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Research Note

Heterosis and inbreeding depression for yield and yield components in safflower (*Carthamus tinctorius* L.)

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Abstract:
The results of the experiment on the magnitude of heterosis and inbreeding depression in 38 genotypes (15 F_1s, their 15 F_2s and 8 parents) for yield and its attributes revealed highly significant variations for all the genotypes and for all the characters studied. Two hybrids for earliness and four hybrids for short stature exhibited significant negative standard heterosis, while four hybrids for number of capitula per plant, seven hybrids for number of seeds per capitulum, five hybrids for test weight and three hybrids for seed yield exhibited significant positive standard heterosis. There was positive inbreeding depression in F_2 generation for all the characters in majority of the hybrids. There was non significant heterosis and inbreeding depression for oil content in F_1 and F_2 generations respectively.

Key words:
Safflower, heterosis, inbreeding depression

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. In F_2 generation the segregation and reduction in heterozygosity adversely affect the quantity and quality of the produce of safflower. The present experiment was designed to find out the magnitude of heterosis and inbreeding depression in safflower for yield and yield components.

The experimental material for the present study comprised 15 F_1s, their F_2s and 6 parents. The experiment was conducted under rainfed condition in a randomized block design with three replications. Sowing was done with a spacing of 45 x 20 cm and the plot size was 5 x 1.8 m for each test entry. Observations were recorded on 8 traits, viz., days to 50% flowering, days to maturity, plant height (cm), number of capitula per plant, number of seeds per capitulum, test weight (g), seed yield (kg/ha) and oil content (%). The observations were recorded on plot basis for 50% flowering, and on ten 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):

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

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

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 15 hybrids, two exhibited significant negative heterosis for days to 50% flowering over the standard variety. These two hybrids, Manjira x GMU 6915 and HUS 305 x GMU 6915 are early maturing types. Early maturing hybrids are desirable as they produce more yields per day and fit well in multiple cropping systems. Heterosis for earliness over standard varieties has been reported by Patil *et al*. (1998).

Out of 15 hybrids, only three hybrids viz., A-1 x GMU 2914-15, Manjira x GMU 1702 and Manjira x GMU 3272 recorded less plant height over standard variety, Manjira. Four hybrids exhibited positive standard heterosis for this trait. Present observations are in confirmity with the earlier findings of Patil *et al*., (1998) who reported positive heterosis for plant height. Number of effective capitula per plant is generally associated with higher productivity. Among 15 hybrids, 4 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 A-1 x GMU 3272, Manjira x GMU 3272, Manjira x GMU 6915 and HUS 305 x GMU 2914-15.

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 A-1 x GMU 1702, A-1 x GMU 2914-15, A-1 x GMU 3272, Manjira x GMU 1702, Manjira x GMU 2914-15, Manjira x GMU 3272, Manjira x GMU 6915 and HUS 305 x GMU 2914-15. These results are in agreement with the earlier findings of Rao, (1982).

Test 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 -12.73% to (HUS 305 x GMU 2914-15) to 20.85% (A-1 x GMU 3272). Most of the hybrids showed negative heterosis for this trait. Occurrence of negative heterosis estimates was also reported by Manjare and Jambhale (1995). Heterosis for seed yield varied from -19.08 to (HUS 305 x GMU 6915) to 20.37 (Manjira x GMU 6915). Only three hybrids viz., A-1 x GMU 1702, A-1 x GMU 3272 and Manjira x GMU 6915 exhibited significant positive heterosis for seed yield over standard variety. The standard heterosis estimates for oil content were in positive direction but not significant for all the hybrids studied.

The hybrid vigour expression occurring in F_1 will be less in F2 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). There was significant inbreeding depression for all the characters studied except oil content in the hybrids under the present study. This suggests that oil content should be basically controlled by additive gene action.

Inbreeding depression in F_2 for days to 50% flowering varied from -3.08 (Manjira x GMU 6915) to 9.71 (Manjira x GMU 1702). The average value of inbreeding depression was observed to be 4.39 for plant height, 30.94 for number of capitula per plant, 34.94 for number of seeds per capitulum, 11.03 for test weight and 23.28 for seed yield. Inbreeding depression was high for the characters viz, number of capitula per plant, number of seeds per capitulum, test weight and seed yield in F_2 generation. Inbreeding depression in yield varies from -21.67 (A-1 x GMU 1702) to 58.02 (HUS 305 x GMU 1702). 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 x environment interaction also plays an important role in the expression of these traits.

