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Heterosis, Inbreeding Depression and Inheritance of Seed Yield and its Component Traits in Safflower (*Carthamus tinctorius* L.)

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Abstract

The P_1, P_2, F_1, F_2, BC_1 and BC_2 of four safflower (*Carthamus tinctorius* L.) crosses were studied for eight metric traits. Individual scaling test and joint scaling test indicated that an additive dominance model was adequate in none of the cases. The results suggested that the presence of additive-dominance and epistatic gene effects for the traits indicating the importance of both additive and non-additive gene actions in the expression of these characters. Duplicate type of epistasis was prevalent in most of the cases. A substantial amount of heterosis over better parent was revealed in all the four crosses for seed yield and most of its attributes. Inbreeding depression was also significant for days to 50% flowering, days to maturity, number of capitula plant^{-1} and test weight in the cross Manjira x GMU 1946 and HUS 305 x GMU 1946, whereas plant height and capitula plant^{-1} in the cross A1 x GMU 3272 and plant height, number of capitula plant^{-1}, number of seeds capitulum^{-1} and test weight in the cross Manjira x GMU 12914-15. Suitable breeding strategies were suggested for the improvement of seed yield in safflower

1. Introduction

Safflower is an important oil seed crop of arid and semi-arid regions. Studies on nature of gene action governing complex quantitative traits are of great value to the plant breeders in selecting appropriate breeding methodology for improvement of yield contributing traits. Information on the presence of type of epistatic gene effects in the inheritance of various quantitative traits is important for adopting suitable breeding procedures to improve the traits. In the present study, an attempt has been made to know the nature and magnitude of additive, dominance and epistatic gene effects for eight quantitative traits in the four crosses of safflower.

2. Materials and Methods

Six basic generations, viz. P_1, P_2, F_1, F_2, B_1 and B_2 derived from four crosses, viz. Manjira x GMU 1946, HUS 305 x GMU 1946, Manjira x GMU 2914-15 and A1 x GMU 3272 were produced and evaluated in a Randomized Block Design with three replications during rabi 2008-09 at Agricultural Research Station, ANGRAU, Tandur. GMU 1946, GMU 2914-15 and GMU 3272 are good combiners and wilt resistant lines. Each plot consisted of a single row (5 m) of parents and F_1 each, two rows of B_1 and B_2 each and three rows of F_2 generation. Recommended package of practices were followed timely throughout the crop season. The observations were recorded on individual plant basis in each replication on randomly selected five plants in each parent and F_1, 10 plants in each of B_1 and B_2 and 200 plants in F_2 generation for eight characters in each cross (Table 1). The scaling test (Mather, 1949; Hayman, 1958) and joint scaling test (Cavalli, 1952) were applied simultaneously for the detection of epistasis. Heterosis over better parent (Fonseca and Patterson, 1968) and inbreeding depression were also worked out. X^2 test was followed to test the significance of results.

3. Results and Discussion

The analysis of variance revealed significant differences among six basic generation means in all the four crosses for all the eight characters studied. The estimates of genetic parameters, heterosis over better parent and inbreeding depression for different characters recorded in the four crosses are presented in Table 1. All the cases showed adequacy of additive-dominance model indicating the presence of epistasis for all the characters under study. When both individual scaling test (A, B and C) and joint scaling tests were applied simultaneously in all the

Table 1: Estimates of gene effects, heterobeltiosis (HB) and inbreeding depression (ID) for eight characters in four crosses of safflower

