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Selection of heterotic combinations for seed yield and its component traits in safflower (*Carthamus tinctorius* L.)

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Abstract
An experiment was conducted for estimation of magnitude of relative heterosis, heterobeltiosis and standard heterosis over three checks *viz.*, PBNS 12, A 1 and PKV Pink for seed yield and its components in safflower using 30 hybrids resulted from mating two females and fifteen males in line x tester fashion. All the genotypes were significantly differed for all the traits under study, however, the crosses differed significantly for all traits except days to 50% flowering, days to maturity and 100 seeds weight. Higher range of all three types of heterosis was noticed for capsules per plant followed by seed yield per plant, plant height and seed volume weight than other studied traits. Further, highest and significant magnitude of heterosis over mid parent, better parent and best check was observed for the trait capsules per plant in cross AKS CMS 3A x GMU 7448 (85.40%, 80.05% and 46.29%, respectively) followed by seed yield per plant in AKS CMS 3A x GMU 2273 (84.09%, 75.42% and 27.04%, respectively). The same cross i.e., AKS CMS 3A x GMU 2273 also recorded highest and significant standard heterosis over best check for primary branches per plant and seed filling percentage (30.57% and 11.96%, respectively). The cross AKS CMS 3A x GMU 7448 also exhibited highest and significant average heterosis, heterobeltiosis and standard heterosis (85.40%, 80.05% and 46.29%, respectively) for plant height at harvest. None of the crosses could record significant standard heterosis for days to 50% flowering, days to maturity and 100 seeds weight. Amongst the 30 crosses, AKS CMS 3A x GMU 2273 was found to be superior cross for seed yield and some other contributing traits. However, the magnitude of heterosis was not as per expectation especially over the standard check to exploit it at commercial level. Hence, further investigation is essential for search of best combination with higher magnitude of standard heterosis for seed yield and its contributing traits.

Keywords: Safflower, heterosis, heterobeltiosis, standard heterosis, seed yield, oil content

Introduction
Safflower (*Carthamus tinctorius* L.), is one of the most important *rabi* oilseed crops. It has been gaining increasing popularity in recent years in several parts of the county because of its adaptability under drought conditions (Sarode *et al*., 2008) [17]. Safflower seeds contain 26-30 *per cent* oil which is flavourless, dreary and healthy like sunflower oil. The high quality of safflower oil is used for cooking, which is a rich source of Poly Unsaturated Fatty Acid (Linoleic acid 78%), it also contains tocopherols that is considered to have an antioxidant effect and a high content of vitamin E. It plays an important role in reducing blood cholesterol level. For these reasons, safflower oil is used in the diets of patients with cardiovascular disease because it invigorates the blood circulation (Jhajhariya *et al*., 2013) [9]. Further, it has good dying property and therefore, used in manufacturing of paints, varnishes and linoleum. Additionally, safflower oil cake is a valuable animal feed (Weiss, 2000) [22]. It is utilized chiefly in beautifiers and as a cooking oil, in plate of mixed greens dressing and to produce margarine. Safflower blossoms are known to have numerous therapeutic properties for relieving a few persistent infections, and they are broadly utilized in Chinese natural arrangements (Li and Mundel, 1996) [11].
India produces half of the world's safflower, although average productivity is very low (465 kg/ha) as compared to world average productivity (905 kg/ha) and other major safflower growing countries. As a result, there is a strong need to increase productivity by overcoming current yield barriers, which can be accomplished by developing and releasing high yielding hybrids (with a large magnitude of heterosis) at commercial level. Safflower is an often-cross pollinated crop and amount of cross pollination depends on genotype and insect activity (Knowles, 1969) [10].

As a result, commercialising heterosis has become possible and cost-effective. Plant breeders prioritize convenience of hybrid seed production because it allows them to take advantage of heterosis by producing high-yielding hybrids. Dr. P.D.K.V., Akola has developed cytoplasmic male sterile lines *viz*., AKS CMS 2A and AKS CMS 3A (Deshmukh *et al*., 2014) [6]. Hence, exploitation of heterosis at commercial scale has become most feasible and economical. The ease in hybrid seed production is of great importance to plant breeders for exploitation of heterosis by developing high yielding hybrids. The assessment of magnitude of heterosis assists in the identification of promising cross combinations for heterosis exploitation and genetic improvement of crucial economic features. In any breeding programme that might reflect a high degree of heterotic response, detailed information on the desired parental combination is required. As a result, the aim of this investigation was to find superior hybrids (using CMS lines) with high magnitude of heterosis for seed yield and its component traits.

