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Heterosis and combining analysis in Safflower (*Carthamus tinctorius* Linn.)

S.B.SARODE[1],P.B.GHORPADE[1] ,P.M. WAYAZADE[2], S.B DESHMUKH[3] AND S.S. GOMASHE[4]
[1] Department of Agricultural Botany, Collage of Agriculture, NAGPUR (M.S.) INDIA
[2] Department of Agronomy, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S.) INDIA
[3] Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S.) INDIA
[4] Medicinal and Aromatic Plant Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, AKOLA (M.S.) INDIA

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Top cross analysis consisted of crosses between GMS line AKSMS 1 as a tester (female) and twenty one male lines. Significant heterosis was observed for all the ten quantitative traits except number of capitula per plant and oil content. The magnitude of heterosis and useful heterosis was low and differed for different characters. The highest magnitude of useful heterosis was observed in respect of number of seeds per capitulum (53.78 %), seed yield per plant (27.23 %), 100 seed weight (2.58 %) and days to maturity (-2.87 %). Only one cross, AKSMS 1 X JLSF 228, recorded significant useful heterosis over check variety, Bhima for seed yield per plant (27.23 %). AKSMS 1 X JLSF 228 showed significant highest useful heterosis for number of seeds per capitulum (53.78 %). The estimates of general combining ability indicated that JLSF 288 recorded highest significant general combining ability effect for seed yield per plant (26.27**), plant height (10.41 **) and number of seeds per capitulum (9.87**). A 1 showed significant general combining ability effect for seed yield per plant (15.91**). Bhima was good general combiner for seed yield per plant (13.39**), plant height (6.16**), number of primary branches per plant (1.74**) and 100 seed weight (0.96**).

Key words : Hererosis, Combining analysis, Safflower

INTRODUCTION

Safflower is one of the most important oilseed crop. Safflower has been gaining increasing popularity in recent years in several parts of the county because of its adaptability under drought conditions. The increase in productivity through breeding efforts has not been adequate because of traditional selection methods following hybridization. Heterosis breeding could be a potential alternative for achieving quantum jumps in production and productivity. The significant break through in yield advances could be made through exploitation of heterosis at commercial level (Knowles, 1989).The comprehensive review of heterosis in safflower indicate that there is a significant amount of heterosis over commercial cultivars indicating the possibility of exploiting heterosis at commercial level in safflower. In absence of cytoplasmic male sterility, genetic male sterility offers a vast scope in safflower hybrid development programme (Heaton and Knowles, 1980, Chitanvis *et al*. 1999). In 1997, DSH 129, a safflower hybrid was released for commercial cultivation by DOR, Hyderabad with 20 to 22 % yield increase over national check, A_1. This indicates that GMS can be successfully used in development of safflower hybrid varieties. The present study was undertaken to assess the heterosis, combining ability and identify the experimental potential hybrids.

MATERIALS AND METHODS

The present study was conducted in 2000, at the Farm of Department of Agricultural Botany, College of Agriculture, Nagpur,(India).The experimental material comprised of eleven lines selected for high yield, earliness and wider adaptability *viz.*, JLSF 228,N 7,CTV 209, JLSF 88,Sharda, BLY 652, AKS 65, AKS 68, HUS 305,A_1 Bhima and ten exotic lines *viz.*, S 541, W6-872, PI 401470, PI307029A, PI307029B, PI537601A, PI537601B, PI401473, PI401479A,PI401479B. Each line was crossed with a common tester i.e. AKSMS 1, a genetic male sterile line, to obtain 21 crosses during winter 1999.

Thus, complete set of material; under study consisting of one tester, 21 lines and 21 crosses, among them were raised in randomized complete block design with two replications during winter 2000. The plants were spaced 45 cm between rows and 30 cm between plants. Fifteen plants per genotype per row were grown. Border plants were grown on all sides of the block to avoid border effect.

* Author for Correspondence

Table 1. Estimates of heterosis (H) and useful heterosis (UH) over Bhima for different characters.