Cross/character	Scaling test				Interaction effects							
	A	B	C	D	m	(d)	(h)	(i)	(j)	(l)	HB	ID
Days to 50% flowering												
Manjira x GMU 1946	-2.00	-6.32	-12.36	-2.14	76.18	-0.16	1.52	4.00	2.17	4.29	8.33**	7.28*
HUS 305 x GMU 1946	-9.67	-6.68	-33.00	-8.45	63.50	1.83	20.50*	16.67*	-1.50	-0.42	9.21**	5.62*
Manjira x GMU 2914-15	-5.02	-10.35	-26.54	-5.62	70.68	-1.32	2.35	10.26	2.54	4.58	12.56**	3.58
A1 x GMU 3272	-10.23	-10.25	-16.32	2.36	74.36	1.56	-33.86*	-4.15	-0.16	24.36*	6.11*	2.46
Days to maturity												
Manjira x GMU 1946	-2.35	-8.64	-15.21	-2.15	107.67	-1.16	-1.83	4.14	3.15*	7.54	-1.76	6.56*
HUS 305 x GMU 1946	-10.16	-7.67	-25.78	-3.12	103.50	1.83	-1.16	7.32	-1.54	11.67	-0.29	5.29*
Manjira x GMU 2914-15	-6.12	-11.55	-27.65	-5.32	101.56	-1.16	-0.16	10.36	2.54	6.45	5.20**	3.48
A1 x GMU 3272	-4.69	-2.69	-20.22	-6.35	104.36	1.35	12.03	12.67	-1.14	-5.69	4.07**	3.33
Plant height (cm)												
Manjira x GMU 1946	-4.00	9.67	-19.25	-12.68	64.18	-2.56	47.83*	25.21*	-6.84	-31.00	-1.20	13.71**
HUS 305 x GMU 1946	-19.17	-18.42	-38.33	-0.67	79.16	-1.50	-33.52*	1.38	-0.51	35.67*	-0.83	2.92
Manjira x GMU 2914-15	-7.25	-17.21	-38.23	-6.65	67.25	-3.21	-5.23	13.25*	5.56*	11.32	-8.77**	13.97*
A1 x GMU 3272	-13.68	-25.62	-33.47	2.68	80.00	-5.12	-43.25*	-5.36	5.66*	44.02*	0.00	4.52*
Number of capitula plant^{-1}												
Manjira x GMU 1946	2.14	-2.54	8.69	4.57	23.67	0.45	-7.54	-8.67	2.19	8.67	-4.00	59.72**
HUS 305 x GMU 1946	-20.41	-18.76	-52.34	-6.79	10.17	4.67	-5.33	13.48*	-0.61	25.36*	13.70	44.57**
Manjira x GMU 2914-15	-22.14	-26.47	-52.54	-2.15	25.00	-1.15	-43.21*	4.02	2.33	44.67*	5.33	48.10*
A1 x GMU 3272	-14.12	-26.48	-50.68	-4.68	18.02	-6.00	-22.56*	9.33	6.00	32.00*	24.39**	23.52*
Number of seeds capitulum^{-1}												
Manjira x GMU 1946	-10.44	-8.54	-13.24	2.54	26.51	1.83	-24.50*	-4.65	-0.83	23.42*	-6.90	45.67**
HUS 305 x GMU 1946	-18.67	-5.38	-49.12	-12.67	25.33	5.38*	6.17	26.12*	-6.67	-1.38	-5.61	40.59
Manjira x GMU 2914-15	-11.23	-25.63	-55.32	-9.15	14.26	-6.65*	-0.35	18.56*	7.23*	18.02*	32.18**	52.17**
A1 x GMU 3272	-25.47	-19.21	-71.48	-13.24	5.50	-1.58	14.16	26.67*	-3.16	17.69	10.78*	20.35
Test weight (g)												
Manjira x GMU 1946	-0.26	-0.82	1.10	1.09	7.43	0.32	-4.33	-2.18	0.28	3.27	-8.85**	20.14**
HUS 305 x GMU 1946	0.18	-0.65	-1.66	-0.59	3.93	-0.14	2.30	1.19	0.42	-0.72	-0.68	31.10**
Manjira x GMU 2914-15	-0.26	-0.66	-1.45	-0.26	4.46	0.24	-0.11	0.52	0.20	0.39	-1.64	14.04*
A1 x GMU 3272	-0.41	0.30	-3.83	-1.86	4.34	0.06	6.70	3.72	-0.35	-3.61	20.85**	-3.46
Seed yield (kg ha^{-1})												
Manjira x GMU 1946	142.68	-187.14	-109.68	-32.58	765.50	-71.54*	210.83*	65.18*	164.84*	-21.47	-9.29*	20.82
HUS 305 x GMU 1946	60.00	-489.67	-379.02	25.36	1008.8	-78.36*	-518.50*	-50.68	274.86*	480.34*	-8.99**	48.39*
Manjira x GMU 2914-15	-395.33	-635.25	-1510.7	-240.12	503.26	-66.45*	216.68*	480.14*	120.69*	550.69*	-10.96**	16.74
A1 x GMU 3272	-342.69	-86.69	-700.45	-135.87	845.69	42.59	140.32*	270.69*	-128.00*	158.68*	19.87**	-18.58*
Oil content (%)												
Manjira x GMU 1946	-1.30	1.50	-2.35	-1.43	20.38	1.90	7.60*	2.86	-1.40	-3.06	5.40	2.91
HUS 305 x GMU 1946	-0.90	-7.60	-5.30	1.62	30.18	-1.15	-17.08	-3.20	3.35*	11.70*	3.84	3.26
Manjira x GMU 2914-15	3.14	12.43	0.96	-7.25	24.20	0.75	44.05*	14.46*	-4.71	-29.91*	6.13	9.71
A1 x GMU 3272	-0.36	-3.13	0.30	1.90	25.73	0.51	-7.68	-3.80	1.38	7.30*	-1.18	1.34

