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ORIGINAL ARTICLE

Evaluation of Three Cycles of Recurrent Selection for Improvement of Seed Yield in Safflower Using Genetic Male Sterility

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ABSTRACT
The present study was undertaken to determine extent of yield improvement expected after second cycle of recurrent selection from random mating population of safflower, to estimate genotypic and phenotypic correlations and to select the promising progenies significantly superior over checks AKS-207, Bhima. and PKV Pink. Total 150 half-sib families having sufficient seeds were selected from random mating population in safflower for second cycle evaluation. These half-sib families along with three checks (AKS-207, Bhima and PKV Pink) were grown in augmented block design in rabi 2013-14. The genetic variance among half-sib families ($\sigma^2_{H.S}$) and additive variance (σ^2_A) was high and significant for plant height (260.38 and 1041.52) followed by number of capitula per plant (106.04 and 424.16). Heritability estimates in narrow sense was highest for seeds per capitulam (90.89%) followed by seed yield per plant (88.58%), number of capitula per plant (87.91%), plant height (77.22),100 seed weight (g) (64.30%), number of primary branches per plant (57.38), oil content (55.55%), days to maturity (29.80),days to 50% flowering (27.93). The expected genetic advance was highest for the number of capitulum per plant over population mean (86.13%), over check variety AKS-207 (83.11%), over Bhima(87.87%) and over PKV Pink (80.00%) at 5% selection intensity. The seed yield per plant was significant and positively correlated with plant height (0.59), no. of primary branches per plant (0.71*), no. of capitulum per plant (0.73*) and 100 seed weight (g) (0.27*).The top 20 half-sib families observed to be significantly superior over AKS-207, Bhima and PKV Pink were selected for recombination cycle in further safflower population improvement programme during rabi 2015-16.*
***Keywords**: Safflower, Genetic Male Sterility, capitulum*

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INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is an important *rabi* oilseed crop of India. India is the largest producer of safflower in the world. Safflower is cultivated in more than 60 countries, but more than half is produced in India, mainly for vegetable oil market [10]. The largest hactarage of safflower is in the south –central India. In India, safflower is mainly grown as a rainfed crop. It has a long taproot system, thrives well in lighter soils and can easily adapt with saline alkaline conditions. It gives better option to farmers in dry land for crop rotation and can give more yield under protective irrigation condition [8].

Population improvement is the method mainly applied to cross pollinated crops. Breeders are paying more attention to population improvement programs. The productivity of safflower is very low due to lack of genetically improved cultivars with high oil content. Therefore, there is urgent need to develop improved cultivars for obtaining breakthrough in productivity potential of this crop through genetic manipulations, which can be possible by recurrent selection.

The conventional breeding methods are useful only for recombining simply inherited characters. Therefore, preference is towards population improvement for improving quantitatively inherited characters like seed yield, oil content, tolerance to diseases and insects [4].

The advantages of using recurrent selection are that each cycle of selection is completed in two years and the best lines are being recombined as soon as they have been identified. In more conventional breeding programme, it takes several years to identify and yield test elite lines and it may be eight or ten years before they are used as parents for the next cycle of selection [13].

MATERIAL AND METHODS

The present study entitled "Evaluation of the second cycle half-sib using genetic male sterility in safflower" was conducted at the field of Oilseeds Research Unit, Dr. PDKV Akola during Rabi 2012-2013 and 2013-2014.The experimental material was obtained from the Senior Research Scientist, Oilseeds Research Unit, Dr. PDKV Akola.

