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An Analysis of Association of Components of Yield and Oil in Safflower (*Carthamus tinctorius* L.)

V. Ranga Rao and M. Ramachandram
Soil Conservation Research Demonstration & Training Centre, Bellary (India
V. Arunachalam
Division of Genetics, Indian Agricultural Research Institute, New Delhi (India)

Summary. Inter-relationships of various component characters with yield and oil content were analysed using 215 entries of safflower from India and U.S.A. Correlation of capsule number per plant and capsule weight with yield per plant was pronounced and they showed large direct effects on yield. All other components influenced seed yield mainly through these two components. Seed size had little effect on yield while seed number exerted a positive influence. The proportion of hull expressed as per cent of the whole seed revealed a highly significant and inverse relationship with oil content and was mainly responsible for the observed variability in oil content in the material. Although negative association was indicated between seed size and oil content, it was observed to be due to the indirect effect of hull content and not due to direct effect of seed size. Interestingly, yield per plant and its major components, number of capsules and capsule weight, revealed a negligible relationship with oil content. Both direct as well as indirect effects of hull percent and yield per plant were responsible for the favourable effect of seed number on oil content. The correlation of plant height, days to first flowering and total crop growth period with yield and oil content was either negligible or low, offering scope for developing early maturing and dwarf varieties with high yield and oil content. Spine index showed a non-significant association with yield and oil content. Capsule number, capsule weight and hull per cent were observed to be the most important components in breeding for higher yield and oil content.

Key words: Safflower - *Carthamus tinctorius* - Oil Content - Seed Number - Phenotypic Correlation

Introduction

Although safflower is a crop of antiquity in India (Knowles 1958, 1969a) its vast potential as an oil seed crop, particularly under limiting moisture conditions, has been recognised only recently (Krishnamoorthy et al. 1966; Rege and Chattopadhyay 1966; De et al. 1974; Anonymous 1975; Ranga Rao and Ramachandram 1977). Safflower is reported to be more remunerative than the traditional dryland crops like cotton, wheat and chick pea grown in different parts of India (Anonymous 1975; Ranga Rao and Ramachandram 1977). The crop is predominantly grown in mixed stands with cereals and chick pea and on borders during winter season rather than as a main crop (Knowles 1958, 1967; Chavan 1961). The success of safflower as a commercial crop in traditional areas and its expansion into new areas presently occupied by less efficient crops will largely depend on the extent of improvement made in its yield and oil content. Direct selection for yield and oil is hampered due to large genotype-environmental interaction and low heritability, apart from their complex inheritance. Investigations on character association (Claassen et al. 1950; Argikar et al. 1957; Urie et al. 1968; Abel 1969; Ashri et al. 1974), and other aspects related to yield improvement in this crop are inadequate to provide new directions in breeding. Further, it is essential to understand the indirect and direct forces that influence a particular character association to formulate a fruitful breeding programme. An experiment was hence formulated to obtain information on these aspects and the results are reported in this paper.

Materials and Methods

The experimental material comprised of 210 entries, 189 of which were drawn from important areas of safflower cultivation in India representing a broad spectrum of available genetic variability for different characters, and 21 from U.S.A. In addition, 5 standard Indian varieties were used as checks. The material was grown in an augmented randomised block design (Federer 1956) with 5 replications during the

Table 1. Phenotypic correlation coefficients among component characters in safflower

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.30	0.46	0.46	0.37	-0.06	0.45	0.30	0.38	0.07	0.04	0.07	0.17	-0.13	0.34
2		-0.27	0.29	0.33	-0.06	-0.26	-0.26	-0.29	0.18	-0.17	0.45	0.28	-0.30	-0.14
3			0.25	0.18	0.07	0.58	0.58	0.64	0.06	0.19	-0.20	0.01	0.08	0.55
4				0.70	0.06	0.32	0.23	0.28	0.04	0.07	0.03	0.18	-0.11	0.24
5						0.18	0.00	0.26	0.28	0.07	0.29	0.28	-0.21	0.36
6						0.05	0.06	0.07	0.16	-0.12	0.28	0.15	-0.10	0.18
7							0.56	0.78	-0.10	0.09	-0.22	-0.04	0.07	0.58
8								0.95	-0.02	0.11	-0.14	0.01	0.04	0.79
9									-0.05	0.12	-0.19	-0.01	0.05	0.80
10										0.64	0.32	0.26	-0.12	0.48
11											-0.24	-0.16	0.29	0.43
12												0.51	-0.51	0.05
13													-0.83	0.18
14														-0.03

