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# Evaluation of Safflower Germplasm

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**Twenty five safflower genotypes were evaluated at Agricultural Research Station, Tandur during *Rabi* 2014-15 to determine the genetic divergence and relationship among yield and yield components. The genetic parameters like divergence, genotypic and phenotypic variability, genotypic and phenotypic coefficient of variation, heritability and genetic advance were studied along with correlation coefficient and path analysis for seed yield, oil content and the component traits of safflower. Broad sense heritability estimates and genetic advance as per cent of mean (5%) was the highest for 100-seed weight followed by seed yield/plant. Significant and positive correlation was observed between seed yield/plant and number of seeds/capsule and 100-ssed weight. Path coefficient analysis indicated that 100-seed weight followed by number of seeds/ capsule exhibited the maximum direct effect on seed yield/plant. The genotypes were grouped into four different clusters based on Mahalonobis $D^2$ statistics. Seed yield/plant contributed to the maximum genetic divergence followed by 100-seed weight among the genotypes studied.**

**Key words:** Safflower, Genetic divergence, Path coefficient analysis, Correlation

Safflower (*Carthamus tinctorius* L.) is a member of the family Compositae or Asteraceae cultivated for both seeds and petals. It is grown under receding soil moisture conditions. Information on genetic diversity and correlation of yield components are important for crop improvement since they are highly useful in selection of parents for crop breeding. Genetic parameters like diversity, genotypic and phenotypic variability, genotypic and phenotypic coefficient of variation, heritability and genetic advance are highly useful for effective selections in the breeding material. Identification of the traits that affect seed and oil yield in safflower is very important in genetic improvement of these attributes. Also, considering that seed and oil yield is a polygenic trait and direct selection for its improvement is not effective, the selection through its components can be useful. Therefore, indirect selection through characters that have high heritability and also significantly correlated with seed and oil yield has more genetic efficiency than direct selection in the genetic improvement of these traits. Correlation coefficient studies will enable researchers to identify significant relationship between the traits.

In the hybridization program aiming at yield improvement; it is important to study the nature and extent of genetic variability available in the germplasm, the relationship between yield and yield components and contribution of all the traits towards yield. Keeping in view of the above mentioned objectives the present research work was undertaken to study genetic variability, heritability, genetic advance and correlation of yield with yield components. $D^2$ analysis is useful in the identification of divergent genotypes that are suitable for hybridization program.

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## Materials and Methods

Twenty five safflower genotypes were sown in Randomized Block Design in three replications at Agricultural Research Station, Tandur during *Rabi* 2014-15. The entries were sown in 5m long five row plots with a spacing of 45cm between the rows and 20cm between the plants. The recommended agronomic practices and plant protection methods have been followed for raising a good crop. Five plants were randomly selected for recording data on the following six characters *viz*, days to 50% flowering, days to maturity, number of effective capitula/plant, number of seeds/capitula, test weight (g) and seed yield/plant in each treatment across all the replications. Mahalonobis $D^2$ statistic (Rao, 1952) and Principal Component Analysis (PCA) (Jackson, 1991) has been used to analyze genetic divergence among safflower genotypes. The data has been subjected to statistical analysis to calculate genetic divergence genotypic (GCV) and phenotypic (PCV) coefficients of variation, heritability and genetic advance as per cent of mean. Phenotypic coefficient of correlation was computed according to Al-Jibouri et al. (1958). The phenotypic correlation was partitioned into direct and indirect effects as suggested by Dewey and Lu (1959).

## Results and Discussion

Range of variation was the highest for days to maturity followed by days to 50% flowering (Table 1). Genotypes had the least range of variation for 100-seed weight. Range of variation was least for 100-seed weight. Genetic parameters like genotypic and phenotypic variability, genotypic and phenotypic coefficient of variation, heritability and genetic advance as per cent of mean are presented in Table 2.

