION

Higher values of heterosis and heterobeltiosis for seed yield per plant were recorded by hybrids A-1 x PBNS-12, PBNS-

12 x SSF-902, PBNS-12 x SSF-906, Phule x PBNS-12 and Tara x PBNS-12 could be exploited for safflower improvement in seed yield per plant.

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Table 1: Analysis of variance (mean sum of square) for experimental design for different characters in safflower.

Source	D.f.	Days to Flower Initiation	Days to Flowering	Days to Maturity	Plant Height (cm)	Head Diameter (cm)	Stem Diameter (cm)	Number of Leaves per Plant
Replication	2	6.83642	90.84458	8.51931	4.36336	0.07168	0.23012	12.07064
Treatments	35	29.66828**	65.44644**	51.72620*	61.64323**	0.10343**	0.71615**	65.02089**
Parents	7	16.22088	49.43290**	42.46961	65.44263*	0.01971	0.29869*	74.76852**
Hybrids	27	30.83320**	68.15044**	55.51151*	62.43349**	0.12892**	0.72438**	64.50020**
Parents vs Hybrids	1	92.34746**	104.53306**	14.31893	13.71047	0.00112	3.41620**	10.84614
Error	70	10.08026	20.10956	23.69223	21.00984	0.02029	0.13487	4.57107
Total	107	16.42693	36.26153	32.57861	33.98999	0.04845	0.32679	24.48455

Source	D.f.	Leaf Area (cm ²)	Number of Seeds per Capitulum	Number of Filled Seeds per Capitulum	Number of Unfilled Seeds per Capitulum	100 Seed Weight (g)	Seeds Yield per Plant (g)	Oil Content (%)
Replication	2	12.45533	2.70790	4.16427	12.07064	0.30970	1.75573	0.78996
Treatments	35	38.39589**	11.08547**	38.61076**	65.02089**	0.96691**	16.43824**	24.55443**
Parents	7	14.86243	6.31808	11.62170*	74.76852**	0.57574**	2.96044	12.58697**
Hybrids	27	44.26995**	12.71915**	45.77418**	64.50020**	1.10410*	20.45802**	28.56333**
Parents vs Hybrids	1	44.53032**	0.34774	34.12208*	10.84614	0.00091	2.24871	0.08625
Error	70	9.48013	3.35257	3.64901	4.57107	0.07534	2.94729	1.14050
Total	107	18.99417	5.86997	15.09473	24.48455	0.37135	7.33794	8.79271

