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Evaluation of three cycles of recurrent selection for improvement of seed yield in safflower using genetic male sterility

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Abstract
Three cycles of recurrent selection for seed yield were conducted in a genetically broad-based population of safflower segregating for genetic male sterility for development of safflower varieties with broad genetic base. Four families from C_1, 26 families from C_2 and 41 families from C_3 significantly out-yielded the check variety, Bhima. The percent increase in seed yield over check variety, Bhima ranged from 24.37 to 35.52%. The highest yield was recorded by half-sib 68 (2131 kg/ha) followed by half-sib 109 (2091 kg/ha) and half sib 92 (1985 kg/ha) in advanced yield trials. The application of recurrent selection procedure provides a better approach for development of higher yielding safflower varieties with a broad genetic base.

Key words : *Carthamus tinctorius* L - recurrent selection - breeding method - genetic male sterility

Introduction
Genetic improvement in self-pollinated species has been largely confined to varietal improvement methods based on pedigree, bulk and backcross methods. These methods have limitation such as limited use of available genetic variability resulting in the development of varieties with narrow genetic base, successive loss of genes in the segregating generations with no chance of recombination (Jensen, 1970). Recurrent selection is applicable to both out crossing and self pollinating species and is a powerful procedure to accumulate desirable genes and facilitates breking of linkages (Frey, 1983). However, due to necessity for recombination in each cycle, this system has been principaly used in out crossing species. In past 30 years some recurrent selection methods utilizing both hand crossing (Compton, 1968) and out crossing mechanism like genetic male sterility have been proposed for self pollinated crops (Gilmore,1964; Doggett and Eberhart, 1968; Brim and Stuber, 1973 and Rachie and Gardner, 1975). The recurrent selection programme can be used with self pollinated crops such as safflower for development of high yielding varieties with broad genetic base.

Therefore, the objective of this paper is to describe the application of recurrent selection method in a broad based random mating population of safflower for development of higher yielding varieties with broad genetic base.

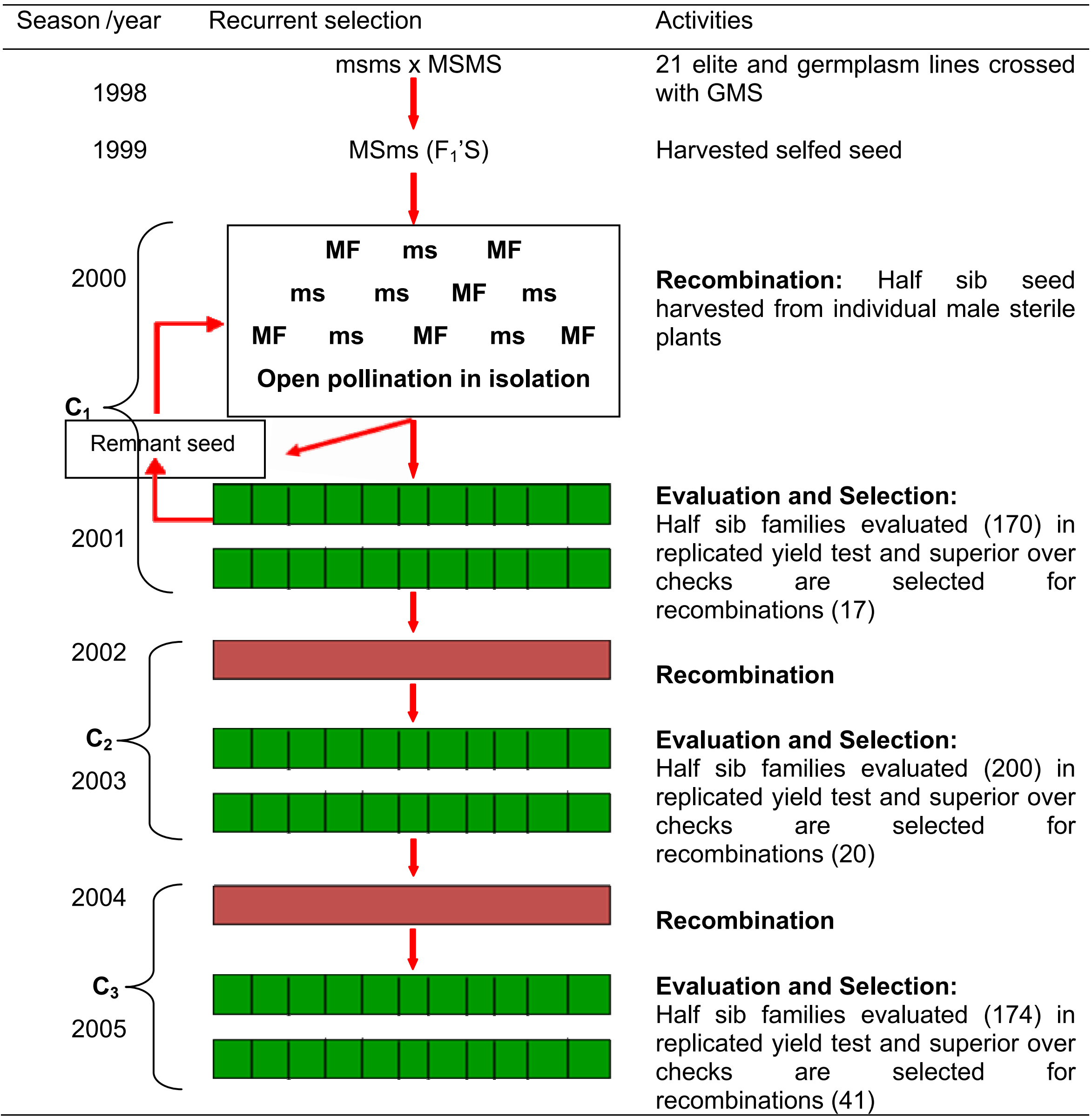
Materials and Methods
Development of Random Mating Population
The development of random mating population was initiated in 1998 by crossing 21 diverse elite and germplasm lines viz., Bhima, A1, AKS-68, AKS-65, Sharada, JLSF-88, CTV-209, N-7, JLSF-228, AKS-207, AKS-82, AKS-96 and HUS-305 from high yielding group and 8 germplasm lines viz., BLY-652, S-541, PI-307029, PI-401470, PI-401473, PI-401479, PI-537601 and WS-872 with high oil content were crossed with genetic male sterile line, AKSMS-1 in *rabi*, 1998. All these F_1's were raised in *rabi* 1999. The F_1 plants were selfed and harvested separately. Equal amount of F_1 seed (300) from each F_1 was composited and planted in *rabi* 2000 to form base

