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Correlation and path analysis in safflower (*Carthamus tinctorius* L.) genotypes

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Abstract
In order to evaluate the association among yield components and their direct and indirect influence on grain yield of safflower *(Carthamus tinctorius* L.), an experiment was carried out in a complete randomized block design with three replications using 11 genotypes at ARS Annigeri during 2012-13. The phenotypic correlation among the traits and their path coefficients were estimated. Positive and significant correlations were observed between grain yield and number of capitula per plant and 100 seed weight. Plant height, number of seeds per capitulum and oil content exhibited significant negative correlation with seed yield. Positive direct effects were exhibited for number of capitula per plant and 100 seed weight. Negative direct effects were observed for plant height, number of seeds per capitulum and oil content. Therefore, improvement of the seed yield will be efficient via selection for number of capitula per plant and 100 seed weight.

Keywords: *Carthamus tinctorius* L., correlation, path

Introduction
Safflower, a multipurpose crop, has been grown for centuries in India for the orange-red dye (carthamin) extracted from its brilliantly coloured flowers and is cultivated mainly for its seed, which gives edible oil. Traditionally, this crop was grown for its flowers, fabric dyes, food colouring and for medicinal purposes (Harlan 1992; Weiss, 2000) [8, 24]. However, it is currently grown as an oilseed crop worldwide. Safflower has some agronomic advantages such as drought resistance and adaptation to arid and semi-arid climatic conditions (Weiss, 2000) [24].
Safflower is being grown in over 60 countries, among which India, China, Mexico, USA, Ethiopia, Argentina and Australia are the major growing countries. China mostly grows safflower for medicinal purposes. India is the largest producer of safflower (2.0 lakh tonnes) in the world with highest acreage (4.3 lakh hectares) but with an average productivity of only 465 kg/ha. Poor crop management under input-starved conditions is the most important reason for such low per hectare yields. It is mainly grown in Maharashtra, Karnataka and parts of Andhra Pradesh, Madhya Pradesh, Orissa, Bihar, etc. Maharashtra and Karnataka are the two most important safflower growing states accounting for 72 and 23 per cent of area and 63 and 35 per cent of production, respectively (Nimbkar, 2020) [16].
The success of safflower as a commercial oil seed crop in traditional areas and its expansion to new areas will largely depend on the extent of improvement made in both its yield and oil content. Yield components not only directly affect the yield, but also indirectly by affecting other yield components in negative or positive ways. Beyyavas *et al.* (2011) [3] demonstrated that correlation coefficients were positive and significant between seed yield and number of capitula per plant and between 1000 seed weight and oil yield. Omidi *et al.* (2009) [17] showed that seed yield per plant was significantly correlated with seed yield per plot, biomass, number of capitula, 100-seed weight, number of secondary branches and oil yield per plant. Roopa and Ravikumar (2008) [20] showed a positive correlation between seed yield per plant and number of capitula per plant, number of branches per plant and test weight.
Path analysis is used in most cases to establish the cause and effect association, because simple correlation analysis will not provide the real relationship between response and predictor variables. Path analysis developed by Wright (1921) [25] as a statistical tool, allows studying complex relationships between traits and determines the causal relationships between predictor and response variables. This technique is useful in determining the direct influence of one variable on another and also separates the correlation coefficient into direct effect (path coefficient) and indirect effects (effects exerted through other independent variables). Burhan (2007) [4] indicated that safflower seed yield was determined by capitula diameter, capitula per plant and seeds per capitula and these traits had highly positive significant direct effects on seed yield. Hajghani *et al.* (2009) [7] indicated that there was a strong positive direct effect of the

number of capitula per plant on seed yield. The objective of the study reported here was to evaluate safflower yield components and their interrelationship by path coefficient analysis.

Material and Methods

The present investigation for correlation and path analysis in to the morphological traits of safflower (*C. tinctorius* L.) was conducted in Agricultural Research Station, Annigeri, UAS, Dharwad under rain fed conditions during *rabi* 2012-13. The experimental material consisted of 11 genotypes of safflower. These genotypes were planted in the field based on the randomized complete block design with three replications. Each genotype was grown in five rows of four meters length with a spacing of 45 cm between rows and 20 cm between plants within a row. Recommended agronomic and plant protection practices were followed to ensure good crop stand. The mean data were recorded on nine yield contributing characters *viz.*, days to 50 per cent flowering, plant height, number of capitula per plant, capitulum diameter, number of seeds per capitulum, 100 seed weight, hull content, oil content and seed yield per plant by taking five plants randomly in each plot. Phenotypic correlations were computed as suggested by Weber and Moorthy (1952) [23]. Path coefficient analysis was carried out for traits which showed significant phenotypic correlation coefficients with seed yield to know the direct and indirect effects as suggested by Wright (1921) [25] and illustrated by Dewey and Lu (1959) [6].