Material and Methods

Plant Material: Genetically diverse parents were deliberately selected on the basis of their distinguishing characters i.e. two CMS lines *viz*., AKS CMS 2A/B and AKS CMS 3A/B as females and 15 males *viz*., GMU 1758, GMU 7355, GMU 1654, GMU 7448, GMU 1397, GMU 7573, GMU 1731, GMU 590, GMU7612, GMU 589, GMU 2928, GMU 2273, GMU 6691, GMU 2830 and GMU 579. The crosses were effected in line x tester scheme for obtaining F_0 seeds of 30 crosses at the experimental field of Oilseeds Research Unit, Dr, P.D.K.V., Akola. Utilising CMS based system, only hand pollination using pollens from protected flowers from male parents was done with the protected flowers of CMS based females in the morning hours. The parental seeds were multiplied by selfing.

Field Trial: A field trial of 50 genotypes, including 17 parents, 30 F_1s and three checks *viz*., PKV PINK, A 1 and PBNS 12 were raised in Randomized Block Design with three replications during *rabi* 2019-20. Each genotype was planted in a single row of 3 m length with 45 cm spacing between rows and 20 cm within rows. All the recommended agronomical package of practices and plant protection measures were followed timely to raise a healthy crop.

Observations: The observations were recorded on randomly selected five competitive plants per plot per replication in parents, F_1s and checks for plant height at harvest, number of primary branches per plant, number of capsules per plant, 100 seed weight in gram and seed yield per plant gram and oil content (%). Whereas the observations were recorded on plot basis for days to 50 *per cent* flowering and days to maturity. The oil content (%) was determined by following technique on instrument i.e. Bench top Pulse Nuclear Magnetic Resonance (NMR) Spectrometer (Model MQC OXFORD). The samples of 5-10 grams of all the genotypes in all three replications were taken for determination of oil content, before it, calibration had been done in the NMR. The samples were enclosed in a moisture-proof (i.e. Ziplock) bag for determination of oil content using NMR.

Statistical Analysis: The analysis of variance was performed as per the procedure given by Panse and Sukthame (1967) [12] from the data obtained in the field trials. Whereas, the heterosis over the mid parent (MP), better parent (BP), and standard check (SC) was calculated as per the method suggested by Hays *et al*. (1955) [8] and Turner (1953) [20].

Results and Discussion

It has been revealed from the analysis of variance *(*Table 1*)* that there was presence of substantial genetic variability for all the characters studied. Further, partitioning of genotype into components *viz*., parents, crosses and parents v/s crosses revealed that parents differed among themselves significantly for all the characters except for plant height at harvest and seed filling percentage. Crosses also showed significant differences for all the traits studied except days to 50% flowering, days to maturity and 100 seeds weight. The mean sum of squares due to Parents v/s crosses indicated the significant differences between parents and crosses for all the traits under study except 100 seeds weight, seed volume weight, seed yield per plant and oil content. This depicts the presence of considerable genetic variation in the parents and their crosses in respect of various traits studied. Similar results were also obtained by Rathod and Gawande (2019) [15] in safflower.