New random mating population using new GMS line *viz* HUS-MS-305 which was supplied by Nagpur center has been developed in collaboration with two safflower AICRP center, viz., Akola and Solapur. Akola center were effected 25 crosses using 25 males viz., NARI-SPS-34-46, NARI-SPS-50-1, AKS/S 41, GMU-2924, AKS-NS-1, PBNS-33, PBNS-58, GMU-148, GMU 2914-2, GMU 4811, PBNS-40, AKS-207, N-7, AKS 311, SSF 674, Bhima, A-1, JSI 99, GMU 3293, GMU 3420, PI-SPS-21-8, GMU 2724, C-2829-5-39-6, MMS during the year 2008-09 and F_1s were raised during 2009-10. At Solapur 25 crosses were effected and parents used were IVT 07-1, IVT 07-6, SSF 687, SSF 674, SSF 710, SSF 714, SSF 678, NARI 42, SSF 682, SSF 679, SSF 33, NARI 36, SSF 698, SSF 648, 99-1-1, 97-12—B, 11-17-2, 8-10-4-10, 6-9-2, 8-1-4, AV 98933, SSF 625, 24, Bhima. F1 seeds from Akola and Solapur centre mixed in equal quantity to construct base population and sown for the first cycle recombination during 2010-11. First cycle of evaluation was carried out with 135 families having sufficient seeds. Remnant seeds of top ranking families were mixed together in equal quantity to carry out second cycle of recombination. It was sown for second cycle recombination during 2012-13. One hundred and fifty male sterile plants were selected. Out of these 150 plants,120 having sufficient seeds were selected for evaluation and sown in Augmented Block Design in three replications along with three checks (AKS-207,BHIMA and PKV Pink), for second cycle evaluation keeping remnant seeds. In 2013-14 at Oilseed Research Unit, Dr. PDKV Akola.

The data were recorded on five randomly selected competitive fertile plants from each progeny for days to 50 per cent flowering, days to maturity, plant height (cm), number of primary branches plant-1, number of capitula plant-1, number of seeds capitulum-1, 100 seed weight (g), oil content (%) and seed yield plant-1 (g).

RESULTS AND DISCUSSION

Progeny components of variances

The significant and large genetic variation among progenies is prerequisite of recurrent selection programme. In the present study, the variability parameters like, genotypic variance, phenotypic variance, genotypic coefficients of variation (G.C.V.), phenotypic coefficient of variation (P.C.V.) and heritability estimates in broad sense (h2 b.s.) were estimated for all the nine characters and results obtained have been presented in Table 1.

The mean sum of square due to the half-sib families were found significant for number of capitulas per plant, number of seeds per capitulum, and seed yield per plant (g) indicating substantial genetic variability existed among half sib families after second cycle of recurrent selection. Except days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant,100 seed weight and oil content.

Estimation of half-sib family component of variance and heritability

The genetic variance among half-sib families ($\sigma^2_{H.S}$) and additive variance (σ^2_A) was high and significant for plant height (260.38 and 1041.52) followed by number of capitula per plant (106.04 and 424.16), number of seeds per capitulum (96.29 and 385.16),seed yield per plant (90.39 and 361.56), days to 50% flowering (27.45 and 109.80),days to maturity (23.29 and 93.16), oil content (5.29 and 23.16), 100 seed weight (g) (2.09 and 8.36) and number of primary branches per plant(1.71 and 6.84) respectively.

The significant and high genetic variance among half-sib families was reported Reddy [12], Mummaneni [6], Tayade [14].

The estimates of heritability in safflower population segregating for genetic male sterility are useful in determining the best method of selection to improve population for specific traits and genetic study of quantitative traits in its predictive role, expressing the reliability of the phenotypic value as guide to breeding value.

In the present study, narrow sense heritability estimates ranged from 27.93 per cent for days to 50% flowering to 90.89 per cent for number of seeds per capitulam. The heritability was found slightly higher for seed yield per plant (88.58%), followed by number of capitula per plant (87.91%), plant height

(77.22),100 seed weight (g) (64.30%), number of primary branches per plant (57.38), oil content (55.55%), days to maturity (29.80),days to 50% flowering (27.93%). High estimates of heritability have been reported in random mating population of safflower for several agronomic traits by Reddy [12], Mummaneni [6], Naole [7], Lande *et al*.[5] and Deshmukh *et al*. [1], Tayade [14].

Expected genetic advance with half-sib family selection

Genetic advance is measure of expected progress under selection and it depends on the magnitude of genetic variance, heritability and selection intensity. The information about magnitude of genetic variance and heritability can be used in ascertaining the possibility of extracting superior half-sib families for use in the development of superior safflower varieties.

