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Towards developing a productive and non-spiny genotype in safflower(*Carthamus tinctorius* L.)

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Abstract
Safflower, being the source of healthy cooking oil, is a valuable oil seed crop of central and southern parts of India. Developing a productive and non-spiny variety is an important breeding objective. The results from such initiative which is underway are discussed. Using A-1, a popular productive spiny variety and SS-101, a less productive but non-spiny variety, straight F_2 and two backcross F_2s derived by backcrossing F_1 twice to SS-101 were generated. It thus ensured genomic proportion of A-1 and SS-101 in 50:50, 25:75 and 12.5:87.5 respectively. Considering mean, range and coefficient of variance, straight F_2 appeared to be better population than backcross F_2 populations. The proportion of transgressive segregants in the positive direction was higher in straight F_2 compared to backcross F_2 populations. But with the objective of obtaining the segregants which are not only non-spiny but also productive, straight F_2 appeared to be promising. A proportion of 5.45% of F_2 population was productive and non-spiny while, it was just 3.45% and 1.45% in BC1F_2 and BC2F_2, respectively. In case of straight F_2 the productivity of three top non-spiny types ranged from 56g to as high as 76g plant^{-1}. But in BC_1F_2 and BC_2F_2 the productivity of each of the non-spiny types was just 54 and 50g plant^{-1}, respectively. Based on the present results, it is suggested that the F_1 of A-1 x non-spiny type may be backcrossed to A-1 which may provide better opportunity of recovering still more productive segregants. Intermating in the F_3 of this backcross population as well as F_2 progeny may help in recovering higher percentage of segregants combining productivity and non-spiny nature.

Key words: Safflower, non-spiny, productivity, intermating, backcross

Introduction
Safflower (*Carthemus tinctorius* L.) is an important oil seed crop known for its better quality oil and contains high linoleic acid associated with the reduction of cholesterol level in the blood of humans (Weiss, 1983). It is also a source of important biochemicals like $\propto$-tocopherol and carthemin. But unfortunately, the area and production of safflower in India has experimented a downward trend for the last 4-5 years due to various constraints (Damodaram and Hegde, 2007). One of the major constraints is the spiny nature of traditional varieties causing major hindrance for spread of safflower to non-conventional areas and decrease in the area in traditional belts as well as causing lot of problems in its cultivation including harvesting. Non-spiny genotypes are now available for cultivation and are becoming popular to the farmers. However, they are found to be highly susceptible to aphids and associated with low yield and longer duration for maturity (Patil and Ravikumar, 2005). Therefore, it is required to improve the yield potentiality of non-spiny genotypes coupled with resistance to aphid, which may help in reviving the interest of farmers in safflower cultivation. In this direction, breeding efforts are underway at the Agricultural Research Station, Annigeri in Karnataka State of India.

Materials and Methods
A widely adapted and very popular cultivar A-1 was crossed to non-spiny genotype SS-101 in order to recombine the yield parameters and adaptability of A-1 with non-spiny nature of SS-101. The F_1s were selfed to obtain F_2, and backcrossed to the non-spiny SS-101 for BC_1F_2 and BC_2F_2 populations. It thus ensured genomic proportion of A-1 and SS-101 in 50:50, 25:75 and 12.5:87.5 respectively.

All the three populations were evaluated by sowing in a non-replicated blocks along with parents. Crop management practices like spacing (45 x 15 cm), fertilizer dose (40:40:20 kg/ha) and plant protection as per recommended schedule were followed. Observations on quantitative traits were recorded in 10-plants of parents and 150-plants each in F_2, BC1F_2 and BC2F_2 populations.

Results and Discussion

The results indicated that the F_2 population with genomic proportions of 50:50 of A-1 and SS-101 was better than backcross populations for obtaining segrants with improved yield and non-spiny type. The mean, range and coefficient of variance were higher for seed yield per plant in the F_2 population than backcross F_2 populations (Table 1 and Fig. 1&2). The same trend was observed for head diameter. The mean of F_2 was also high in respect of all the parameters studied as compared to backcross F_2 populations. In respect of range, the F_2 showed desirable range in respect of number of branches, number of seeds per head and also head diameter. More or less similar trend was observed with respect to coefficient of variance for all the traits.