1. Plant height at maturity (cm) 2. Height of branching from ground level (cm) 3. Length of branches (cm) 4. Days to first flowering 5. Days to maturity 6. Spine index 7. Number of secondary branches 8. Number of tertiary branches 9. Number of heads per plant 10. Capsule weight (gm) 11. Number of seeds per head 12. Seed size (gm) 13. Hull per cent 14. Oil per cent 15. Yield per plant (gm)
Correlation coefficients at 1 % and 5 % level of significance are 0.18 and 0.13 respectively for n=215.

winter season of 1972-73 at the Soil Conservation Research Demonstration & Training Centre, Bellary (Longitude 77°E, Latitude 15°N) in plots of 1.35 m × 4.5 m (3 rows) with an intra row spacing of 30 cm. The soils are 'vertisol' with depth varying from 60-90 cm. They are alkaline in reaction and poor in available N and P. Fertilizers were band-placed by the side of the seed rows at the rate of 60 kg N and 60 kg P_2O_5/ha as basal dose. The crop was irrigated when and as required to supplement seasonal rainfall and stored moisture. Observations were recorded on 5 plants selected at random from the central row. The number of days to first flowering and complete maturity were computed for individual plants as the period from the date of planting to the date on which blooming commenced in the primary head for the former, and from the date of planting to the date of complete maturity for the latter. Height of branching was measured as the height of the plant from ground level to the point at which branching commenced on the main axis. Observations on the length and angle of branches were based on measurements taken from the longest two branches originating on the main stem. Height of plant at maturity was measured from the ground level to the apex of the central stem. Number of secondaries included primary head and first order branches on the central axis, while effective number of tertiaries and higher order branches constituted number of tertiary branches per plant. Spine index for individual plants was calculated as a product of number of spines and length of the longest spine on the outer involucral bracts of three secondary heads using the formula suggested by Claassen et al. (1950). Capsule weight was calculated by dividing total yield per plant by the total number of effective heads per plant. Seed size (100-seed weight) for individual plants was obtained from 3 random determinations per plant. Total seed number per plant was divided by the number of effective heads per plant for obtaining number of seeds per capsule. To estimate hull per cent, fully air-dried seeds of known weight were germinated for 24-30 hours in water. The hulls including seed coat were separated from the kernels and weighed after drying in an oven at 60°C for 24 hours. Oil content in the seed was estimated using an NMR spectrometer at the Nuclear Research Laboratory, New Delhi. Oil and hull estimations were done on three samples per plant. Statistical analysis was based on the means of five plants for the various characters. All possible correlations among 17 characters were calculated using the variance covariance matrix obtained after eliminating block effects. Since the correlations exhibited by the characters, capsule diameter and angle of branches with all others were negligible, they were subsequently deleted from the correlation table. Path coefficient analysis (Dewey and Lu 1959) was used to partition the complex correlations of component characters with oil and yield into direct and indirect contributions.

Results

Phenotypic correlations: Number of capsules per plant exhibited the highest correlation coefficient of 0.80 with yield (Table 1). Tertiary branches appeared to be more closely correlated with yield (r = 0.79) than secondary branches (r = 0.58). These two variables, in fact, exhibited a highly significant positive relationship with capsule number. The correlation of length of branches, capsule weight and number of seeds per capsule with yield was positive and significant. The magnitude of the association of length of period to first flowering, crop growth period, plant height at maturity, and per cent hull with yield

Table 2. Direct and indirect effects of component characters influencing yield in safflower

	1	2	3	4	5	6	9	10	11	12	13	14	r
1	-0.02	0.01	0	-0.01	0	0	0.32	0.03	0	0	0.02	-0.01	0.34**
2	-0.01	0.03	0	-0.01	0	0	-0.25	0.08	-0.01	0.02	0.04	-0.03	-0.14*
3	-0.01	-0.01	-0.01	-0.01	0	0	0.55	0.03	0.01	-0.01	0	0.01	0.55**
4	-0.01	0.01	0	-0.03	-0.01	0	0.24	0.02	0	0	0.03	-0.01	0.24**
5	-0.01	0.01	0	-0.02	0	0	0.22	0.12	0	0.02	0.04	-0.02	0.36**
6	0	0	0	0	0	0.04	0.06	0.07	-0.01	0.01	0.02	-0.01	0.18**
9	-0.01	-0.01	-0.01	-0.01	0	0	0.85	-0.02	0.01	-0.01	0	0.01	0.80**
10	0	0	0	0	0	0	-0.04	0.43	0.04	0.02	0.04	-0.01	0.48**
11	0	-0.01	0	0	0	-0.01	0.10	0.28	0.07	-0.01	-0.02	0.03	0.43**
12	0	0.01	0	0	0	0.01	-0.16	0.14	-0.02	0.06	0.07	-0.06	0.05
13	0	0.01	0	-0.01	0	0.01	-0.01	0.11	-0.01	0.03	0.14	-0.09	0.18**
14	0	-0.01	0	0.01	0	0	0.04	-0.05	0.02	-0.03	-0.12	0.11	-0.03