*, ** significant at 0.05% and 0.01% levels of probability, respectively

Table 2: Estimates of heterosis and heterobeltiosis for various traits

Sr. No.	Crosses	Days to Flower Initiation		Days to Flowering		Days to Maturity		Plant Height (cm)		Head Diameter (cm)	
		MP	BP	MP	BP	MP	BP	MP	BP	MP	BP
1	A-1 × Phule	-1.98	-3.75	-0.27	-3.12	-3.31	-4.88	-4.54	-6.84	-0.07	-4.54
2	A-1 × Tara	-0.70	-2.93	-2.59	-5.90*	-4.14	-7.80	0.59	-5.63	1.48	-3.06
3	A-1 × AKS-311	-1.47	-4.80	0.18	-2.09	-4.76	-5.69	1.36	-5.03	1.16	-3.86
4	A-1 × SMVT	-1.41	-5.03	1.66	-0.40	-4.52	-7.32	1.53	-1.44	1.76	-4.46
5	A-1 × PBNS-12	-8.97 **	-9.84 *	-2.54	-3.11	22.57 **	19.44 **	-16.63 **	-16.85 **	-9.10 *	-9.47
6	A-1 × SSF-906	1.60	-0.67	1.98	0.62	11.54 *	9.27	-0.04	-1.25	1.30	-3.00
7	A-1 × SSF-902	0.83	-1.26	0.81	-1.18	-6.69	-8.13	1.84	0.67	3.25	-1.58
8	Phule × Tara	-1.45	-1.90	0.97	0.39	2.15	-0.17	0.43	-3.55	0.02	0.02
9	Phule × AKS-311	-2.02	-3.62	1.76	1.13	-1.67	-2.32	3.38	-0.86	-1.49	-2.02
10	Phule × SMVT	-4.39	-6.24	-3.89	-4.73	-3.24	-4.54	-0.30	-0.84	-1.27	-3.05
11	Phule × PBNS-12	-9.21 **	-11.69 **	-4.21	-7.47*	9.41	4.94	-11.58 **	-13.92 **	-11.17 **	-15.47 **
12	Phule × SSF-906	-2.36	-2.78	-0.54	-2.10	1.10	0.67	0.48	-0.75	-1.92	-2.17
13	Phule × SSF-902	1.88	1.60	-1.96	-2.87	-6.63	-6.71	-0.69	-1.97	-0.01	-0.24
14	Tara × AKS-311	-4.59	-5.73	-1.26	-2.43	-2.65	-5.47	4.80	4.64	-4.01	-4.52
15	Tara × SMVT	-3.56	-5.01	-1.96	-3.36	-5.84	-6.74	4.02	0.41	-2.96	-4.71
16	Tara × PBNS-12	5.49	2.16	-4.19	-7.97*	14.80 **	7.72	-7.74 *	-13.65 **	-10.85 **	-15.17 **
17	Tara × SSF-906	-1.16	-1.17	-1.62	-3.70	-5.35	-7.12	6.80	1.36	-1.34	-1.60
18	Tara × SSF-902	-0.44	-0.62	-1.79	-3.25	-4.47	-6.71	4.57	-0.81	-1.19	-1.41
19	AKS-311× SMVT	-7.87 *	-8.16 *	0.79	0.54	-1.35	-3.32	4.36	0.60	-6.86	-8.06
20	AKS-311× PBNS-12	-5.62	-9.65 **	2.06	-0.82	-4.40	-7.72	5.84	-1.08	0.98	-4.40
21	AKS-311× SSF-906	-3.28	-4.44	-1.33	-2.27	-3.44	-4.48	4.60	-0.86	-2.61	-3.38
22	AKS-311× SSF-902	-5.31	-6.60	2.66	2.35	-0.08	-0.66	-3.67	-8.75 *	-4.21	-4.50
23	SMVT × PBNS-12	-1.68	-6.16	5.14*	2.42	-7.25	-12.19 *	3.48	0.20	-0.33	-6.78
24	SMVT × SSF-906	-3.10	-4.56	-0.38	-1.09	-3.85	-4.75	-4.54	-6.84	-2.69	-4.69
25	SMVT × SSF-902	-6.21 *	-7.78 *	1.81	1.75	-6.72	-8.05	0.59	-5.63	-6.04	-7.52
26	PBNS-12 × SSF-906	-11.00 **	-13.80 **	-3.55	-5.39	18.58 **	13.27 *	1.36	-5.03	-12.49 **	-16.52 **
27	PBNS-12 × SSF-902	-9.64 **	-12.34 **	-3.75	-6.19*	13.50 **	8.95	1.53	-1.44	-11.57 **	-16.03 **
28	SSF-906 × SSF-902	1.52	1.36	1.84	1.17	-5.90	-6.38	-16.63 **	-16.85 **	0.62	0.14
	S.E. (d) ±	2.24	2.59	3.44	3.97	0.10	0.11	3.24	3.74	3.17	3.66
	CD 0.05	4.47	5.17	6.86	7.92	0.20	0.23	6.46	7.46	6.32	7.30
	CD 0.01	5.94	6.86	9.11	10.52	0.26	0.30	8.58	9.90	8.39	9.69

Table 2: Conti...

