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Efficiency of early generation selections for yield and related characters in safflower (*Carthamus tinctorius* L.)

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Abstract The efficiency of early generation selection for yield and related characters in safflower (*Carthamus tinctorius* L.) was studied in the F_2, F_3 and F_4 generations. Twenty-five F_2 progenies derived from various crosses were studied. In the F_2 generation, number of capitula per plant (CNSP), number of seeds per capitulum (SPSP), test weight (SWSP), and seed yield (SYSP) were the criteria used for single plant selection. The analysis of variance showed significant differences for all of the characters in the F_2, F_3, and F_4 generations. The analysis of variance in each of the selection classes showed highly significant genotypic differences. A large number of selections in the CNSP and SYSP classes showed greater yield than the check variety. In each class the mean for that particular character showed a positive shift. The observed F_3 and F_4 means for seed yield per plant was higher in SYSP, indicating the effectiveness of single plant selection for yield. Correlated response showed that selection for number of capitula per plant was effective for improvement of yield.

Key words Plant breeding · Early generation selection · Selection method

Introduction

The importance of early generation testing in order to know the genetic potential of the selected lines has been emphasised by Cooper (1976), Ntare et al. (1984), Dahiya et al. (1984), and Salimath and Bahl (1985). These authors followed different methods of selection in early generation and reported its usefulness in self-pollinated crops. Safflower (*Carthamus tinctorius* L.) is one of the most important oilseed crops in the semi-arid tropics, but as yet, no information is available on the efficiency of early generation selection in relation to the improvement of yield and related characters. The objective of the investigations presented here were to study the selection response based on the selection for yield and related characters in early generations.

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Materials and methods

The experimental material included F_2 progenies of 25 hybrids of safflower developed at the Department of Genetics and Plant Breeding, Marathwada Agricultural University, Parbhani. These progenies were selected on the basis of the general combining ability of the parents and the per se performance of the crosses in the F_1 generation (Pandya 1988). The segregating progenies studied included five dominant genetic male steriles (MS 101–105) crossed with ten male parents ('Annigeri', 'Bly 652', 'B-3-16-57', 'BSF 9–97', 'JLSF 49', 'JLSF 88', 'NDS 1', 'NS 1016', 'PS 1', and 'Bhima'). Only fertile plants were used.

In 25 F_2 progenies selection was carried out for number of capitula per plant (CNSP), number of seeds per capitulum (SPSP), test weight (SWSP), and seed yield per plant (SYSP). In each of the selection groups 60 selections were included for further study.

Half of the seed from each of the selected plants for the capitula number (CNSP) and seed yield per plant (SYSP) group was grown during the *summer* season to advance to the F_4 generation.

Table 1 Percentage of progenies with a higher mean than the check variety 'Bhima' in different selection series (*CNSP* Capitula number selection pressure, *SPSP* seeds per capitulum selection pressure, *SWSP* seed weight selection pressure, *SYSP* seed yield selection pressure)

	Number of capitula/ plant	Number of seeds/ capitulum	Test weight (g)	Seed yield/ plant (g)
F_3 Generation				
CNSP	50.0	28.3	20.0	43.3
SPSP	60.0	60.0	28.3	40.0
SWSP	30.0	48.3	78.3	23.3
SYSP	63.0	95.0	30.0	85.0
F_4 Generation				
CNSP	60.0	93.3	38.3	90.0
SYSP	90.0	76.6	6.6	83.3

Table 2 Response to selection for yield and other characters (*GA* Genetic advance)