In the present study it was found that among female parents, AKS CMS 3B was found to be superior for days to 50% flowering, plant height at harvest, number of primary branches per plant, number of capsules per plant, 100 seed weight, volume weight and seed yield per plant (Table 2). Among the males, GMU 1758 and GMU 1654 were superior in relation to mean performance for seed yield per plant. GMU 1731 was significantly superior for seed volume weight, plant height at harvest, number of capsules per plant, oil content; GMU 7355 for 100 seed weight, days to maturity, seed volume weight; GMU 1397 for days to maturity, number of capsules per plant; GMU 7573 for number of capsules per plant, oil content and GMU 2830 for oil content. Among the crosses, AKS CMS 3A x GMU 2273 exhibited highest and significant mean performance for the trait seed yield per plant along with number of primary branches per plant, number of capsules per plant and seed filling percentage over the best check *viz.* PBNS 12. Whereas, a cross AKS CMS 3A x GMU 589 was found significantly superior for seed yield per plant, number of capsules per plant, seed volume weight and seed filling percentage. The cross AKS CMS 3A x GMU 7448 found to be significantly good for number of capsules per plant, plant height at harvest and oil content, whereas, a AKS CMS 3A x GMU 1731 was found to be earliest for days to maturity and oil content too. The superior performance of parents and crosses for various traits in safflower has also been reported earlier by Singh *et al.* (2003) [19] and Patel *et al.* (2018) [14]. These promising parents and crosses can be exploited in further breeding programme of safflower.

Substantial range of magnitude of heterosis over the standard variety (best check), better parent and mid-parent was observed for the characters seed yield per plant, number of capsules per plant, number of primary branches per plant, seed volume weight and plant height at harvest (Table 2). However, very low range of heterosis was noticed for earliness i.e. for days to 50% flowering and days to maturity. Ahmed *et al.* (2015) [1] and Rathod and Gawande (2019) [15] has also reported considerable range of heterosis over mid parent, better parent and standard check for all the characters under study.

In safflower or any crop earliness in flowering and maturity is most desirable trait to fit in various cropping systems and to avoid terminal draught or heat stress. Hence, the crosses displaying negative and significant heterosis are of immense value (Table 3 and 4). In case of days to 50% flowering, the highest, significant and negative heterosis over mid parent was observed in cross AKS CMS 3A x GMU 6891 (-7.99%); however, over better parent and best standard check it was highest in cross AKS CMS 3A x GMU 2830 (-4.88 and 4.49%, respectively). For days to maturity, all the 30 crosses displayed negative heterosis out of which 29 crosses showed significant heterosis. A cross AKS CMS 3A x GMU 590 recorded highest and highly significant magnitude of heterosis over mid-parent and better parent, whereas none of the crosses was found to record negative and significant heterosis over standard check. Ahmed *et al.* (2015) [1] and Rathod and Gawande (2019) [15] also reported significant heterosis over mid and better parent and non-significant standard heterosis for days to 50% flowering and days to maturity. Jhajhariya *et al.* (2013) [9] also noticed significant heterosis for earliness in safflower. The cross AKS CMS 3A x GMU 7573 exhibited highly significant and positive heterosis for plant height at harvest over mid parent (22.29%) and another cross AKS CMS 3A x GMU 7448 showed significant and positive heterosis over better parent and best check (14.38% and 17.00%, respectively). Similar results were obtained by Fokmare (2001) [7] and Rathod and Gawande (2019) [15] for plant height at harvest in safflower. In case of number of primary branches per plant, a cross AKS CMS 3A x GMU 579 showed highly significant and positive heterosis over mid parent (44.75%) and better parent (41.98%), whereas another cross AKS CMS 3A x GMU 2273 (30.57%) exhibited heterosis over best check for same trait. This is in confirmation with the results noticed by Deshmukh (1991) [5] and Waghmode *et al.* (2021) [21] and for this trait over mid parent by Iqbal *et al.* (2015) over mid-parent, better parent and best check in safflower.