population. The total number of plants grown were 2000. At flowering 373 male sterile plants were identified, tagged and harvested separately as half-sibs. Out of which 170 half-sibs were selected with sufficient seed so as to keep remnant seeds for next recombination cycle.

Recurrent Selection

Three cycles of recurrent selection were completed as described in Fig. 1. In *rabi* 2001 (C_1), 2003 (C_2) and 2005 (C_3), 170, 200 and 174 half-sib families respectively were developed and evaluated along with 3 checks viz : Bhima, A1, HUS-305 in two replications in a modified randomized block design as followed by Eckebil *et al.* (1977). Each replicate consisted of 10 blocks with 17-20 half-sibs along with 3 checks in each block. The plant spacing within a row was 30 cm and row to row spacing was 45 cm. The data were recorded for days to 50%

Fig. 1: Outline of procedure of half sib recurrent selection in a safflower population segregating for genetic male sterility



flowering, days to maturity, plant height (cm), number of primary branches per plant, number of capitula per plant, number of seeds per capitulum, 100 seed weight (g), oil content and seed yield per plant (g). Seventeen of the 170 half-sib families from C_1, 20 of the 200 half sibs from

C_2 and 41 of the 174 half sibs from C_3 were selected on the basis of high yield and were used to initiate the recombinational phase of the next cycle.

Statistical analysis

The family and genetic component of variance, heritability, expected genetic advance were estimated as suggested by Empig *et al.* (1972) and Hallauer & Miranda (1989). The genetic correlations were estimated as suggested by Falconer & Mackey (1996).

Isolation of Purelines:

Forty one (41) half sib families selected from 3rd cycle of recurrent selection were evaluated in *rabi* 2006 in a randomized complete block design with three replication and selected 21 half sib families significantly superior over Bhima. In *rabi* 2007, only fertile plants were taken from twenty one (21) half sib families and were planted along with three checks viz., Bhima, A_1 and AKS-207 in Randomized Complete Block Design with three replications in advanced yield trial with plot size of 5 x 2.70 m (6 row plot) to assess the observed response for seed yield (kg/ha).

Results and Discussion

The basic objectives of all recurrent selection methods was to increase the frequency of desirable genes in a population so that the opportunity to extract superior genotypes are enhanced. In the present study, 3 cycles of recurrent selection for seed yield were completed in a broad genetic based population which is segregating for genetic male sterility (Table 1). The 170 (C_1), 200 (C_2) and 174 (C_3) half sib families were evaluated for yield in 2001, 2003 and 2005 respectively.