	Number of capitula/plant	Number of seeds/capitulum	Test weight (g)	Seed yield/ plant (g)
a In capitula number selection pressure				
$F_2 \pm GA$	26.4 ± 4.0	34.9 ± 0.7	6.0[a] ± 0.7	32.1 ± 5.5
Control	21.5	33.0	5.7[a]	25.8
Expected F_3 (% over control)	141.4	108.1	153.5	146.0
Observed F_3	19.5	24.3	58.6[b]	15.5
Control	19.0	27.5	64.3[b]	15.8
Observed F_3 (% over control)	102.7	88.5	91.2	98.3
$F_3 \pm GA$	19.5 ± 5.0	24.3 ± 3.5	58.8[b] ± 13.8	15.5 ± 4.4
Control	19.0	27.5	64.3[b]	15.8
Expected F_4 (% over control)	129.1	101.3	112.7	128.2
Observed F_4	21.9	24.6	57.1[b]	25.9
Control	20.2	18.5	58.0[b]	17.9
Observed F_4 (% over control)	108.8	133.0	98.5	145.0
b In seeds per capitulum selection pressure				
$F_2 \pm GA$	26.4 ± 4.0	34.9 ± 2.7	6.0[a] ± 2.7	32.1 ± 5.5
Control	21.5	33.0	5.7[a]	22.8
Expected F_3 (% over control)	141.4	108.1	153.5	146.0
Observed F_3	17.6	32.4	48.3[b]	15.9
Control	16.5	29.9	50.6[b]	16.6
Observed F_3 (% over control)	106.7	108.3	94.4	95.6
c In seed weight selection pressure				
$F_2 \pm GA$	26.4 ± 4.0	34.9 ± 0.7	6.0[a] ± 0.7	32.1 ± 5.5
Control	21.5	33.0	5.7[a]	25.8
Expected F_3 (% over control)	141.4	108.1	153.5	146.0
Observed F_3	18.5	23.6	68.0[b]	16.4
Control	19.1	24.9	64.1[b]	17.9
Observed F_3 (% over control)	96.7	95.0	106.0	91.4
d In seed yield selection pressure				
$F_2 \pm GA$	26.4 ± 4.0	34.9 ± 0.7	6.0[a] ± 0.7	32.1 ± 5.5
Control	21.5	33.0	5.7[a]	25.8
Expected F_3 (% over control)	141.4	108.1	153.5	146.0
Observed F_3	18.6	23.9	58.6[b]	22.1
Control	17.9	16.9	61.0[b]	16.4
Observed F_3 (% over control)	104.0	141.6	96.0	134.8
$F_3 \pm GA$	18.6 ± 5.0	23.9 ± 10.2	58.6[b] ± 11.6	22.1 ± 10.6
Control	17.9	16.9	61.00[b]	16.4
Expected F_4 (% over control)	132.3	202.1	115.1	119.5
Observed F_4	19.2	24.9	57.9[b]	17.2
Control	16.6	20.1	65.0[b]	15.6
Observed F_4 (% over control)	115.8	123.9	89.2	110.5

[a] Test weight (g) for 100 seeds
[b] Test weight (g) for 1000 seeds

During rabi 1989–1990 two sets of experiments were planted in the F_3 and the F_4 generations. In the F_3 generation four experiments, one for each of the selection groups CNSP, SPSP, SWSP and SYSP, were conducted, whereas in the F_4 generation two experiments for selection group CNSP and SYSP were conducted with the check 'Bhima' and 'N 62–8'. All of the experiments were conducted in a randomised complete block design with two replications. Two-row plots were used with 45 cm between rows; the row length was 3 m and the plants in each row were spaced 15 cm apart. Data were collected from each progeny on an individual plant basis with the progeny means used for statistical analysis. The data were analysed as a randomised complete block design for each generation using the appropriate statistical procedures. Correlated response was calculated according to Falconer (1960).