In the present study, the expected genetic advance at 5, 10 per cent selection intensity expressed as per cent of population mean, per cent over check varieties AKS-207, Bhima and PKV Pink have been presented in table-3 and discussed as under.

The expected genetic advance expressed as per cent of population mean at 5 and 10 per cent selection intensity was highest for number of capitulum per plant (86.13 and 73.17 respectively), followed by number of seeds per capitulum (75.28 and 63.95 respectively), plant height (41.25 and 35.04 respectively), 100 seed weight (g) (40.96 and 34.79), seed yield per plant (31.00 and 26.34 respectively), number of primary branches per plant (28.74 and 24.41respectively), oil content (12.21 and 10.37 respectively), day to 50% flowering (6.56 and 5.57 respectively), day to maturity (3.27 and 2.77 respectively).

The expected genetic advance over AKS-207 at 5 and 10 per cent was high for number of capitulum per plant (83.11 and 70.60 respectively) followed by no. of seed per capitulum (74.29 and 63.11 respectively), plant height (45.03 and 38.29 respectively), 100 seed weight (g) (43.42 and 36.88 respectively), seed yield per plant(34.44 and 29.56 respectively), no. of primery branches per plant (31.11 and 26.49 respectively), oil content (11.77 and 10.00 respectively), day to 50% flowering (6.70 and 5.59 respectively), day to maturity (3.26 and 2.77 respectively).

The expected genetic advance over Bhima at 5 and 10 per cent was high for number of capitula per plant (87.87 and 74.31 respectively), no. of seed per capitulum (73.06 and 62.07 respectively), followed by plant height (48.18 and 40.93 respectively), 100 seed weight (g) (43.74 and 37.15 respectively), seed yield per plant(33.12 and 28.14 respectively),no. of primery branches per plant (30.27 and 25.71 respectively), oil content (12.11 and 10.29 respectively), day to 50% flowering (6.81 and 5.78 respectively) and day to maturity (3.27 and 2.77 respectively).

The expected genetic advance over PKV Pink at 5 and 10 per cent was high for no. of capitulum per plant (80.00 and 67.96 respectively), followed by no. of seed per capitulum (65.31 and 55.48 respectively), plant height (41.59 and 32.42 respectively), 100 seed weight (37.47 and 31.83 respectively), seed yield per plant (31.66 and 26.89 respectively), no. of primary branches per plant (23.74 and 20.17 respectively), oil content (11.55 and 9.81 respectively), days to 50% flowering (6.80 and 5.77 respectively), and day to maturity (3.22 and 2.73 respectively). Considerable genetic variability was observed for the characters under study, this indicated that, there is scope for further improvement of yield and its contributing characters.

In safflower, Reddy (2002) reported 11.52, 9.84 and 7.82 per cent genetic advance in seed yield per plant at 5, 10 and 20 per cent selection intensity in random mating population of safflower after one cycle of recurrent selection. Naole [7] revealed expected genetic advance obtained from second cycle of recurrent selection was 28.80, 23.99 and 19.08 percent at 5, 10 and 20 per cent selection intensity. The same from 3rd cycle of recurrent selection was 42.12, 35.90 and 28.62 with 5, 10 and 20 per cent selection intensity respectively. This clearly indicates the accumulation of favorable genes for yield.

Simple correlation

The simple correlation among different traits were estimated and have been presented in table 4. The experiment of recurrent selection are mainly designed and conducted for improving seed yield per plant. However, this does not means that other traits are unimportant. Selection for high yield does some extent is indirect selection for disease and insect resistance and for this correlated with yield [3]. However, if selection is for high seed yield alone undesirable correlated response may occurs in other traits as pointed out by Doggett [2]. In the present study the simple correlations among nine different yield contributing characters have been presented in table-5.

The simple correlation for days to 50% flowering showed positive and significant correlation with days to maturity (0.44**). Plant height exhibited significant and positive correlation with number of primary branches per plant (0.63**), number of capitula per plant (0.57**), number of seeds per capitula (0.61**), seed yield per plant (0.59**). Number of primary branches per plant showed significant and positive correlation with number of capitula per plant (0.53**), seed yield per plant (0.71**). Number of capitula per plant showed significant and positive correlated with 100 seed weight (0.21*) and seed yield per plant (0.73**). 100 seed weight (g) shows significant and positive correlation with seed yield per plant (0.27**).