r = Phenotypic correlation coefficient;
Residual factor ≈ 0.26; Underlined figures denote direct effects;
**Significant at 1 % level; *Significant at 5 % level

was, in general, low albeit significant. Surprisingly, seed yield per plant showed a weak but positive association with spine index (r = 0.18) possibly due to inclusion of a large number of moderate to intense spiny forms in the material. The association of all other characters with yield was either too low or negligible.

A highly significant and negative association was observed between oil and hull content. Oil content depended considerably on seed size (r = -0.51) and was inversely related to the height of branching which in turn, was inversely associated with secondary and tertiary branches and number of capsules per plant. While days to first flowering did not greatly influence the oil content, total crop growth period revealed a significant negative association with it. Such an undesirable effect of long crop growth period on oil content might be attributed to the adverse effects of warm and dry weather prevailing in the region during the period of seed development and maturation (January-February) affecting the synthesis and accumulation of oil in the seed. This emphasizes the need to shorten the total growth period by either reduction of pre-flowering period or suitable agronomic practices or both to allow the crop to mature before climatic and soil conditions become unfavourable.

Fortunately, yield per plant and a principal yield component, number of capsules per plant, showed a negligible association with oil content. Plant height and spine index were not associated with oil content. Among other factors influencing oil content, number of seeds per head revealed a highly significant positive relationship with oil per cent (r = 0.29).

Days to first flowering was found to have a positive association with location and length of branches, number of capsules, hull per cent and plant height. Early flowering types, in general, tended to be early maturing and vice versa and consequently all characters that were associated with the length of period to flowering were also correlated with maturity period. Variability in capsule number was independent of the variability in capsule weight and seed number. The association of seed size with hull per cent was highly significant and positive. Capsule weight revealed a significant and positive correlation with seed number per capsule.

The correlation analysis made above could not point out the characters that would influence yield or oil content due to the mutual association among component characters. Hence, path coefficients were computed (a) using all the characters presented in Table 1 and (b) deleting the number of effective secondaries and tertiaries from the correlation table. The results were identical in both cases, with the exception of the different order of branches which showed a negligible contribution to yield and oil in (a) due to confounding of their effects with total number of heads per plant. Hence, only the results of path analysis (b) are discussed in this paper (Table 2).

Path Analysis

Seed yield per plant: A study of direct effects showed the number of capsules per plant followed by capsule weight were the only characters directly influencing yield. The indirect effects of these two component characters through all other associated variables were either negligible or very low. Days to first flowering, plant height and length of branches showed a positive association with yield only as a consequence of the high and positive indirect effects through capsule number per plant, their own direct contributions being negligible. The indirect positive contributions through capsule weight and capsule number combined with the positive direct effect was mainly responsible for the observed positive correlation between seed number per capsule and yield. Per cent hull influenced seedyield both through direct and indirect paths. The indirect effect was through capsule weight and oil per cent, the contribution of the latter being negative owing to the occurrence of a high inverse relationship between hull and oil. The combined negative indirect effects of oil content through hull per cent and capsule weight outweighed its positive and direct contribution, thereby resulting in a negligible negative phenotypic association of oil content with seed yield. All other characters that exhibited a significant phenotypic association with yield influenced yields mainly by their indirect effects exerted through either capsule number or capsule weight or both.

