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HETEROSIS AND INBREEDING DEPRESSION FOR YIELD AND ITS COMPONENTS IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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Safflower, *Carthamus tinctorius* L. is an important rabi oilseed crop of deccan plateau region of India. It is grown mostly under rainfed conditions in residual soil moisture with low inputs. Improvement of genetic architecture of any crop depends upon the presence of nature and extent of genetic variability. The selective advantage of any population depends upon an amount of heritable variability present in the population. Heritability estimates are useful in understanding the pattern of inheritance of quantitative traits and genetic advance is also a useful measure to predict gain in specified selection intensity. Of the various options available, the genetic enhancement is one of the important tools to improve the productivity of any crop. The hybrid technology, a modern approach to enhance the genetic potential has been widely acclaimed and established in various crop species.

The present experiment was designed to find out the magnitude of heterosis in safflower for yield and yield components. The experimental material for the present study comprised 7 parents, 12 F_1s and their F_2s. The experiment was conducted in a randomized block design with three replications. Sowing was done with a spacing of 45 × 20 cm. Observations were recorded on 14 traits, *viz*., total plant stand, rosette period, plant height, number of branches per plant, number of capitulum per plant, number of seeds per capitulum, days to 50% flowering, days to maturity, biological yield per plant, seed yield per plant (g), 100 seed weight, harvest index, hull content and oil content. The observations were recorded on plot basis for 50% flowering, and on five random competitive plants for other characters. Heterosis was calculated over the standard parent-Manjira, a commercial variety and inbreeding depression (ID) in F_2 generation over F_1s was estimated by using the formulae (Kempthorne, 1957):

$$H = \frac{F_1 - \text{CV (Over standard parent)}}{\text{CV}} \times 100$$

$$ID = \frac{F_1 - F_2}{F_2} \times 100$$

The analysis of variance revealed that variances due to genotypes were highly significant for all the traits studied (table 1). Heterosis was estimated as per cent increase or decrease of F_1 values over standard variety, Manjira. The nature and magnitude of heterosis (table 2) revealed that among 12 hybrids, three exhibited negative heterosis for rosette period over check variety. Indicated faster development ability of hybrids and competitiveness with weeds due to faster development at initial stage.

Number of effective capitula per plant is generally associated with higher productivity. Among 12 hybrids, 11 hybrids showed positive heterosis for number of capitula per plant as observed earlier by Patil and Narkhede (1996). The hybrids with high heterosis for number of capitula per plant are GMU 224 × GMU 1303, GMU 224 × RVS-2012-13, MMS-white × GMU 1769 and MSV-10-5-1 × RVS-2012-13.

Number of seeds per capitulum is one of the most important components for seed yield and will be helpful in breaking the yield ceiling. Thus, the hybrids with positive heterosis were desirable for this important trait. Heterosis for number of seeds per capitulum in general was relatively low but overall it was expressed in positive direction over standard variety. The hybrids exhibiting high heterosis for this trait are MMs-white × GMU 1303, TMS-3-6-7-9 × RVS-2012-13, GMU 224 × GMU 1303 and MSV-10-5-1 × GMU 1769. These results are in agreement with the earlier findings of Rao (1982), Manjare and Jambhale (1995).

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Table 1 : Estimates of heterosis over standard checks for seed yield and its components in safflower hybrids.