Among the crosses, AKS CMS 3A X GMU 7448 exhibited highest and significant positive heterosis over mid parent (85.40%), over better parent (80.05%), over standard check *viz.*, PBNS 12 (46.29%) for number of capsules per plant. Iqbal *et al.,* (2015) and Rathod and Gawande (2019) [15] also found similar results i.e. the same cross recording highest and positively significant heterosis over the best check in safflower. Further, Deshmukh (1991) [5], Shivani *et al.* (2011) [18] and Waghmode *et al.* (2021) [21] also reported significant heterosis for capsules per plant in safflower. Among all the crosses, AKS CMS 2A x GMU 1397 exhibited highest, positive and significant average heterosis (40.00%) and heterobeltiosis (35.17%) for 100 seeds weight and also for seed volume weight (39.66% & 37.78%, respectively). The cross AKS CMS 3A x GMU 1397 also showed positive and significant average heterosis and heterobeltiosis (i.e. 27.59% each) for 100 seeds weight. Whereas, for the character seed volume weight, positive and significant heterosis over mid and better parent was also recorded by AKS CMS 2A x GMU 2928 (36.95% and 26.40%, respectively) and AKS CMS 2A x GMU 6891 (32.59% and 20.96%, respectively) and a cross AKS CMS 2A x GMU 2928 displayed highest, positive and significant heterosis over best check A 1 (i.e. 26.54%) followed by AKS CMS 2A x GMU 1397 (16.69%) for seed volume weight. These results are in confirmation with result obtained by earlier workers (Deshmukh, 1984; Sarode *et al.,* 2008; Patel *et al*., 2018; and Ahmed *et al.,* 2016) [17, 4, 14, 2] for these traits in safflower.

In case of seed yield per plant, only one cross *viz.*, AKS CMS 3A x GMU 2273 displayed highest, positive and highly significant standard heterosis (27.04%) over the best check PBNS 12. The same cross also recorded highest and significant heterosis in desirable direction over the mid and better parent (84.09% and 75.42%, respectively) followed by cross AKS CMS 3A x GMU 589 (53.20% and 43.99%, respectively), AKS CMS 3A x GMU 2830 (43.95% and 38.37%, respectively), AKS CMS 3A x GMU 590 (37.85% and 31.12%, respectively) and AKS CMS 3A x GMU 7448 (35.44% and 31.02%, respectively) for the character seed yield per plant. Sarode *et al.* (2008) [17], Parde *et al.* (2010), Shivani *et al.* (2011) [18], Baydar and Erbas (2014) [3], Rathod and Gawande (2019) [15], Rathod *et al,* (2020) [16] and Waghmode *et al.* (2021) [21] also reported significant heterosis over mid parent, better parent and standard check for the trait seed yield per plant in safflower. None of the crosses could exhibit significant relative heterosis or heterobeltiosis, however, the cross AKS CMS 3A x GMU 2273 (11.96%) showed highly significant heterosis over best check in desirable direction for seed filling percentage. The crosses AKS CMS 2A x GMU6891 and AKS CMS 2A x GMU 7573 displayed highest and highly significant heterosis in favourable direction over mid parent and best check A 1 (15.08% and 16.59%, respectively) for the trait oil content. Fokmare (2001) [7] and Rathod and Gawande (2019) [15] also noticed significant relative heterosis, better parent heterosis and standard heterosis for oil content in safflower.

In the present investigation it has been revealed that there was presence of large amount of genetic diversity among the males and the females as their combinations have exhibited significant mid-parent heterosis, heterobeltiosis and standard heterosis for seed yield and other characters under study. Substantially higher magnitude of all three types of heterosis in desirable direction was displayed by cross AKS CMS 3A x GMU 7448 for the character number of capsules per plant. However, the magnitude of heterosis was recorded either non-significant or significant but low for earliness. For other traits including seed yield per plant, the various types of heterosis were found significant, whereas, the magnitude was not as per expectation especially over the standard check for exploiting the hybrid vigour at commercial level. Which may be due to absence of higher amount of genetic diversity among the parental material used in the present study. Hence, further investigation for search of best combination exhibiting considerably higher magnitude of standard heterosis for seed yield and its contributing traits is essential.

Table 1: Analysis of variance for various characters in safflower

Sources of variation	d.f.	Mean sum of squares (MSS)									
		Days to 50% flowering	Days to maturity	Plant height at harvest	Number of primary branches/ Plant	Number of capsules/ plant	100 seeds weight	Volume/ weight	Seed yield per plant	Seed filling percentage	Oil content
Replications	2	105.752	85.837	101.018	1.574	7.288	16.050	40.929	48.009	0.591	5.491
Treatments	46	28.217*	72.925**	82.866**	5.589**	66.968**	1.249**	172.283**	46.703**	820.431**	23.478**
Parents	16	36.990*	155.664**	41.639	4.298**	93.695**	2.240**	230.821**	19.382**	1.176	19.020**
Crosses	29	15.907	10.655	101.198**	6.074**	51.048**	0.727	145.307**	63.381**	367.265**	26.671**
Parents v/s Crosses	1	244.840**	554.923**	210.886**	12.212**	101.017**	0.520	17.949	0.155	2707.920**	2.199
Error	92	17.679	12.815	23.748	1.295	5.233	0.471	5.022	5.200	26.128	4.675