Sr. No.	Crosses	Stem Diameter (cm)		Number of Leaves per Plant		Leaf Area (cm ²)		Number of Seeds per Capitulum		Number of Filled Seeds per Capitulum	
		MP	MP	BP	MP	BP	MP	BP	MP	BP	BP
1	A-1 × Phule	-4.04	-14.43 *	-25.89 **	-7.79	-12.67	-36.73 **	-44.90 **	-2.50	-4.66	-6.05
2	A-1 × Tara	3.63	6.93	-11.00	-1.80	-4.05	-10.54	-18.11	-1.19	-5.01	3.20
3	A-1 × AKS-311	2.10	1.67	-19.01 **	-5.10	-10.30	-27.01 **	-33.66 **	21.39 **	14.90 *	0.17
4	A-1 × SMVT	5.65	-11.33 *	-16.09 **	-7.70	-10.56	-32.25 **	-36.87 **	-3.76	-7.33	2.12
5	A-1 × PBNS-12	27.78 **	15.06 **	14.36 *	12.42 *	7.36	23.44 **	16.56	18.43 **	14.39 *	16.60 **
6	A-1 × SSF-906	20.15 **	-3.14	-3.83	-3.77	-5.06	-18.60 *	-19.79 *	-4.91	-6.16	17.68 *
7	A-1 × SSF-902	20.54 **	-1.70	-5.90	-5.68	-5.83	-35.80 **	-38.31 **	-8.98	-9.22	14.35 *
8	Phule × Tara	7.86	-7.87	-12.11	-6.88	-9.82	-21.49 *	-25.71 *	-0.04	-1.76	5.16
9	Phule × AKS-311	1.13	-7.54	-16.31 *	-1.86	-2.05	-12.04	-16.14	5.02	1.57	-2.82
10	Phule × SMVT	4.89	11.52	1.49	-0.04	-2.37	-20.55	-26.16 *	0.37	-1.20	3.53
11	Phule × PBNS-12	20.00 **	15.58 **	-0.41	12.90 *	2.38	41.03 **	16.98	19.96 **	13.39 *	11.67
12	Phule × SSF-906	10.77	0.29	-12.61 *	1.23	-5.34	-7.00	-17.97	-0.44	-3.89	10.73
13	Phule × SSF-902	15.13 *	2.51	-7.72	-2.26	-7.58	-10.67	-19.40	-5.13	-6.98	11.48
14	Tara × AKS-311	11.16	-9.25	-14.12	-10.77	-13.76	-20.65 *	-21.27	3.59	1.92	9.51
15	Tara × SMVT	6.90	19.82 **	4.51	-9.99	-10.76	-24.59 *	-26.02 *	10.41	10.23	2.91
16	Tara × PBNS-12	20.55 **	21.56 **	0.69	8.10	0.99	33.16 **	15.74	14.81 *	6.76	9.58
17	Tara × SSF-906	12.37	-10.52	-25.09 **	5.92	2.15	-13.57	-19.80	0.33	-4.75	9.60
18	Tara × SSF-902	12.39	-7.75	-20.35 **	-0.92	-3.34	-13.76	-18.01	1.62	-2.05	6.19
19	AKS-311× SMVT	0.41	6.46	-11.39	7.36	4.64	-4.43	-6.96	6.99	5.10	-4.71
20	AKS-311× PBNS-12	1.28	17.70 **	-6.66	1.15	-8.44	-23.84 **	-34.24 **	-3.57	-11.67	-9.17
21	AKS-311× SSF-906	6.30	-1.04	-20.73 **	-5.55	-11.84	-13.06	-19.90 *	-2.27	-8.64	2.18
22	AKS-311× SSF-902	2.07	0.22	-17.38 **	-4.53	-9.89	-13.24	-18.12	3.44	-1.84	-4.91
23	SMVT × PBNS-12	3.87	6.42	0.14	-1.41	-8.63	-27.93 **	-36.31 **	9.27	1.76	-2.15
24	SMVT × SSF-906	7.32	-3.83	-8.37	-11.14	-15.01 *	-5.79	-10.99	3.83	-1.29	5.89
25	SMVT × SSF-902	9.20	-7.95	-9.05	-6.01	-9.07	-21.67 *	-24.13 *	-1.96	-5.35	7.10
26	PBNS-12 × SSF-906	24.08 **	14.56 **	13.06 *	9.06	5.51	24.61 **	16.05	16.87 **	14.34 *	15.42 *
27	PBNS-12 × SSF-902	17.80 **	18.34 **	12.64 *	9.10	4.35	27.70 **	16.14	18.09 **	13.76 *	13.06 *
28	SSF-906 × SSF-902	10.18	2.20	-1.48	2.25	1.04	-13.15	-15.34	-1.45	-3.00	6.65
	S.E. (d) ±	0.25	1.51180	1.74567	1.29	1.49	1.35	1.55	2.17717	2.51398	0.29
	CD 0.05	0.51	3.01519	3.48165	2.58	2.98	2.69	3.11	4.34224	5.01399	0.59
	CD 0.01	0.68	4.00310	4.62238	3.42	3.95	3.57	4.12	5.76494	6.65678	0.79

*, ** Significant at 5 % and 1 % levels, respectively.

Table 2: Conti...