Phenotypic coefficient of variation revealed relatively high values when compared to corresponding genotypic coefficient of variation for all the characters studied, indicating the influence of environment on these traits. The range of PCV observed was from 5.15 to 18.6% for the characters studied, which indicates the extent of phenotypic variability in the population. Moderate coefficients of variation were observed for 100-seed weight followed by seed yield/plant. Characters like days to 50% flowering (7.28) and days to maturity (5.15) exhibited low PCV. Genotypic coefficient of variation, which indicates the extent of genetic variability ranged from 4.98 to 18.23%. Maximum GCV was observed for 100-seed weight (18.23%) followed by number of seeds/capsule (16.33%) and seed yield/plant (15.18%) providing an opportunity for genetic improvement. Very low estimates of GCV and PCV have been observed for the traits days to 50% flowering and days to maturity. Heritability along with genetic advance indicates the efficiency of selection (Burton, 1952). Broad sense heritability estimates was the highest for 100-seed weight (96%) and seed yield/plant (96%) indicating that these characters were the least affected by environmental variation and hence, selection for these characters based on phenotype may be more effective for improvement of seed yield in safflower. Gupta and Singh (1988) observed that low heritability for oil content and seed yield. On the contrary, Vijaya kumar and Giriraj (1985) reported high heritability estimates ranging from 0.67 to 0.92 for oil content. The estimated genetic advance was moderate for 100-seed weight (36.83%), number of seeds/capsule (30.84%) and seed yield/plant (30.69%) and the least for days to maturity (9.92%). Earlier researchers have reported that genotypic component of variation was greater than environmental component for all the traits except for branches/plant, capitula/plant and oil content. Genetic advance as percentage of mean was moderate for seed yield/plant, plant height, height of branching from base and 100-seed weight, whereas it was low for the remaining traits (Anjani, 2005).

**Table 1. Mean, range, minimum, maximum, SE and coefficient of variability (CV %) of characters studied in safflower genotypes**

| Characters | Mean | Minimum | Maximum | SE | CV % |
|---|---|---|---|---|---|
| Days to 50% flowering | 80.06 | 57.6 | 85.6 | 1.49 | 3.24 |
| Days to maturity | 113.06 | 90.6 | 118.6 | 1.49 | 2.29 |
| No. of effective capsules/plant | 22.68 | 14.8 | 28.3 | 1.68 | 12.86 |
| No. of seeds/capsule | 23.26 | 15.2 | 31.5 | 1.65 | 12.33 |
| 100-seed weight (g) | 4.96 | 3.18 | 5.85 | 0.18 | 6.33 |
| Seed yield/plant (g) | 20.52 | 14.85 | 24.69 | 0.61 | 5.20 |
| Oil content (%) | 29.41 | 25.65 | 36.64 | 0.70 | 4.15 |

**Table 2. Estimation of GCV, PCV, h2b and Genetic Advance of seven characters of safflower genotypes**

| Characters | Variance | | Coefficient of variation | | $h^2b$ (%) | GA (5%) | GA as % of Mean (5%) |
|---|---|---|---|---|---|---|---|
| | Genotypic | Phenotypic | GCV (%) | PCV (%) | | | |
| Days to 50% flowering | 31.75 | 34.0 | 7.03 | 7.28 | 0.93 | 11.21 | 14.0 |
| Days to maturity | 31.75 | 34.0 | 4.98 | 5.15 | 0.93 | 11.21 | 9.92 |
| No. of effective capsules/plant | 11.72 | 14.56 | 15.09 | 16.82 | 0.80 | 6.33 | 27.90 |
| No. of seeds/capsule | 14.44 | 17.19 | 16.33 | 17.82 | 0.84 | 7.17 | 30.84 |
| 100-seed weight (g) | 0.82 | 0.85 | 18.23 | 18.60 | 0.96 | 1.83 | 36.83 |
| Seed yield/plant (g) | 9.71 | 10.09 | 15.18 | 15.48 | 0.96 | 6.3 | 30.69 |
| Oil content (%) | 6.72 | 7.22 | 8.81 | 9.13 | 0.93 | 5.15 | 17.52 |

**Table 3. Estimates of phenotypic correlation coefficients for yield related traits of safflower genotypes**

| Characters | Days to 50% flowering | Days to maturity | No. of effective capsules/plant | No. of seeds/ capsule | 100-seed weight (g) | Seed yield/ plant (g) |
|---|---|---|---|---|---|---|
| Days to 50% flowering | | 1.00** | -0.123 | -0.086 | 0.206 | -0.127 |
| Days to maturity | | | -0.123 | -0.086 | 0.206 | -0.127 |
| No. of effective capsules/ plant | | | | 0.069 | -0.114 | -0.010 |
| No. of seeds/capsule | | | | | -0.456** | 0.234* |
| 100-seed weight (g) | | | | | | 0.258* |

*, **, *** Significant at P=0.05, 0.01 and 0.005, respectively

Kotecha and Zimmerman (1978) and Nie *et al.* (1987) reported that 1000-seed weight had high heritability values. Similar results were also found for 1000-seed weight by other researches (Patil *et al.* 1991; Pandya *et al.* 1996; Gupta and Singh 1997; Patil 1997). Abel and Driscoll (1976) reported that 1000-seed weight was generally little affected by different environments, but seeds/capsule was more influenced.