*, ** Significant at 0.05, 0.01 probability level, respectively

Table 2: Mean performance of crosses, their parents and checks for various traits in safflower

Sr. No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height at harvest (cm)	Number of primary branches/ plant	Number of capsules/ plant	100 seeds weight (gm)	Volume/ weight (100ml)	Seed yield per plant (gm)	Seed filling percentage	Oil content (%)
	Crosses										
1	AKS CMS 2A x GMU 1758	82.67	117.33	68.37	8.53	11.98	6.17	63.32	17.97	68.5	31.92
2	AKS CMS 2A x GMU 7355	82.33	118.67	70.77	9.00	13.22	5.50	49.62	15.97	65.2	31.36
3	AKS CMS 2A x GMU 1654	85.33	117.00	66.73	8.80	11.55	6.93	59.78	14.00	59.9	34.49**
4	AKS CMS 2A x GMU 7448	88.00	118.67	71.90	8.10	12.05	5.50	55.43	14.22	60.1	31.37
5	AKS CMS 2A x GMU 1397	86.67	121.33	68.10	9.17	11.22	6.53	69.87**	17.60	70.2	32.4
6	AKS CMS 2A x GMU 7573	80.00	122.00	66.13	9.50	12.45	6.00	58.93	14.00	59.8	38.02**
7	AKS CMS 2A x GMU 1731	81.33	119.00	68.90	8.83	14.25	5.83	63.65	11.82	56.5	28.45
8	AKS CMS 2A x GMU 590	85.00	120.67	56.93	11.90	16.73	6.33	64.83*	19.10	75.9	32.58
9	AKS CMS 2A x GMU 7612	84.33	121.33	59.97	9.90	12.05	5.17	47.32	10.20	50.4	31.57
10	AKS CMS 2A x GMU 589	82.33	118.67	58.53	11.73	16.13	6.00	54.80	19.90	77.6	29.37
11	AKS CMS 2A x GMU 2928	87.00	118.67	60.33	10.97	11.35	5.83	75.80**	11.90	56.5	32.61
12	AKS CMS 2A x GMU 2273	81.33	119.67	55.83	11.93	22.17**	6.17	58.53	20.33	81.2	28.45
13	AKS CMS 2A x GMU 6891	86.33	116.67	63.90	8.77	14.15	5.17	61.35	19.63	76.7	36.52**
14	AKS CMS 2A x GMU 2830	83.67	119.33	64.40	12.73*	14.95	5.83	61.23	18.60	75.1	36.92**
15	AKS CMS 2A x GMU 579	81.33	118.00	61.93	8.93	14.12	6.17	59.22	15.93	66.2	32.48
16	AKS CMS 3A x GMU 1758	82.33	118.00	65.33	10.57	18.62	5.17	62.00	15.97	66.7	29.51
17	AKS CMS 3A x GMU 7355	84.00	117.67	71.17	9.30	14.88	7.03	50.50	16.27	67.5	34.09*
18	AKS CMS 3A x GMU 1654	83.33	117.33	60.80	9.73	17.28	5.50	65.47*	14.15	60.9	34.13*
19	AKS CMS 3A x GMU 7448	84.33	117.33	78.47**	9.83	24.95**	6.17	62.45	21.40	82.5	34.07*
20	AKS CMS 3A x GMU 1397	84.00	116.67	65.30	9.73	19.07	6.17	61.33	16.37	67.9	31.71