Oil Content: Oil content was found to be influenced by the direct effects of three components, hull per cent (-0.80), yield per plant (0.40) and number of capsules per plant (-0.37). The direct contribution of hull per cent was nearly equal in magnitude to its phenotypic correlation coefficient with oil content. The indirect effects of other characters on the above association were negligible. Interestingly, yield per plant which was slightly associated with oil content ($r = -0.03$ not significant) had a substantial positive direct effect. Such a favourable direct effect of yield on oil content was, however, masked by the negative indirect effects of number of capsules, hull per cent and capsule weight. Such a mutual cancellation among the principal components of oil was also responsible for the very weak and non-significant phenotypic association of capsule number and weight with oil content. The significant inverse association that was recorded between seed size and oil content ($r = -0.51$) was found to be a consequence of the sizeable negative indirect effect of hull per cent in addition to a relatively low direct effect. Favourable influence of seed number on oil content appeared to be the result of a positive direct effect and positive indirect effects through yield and hull per cent. When the association of oil content with the duration to flowering, total crop growth period, plant height and height of branching were partitioned, it was found that the indirect effects of hull per cent, number of capsules per plant and yield exerted a major influence. The direct effects of the above variabels were small.

Discussion

An analysis of phenotypic correlation of component characters with yield and oil content and the paths of association clearly brought out the important influence of capsule number, capsule weight on yield, and hull per cent along with these components on oil content. The influence of all other characters on yield and oil content were found to be either negligible or a mere manifestation of the indirect effects of these principal components on their association with yield and oil. But mutual compensation at the component level appeared to be an important factor influencing character associations in safflower. This casts doubts on the merits of these component characters in breeding for superior production levels combined with higher oil content in the seed. It would therefore be of relevance to discuss the role of the principal components in determining yield and oil content in the light of published work.

Capsule Number per plant: This component character was positively correlated with yield and also posseed a marked direct effect. Other components did not influence indirectly the association of capsule number with yield. The character also exercised pronounced indirect influence on the association of a host of other component characters with yield. This would mean that it would be possible to breed for a simultaneous improvement in various components of yield by proper breeding methods and selection processes. However, the success would depend on the stability of the association of this character with yield, in addition to the choice of parents and the breeding procedure. It was encouraging to observe that number of capsules per plant accounted for a major portion

Table 3. Direct and indirect effects of component characters influencing oil content in safflower

	1	2	3	4	5	6	9	10	11	12	13	15	r
1	0	-0.01	0.02	0.01	0.01	0	-0.14	-0.01	0	-0.01	-0.14	0.14	-0.13*
2	0	-0.03	-0.01	0	0.01	0	0.11	-0.03	-0.01	-0.05	-0.23	-0.06	-0.30**
3	0	0.01	0.05	0.01	0.01	0	-0.24	-0.01	0.02	0.02	-0.01	0.22	0.08
4	0	-0.01	0.01	0.02	0.01	0	-0.11	-0.01	0.01	0	-0.14	0.10	-0.11
5	0	-0.01	0.01	0.01	0.02	0	-0.10	-0.04	0.01	-0.03	-0.22	0.14	-0.21**
6	0	0	0	0	0	0.04	-0.03	-0.02	-0.01	-0.03	-0.12	0.07	-0.10
9	0	0.01	0.03	0.01	0.01	0	-0.37	0.01	0.01	0.02	0	0.32	0.05
10	0	-0.01	0	0	0.01	0.01	0.02	-0.15	0.05	-0.04	-0.21	0.20	-0.12
11	0	0	0.01	0	0	0	-0.04	-0.09	0.08	0.03	0.13	0.17	0.29**
12	0	-0.01	-0.01	0	0.01	0.01	0.07	-0.05	-0.02	-0.12	-0.41	0.02	-0.51**
13	0	-0.01	0	0	0.01	0.01	0	-0.04	-0.01	-0.06	-0.80	0.07	-0.83**
15	0	0	0.03	0	0.01	0.01	-0.30	-0.07	0.04	-0.01	-0.14	0.40	-0.03

r = Phenotypic correlation coefficient;
Residual factor = 0.51; Underlindes figures denote direct effects;
**Significant at 1 % level; *Significant at 5 % level

of the total variance in yield in Indian (58.3 %), Iranian (42.8 %) and the whole germplasm (48.6 %) accessions evaluated at Utah, U.S.A. (Ashri et al. 1974). Argikar et al. (1957), Leininger (1968) and Abel (1969) had also reported a high degree of positive association between the two variables in question.

However, the association of capsule number per plant with oil content was not intense (Table 3). The path coefficient analysis has provided the underlying causes; its direct effect was negative on oil content (= -0.37) but it was compensated by the indirect effect of yield (= 0.32). Interestingly, yield per plant was not associated with oil content in our material. Similarly, yield per plant and its principal component, capsule number, failed to show any significant association with oil content in the gene pools from India, Egypt, Portugal and in the world safflower collections (Ashri et al. 1974). The results suggest that selection pressure for capsule number does not lead to a negative response for oil content.