Table 1. Expected genetic advance in three cycles of recurrent selection for seed yield

Sr. No.	Unit of evaluation and selection	Selection intensity	Genetic advance for seed yield per plant (g)		
			C_1 (2001)	C_2 (2003)	C_3 (2005)
1.	Half-sib families	10	4.07	9.33	14.75
2.	Percent increase over population mean	10	9.84	23.99	42.29
3.	Percent increase over Bhima	10	10.27	23.87	35.98
4.	Number of significantly superior families over Bhima and A1		4	26	41

In the first cycle of recurrent selection (C_1) the expected genetic gain through half-sib family selection and testing for seed yield was 9.84 percent over population mean and 10.27 percent increase over check cultivar Bhima. In the second cycle of recurrent selection (C_2), the expected genetic gain was 23.99 per cent over population mean and 23.87 per cent increase over check cultivar, Bhima. Expected genetic gain in the third cycle of recurrent selection (C_3), was 42.29 per cent over population mean and 35.98 per cent increase over check cultivar, Bhima. The expected genetic advance obtained from third recurrent selection was three times greater as compared to response obtained from first cycle of recurrent selection of safflower population. The total number of significantly superior recombinant lines better than check cultivar Bhima were 4, 26 and 41 in C_1, C_2 and C_3 respectively indicating the accumulation of favourable genes for seed yield by adopting recurrent selection method and recurrent selection has been effective in increasing yield of the population.

The response to recurrent selection for seed yield was evaluated by testing C_3 derived lines from C_3 of recurrent selection in 2006 and 2007. The result indicated that (Table 2) there is a close agreement between predicted and observed response to selection for seed yield per plant (46.08 and 49.53), number of primary branches per plant (8.39 and 8.75) and number of capitula per plant (38.05 and 32.32). However, for oil content, there is a lack of agreement between predicted (31.59) and actual response (27.88). This may be due to fact that the selection was mainly based on seed yield rather than oil content and non significant genetic correlation between seed yield and oil content. Therefore, for the improvement of oil content, the unit of evaluation and selection should be oil content or simultaneous selection for seed yield and oil content in safflower to accumulate favorable genes for yield and oil content. The selection for seed yield has resulted in non-significant and negative correlation with days to 50% flowering and days to maturity (Table 3) which may be due to breaking of positive correlation between maturity and yield due to intermating, suggesting that selection of recombinant lines with high yield and earliness.

Table 2. Expected and observed response to selection for seed yield and its components in random mating population of safflower (2007)

Sr. No.		Characters		Genetic Advance		Seed yield kg/ha	
				Expected	Observed	Selected line	Bhima
1		Seed yield/ Plant (g)		46.08	49.53	-	-
	i)	% increase over population mean		32.45	42.37	-	-
	ii)	% increase over Bhima (Check Variety)	(a)	24.92	9.34	1985 (24.37)	1596
			(b)	24.92	18.43	2091(31.0)	-
			(c)	24.92	42.71	2131 (35.52)	-
2		No. of primary branches/ plant		8.39	8.75		
	i)	% increase over population mean		11.87	16.67		
3		No. of Capitula/ plant		38.05	32.32		
	i)	% increase over population mean		11.95	23.83		
4		Oil content (%)		31.59	27.88		
	i)	% increase over population mean		4.53	-7.74		
5		C.D. ± at 5%				455	

Figure in parenthesis indicate % increase over check Bhima
Where, (a) – Mean of 10 % selected lines (4 lines) (b) – Mean of top yielding line from 10 % selected lines (c) – Mean of top yielding line from population.

Table 3. Genetic correlation with seed yield

Cycle	Days to flowering	Days to maturity	Oil content	No. of capitula per plant
C_1	-0.282**	-	-	0.173*
C_2	-0.015^{NS}	-0.377**	-	0.687**
C_3	-0.204**	-0.316**	0.217^{NS}	0.818**

NS : Non significant *, ** : Significant at 5% and 1% level respectively

The seed yield of 21 half sib families selected from C_3 ranged from 1040 to 2131 kg/ha compared to 1596 kg/ha for Bhima, AKS-207 (1535 kg/ha) and A_1 (1495 kg/ha). The percent increase in seed yield over check variety Bhima ranged from 24.37 to 35.52% (Table 2). The highest yield was recorded by half sib 68 (2131 kg/ha) followed by half sib 109 (2091 kg/ha) and half sib 92 (1985 kg/ha). The significant improvement in seed yield suggest that recurrent selection has been effective in increasing yield of population as well as extraction of superior yielding lines with broad genetic base.

These results indicate that the application of half sib recurrent selection method in a random mating population of safflower, segregating for genetic male sterility with 10 percent selection intensity is effective for safflower. The results also suggest that pure lines developed from a broad based population improved through recurrent selection can be selected that have yields superior to existing check varieties (Bhima, AKS-207 and A_1). Furthermore, these findings suggest that safflower breeders can utilize recurrent selection method for development of higher yielding varieties with broad genetic base.

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