**Table 3a . Estimates of phenotypic correlation coefficients for yield related traits of safflower genotypes**

| Characters | Days to 50% flowering | Days to maturity | No. of effective capsules/ plant | No. of seeds/ capsule | 100-seed weight (g) | Oil content % |
|---|---|---|---|---|---|---|
| Days to 50% flowering | | 1.00** | -0.123 | -0.086 | 0.206 | 0.139 |
| Days to maturity | | | -0.123 | -0.086 | 0.206 | 0.139 |
| No. of effective capsules/plant | | | | 0.069 | -0.113 | 0.031 |
| No. of seeds/capsule | | | | | -0.456*** | 0.329*** |
| 100-seed weight (g) | | | | | | -0.497 |

Phenotypic correlations estimated among the seven traits recorded in the genotypes indicated inherent association between any two variables. Seed yield/plant was positively and significantly correlated with number of seeds/capsule (0.234) and 100-seed weight (0.258) (Table 3). Ekshing *et al.,* (1994) and Rafiei (2002) reported positive and high correlation between seed yield/plant and number of seeds per

**Table 3b. Estimates of genotypic correlation coefficients for yield related traits of safflower genotypes**

| Character | Days to 50% flowering | Days to maturity | No. of effective capsules/plant | No. of seeds/ capsule | 100-seed weight (g) | Seed yield/ plant (g) |
|---|---|---|---|---|---|---|
| Days to 50% flowering | | 1.00 | -0.123 | -0.086 | 0.217 | -0.128 |
| Days to maturity | | | -0.123 | -0.086 | 0.217 | -0.128 |
| No. of effective capsules/plant | | | | 0.079 | -0.130 | -0.005 |
| No. of seeds/capsule | | | | | | 0.266* |
| 100-seed weight (g) | | | | | | 0.266* |

head in their studies. Rafiei (2002) found negative, but Abulhasani (2003) reported a positive correlation between seed yield and 100-seed weight. A positive correlation of number of capitula/plant and 100-seed weight with seed yield/plant was also reported by Parameshwarappa (1981), Malleshappa (2000) and Bidgoli *et al.,* (2001). Number of seeds/capsule was negatively correlated with 100-seed weight. Hence genotypes with bold seeds had less number of seeds/ capsule. There existed significant positive

**Table 3c. Estimates of genotypic correlation coefficients for yield related traits of safflower genotypes**

| Character | Days to 50% flowering | Days to maturity | No. of effective capsules/plant | No. of seeds/ capsule | 100-seed weight (g) | Seed yield/ plant |
|---|---|---|---|---|---|---|
| Days to 50% flowering | | 1.00 | -0.123 | -0.086 | 0.217 | 0.155 |
| Days to maturity | | | -0.123 | -0.086 | 0.217 | 0.155 |
| No. of effective capsules/plant | | | | 0.079 | -0.130 | 0.067 |
| No. of seeds/capsule | | | | | | 0.362*** |
| 100-seed weight (g) | | | | | | -0.531 |

correlation between days to 50% flowering and days to maturity. Similar results have been published by earlier researchers in safflower (Rafiei, 2002 and Abulhasani, 2003). Number of seeds/capsule was significantly and positively correlated with oil content (0.329), but negatively correlated with 100-seed

**Table 4. Genotypic path coefficient showing direct and indirect effect of characters on seed yield in safflower**

| Character | Days to 50% flowering | Days to maturity | No. of effective capsules/ plant | No. of seeds/ capsule | 100-seed weight (g) | Genotypic correlation with seed yield/plant (g) |
|---|---|---|---|---|---|---|
| Days to 50% flowering | -0.2090 | -0.2090 | 0.0258 | 0.0180 | -0.0455 | -0.128 |
| Days to maturity | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.128 |
| No. of effective capsules/plant | -0.0002 | -0.0002 | 0.0016 | 0.0001v | -0.0002 | -0.005 |
| No. of seeds/capsule | -0.0471 | -0.0471 | 0.0434 | 0.5463 | -0.2781 | 0.266* |
| 100-seed weight (g) | 0.1275 | 0.1275 | -0.0763 | -0.2983 | 0.5860 | 0.266* |