21	AKS CMS 3A x GMU 7573	81.33	115.33*	78.17**	11.50	16.65	6.17	50.77	19.95	77.6	36.54**
22	AKS CMS 3A x GMU 1731	83.33	113.00**	66.47	9.23	10.35	5.33	55.43	15.70	65.3	37.61**
23	AKS CMS 3A x GMU 590	83.67	115.67*	71.77	11.47	22.57**	6.50	63.80	23.73	89.9*	29.33
24	AKS CMS 3A x GMU 7612	84.00	116.33*	62.43	10.10	14.98	5.33	41.33	18.18	77.4	33.64*
25	AKS CMS 3A x GMU 589	83.67	118.00	71.87	11.67	22.42**	6.17	67.40**	27.83*	92.6**	31.72
26	AKS CMS 3A x GMU 2928	83.00	118.00	69.93	11.20	12.75	5.67	56.78	15.60	65.1	28.88
27	AKS CMS 3A x GMU 2273	83.33	117.67	73.07	13.67**	24.42**	6.50	62.18	31.62**	95.5**	26.8
28	AKS CMS 3A x GMU 6891	78.67*	117.00	69.00	10.27	14.68	5.67	60.17	11.56	56.3	29.08
29	AKS CMS 3A x GMU 2830	78.00*	116.33*	73.27	10.97	19.43	5.50	64.10	22.60	84.7	34.7**
30	AKS CMS 3A x GMU 579	86.00	118.33	61.77	12.40*	15.00	5.17	61.50	15.42	65.4	29.6
	Males										
31	GMU 1758	83.67	124.33	64.53	9.63	22.88**	6.17	73.37**	25.87	99.5*	29.85
32	GMU 7355	87.00	115.33*	56.57	9.60	14.78	8.17**	66.65**	17.30	99.5	31.18
33	GMU 1654	83.33	115.33*	66.07	10.50	24.07**	5.83	54.40	19.55	99.5	33.6*
34	GMU 7448	90.33	121.00	64.57	8.60	13.85	5.33	50.00	15.27	98.6	30.8
35	GMU 1397	86.67	113.67**	67.60	10.63	28.27**	4.83	49.35	16.60	99.6	29.9
36	GMU 7573	88.67	123.00	59.23	11.43	24.97**	6.17	59.88	18.07	99.7	37.8**
37	GMU 1731	83.00	114.00**	58.97	8.53	24.10**	6.00	76.00**	17.67	98.7	37.83**
38	GMU 590	92.00	126.67	65.03	10.37	15.77	6.17	62.73	18.10	98.4	31.39
39	GMU 7612	86.33	120.33	71.30	9.40	13.35	4.83	65.93*	14.63	98.1	31.89
40	GMU 589	92.00	127.00	65.43	10.10	15.67	5.17	61.65	18.57	99.2	30.82
41	GMU 2928	85.67	114.33**	67.30	8.73	10.95	6.33	59.97	16.20	99.5	31.73
42	GMU 2273	85.67	128.00	61.27	11.30	22.20**	6.33	54.18	18.03	99.5	32.75
43	GMU 6891	89.00	119.00	64.27	9.10	12.42	6.17	41.83	15.70	99.1	29.9
44	GMU 2830	86.00	122.33	62.17	12.23	19.22	5.67	58.72	15.07	98.5	35.95**
45	GMU 579	79.67	118.33	65.03	8.73	12.02	5.50	61.20	16.67	98.2	32.01
	Females										
46	AKS CMS 2A	82.67	135.33	63.00	8.20	12.43	4.50	50.73	17.60	99.9	33.57*
47	AKS CMS 3A	82.00	138.00	68.60	8.40	13.05	4.83	54.48	18.33	99.9	33.07