Patil *et al*. [11], Pandya *et al*. [9], Reddy [12] and Naole [7] reported significant positive correlations between seed yield and yield contributing characters.

Identification of promising half-sib families over checks

The objective to study recurrent selection method is to increase the frequency of desirable genes thereby increase frequency of better lines than check variety. In present study, 20 half-sib families were selected on basis of high seed yield per plant and other top ranking half sib selected for yield contributing character significantly superior over checks AKS-207, Bhima and PKV Pink.

Reddy [12], Naole [7] reported 4, 26 and 41 lines significantly superior over Bhima and A1 from first, second and third cycle of recurrent selection respectively suggesting that accumulation of favorable genes for seed yield results in increased frequency of superior lines over three cycles.

Table 1. Analysis of variance for various characters in half-sib families of safflower

Source of variation	**Df**	**Days to 50% flowering**	**Days to maturity**	**Plant height (cm)**	**No. of Primary branches per plant**	**No.of capitulas per plant**	**No.of seeds per capitulum**	**100 seed weight (g)**	**Oil content (%)**	**Seed yield per plant (g)**
Block (ingnoring treatment)	2	9.41	49.69	41.00	0.89	22.02	4.51	0.07	1.26	9.46
Entries (ingnoring Block)	122	35.26	23.87	353.88	3.17	127.82 *	114.99 **	1.3	10.47	107.54 *
Checks	2	42.46	44.91	1303.75 *	15.63 *	566.66 **	665.76 **	4.26	14.09	448.88 **
Checks + half sib vs. half-sib	120	98.14	76.52	338.05	2.96	120.51 *	105.81 **	3.2	10.41	101.85 *
Error	4	70.82	54.85	76.80	1.27	14.58	9.64	1.16	4.70	11.65
Block eliminating (check+ half-sib)	2	18.88	2.28	20.24	0.86	2.04	1.37	0.10	1.49	7.15
Entries (ingnoring Block)	122	35.11	24.65	354.22	3.17	128.15 *	115.04 **	1.29	10.47	107.58 *
Checks	2	42.46	44.91	1303.75 *	15.63 *	566.66**	665.76 **	4.26	14.09	448.88 **

102.04 *	83.867 *	11.65
10.49	0.04	4.70
3.25	0.952	1.16
105.93 **	97.67 *	9.64
120.62 *	147.63 *	14.58
2.98	0.90	1.27
337.18	483.41	76.80
78.14	44.57	54.85
98.27	1.57	70.82
119	1	4
Half-sib	Checks vs. half-sib	Error

Table 2. Estimation of half-sib family component of variance and heritability in narrow sense

Seed Yield per plant (g)	90.39	361.56	102.04	0.88
Oil content %	5.79	23.16	10.49	0.55
100 seed weight (g)	2.09	8.36	3.25	0.64
No. of seed per capitulum	96.29	385.16	105.93	0.90
No. of capitula per plant	106.04	424.16	120.62	0.87
No. of Primary branches per plant	1.71	6.84	2.98	0.57
Plant height (cm)	260.38	1041.52	337.18	0.77
Days to maturity	23.29	93.16	**78.14**	0.29
Days to 50 % Flowering	27.45	109.8	**98.27**	0.27
Half- sib family Component	σ^2 (H.S.) = M_F - M_E	$\hat{\sigma}^2 A = 4 \times \hat{\sigma}^2$ (H.S.)	$\hat{\sigma}^2 P$ (H.S.) = $\frac{1}{4}\hat{\sigma}^2_A + \hat{\sigma}^2_e$	h^2 (n.s.) = $\frac{\frac{1}{4}\sigma^2_A}{\frac{1}{4}\sigma^2_A + \sigma^2_e}$

Table 3. Expected genetic advance in per cent per cycle using recurrent selection system in safflower