S. no.	Hybrids	Total plant stand	Rosette period	Plant height (cm)	Number of branches /plant	Number of capitulum /plant	Days to 50% flowering	Days to maturity	Number of seeds/ capitulum	Biological yield (g)	Seed yield /plant (g)	100 seed weight (g)	Harvest index (%)	Hull content (%)	Oil content (%)
1.	GMU 224 × GMU 1303	-65**	2.38	85.12**	88.88*	217.64**	31.52**	19.53**	8.57	440.8**	949.63**	8.06	95.7**	19.19	-22.53
2.	GMU 224 × GMU 1769	-75**	0	76.78**	66.66	152.94**	25**	23.43**	-22.85	200.44**	459.58**	40.69	87.35**	54.17**	-13.27
3.	GMU 224 × RVS-2012-13	-65**	-4.76	84.51**	77.77	194.11**	29.34**	22.65**	-14.28	320.62**	496.38**	7.48	42.54	61.8**	-6.81
4.	MMS-white × GMU 1303	-60**	-4.76	97.01**	0	70.58**	31.52**	21.87**	54.28**	50.22**	123.15**	3.64	45.61*	72.52**	-5.74
5.	MMS-white × GMU 1769	-70**	0	89.28**	55.55	188.23**	23.91**	24.21**	-45.71**	80.26**	13.12	51.82	-40.82	81.99**	-16.66
6.	MMS-white × RVS-2012-13	-60**	-4.76	75**	33.33	135.29**	29.34**	20.31**	-25.71*	200.44**	56.63*	12.28	-47.88*	67.6**	-2.51
7.	MSV-10-5-1 × GMU 1303	-70**	0	73.8**	0	52.94*	29.34**	21.09**	-31.42**	20.17**	18.65	2.68	-2.39	-0.95	-50.45**
8.	MSV-10-5-1 × GMU 1769	-45*	0	88.69**	66.66	111.76**	27.17**	21.87**	5.71	188.42**	190.48**	28.4	0.3	45.28**	-13.63
9.	MSV-10-5-1 × RVS-2012-13	-55**	0	94.05**	44.44	170.58**	29.34**	21.87**	-28.57**	157.42**	169.61**	50.28	6.75	117.13**	-18.55
10.	TMS-3-6-7-9 × GMU 1303	-60**	0	78.57**	33.33	105.88**	22.82**	26.56**	-48.57**	-9.86*	268.87**	14.39	308.1**	57.53**	-14.48
11.	TMS-3-6-7-9 × GMU1769	-55**	2.38	63.69**	-22.22	-11.76	31.52**	24.21**	-60**	60.23**	41.51	19	-13.75	-3.81	-4.95
12.	TMS-3-6-7-9 × RVS-2012-13	-70**	0	69.64**	55.55	76.47**	28.26**	23.43**	31.42**	200.44**	177.21**	80.03	-8.1	94.73**	-31.37*

Table 2 : Estimates of Inbreeding depression for seed yield and its components in safflower hybrid.

S. no.	Hybrid	Total plant stand	Rosette period	Plant height (cm)	Number of branches /plant	Number of capitulum /plant	Days to 50% flowering	Days to maturity	Number of seeds/ capitulum	Biological yield (g)	Seed yield /plant (g)	100 seed weight (g)	Harvest index (%)	Hull content (%)	Oil content (%)
1.	GMU 224 × GMU 1303	40	2.38	-0.74	-5.55	-27.02**	-0.81	0.65	-11.62	0.44	2.5	0.17	2.01	3.96	-2.34
2.	GMU 224 × GMU 1769	0	2.43	-1	-11.76	-36.76**	-0.86	0	3.84	0.8	1.76	0	0.92	-0.04	-0.41
3.	GMU 224 × RVS-2012-13	-30	-2.43	-0.64	-11.11	-24.24**	-0.83	0.64	-11.76	0.57	1.62	-0.7	1.04	-0.32	-1.03
4.	MMS-white × GMU 1303	-11.11	-2.43	-1.08	-25	-6.45	-0.81	0.64	-25	-10.71**	-5.81	-0.18	5.46	-1.35	-0.89
5.	MMS-white × GMU 1769	20	-4.54	5.07	-6.66	2.08	-1.72	1.27	46.15	-6.25*	-15.33	-0.12	-9.73	-0.56	0.03
6.	MMS-white × RVS-2012-13	-20	0	6	-25	-4.76	0.84	-0.64	8.33	0	-0.23	0	-0.11	-0.76	-2.35
7.	MSV-10-5-1 × GMU 1303	0	-2.32	-2	-40	13.04	1.7	-0.64	9.09	-9.09*	-3.51	-0.37	6.14	-0.42	-0.58
8.	MSV-10-5-1 × GMU 1769	-26.66	-6.66	-9.6	-11.76	-5.26	-0.84	0.64	-17.77**	-4*	-1.18	-1.61	0.12	-0.39	-0.67
9.	MSV-10-5-1 × RVS-2012-13	12.5	-2.32	-0.11	-18.75	2.22	0.84	-0.63	-3.84**	7.1**	5.91	-0.76	-7.05	-0.21	-0.02
10.	TMS-3-6-7-9 × GMU 1303	-33.33	-2.32	-3.4	-25	6.06	-0.87	0.62	-18.18	-62.5	-0.95	-0.16	5.64	-1.38	0.22
11.	TMS-3-6-7-9 × GMU1769	0	2.38	-3.96	-22.22	-16.66	0.833	0	100	-4.76	-6.67	-0.16	-2.02	-2.13	-0.1
12.	TMS-3-6-7-9 × RVS-2012-13	0	5	0	-22.22	7.14	-0.84	2.59	-23	-3.84*	-1.21	-0.1	2.67	-0.13	-1.08