Table 1: Variability parameters for different quantitative traits in straight and backcross populations of safflower

Character	Parameter	A-1	SS-101	A-1 x SS-101	A-1 x SS-101 x SS-101	A-1 x SS-101 x SS-101 x SS-101
		Parent 1	Parent 2	F_2	BC_1F_2	BC_2F_2
No. of Branches	Mean	12.30	11.67	13.8	9.58	6.60
	Range			5-29	4-30	3-15
	Coeff. Of Variance			38.64	49.60	30.10
No. of capitula/plant	Mean	31	15.44	22.09	18.49	13.15
	Range			4-43	5-50	5-26
	Coeff. Of Variance			36.30	68.80	37.20
Capitula diameter(cm)	Mean	2.23	2.93	2.61	2.37	2.57
	Range			2-3.4	1.9-2.8	1.5-3.1
	Coeff. Of Variance			11.40	8.40	10.30
No. of seeds/plant	Mean	26.80	56.67	35.67	25.37	34.16
	Range			0-90	1-68	0-74
	Coeff. Of Variance			44.9	55.5	42.2
Seed yield/plant	Mean	49.40	21.67	28.62	24.90	23.62
	Range			0-86	2-54	2-50
	Coeff. Of Variance			57.1	52.7	41.6

A critical analysis of nature of transgressive segregation also suggested that the transgressive segregants in the positive direction were higher in F_2 for all the traits including seed yield. It thus indicated that F_2 provides better opportunity for selecting high yielding lines than from other backcross F_2 populations. Further, the percentage of non-spiny types gradually increased from straight F_2 (58.5%) to BC_1F_2 (63.0%) and BC_2F_2 (77.5%) (Table 2). This is expected since backcross with non-spiny types was expected to recover higher proportion of genome of non-spiny types. But with the objective of obtaining the segregants which are not only non-spiny but also productive, then straight F_2 appeared to be promising with three of the segregants showing both non-spiny nature and yield exceeding A-1, which is a high yielding and widely adopted spiny variety.

But in the BC_1F_2 and BC_2F_2 there was only one segregant in each of desirable type. In terms of the proportion of total population 7.7% of F_2 population was non-spiny and productive and this reduced with backcrossing from 5.9% in BC_1F_2 to 5.0% in BC_2F_2.

Table 2: Transgressive segregants obtained for spiny and non-spiny nature of safflower in straight and its backcross populations.

Population	No. of spiny plants	No. of non-spiny plants	Total plants	Non-spiny (%)	No. of desirable non-spiny segregants	Desirable non-spiny segregants (%)
F_2	39	55	94	58.5	3	7.7
BC_1F_2	17	29	46	63.0	1	5.9
BC_2F_2	20	69	89	77.5	1	5.0

In case of straight F_2 the productivity of three top non-spiny types ranged from 56gm per plant to as high as 76g per plant compared with 49.4g for A-1. But in BC_1F_2 and BC_2F_2 the productivity of each of the non-spiny types was just 54 and 50g respectively which was higher than A-1 but much lower than the productivity of non-spiny high yielding segregants obtained in straight F_2 (Table 3).

Table3: Performance of spiny and non-spiny genotypes for seed yield per plant in three F2, BC_1F_2 and BC_2F_2 populations

Population	F_2		BC_1F_2		BC_2F_2	
	Seed yield per plant (g)					
Sl. No.	Spiny	Non-Spiny	Spiny	Non-Spiny	Spiny	Non-Spiny
1	66	68	50	54	-	50
2	86	76	50	-	-	-
3	56	56	-	-	-	-

It is very interesting to note here that top six entries obtained in straight F_2 differed in yield attributing traits indicating importance of different traits in manifestation of higher yield (data not shown). Such segregants can be explored to pool all positive alleles by involving them in an intermating programme in the next generation, and thus eliminating negative alleles contributed by SS-101 by recombination. Contribution of negative alleles by SS-101 lowered the mean performance of backcross populations

Based on the present results, it is suggested that the F_1 of A-1 x SS-101 should be backcrossed to A-1 which may provide better opportunity of recovering still better productive non-spiny segregants. However, that may result in lower frequency of non-spiny types but intermating the BC_1F_2 progeny of the backcross population, and with promising F_2 progeny, may help in recovering a higher percentage of segregants combining productivity and non-spiny nature. Recombination of the two traits spinelessness and high yield would definitely pave way for the future high yielding spineless safflower varieties.