Results and discussion

The analysis of variance for number of capitula per plant, number of seeds per capitulum, test weight, and

Table 3 Correlated response for seed yield per plant in F_3 and F_4 generations (*NI* Not Included in this study)

Selection character	Expected Correlated response over (%control)	Observed F_3 mean	Control mean	Observed correlated response over (%control)	Expected correlated response (% control)	Observed F_4 mean	Control mean	Observed correated response over (% control)
Number of capitula/plant	165.5	15.5	15.8	98.3	112.4	25.9	17.9	145.0
Number of seeds/capitulum	149.6	15.9	16.6	95.7	NI	–	–	–
Test weight	148.7	16.4	17.9	91.4	NI	–	–	–

seed yield conducted for the F_2, F_3, and F_4 generations showed highly significant differences. This indicated a significant variability among progenies for these characters. The variance analysis of the F_3 generation in the four selection classes (CNSP, SPSP, SWSP, and SYSP) indicated highly significant differences for these characters in each of the selection groups, which confirms the additive genetic control of these characters in the parental lines used (Pandya et al. 1990). In the F_4 generation of the CNSP and SYSP selection classes, the differences were also highly significant.

Mean performance in the F_3 and F_4 generations

In the three CNSP, SPSP and SWSP selection groups some of the selections surpassed the check 'Bhima', but at a frequency less than 50%. The frequency of superior genotypes for each character was always maximum in that group of progenies derived from the application of selection pressure for that particular character (Table 1). Similar results have been reported by Salimath and Bahl (1985) in chick pea (*Cicer arietinum* L.). In the yield per plant selection group (SYSP), the general mean of the progenies was higher than the mean of the check variety. These results suggest that selection based on individual plant yield is more effective than selection based on the other three characters. Dahiya et al. (1984) reported that an early generation yield testing selection procedure is more efficient than visual selection for yield improvement in chick pea. They emphasised that the F_3 yield trials were more effective.

The major disadvantage of yield testing F_3 lines is the limited number of progenies that can be tested. A second consideration is the importance of interplant competition within plots. Allard and Adams (1966) found that high yielding lines of poor competitive ability suffer heavy reduction in productivity in mixtures. In the present study, the rejection of lines solely on the basis of yield in the F_3 generation yield trial may reduce the number of desirable segregants in future generations because there is severe interplant competition in safflower. Secondly, nonadditive gene action is predominant in the control of yield and related characters (Ramchandram and Goud 1982; Pandya 1988).

In the F_4 generation, 90% and 83% of the progenies in the CNSP and SYSP selection group, respectively, showed high yield. The percentage of selections with higher yield in the F_3 and F_4 generations was more or less equal in the SYSP selection group. Similar results have been reported by Whan et al. (1981) in wheat (*Triticum aestivum* L.), and these investigators concluded that selection for yield in the F_2 is effective under the same set of environments. Ntare et al. (1984) reported significant correlations between F_3 yield and that of later generations.

Selection response

In each of the selection groups there was a positive shift in mean values for the characters selected, suggesting the effectiveness of selection. In CNSP F_4 the shift of mean yield per plant indicated that breeding for higher yield through increased number of capitula per plant is important in safflower (Table 2). The observed F_3 and F_4 means for seed yield per plant in SYSP were higher than that of the respective control. This indicated the effectiveness of selection. The data suggest the importance of capitula per plant and yield as a selection criterion in early generations. The response in the SPSP and SWSP selection group was poorer, indicating an ineffectiveness in selection for yield.

Correlated response

The calculated correlated responses for seed yield when selection was conducted for number of capitula per plant, number of seeds per capitulum, and test weight revealed that the expected and observed correlated responses of the F_3 deviate from each other (Table 3). However, the observed correlated response was higher than expected correlated response in the CNSP class of selections. The mean of some of the selected families was significantly higher than that of the check 'Bhima' because the correlation between capitula per plant and yield was highly significant. This implies that indirect selection for yield through number of capitula per plant was effective. The overall deviations of selection responses in safflower can be at-

tributed to the greater responsiveness of this crop to growing conditions and higher genotype-environment interactions.

The present study revealed that number of capitula per plant and yield per plant have to be considered important in individual plant selection in early segregating generations. Selection based on these characters may help in improving the genetic potential of productivity in safflower.

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