	Checks										
48	PBNS 12	85.67	122.33	67.07	10.47	17.05	5.80	58.50	23.87	80.3	26.19
49	PKV Pink	88.7	126.3	64.4	8.30	12.9	5.30	61.10	19.00	78.80	29.28
50	A 1	85.7	122.7	61.4	9.00	14.9	6.30	59.90	17.90	71.10	29.61
	General Mean	84.48	119.73	65.71	10.07	16.42	5.85	59.38	17.71	80.49	32.18
	SE± (m)	3.43	2.92	3.97	0.92	1.86	0.56	1.82	1.86	4.17	1.77
	CD (0.05)	6.87	5.85	7.96	1.85	3.73	1.12	3.66	3.72	8.35	3.53
	CD (0.01)	9.14	7.78	10.59	2.47	4.97	1.49	4.87	4.95	11.12	4.70
	CV (%)	3.60	4.10	7.80	13.40	28.44	11.02	12.37	22.47	19.98	9.02

Table 3: Range of heterosis (%) for various traits in safflower

Sr. No.	Traits	Range of heterosis (%) over		
		Mid parent	Better parent	Standard (best) check#
1.	Days to 50% flowering	-7.99 to 6.39	-4.88 to 7.95	-4.49 to 7.76
2.	Days to maturity	-12.59 to -2.54	-8.68 to 6.74	-3.69 to 3.98
3.	Plant height at harvest	-11.06 to 22.29	-15.90 to 14.38	-16.75 to 17.0
4.	Number of primary branches/plants	-5.88 to 44.75	-16.91 to 41.98	-22.61 to 30.57
5.	Number of capsules/ plants	-44.80 to 85.40	-60.26 to 80.05	-39.26 to 46.29
6.	100 seeds weight	-13.16 to 40.00	-32.65 to 35.17	-20.51 to 8.21
7.	Seed volume weight	-31.36 to 39.66	-37.31 to 37.78	-31.00 to 26.54
8.	Seed yield/ plant	-32.89 to 84.09	-41.86 to 75.42	-58.90 to 27.04
9.	Seed filling percentage	-49.09 to -4.21	-49.55 to -4.40	-40.91 to 11.96
10.	Oil content	-20.31 to 15.08	-24.80 to 8.79	-17.82 to 16.59

Best check PBNS 12 for all concerned traits except for 100 seeds weight, seed volume weight and oil content for which it was A 1

Table 4: Crosses with maximum heterosis in desirable direction for various traits in safflower

Sr. No.	Traits	Maximum beneficial heterosis (%) over mid parent		Maximum beneficial heterosis (%) over better parent		Maximum beneficial heterosis (%) over standard (best) check#	
		Crosses	%	Crosses	%	Crosses	%
1.	Days to 50% flowering	AKS CMS 3A x GMU 6891	-7.99*	AKS CMS 3A x GMU 2830	-4.88	AKS CMS 3A x GMU 2830	-4.49
2.	Days to maturity	AKS CMS 3A x GMU 590	-12.59**	AKS CMS 3A x GMU 590	-8.68**	AKS CMS 3A x GMU 1731	-3.69
3.	Plant height at harvest	AKS CMS 3A x GMU 7573	22.29**	AKS CMS 3A x GMU 7448	14.38*	AKS CMS 3A x GMU 7448	17.0**
4.	Number of primary branches/ plants	AKS CMS 3A x GMU 579	44.75**	AKS CMS 3A x GMU 579	41.98**	AKS CMS 3A x GMU 2273	30.57**
5.	Number of capsule/ plants	AKS CMS 3A x GMU 7448	85.40**	AKS CMS 3A x GMU 7448	80.05**	AKS CMS 3A x GMU 7448	46.29**
6.	100 seed weight	AKS CMS 2A x GMU 1397	40.00**	AKS CMS 2A x GMU 1397	35.17**	AKS CMS 3A x GMU 7355	8.21
7.	Seed volume weight	AKS CMS 2A x GMU 1397	39.66**	AKS CMS 2A x GMU 1397	37.78**	AKS CMS 2A x GMU 2928	26.54**
8.	Seed yield/ plant	AKS CMS 3A x GMU 2273	84.09**	AKS CMS 3A x GMU 2273	75.42**	AKS CMS 3A x GMU 2273	27.04**
9.	Seed filling percentage	AKS CMS 3A x GMU 2273	-4.21	AKS CMS 3A x GMU 2273	-4.40	AKS CMS 3A x GMU 2273	11.96*
10.	Oil content	AKS CMS 2A x GMU 6891	15.08**	AKS CMS 2A x GMU 6891	8.79	AKS CMS 2A x GMU 7573	16.59**

*, ** Significant at 0.05, 0.01 probability level, respectively
Best check PBNS 12 for all concerned traits except for 100 seeds weight, seed volume weight and oil content for which it was A 1.

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