Capsule weight: The positive and significant correlation of capsule weight with yield was found to be mainly due to its direct effect, the indirect effects through other characters being negligible. This association was thus as important as the one between number of capsules and yield. The authors could not find any published work on the inter-relationship of capsule weight with yield and oil content. However, Argikar et al. (1957), Abel (1969) and Ashri et al. (1974) reported a weak positive association between head diameter and yield, while they were independent of each other in our studies.

The association of capsule weight with oil content was non-significant; however, it had a negative direct effect. The positive indirect effect through yield (=0.20) was offset by the negative indirect effect through hull per cent (= -0.21). Again we noticed compensating associations at the component level which need to be streamlined in the desired direction for achieving improvement in yield and oil.

Seed size and seed number were the two other components that were reported to be both important (Urie et al. 1968; Leininger 1968; Abel 1969) and nonimportant (Ashri et al. 1974) for yields. Though seed number had a positive association with yield, seed size was not associated with it in our study. The magnitude of association of seed size and number with capsule number was very low in our material and in the world germplasm collections of Ashri et al. (1974). Both these components were, however, positively correlated with capsule weight (Table 1). Hence, the role of seed size and number sould also be properly taken into account in breeding programmes.

The two principal components of yield, namely capsule number and weight, did not exhibit any association per se. Hence, it is essential to give proper weightage to both of these components in breeding for higher yields. On the other hand, plant types with fewer but larger heads having more or heavier seed were thought to be more suitable than lines with large number of heads for limiting moisture conditions of arid and semi arid regions in safflower (Ashri et al. 1974), castor and wheat (Swaminathan 1969). Further, head number cannot be wholly reliably used as a criterion for selection because of its low heritability and high genotype environmental interactions. Hence, these aspects need to be examined in detail before planning a strategy for a simultaneous improvement of yield and oil in safflower.

Hull per cent: This character was negatively correlated with oil content (r = -0.83**) as was the case with several other studies (Claassen et al. 1950; Leininger and Urie 1964; Urie et al. 1968) and possessed a substantial direct effect (= -0.80). Seed size which had little or no association with yields in our studies and those of others (Argikar et al. 1957; Leininger 1968; Ashri et al. 1974) showed an inverse association of considerable magnitude with oil content in the material (see also Urie et al. 1968). Such a negative correlation was also observed by Ashri et al. (1974) in Egyptian (r = -0.32) and Iranian (r = -0.33) germplasm collections but not in the lines from India. The negative association of seed size with oil content was found to be due more to an indirect effect through hull per cent (-0.41) than due to a direct effect (-0.12). Claassen et al. (1950) could not obtain any significant association between seed size and hull, while seed size and oil content exhibited a weak phenotypic positive correlation in the F_2 population of a cross. Obviously, the increase in seed size in our material was associated more with an increase in the proportion of hull than with an increase in kernel size. This apparently resulted in a high inverse association between seed size and oil content. In fact, the sclerenchymatous pericarp of the seed and seed coat, neither of which has any food or feed value (Knowles 1969b), formed 45 to 50 % of the whole seed by weight and was mainly responsible for the low oil content of the seed and the protein content of the meal in a majority of Indian collections. The significant and positive relationship of seed number with oil content (r = 0.29) was due to its direct effect and the indirect effect through hull per cent and yield. However, the association of seed number with oil content was found to be significant and positive only in the Iranian and Egyptian lines, while it was weak and non-significant in the Indian lines (Ashri et al 1974). The stability of association of seed size and number with hull per cent, yield and oil content would need further study to determine the role of these two components in breeding programmes.

Nevertheless, the existance of considerable negative direct and indirect effects of hull per cent on oil content would suggest breeding for reduced hull per cent to increase oil content. Such a step could also lead to marked improvements in protein content of the meal. The incorporation of stripped, reduced and thin hull mutants offers a new source of material for improving the oil content in the kernel and protein level in the meal. Despite the low positive direct effect and weak association of hull per cent with yield, selection pressure for low hull might impose restrictions on the extent to which improvements in yield could be made. This could be partly offset by the inclusion of capsule weight as one of the components in the breeding programmes. However, other sources of variability for oil content will have to be exploited in view of these limitations and other drawbacks of available hull mutants (Ebert and Knowles 1966). According to Claassen et al. (1950), the character, hull per cent, can be very useful for initial screening with a high degree of accuracy in a large population for oil content and would hence eliminate the need for large oil estimations by complex and expensive laboratory procedures.