Figures in bold letters indicate the direct effects, Residual effect = 0.7939

weight (Table 3a). Genotypic correlation studies indicated that seed yield/plant was significantly and positively correlated with number of seeds/capsule and 100-seed weight, while oil content and positively correlated with number of seeds/capsule and negatively correlated with 100-seed weight (Table 3b and 3c). The study indicated that high oil genotypes had less 100-seed weight. Bratulin (1993) reported

**Table 4a. Genotypic path coefficient showing direct and indirect effect of characters on oil content in safflower**

| Character | Days to 50% flowering | Days to maturity | No. of effective capsules/ plant | No. of seeds/ capsule | 100-seed weight (g) | Genotypic correlation with Oil Content (%) |
|---|---|---|---|---|---|---|
| Days to 50% flowering | 0.2838 | 0.2838 | -0.0351 | -0.0245 | 0.0618 | 0.155 |
| Days to maturity | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.155 |
| No. of effective capsules/plant | -0.0029 | -0.0029 | 0.0237 | 0.0019 | -0.0031 | 0.067 |
| No. of seeds/capsule | -0.0098 | -0.0098 | 0.0090 | 0.1137 | -0.0579 | 0.362*** |
| 100-seed weight (g) | -0.1158 | -0.1158 | 0.0693 | 0.2709 | -0.5322 | -0.531 |

Figures in bold letters indicate the direct effects, Residual effect = 0.7939

**Table 5. Average Inter and intra cluster distances (D2) of four clusters of safflower genotypes**

| Cluster | I | II | III | IV |
|---|---|---|---|---|
| I | 3.88 | 6.36 | 6.13 | 6.88 |
| II | | 0.0 | 5.12 | 7.98 |
| III | | | 0.0 | 8.22 |
| IV | | | | 0.0 |

positive and significant relation between seed yield/ plant and capitulum number/ plant and 1000-seed weight in safflower genotypes, while Cassato *et al.,* (1997) observed positive and significant correlation of capitulum number/ plant with seed yield /plant in safflower. In the present investigation genotypic path coefficient analysis was carried out to estimate the direct and indirect contribution of various traits to seed yield/plant and oil content. Compartmentalization of correlation coefficients into direct and indirect effects differentiated the true nature of association observed among various characters. Number of seeds/capsule (0.5463) and 100-seed weight (0.5860) exhibited the highest positive and direct effects for seed yield/plant, while days to 50% flowering (0.2838), number of effective capsules/plant (0.0237) and number of seeds/capsule (0.1137) exhibited positive direct effects for oil content (Table 4 and 4a). These characters are principal components of seed and oil yield and may be helpful in increasing the seed and oil yield of safflower. Earlier studies by Malleshappa *et al.,* (2000) and Pandya *et al.,* (1996a) indicated that the direct effect of number of capitula was more pronounced followed by test weight, plant height

**Table 6. Cluster means of four clusters for seven characters in safflower genotypes**

| Cluster | Days to 50% flowering | Days to maturity | No. of effective capsules/ plant | No. of seeds/ capsule | 100-seed weight (g) | Seed yield/ plant (g) | Oil content % |
|---|---|---|---|---|---|---|---|
| I | 80.73 | 113.73 | 22.51 | 22.50 | 5.20 | 20.76 | 29.22 |
| II | 82.0 | 115.0 | 20.43 | 26.73 | 2.99 | 21.32 | 36.64 |
| III | 86.0 | 119.0 | 28.07 | 29.20 | 3.19 | 13.54 | 29.68 |
| IV | 57.67 | 90.67 | 23.27 | 30.60 | 3.61 | 21.55 | 26.38 |

and capitulum diameter on seed yield/plant. Days to maturity had negative direct effect on seed yield/plant (-0.2090). The 100-seed weight has shown positive direct effect on seed yield, while it has shown direct negative effect on oil content (-0.5322). Indirect