*, ** = significant at 5% and 1% level of probability.

100 seed weight weight is also one of the most important components of yield which influences the yield conspicuously. Heterosis for test weight over standard variety varied from 2.68 per cent (MSV-10-5-1 × GMU 1303) to 80.3 per cent (TMS-3-6-7-9 × RVS-2012-13). Most of the hybrids showed positive heterosis for this trait. Heterosis for seed yield varied from 13.12 per cent (MMs white × GMU 1769) to 949.63 per cent (GMU 224 × GMU 1303). Only nine hybrids *viz*., GMU 224 × GMU 1303, GMU 224 × GMU 1769, GMU 224 × RVS-2012-13, TMS-3-6-7-9 × GMU 1303, MSV-10-5-1 × GMU 1769, TMS-3-6-7-9 × RVS-2012-13, MSV-10-5-1 × RVS-2012-13 and MMS-white × GMU 1303 exhibited significant positive heterosis for seed yield over standard variety. In safflower high degree of heterosis for seed yield was also recorded previously by Ramachandram and Goud (1982) and Kulkarni *et al*. (1992). The standard heterosis estimates for oil content were in negative direction but significant for 2 hybrids studied.

The hybrid vigour expression occurring in F_1 will be less in F_2 due to segregation. As a result, there is generally a decline in seed yield and also expression of component traits. To assess the extent of decline in performance, the F_2 generation was raised and the extent of inbreeding depression was estimated for the various characters (table 2). Inbreeding depression in F_2 for days to 50% flowering varied from -0.87 (TMS-3-6-7-9 × GMU 1303) to 1.70 (MSV-10-5-1 × GMU 1303). The value of inbreeding depression was varied from -9.60 (MSV-10-5-1 × GMU 1769) to 6.00 (MMS-white × RVS-2012-13) for plant height, for number of capitula per plant varied from -36.76 (GMU 224 × GMU 1769) to 13.04 (MSV-10-5-1 × GMU 1303), for number of seeds per capitulum varied from -23.00 (TMS-3-6-7-9 × RVS-2012-13) to 100.00 (TMS-3-6-7-9 × GMU 1769), for 100 seed weight varied from -1.61 (MSV-10-5-1 × GMU 1769) to 0.17 (GMU 224 × GMU 1303) and for seed yield varied from -15.33 (MMS-white × GMU 1769) to 5.91 (MSV-10-5-1 × RVS-2012-13). Negative inbreeding depression for seed yield was also reported by Patil and Narkhede (1996). The present investigation needs further evaluation under different environments, since genotype × environment interaction also plays an important role in the expression of these traits.

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