The other components of yield, namely plant height, length and height of branches, days to flowering, days to maturity and spine index, had no pronounced influence either on yield or oil content. The findings of Argikar et al. (1957), Ashr et al. (1974, 1975) and Claassen et al. (1950) confirm these results.

The results would suggest that the major components in question can be altered in breeding programmes freely to bring about concomittant and desirable associations among the component characters in the process of genetic upgradation for yield and oil content.

Literature

Anonymous: Proc. of Crop Management Seminar on Dryland Agriculture, All India Co-ordinated Research Project for Dryland Agriculture, Hyderabad, (1975).

Abel, G.H.: An analysis of yield components in safflower. Proc. of 3rd Safflower Res. Conf., Univ. of California, Davis. pp. 18-22 (1969)

Argikar, G.P.; Morbad, I.R.; Thobbi, V.V.: The range of variation of some quantitative characters in *Carthamus tinctorius* L. Ind. Oilseeds Jour. 1 (4), 232-234 (1957)

Ashri, A.; Zimmer, D.E.; Urie, A.L.; Cahaner, A,; Marani, A.: Evaluation of the world collection of safflower *Carthamus tinctorius* L. IV. Yield and yield components and their relationships. Crop. Sci. 14, 799-802 (1974)

Ashri, A.; Zimmer, D.E.; Urie, A.L.; Knowles, P.F.: Evaluation of the Germplasm collections of safflower *Carthamus tinctorius* L. VI. Length of planting to flowering period and plant height in Israel, Utah and Washington. Theor. Appl. Genet. 46, 359-364 (1975)

Chavan, V.M.: Niger and safflower. Indian Central Oilseeds Committee, Hyderabad, India, pp. 57-150 (1961)

Claassen, C.E.; Ekdahl, W.G.; Severson, G.A.: The estimation of oil percentage in safflower seed and the association of oil percentage with hull and nitrogen percentages, seed size and degree of spininess of the plant. Agron. J. 42, 478-482 (1950)

De, Rajat; Turkhede, B.B.; Gangasaran: Safflower a good Rabi crop for Dryland. Indian Fmg. 24(2), 26 (1974)

Dewey, D.R.; Lu, K.H.: A correlation and path coefficient analysis of components of crested wheat grass seed production. Agron. J. 51, 515-518 (1959)

Ebert, W.W.; Knowles, P.F.: Inheritance of pericarp types, sterility and dwarfness in several safflower crosses. Crop. Sci. 6, 579-582 (1966)

Federer, W.T.: Augmented designs. Hawaiian Planters Record 55, 191-207 (1956)

Knowles, P.F.: Safflower. Adv. Agron. 10, 289-323 (1958)

Knowles, P.F.: Processing seeds for oil in towns and villages of Turkey, India and Egypt. Econ. Bot. 21, 156-162 (1967)

Knowles, P.F.: Centres of plant diversity and conservation of crop germ plasm. Econ. Bot. 23, 324-329 (1969a)

Knowles, P.F.: Modification of quantity and quality of safflower oil through plant breeding. J. Amer. Oil Chem. Soc. 46, 130-132 (1969b)

Krishnamoorthy, Ch.; Chattopadhyay, S.; Rao, S. B.P.: Safflower for better utilization of shallow and medium black cotton soils of Bellary area. Ann. Arid Zone. 5, 44-48 (1966)

Leininger, L.N. 1968: In: Castor, Sesame and safflower, (Weiss, E.A.) pp. 529-744. London: Leonard Hill 1974

Leininger, L.N.; Urie, A.L.: Development of safflower seed from flowering to maturity. Crop Sci. 4, 83-87 (1964)

Ranga Rao, V.; Ramachandram, M.: Substitute safflower for rainfed cotton in the rabi black soils of Bellary region for higher and stable returns. Indian Fmg. (in press) (1977)

Rege, N.D.; Chattopadhyay, S.: Safflower for shallow and salty lands. Indian Fmg. XIV, p. 39 (1966)

Swaminathan, M.S.: Role of mutation breeding in a changing agriculture. In: Induced mutations in plants, pp. 719-734. Vienna: I.A.E.A. 1969

Urie, A.L.; Leininger, L.N.; Zimmer, D.E.: Effects of degree and time of defoliation on yield and related attributes of safflower. Crop Sci. 8, 747-750 (1968)

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V. Ranga Rao and M. Ramachandram
Soil Conservation Research Demonstration
& Training Centre
Bellary (India)

V. Arunachalam
Division of Genetics
Indian Agricultural Research Institute
New Delhi-110012 (India)