Unit of evaluation and Selection	Cycle	Selection intensity	Days to 50 % flowering	Days to maturity	Plant height (cm)	No. of Primary branches per plant	No. of capitula per plant	No. of seed per capitulum	100 seed wt (g)	Oil content (%)	Seed yield per plant (g)
Expected genetic advance over mean population											
Half-Sib	2	5%	6.56	3.27	41.25	28.74	86.13	75.28	40.96	12.21	31.00
		10%	5.57	2.77	35.04	24.41	73.17	63.95	34.79	10.37	26.34
Expected genetic advance over AKS- 207											
Half-Sib	2	5%	6.70	3.26	45.07	31.18	83.11	74.29	43.42	11.77	34.44
		10%	5.69	2.77	38.29	26.49	70.60	63.11	36.88	10.00	29.56
Expected genetic advance over Bhima											
Half-Sib	2	5%	6.81	3.27	48.18	30.27	87.87	73.06	43.74	12.11	33.12
		10%	5.78	2.77	40.93	25.71	74.31	62.07	37.15	10.29	28.14
Expected genetic advance over PKV Pink											
Half-Sib	2	5%	6.80	3.22	41.69	23.74	80.00	65.31	37.47	11.55	31.66
		10%	5.77	2.73	35.42	20.17	67.96	55.48	31.82	9.81	26.89

CONCLUSIONS

On the basis of population mean, heritability estimates in narrow sense was highest for seeds per capitulam (90.89%) followed by seed yield per plant (88.58%), number of capitula per plant (87.91%), plant height (77.22),100 seed weight (g) (64.30%), number of primary branches per plant (57.38), oil content (55.55%), days to maturity (29.80),days to 50% flowering (27.93%). The estimates of heritability in safflower population segregating for genetic male sterility is useful method of selection to improve population for specific trait.

The expected genetic advance over population mean was observed highest for the character number of capitulum per plant at 5 (86.13) and 10 (73.17) per cent selection intensity followed by number of seed per capitulum at 5 (75.28) and 10 (63.95) percent. Highest expected genetic advance over AKS-207 was recorded for number of capitulum per plant at 5 (83.11) and 10 (70.60) followed by number of seed per capitulum at 5 (74.29) and 10 (63.11) percent selection intensity. Over PKV Pink the expected genetic advance recorded was highest for the character number of capitula per plant at 5 (80.00) and 10 (67.96) percent selection intensity followed by number of seeds per capitulam at 5 (65.31) and 10 (55.48) percent. Highest expected genetic advance over Bhima was recorded for number of capitula per plant at 5 (87.87) and 10 (74.31) selection intensity followed by number of seeds per capitulam at 5 (73.06) and 10 (62.07) percent.

In 2nd cycle of recurrent selection for, the seed yield per plant was significant and positively correlated with plant height (0.598*), no. of primary branches per plant (0.71**), no. of capitulum per plant (0.73**) and 100 seed weight (g) (0.27*).

The top 20 half-sib families significantly superior over AKS-207, Bhima and PKV Pink were selected for recombination cycle in safflower population improvement programme during *rabi* 2015-16.

Promising lines/plant for yield and oil content will be sort out and after selection these lines will be utilized in breeding programme or can be tested in PYT/MVT trials for testing their potential.

Table 4. Simple correlations among nine quantitative yield contributing characters for the half-sib selection of safflower.

Character	Days to 50% flowering	Days to maturity.	Plant height (cm)	No.of Pr.branches /plant	No.of capitulas /plant	No. of seed /capitulum	100 seed weight	Oil content	seed yield per plant
Days to 50% flowering	1								
Days to maturity.	0.44**	1							
Plant height (cm)	0.01	0.05	1						
No.of Primary branches per plant	0.06	0.05	0.63**	1					
No.of capitula per plant	0.08	0.04	0.57**	0.53**	1				
No.of seeds per capitulum	0.09	0.02	0.61**	0.12	0.07	1			
100 seed wt (g)	-0.01	-0.08	0.06	0.16	0.21*	0.17	1		
Oil Content (%)	-0.16	-0.16	0.03	0.02	0.03	0.13	0.03	1	
Seed yield per plant (g)	0.10	0.05	0.59**	0.71**	0.73**	0.17	0.27**	0.16	1

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