Results and Discussion

Correlation analysis for seed yield per plant

The simple correlation coefficients determined between the characteristics investigated are presented in Table 1. Strong positive correlation between seed yield per plant and number of capitula per plant, number of branches per plant and test weight is evident. There was a strong positive association of number of capitula per plant with test weight and with seed yield. Similar results were obtained by Tariq *et al*., (2014) [22], Pavithra *et al*., (2016) [18], Dambal and Patil (2016) [5], Semahegn and Tesfaye (2016) [21], Pushpavalli and Kumar (2017) [19] and Mohamed and Elmogtaba (2018). On the other hand, significant negative correlation was observed between seed yield and plant height, number of seeds per capitulum and oil content. Similar findings were obtained by Lakshyadeep *et al.* (2005) [11], Alizadeh and Carpetain (2006) [2], Omidi *et al.* (2009) [17], Mohammadi *et al.* (2012) [15] and Hoshang *et al.* (2013) [9]. The days to 50 per cent flowering, capitulum diameter and hull content exhibited non-significant association with seed yield. These results indicate that, selection of genotypes with high number of capitula per plant, higher 100 seed weight, optimum plant height and lower oil content will help in increasing the seed yield.

Path coefficient analysis for seed yield per plant

Among the different characters studied for the direct as well as indirect contribution towards seed yield (Table 2), the positive direct effect of 100 seed weight was more pronounced followed by number of capitula per plant as observed in earlier studies of Karimi *et al*., (2014) [10], Dambal and Patil (2016) [5], Pavithra *et al*., (2016) [18], Pushpavalli and Kumar (2017) [19] and Mohamed and El Fadl (2018) [14]. Therefore, considering these traits as selection criteria in improving seed yield of safflower would be worthy. Several other characters *viz.*, plant height, number of seeds per capitulum and oil content contribute indirectly through number of capitula per plant and 100 seed weight. Significant negative direct effects were observed for plant height, number of seeds per capitulum and oil content. Lucy Kumari and Ravikumar (2010) [20], Moghaddasi and Omidi (2010) [13] and Ahmadzadeh *et al.* (2012) [1] reported similar results. Thus from the knowledge of direct influence of principal yield traits, the characters like number of capitula per plant and 100 seed weight appear to be principal traits governing seed yield in safflower and should be given due importance in any safflower improvement programme.

Table 1: Phenotypic correlation among nine characters in eleven safflower genotypes (*Carthamus tinctorius* L.) at Annigeri during *rabi* 2012-13

	Days to 50% flowering	Plant height	Number of capitula per plant	Head diameter	Number of seeds per capitulum	100 seed weight	Hull content	Oil content	Seed yield per plant
Days to 50% flowering	1	0.49*	-0.04	-0.19	-0.07	-0.13	0.09	0.09	-0.3
Plant height		1	-0.07	0	0.15	0.15	0.19	0.46*	-0.38*
Number of capitula per plant			1	-0.03	-0.36*	0.31	-0.1	0.03	0.35*
Capitulum diameter				1	0.33	0.19	0.04	-0.15	0.25
Number of seeds per capitulum					1	0.03	0.14	0.29	-0.36*
100 seed weight						1	0.77*	-0.29	0.56*
Hull content							1	-0.18	0.22
Oil content								1	-0.70*
Seed yield per plant									1

Table 2: Direct and indirect effects of different characters on seed yield at phenotypic level in eleven safflower genotypes (*Carthamus tinctorius* L.) at Annigeri during *rabi* 2012-13

	Direct effect	Indirect effect					Correlation with seed yield
		Plant height (cm)	Number of capitula per plant	Number of seeds per capitulum	100 seed weight (g)	Oil content	
Plant height (cm)	-0.42	-	-0.06	-0.07	0.09	0.08	-0.38*
Number of capitula per plant	0.08	0.03	-	0.11	0.2	-0.07	0.35*
Number of seeds per capitulum	-0.31	-0.06	-0.02	-	0.02	0.01	-0.36*
100 seed weight (g)	0.63	-0.07	0.04	-0.01	-	-0.03	0.56*
Oil content	-0.65	-0.03	-0.02	0.01	-0.01	-	-0.70*

Residual effect: 0.44

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