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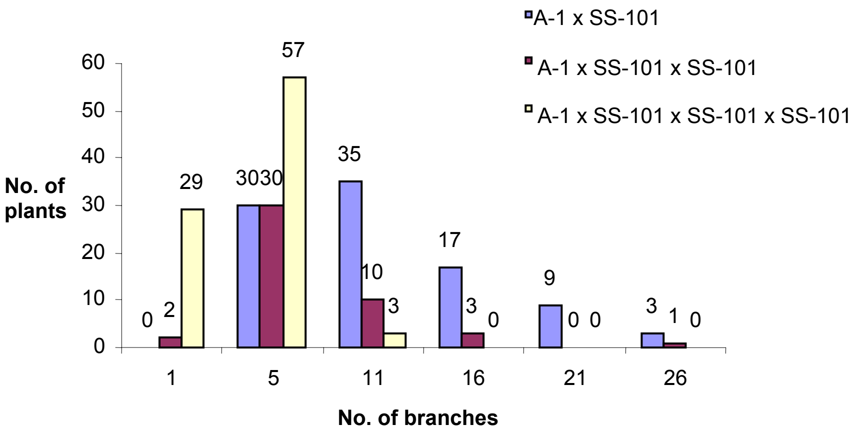

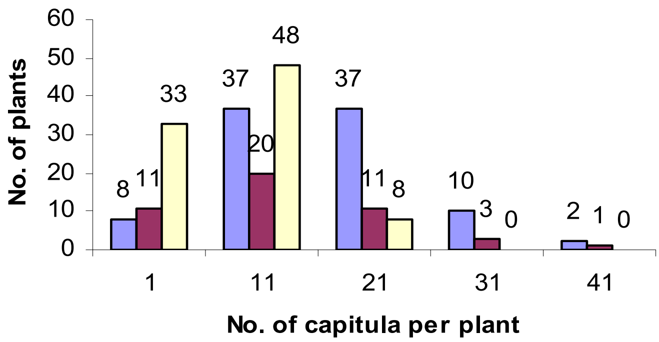

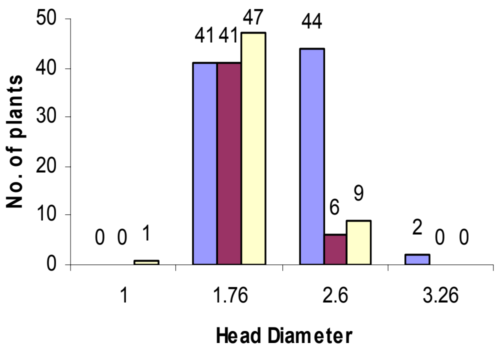

Fig. 1: Frequencies of F2, BC1 and BC2 generations of safflower for no. of branches, capitula / plant and diameter of main capitula

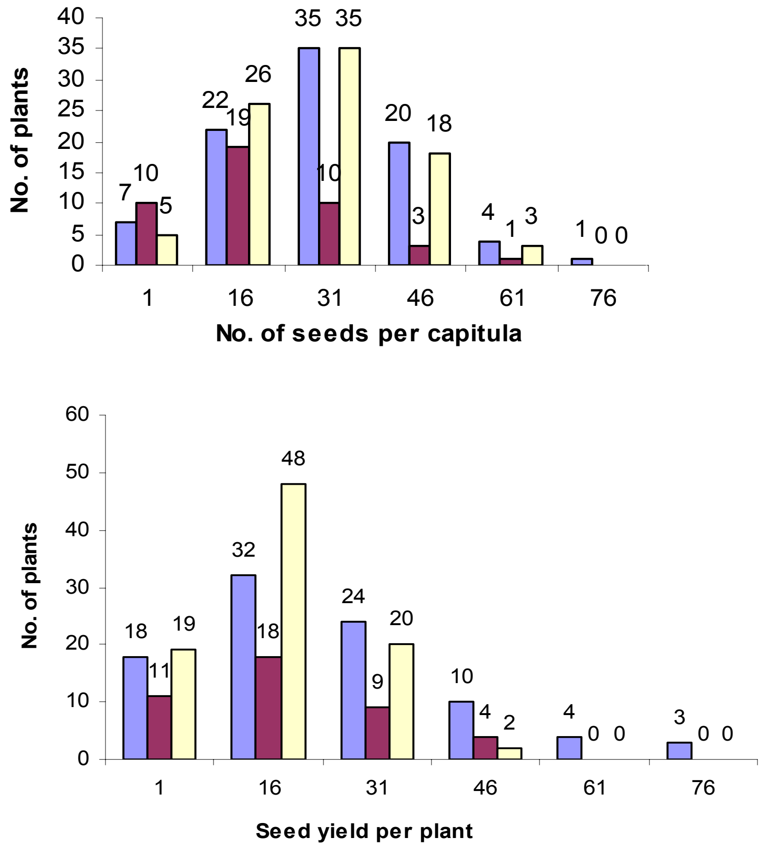

Fig. 2: Frequencies of F_2, $BC1F_2$ and $BC2F_2$ generations of safflower for no. of seeds per capitula and seed yield per plant