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Table 1. Genetic parameters for yield contributing characters in safflower

Genetic parameters	Mean	Range		SEm	GCV (%)	PCV (%)	H^2 (bs) (%)	GA (% over mean)
		Min	Max					
Days to 50% flowering	78.65	72	83	1.01	3.70	4.32	73.4	5.14
Days to maturity	109.91	104	115	0.94	2.73	3.10	77.2	5.43
Plant height (cm)	76.82	65	85	1.35	6.13	6.84	80.1	8.68
Number of capitula per plant	23.50	9	34	1.34	24.68	26.59	86.1	11.06
Number of seeds per capitulum	28.21	13	40	1.68	28.36	30.18	88.3	15.49
Test weight (g)	4.82	3.45	5.70	0.13	12.19	13.10	86.6	1.12
Seed yield (kg/ha)	946.47	555.00	1322.34	31.89	22.29	23.04	93.6	420.57
Oil content (%)	22.56	16.8	24.9	0.84	7.31	9.79	55.9	2.54

Table 2. Heterosis and inbreeding depression for yield contributing characters in safflower

Cross	Days to 50% flowering		Days to maturity		Plant height (cm)		Number of capitula per plant		Number of seeds per capitulum		Test weight (g)		Seed yield (kg/ha)		Oil content (%)	
	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%	Het (BP)	ID%
A-1 x GMU 1702	0.00	6.75*	4.94**	-5.19**	6.17**	-6.57*	4.88	-5.12	15.69*	-18.60	17.35**	-20.98**	17.81**	-21.67**	4.67	7.12
A-1 x GMU 1946	5.70*	7.46*	-2.62	2.38	5.76**	2.33	-12.20	-4.16	-16.67*	-2.35	-9.81**	5.31	-3.99	3.24	2.56	5.95
A-1 x GMU 2914-15	9.87**	9.38*	0.58	1.73	-6.17**	0.00	-1.22	9.87	13.73*	7.75	-19.04**	-15.07*	-0.76	-13.26*	2.06	7.22
A-1 x GMU 3272	6.11*	2.46	4.07**	3.33	0.00	4.52*	24.39**	23.52*	10.78*	20.35	20.85**	-3.46	19.87**	-18.58*	-1.18	1.34
A-1 x GMU 6915	-0.41	5.39*	-3.78*	-3.02	1.23	2.03	-10.98	1.37	-3.92	11.22	-3.91	1.03	-7.28	0.25	4.23	3.16
Manjira x GMU 1702	4.22	9.71*	5.20**	7.55*	-10.36**	10.67**	7.69	39.28**	14.44*	50.48**	14.84**	22.21**	-9.98*	26.55**	6.33	8.31
Manjira x GMU 1946	8.33**	7.28*	-1.76	6.56*	-1.20	13.71**	-4.00	59.72**	-6.90	45.67**	-8.85**	20.14**	-9.29*	20.82	5.40	2.91
Manjira x GMU 2914-15	12.56**	3.58	5.20**	3.48	-8.76**	13.97*	5.33	48.10*	32.18**	52.17**	-1.64	14.04*	-10.96**	16.74	6.13	9.71
Manjira x GMU 3272	2.62	4.25	-0.61	3.38	-6.77**	8.54*	16.00*	49.42**	13.79	58.58**	12.65**	27.44**	4.80	33.54**	5.15	1.20
Manjira x GMU 6915	-6.20**	-3.08	12.71*	0.61	11.95**	3.62	16.67*	22.50*	11.15*	53.48**	12.53*	6.73*	20.37**	56.20**	6.01	2.30
HUS 305 x GMU 1702	0.84	7.11*	-2.65	5.43**	-4.31	-10.81**	3.85	29.63**	8.41	58.62**	4.89*	26.59**	3.55	58.02**	5.53	3.38
HUS 305 x GMU 1946	9.21**	5.62*	-0.29	5.29*	-0.83	2.92	13.70	44.57**	-5.61	40.59	-0.68	31.10**	-8.99**	48.39**	3.84	3.26
HUS 305 x GMU 2914-15	6.73**	-2.52	-4.12**	-2.76	-2.19	5.83*	21.92**	65.16**	12.15	52.12*	-12.73**	25.64*	-2.30	46.19**	5.14	5.46
HUS 305 x GMU 3272	6.11*	1.64	-2.35	1.20	7.89**	8.53*	6.85	39.74**	-14.95*	39.56*	-0.31	17.42**	-16.16**	49.47**	6.85	1.35
HUS 305 x GMU 6915	-6.20**	3.96	-5.59**	1.24	6.14**	6.61	15.07	40.47**	4.67	54.46**	-6.14*	7.28*	-19.08**	43.32**	5.42	3.47
Average	3.97	4.60	0.60	2.08	-0.10	4.39	7.20	30.94	5.93	34.94	1.33	11.03	-1.49	23.28	4.54	4.41