Crosses	Plant height (cm)		No. of primary branches/plant		No.of seeds /capitulum		100seed weight (g)		Seed yield/plant (g)		Days to maturity	
	H	UH	H	UH	H	UH	H	UH	H	UH	H	UH
AKSMS 1 X JLSF 228	2.10	15.17**	5.71**	-	39.70**	53.78**	-0.45	-	59.69**	27.23**	-6.54**	-
AKSMS 1 X N 7	-11.23**	-	-7.10**	-	35.37**	48.00**	-11.02**	-	20.23**	-	-4.80**	-
AKSMS 1 X CTU 209	-0.81	10.19*	-13.02	-	15.17**	14.10**	25.34**	2.58**	27.29**	-	-3.49**	-
AKSMS 1 X JLSF 88	-4.62	5.76	-3.21**	-	-1.26	6.89	4.23**	-	14.69*	-	-4.37**	-
AKSMS 1 X Sharda	-2.42	5.76	-15.34**	-	26.79**	29.43**	1.93**	-	10.38	-	-3.08**	-
AKSMS 1 X BLY 652	0.42	9.62*	-6.34**	-	7.72*	21.54**	-4.56**	-	9.22	-	-5.09**	-
AKSMS 1 X AKS 65	-3.37	1.85	-11.92**	-	-3.55	10.73**	-10.92**	1.51**	-20.45**	-	-4.69**	-
AKSMS 1 X AKS 68	-7.76*	-	-7.61**	-	-2.94	8.67*	-5.01**	-	0.13	-	-3.69**	-
AKSMS 1 X HUS 305	-15.13**	-	-6.71**	-	3.57	17.78**	-0.09	-	9.01**	-	-4.55**	-
AKSMS 1 X A 1	-3.77	9.00*	-1.20	-	17.52**	34.53**	-5.49**	-	26.50**	4.66	-3.44**	-
AKSMS 1 X Bhima	-4.06	10.08*	11.98**	-	14.95**	26.34**	10.08**	2.41**	29.57**	1.20	-6.77**	-
AKSMS 1 X S 541	15.99**	10.80*	-4.56**	-	-18.55**	-	22.61**	-	15.58*	-	-6.02**	-1.03
AKSMS 1 X W6-872	-7.67*	-	16.11**	-	3.69	-	1.30**	-	47.47**	-	-4.15**	-2.28*
AKSMS 1 X PI 307029 A	7.79*	11.16**	-4.59**	-	-9.29**	-	6.91**	-	-1.73	-	-8.12**	-2.87**
AKSMS 1 X 307029 B	-1.64	0.62	5.06**	-	-4.75	-	2.84**	-	37.06**	-	-6.10**	-0.74
AKSMS 1 X PI 537601 A	-6.55	0.10	-2.89**	-	23.50**	14.38**	1.89**	-	35.12**	-	-5.81**	-1.73
AKSMS 1 X PI 537601B	6.43	11.47**	11.46**	-	20.16**	21.66**	6.42**	-	82.22**	-	-5.70**	-1.58
AKSMS 1 X PI 401473	14.58**	10.34*	8.28**	-	28.44**	19.84**	14.70**	-	113.72**	-	-5.07**	-0.59
AKSMS 1 X PI 401479 A	12.72**	10.08*	23.64**	-	14.58**	16.12**	-2.36**	-	26.69**	-	-5.39**	-1.03
AKSMS 1 X PI 401479 B	-5.29	-	-0.63	-	14.44**	8.12*	-1.04*	-	22.30**	-	-6.38**	-2.09*
AKSMS 1 X PI 401470	5.25	2.42	9.83**	-	28.45**	5.15	20.00**	-	76.36**	-	-5.28**	-1.18
SE (Diff) (±)	3.49	4.03	0.68		3.23	3.74	0.39	0.45	7.21	8.33	0.80	0.93

* -P $\leq$ 0.05 ** -P $\leq$ 0.01

Table 2. General combining ability effect of parental lines.

Sr. No.	Parents	Plant height (cm)	No. of primary branches/plant	No. of capitula/ plant	No. of seeds/ capitulum	100 seed weight (g)	Seed yield/ plant (g)	Oil content (%)	Days to maturity
1	JLSF 228	10.41**	0.94	5.98	9.87**	0.50	26.27**	-1.73	0.24
2	N 7	-9.44**	0.19	-5.12	8.41**	-0.72	2.97	0.62	3.29**
3	CTV 209	5.56	-0.46	-3.12	-0.15	0.97**	1.35	1.48	3.34**
4	JLSF 88	1.26	-0.01	2.13	-1.95	0.56	0.68	2.04	2.94**
5	Sharda	5.01	-0.86	2.13	3.72	0.28	8.17	2.19	3.59**
6	BLY 652	-2.54	0.19	0.23	1.73	-0.07	1.57	4.21*	3.39**
7	AKS 65	-6.99*	0.19	-1.07	-1.00	-0.43	-3.50	0.49	1.59*
8	AKS 68	-7.89**	0.49	3.58	-1.52	-0.26	-4.87	-4.68**	3.04**
9	HUS 305	4.41	-0.31	0.08	0.78	0.62	6.61	-2.55	2.04**
10	A 1	5.46	-0.06	4.73	5.01	0.51	15.19*	0.72	3.14**
11	Bhima	6.16*	1.74**	0.43	2.94	0.96**	13.49*	0.70	-0.51
12	S 541	-4.89	-0.46	-6.97	-8.23**	0.84*	-10.83	-0.40	-1.86**
13	W6-872	6.51*	0.34	0.93	-5.23	-0.30	-5.53	-2.50	-3.56**
14	PI 307029A	-3.74	-0.54	-4.57	-7.85**	0.19	-14.61*	1.38	-4.36**
15	PI 307029B	-4.28	-0.01	-3.82	-5.80	-0.10	-6.29	-1.60	-1.46*
16	PI 537601A	6.81*	0.09	5.33	-0.08	0.13	2.24	2.53	-2.81**
17	PI 537601B	5.71	0.44	4.78	1.76	-0.43	3.88	3.42*	-2.61**
18	PI 401473	5.46	-0.46	5.38	1.30	-1.01**	-2.71	-1.79	-1.26
19	PI 401479A	-9.34**	0.19	-1.57	0.36	-1.28**	-14.33*	-3.36*	-1.86**
20	PI 401479B	-11.64**	-0.46	-3.82	-1.66	-0.21	-9.97	0.08	-3.31**
21	PI 401470	-1.99	-1.16*	-5.57	-2.41	-0.74*	-9.73	-1.27	-2.06**
	SE (±)	2.85	0.56	3.63	2.64	0.32	5.89	1.59	0.65