cases epistasis was evident. The joint scaling test was found to be more efficient in detection of epistasis compared to individual scaling tests. Golakia et al. (2004) in castor had also concluded superiority of joint scaling test over the simple scaling tests. Among interacting crosses additive gene effects contributed significantly towards the inheritance of number of seeds capitulum^{-1} in the cross HUS 305 x GMU 1946 while dominance gene effects were significant for plant height, seed yield and oil content in the cross Manjira x GMU 1946, seed yield and oil content in the cross Manjira x GMU 2914-15 and days to 50% flowering in the cross HUS 305 x GMU 1946. These results were in agreement with the earlier findings of Manjare and Jambhare (1997). In addition to main effects the digenic additive x additive interaction effect was significant for days to 50% flowering, number of capitula plant^{-1} and number of seeds capitula^{-1} on the cross HUS 305 x GMU 1946, whereas, seed yield and plant height in the cross Manjira x GMU 1946 and number of seeds capitula^{-1}, plant height, seed yield and oil content in the cross Manjira x GMU 2914-15. Additive x additive (i) and additive x dominance (j) effects were significant for plant height, seed yield and number of seeds capitulum^{-1} in the cross Manjira x GMU 2914-15. The fixable gene effects in these crosses could be helpful in isolating superior inbred lines of safflower. The additive x dominance and dominance x dominance gene effects were involved in the inheritance of plant height in the cross A1 x GMU 3272, number of seeds capitulum^{-1} and seed yield in the cross Manjira x GMU 294-15 and seed yield and oil content in the cross HUS 305 x GMU 1946. Only additive x dominance effects were significant for seed yield and days to 50% flowering in the cross Manjira x GMU 1946 and plant height in the cross Manjira x GMU 2914-15. While only dominance x dominance gene effects were significant for the inheritance of the traits, viz. days to 50% flowering, number of capitula plant^{-1} and oil content in the cross A1 x GMU 3272 whereas, plant height and number of capitula plant^{-1} in the cross HUS 305 x GMU 1946. Ragab (1991) reported similar results in safflower. A perusal of gene action revealed that both additive and non-additive gene effects governing seed yield and its related traits were observed in the four crosses of safflower (Table 1). Further duplicate epistasis was observed for most of the traits in all the four crosses except days to 50% flowering and seed yield in the cross Manjira x GMU 2914-15, number of seeds capitulum^{-1} and seed yield in the cross A1 x GMU 3272 and days to 50% flowering in the cross Manjira x GMU 1946, where complementary epistasis was observed. Similar results were reported by Prasad et al. (1993). The presence of duplicate epistasis for most of the cases would be restricting rapid progress, making it difficult to fix genotypes with increased level of character manifestation. It is suggested that for the characters showing influence of digenic interaction in addition to main effects (d) and (h), population improvement approach in the form of biparental mating coupled with recurrent selection may be adopted. Such program shall allow mild inbreeding in the population and enhance the possibilities of transgressive segregation and the span of selection over generations. A substantial amount of heterosis over better parent was observed in the cross Manjira x GMU 2914-15 and A1x GMU 3272 for seed yield and most of its attributes. High and significant heterosis for seed yield plant^{-1} in the cross A1 x GMU 3272 might be due to significant heterosis for number of capitula plant^{-1} and number of seeds capitula^{-1}, respectively. The heterosis in the above cases could be due to presence of dominance and dominance x dominance effects. Joint action of favorable gene combinations at different loci could be responsible for observed heterosis in these crosses for most of the traits. These findings are in agreement with the earlier findings of Manjare and Jambhale (1995). Inbreeding depression was also observed significant for days to 50% flowering, days to maturity, number of capitula plant^{-1} and test weight in the cross Manjira x GMU 1946 and HUS 305 x GMU 1946, whereas plant height and capitula plant^{-1} in the cross A1 x GMU 3272 and plant height, number of capitula plant^{-1}, number of seeds capitulum^{-1} and test weight in the cross Manjira x GMU 12914-15. High inbreeding depression in F_2 population for seed yield plant^{-1} ranged from 16.74% (Manjira x GMU 2914-15) to 48.39% (HUS 305 x GMU 1946) which might be due to wide base of genetic material. All the crosses for most of the traits showed positive inbreeding depression indicated the presence of dominance effects for most of the traits.

4. Conclusion

In the present study, involvement of both additive as well as non-additive gene effects were observed in most of the cases. Therefore, heterosis breeding and population improvement adopting *inter se* mating among promising divergent genotypes and effecting simultaneous selection for seed yield, number of capitula plant^{-1} and number of seeds capitulum^{-1} and other components of yield is recognized as the ideal breeding approach for safflower improvement program.

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