Sr. No.	Crosses	Number of Unfilled Seeds per Capitulum		100 Seed Weight (g)		Seeds Yield per Plant (g)		Oil Content (%)	
		MP	BP	MP	BP	MP	BP	MP	BP
1	A-1 × Phule	36.07 **	20.34	-5.45	-9.74	-7.06 *	-9.79 **	-7.95	-15.82 **
2	A-1 × Tara	11.84	-0.43	1.55	0.86	-6.11 *	-10.25 **	-8.43 *	-15.43 **
3	A-1 × AKS-311	59.99 **	57.96 **	-4.23	-6.13	-12.04 **	-19.86 **	-8.05	-15.82 **
4	A-1 × SMVT	66.11 **	61.30 **	-5.46	-5.88	-12.22 **	-18.12 **	-5.47	-11.35 *
5	A-1 × PBNS-12	-32.12 *	-36.50 *	22.77 **	18.82 **	13.70 **	11.31 **	11.39 **	8.82 *
6	A-1 × SSF-906	35.09 **	33.24 *	11.73	9.32	7.62 **	7.39 *	-7.92 *	-9.95 *
7	A-1 × SSF-902	65.57 **	59.68 **	-5.77	-7.45	6.01 *	3.71	-7.25	-13.46 **
8	Phule × Tara	20.04	19.13	-8.62	-12.19	0.47	-1.09	-0.76	-1.81
9	Phule × AKS-311	20.45	7.72	-7.20	-13.08	3.56	-2.98	-5.11	-5.22
10	Phule × SMVT	74.54 **	58.49 **	-0.41	-4.52	-8.11 **	-11.80 **	-1.38	-4.01
11	Phule × PBNS-12	-33.14 **	-44.19 **	26.41 **	16.99 *	13.96 **	8.34 **	20.31 **	7.73
12	Phule × SSF-906	-6.90	-16.66	20.04 **	12.24	-2.26	-4.95	-1.89	-8.41
13	Phule × SSF-902	3.34	-5.57	-1.52	-7.58	-5.08	-5.85	0.53	-1.62
14	Tara × AKS-311	-7.20	-16.44	-16.09 **	-18.30 **	-0.69	-5.57	-1.94	-2.86
15	Tara × SMVT	7.50	-1.71	-10.98	-11.20	2.06	-0.54	-3.00	-4.59
16	Tara × PBNS-12	-33.04 **	-43.76 **	20.95 **	16.29 *	14.61 **	7.36 *	19.11 **	7.66
17	Tara × SSF-906	75.25 **	57.95 **	1.84	-1.03	-5.77 *	-9.74 **	-3.93	-9.41 *
18	Tara × SSF-902	32.15 **	21.61	-0.92	-3.34	-8.18 **	-10.33 **	4.69	3.53
19	AKS-311× SMVT	59.20 **	56.54 **	-0.18	-2.58	1.44	-1.09	-9.34 *	-11.65 *
20	AKS-311× PBNS-12	78.38 **	64.89 **	-1.42	-2.69	-4.08	-14.27 **	-11.23 **	-20.44 **
21	AKS-311× SSF-906	71.38 **	71.21 **	-10.26	-10.43	2.28	-6.63 *	-9.64 *	-15.54 **
22	AKS-311× SSF-902	66.71 **	62.79 **	-2.00	-2.21	-8.64 **	-15.06 **	-5.37	-7.29
23	SMVT × PBNS-12	89.60 **	72.57 **	2.39	-1.32	-6.11 *	-14.13 **	-6.60	-14.29 **
24	SMVT × SSF-906	9.58	7.86	-11.35	-13.64 *	-0.93	-7.41 *	-6.13	-10.07 *
25	SMVT × SSF-902	9.65	8.89	-7.02	-9.07	-2.73	-7.36 *	12.63 **	12.02 *
26	PBNS-12 × SSF-906	-31.32 *	-36.57 *	19.59 **	18.27 **	13.05 **	10.45 **	12.95 **	7.97
27	PBNS-12 × SSF-902	-35.77 **	-41.90 **	19.56 **	17.79 **	14.79 **	10.00 **	18.19 **	7.91
28	SSF-906 × SSF-902	42.90 **	39.68 **	-1.77	-2.15	-1.80	-3.73	3.05	-1.80
	S.E. (d) ±	0.63447	0.73263	1.21	1.40	0.75	0.87	0.19409	0.22411
	CD 0.05	1.26542	1.46118	2.42	2.79	1.50	1.73	0.38709	0.44698
	CD 0.01	1.68002	1.93992	3.21	3.71	1.99	2.30	0.51392	0.59342

*, ** significant at 0.05% and 0.01% levels of probability, respectively

Table 3: Best heterotic crosses and their performance for safflower seed yield per plant

Best crosses (P₁ x P₂)	Mean Yield (g)	Heterobeltiosis	Relative Heterosis (%)	Significant Standard Heterosis in other Traits in Desired Direction
A- 1 x PBNS- 12	25.21	11.34**	13.70**	days to flower initiation, days to 50 per cent flowering, days maturity, head diameter, stem diameter, number of leaves per plant, leaf area of flowering, number of seed per capitulum, number of filled seeds per capitulum, number of unfilled seeds per capitulum, 100 seeds weight and oil content.
PBNS- 12 x SSF- 906	25.09	10.45**	13.05**	days to flower initiation, days to 50 per cent flowering, days maturity, head diameter, stem diameter, leaf area of flowering, number of unfilled seeds per capitulum and oil content.
PBNS- 12 x SSF- 902	24.99	10.00**	14.79**	days to flower initiation, days to 50 per cent flowering, days maturity, head diameter, leaf area of flowering, number of unfilled seeds per capitulum and oil content.
Phule x PBNS- 12	24.82	8.34*	13.96**	days to flower initiation, days to 50 per cent flowering, stem diameter, leaf area of flowering, number of filled seeds per capitulum, number of unfilled seeds per capitulum, 100 seeds weight and oil content.
Tara x PBNS- 12	24.67	7.36*	14.61**	days to flower initiation, days to 50 per cent flowering, days maturity, head diameter, stem diameter, number of leaves per plant, number of seed per capitulum, number of unfilled seeds per capitulum, 100 seeds weight and oil content.

[MS received: October 05, 2016]

[MS accepted: November 19, 2016]