* -P ≤ 0.05 ** -P ≤ 0.01

Table 3. Estimates of heterosis (H) and useful heterosis (UH) over Bhima for different characters.

Crosses	Plant height (cm)		No. of primary branches/plant		No.of seeds /capitulum		100seed weight (g)		Seed yield /plant (g)		Days to maturity	
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AKSMS 1 X HUS 305	-15.13**	-	-6.71**	-	3.57	17.78**	-0.09	-	9.01**	-	-4.55**	-
AKSMS 1 X A 1	-3.77	9.00*	-1.20	-	17.52**	34.53**	-5.49**	-	26.50**	4.66	-3.44**	-
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AKSMS 1 X PI 401479 B	-5.29	-	-0.63	-	14.44**	8.12*	-1.04*	-	22.30**	-	-6.38**	-2.09*
AKSMS 1 X PI 401470	5.25	2.42	9.83**	-	28.45**	5.15	20.00**	-	76.36**	-	-5.28**	-1.18
SE (Diff) (±)	3.49	4.03	0.68		3.23	3.74	0.39	0.45	7.21	8.33	0.80	0.93

* -P ≤ 0.05 ** -P ≤ 0.01

Recommended package of practices was followed to raise a good crop. Data were recorded for ten competitive plants of each genotype for the following characters viz., plant height (cm), number of primary branches per plant, number of capitula per plant, number of seeds per capitulum, 100 seed weight (g), seed yield per plant (g), oil content (%) and days to maturity.

The estimates of general combining ability effects were estimated by using top-cross method as suggested by Davis (1927) and White and Richmond (1963).

Heterosis was estimated by standard methods.

RESULTS AND DISCUSSION

The phenomenon of heterosis was of general occurrence for most of the characters under study except for number of capitula per plant and oil content. The magnitude of heterosis and useful heterosis was low and differed for different characters. Heterosis have been already reported for various characters in safflower by many workers including Solman *et al*. (1958), Wandhare (1997) and Naoghare (2000). The commercial value of hybrid will depend on whether it is more profitable than the best available commercial cultivar. In this study, the highest magnitude of useful heterosis was observed in respect of number of seeds per capitulum (53.78 %), 100 seed weight (2.58 %) and days to maturity (-2.87 %) indicated in Table 1. On the basis of the result in the study, only one cross, AKSMS 1 X JLSF 228, recorded significant useful heterosis for seed yield per plant (27.23 %) and number of seeds per capitulum (53.78 %) over the check variety, Bhima. The DSH 129, a safflower hybrid released for commercial cultivation had recorded 20 to 22 % increase in yield over national check, A1. Naoghare (2000) reported 16.99 % useful heterosis over Bhima for seed yield per plant. This clearly indicates that the extent of useful heterosis observed is very low for its exploitation at commercial scale. Therefore, there is need to evaluate large number of genetically diverse lines with genetic male sterile lines so as to identify hybrid combinations with very high useful heterosis.

The estimates of general combining ability indicated that JLSF 288 recorded highest significant general combining ability effect for seed yield per plant (26.27**), plant height (10.41 **) and number of seeds per capitulum (9.87**) (Table. 2) A 1 showed significant general combining ability effect for seed yield per plant (15.91**). Bhima was good general combiner for seed yield per plant (13.39**), plant height (6.16**), number of primary branches per plant (1.74**) and 100 seed weight (0.96**). This indicates that rest of the lines are not useful for the development of hybrid variety in safflower particularly with reference to genetic male sterile line, AKSMS 1. In safflower, the seed yield per plant is mainly dependent on number of primary branches per plant and number of capitula per plant. However, in the present study none of the line showed significant general combining ability with AKSMS 1 for these traits. Naoghare (2000) also indicated the poor general combining ability of parental lines with AKSMS 1. This suggests that direct utilization of AKSMS 1, genetic male sterile line for development of hybrid varieties in safflower is not useful. Therefore, there is a need of conversion of AKSMS 1, genetic male sterile line in good agronomic background such as Bhima, A1.

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