**Table 6a. Percent contribution of characters towards genetic diversity**

| Characters | Contribution (%) | Times Ranked 1st |
|---|---|---|
| Days to 50% flowering | 12.33 | 37 |
| Days to maturity | 0.0 | 0 |
| No. of effective capsules/plant | 8.0 | 24 |
| No. of seeds/capsule | 5.33 | 16 |
| 100-seed weight (g) | 27.0 | 81 |
| Seed yield/plant (g) | 37.33 | 112 |
| Oil content (%) | 10.0 | 30 |

selection through selection of traits such as more number of capitula/plant, 1000-seed weight and lower number of branches along with thin hull are required for improvement of seed and oil yield in safflower (Zheng *et al*., 1993; Arslan 2007). Traits such as 1000-seed weight and number of seeds/ plant are the best indirect selection criteria for genetic improvement of oil yield in spring safflower cultivars under drought stress condition. On the other hand, the traits 1000-seed weight, number of seeds/plant and days to physiological maturity are the most promising selection criteria under non-drought stress condition (Golparvar, 2011).

The Mahalonobis $D^2$ values have grouped the twenty five safflower genotypes into four distinct clusters. The average intra and inter cluster distances are depicted in (Table 5). The maximum inter cluster distance was between cluster III and IV (8.22) followed by cluster II and IV (7.98). Cluster III recorded the highest mean values for number

of effective capitula/plant (28.07), while cluster II recorded the highest oil content (36.64). Cluster IV recorded highest the

**Table 7. Eigen values and proportion of total variance represented by four principal components of safflower genotypes**

| | PC1 | PC2 | PC3 | PC 4 |
|---|---|---|---|---|
| Eigen value (root) | 98.37 | 74.61 | 47.72 | 16.57 |
| Per cent var. exp | 38.48 | 29.19 | 18.67 | 6.48 |
| Cumulative var. exp | 38.48 | 67.68 | 86.35 | 92.83 |
| Days to 50% flowering | -0.01 | 0.010 | -0.89 | -0.28 |
| Days to maturity | 0.0 | 0.0 | 0.0 | 0.0 |
| No. of effective capsules/plant | 0.18 | 0.10 | -0.21 | 0.44 |
| No. of seeds/capsule | 0.16 | 0.18 | 0.03 | -0.72 |
| 100-seed weight (g) | -0.82 | 0.12 | -0.19 | 0.19 |
| Seed yield/plant (g) | 0.02 | 0.96 | 0.16 | 0.06 |
| Oil content (%) | 0.49 | 0.06 | -0.29 | 0.38 |

*PC = Principal component

number of seeds/capitula (30.60) and seed yield/plant indicating that neighboring clusters had high yielding genotypes. The genotypes in both these clusters may be utilized in breeding for improvement of seed and oil yield. Similar results have been reported by earlier researchers (Ghongade and Navale, 1995; Shivani and Sreelakshmi, 2013). Cluster IV recorded earliness for days to 50% flowering (57.67) and days to maturity (90.67) indicating that these genotypes can be efficiently utilized for breeding short duration varieties to escape drought situations (Table 6). Genotypes from cluster III and IV can be utilized for development of short duration varieties with high seed yield. The earliness in the flowering and maturity is one of the important characters of drought avoidance mechanism However, earliness in flowering further associated with lower total dry matter and (Senapati, 1999). Maximum contribution towards genetic divergence is by seed yield/plant (37.33%) followed by 100-seed weight (27%) (Table 6a). These characters together recorded for more than 64% of the total divergence among the safflower genotypes studied. Earlier researchers also had reported that seed yield the contributed maximum for genetic divergence (Shivani and Sreelakshmi, 2011, 2013). The first three principal components explained 86.34% variability with PC1 explaining a maximum variability of 38.48% (Table 7).

Our data indicates genotypes having thick hull gave higher seed yield but lower oil yields. Thus, thin hulled genotypes should be selected in breeding varieties with high oil content. Number of seeds/ capsule and number of capsules/plant have given positive and direct effects for both seed and oil yield. The component characters namely, number of seeds/capsule and 100-seed weight are very important characters for seed yield because, they have shown positive and significant correlation with seed yield/plant. Both these characters also had positive and strong direct effects on seed yield/plant. Results of correlation and path analysis suggested that characters having positive association with grain yield are also directly contributing to seed yield and hence, selection of genotypes may be reliably done based on these characters.

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