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Study on relationships among seed yield components in in $F_{3:4}$ population in safflower (*Carthamus tinctorius* L.)

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Abstract
Present study was conducted to estimate relationships among seed yield components in in $F_{3:4}$ population in safflower using simple correlations. The recurrent selection experiments are mainly designed and conducted for improving seed yield plant'[1]. The plant height showed no correlation with flowering, branch number, capitulum number, seed number, oil content and seed yield per plant. Days to 50% flowering was negatively correlated with seed yield per plant (*r*=-0.189**), test weight (*r*=-0.303**) and seed oil content (*r*=-0.166**).Branch number and capitulum number per plant showed highly positive correlation (*r*=0.999**) with each other, which were also positively associated with seed yield per plant (*r*=0.236**).Seed number per capitulum was negatively correlated with test weight (*r*=-0.235**).Test weight showed positive correlation with seed yield per plant (*r*=0.399**) and seed oil content (*r*=0.203**) while it was negatively correlated with days to 50% flowering (*r*=-0.303**) and seed number per capitulum (*r*=-0.217**). Seed oil content was positively correlated to test weight (*r*=0.203**) and negatively correlated with days to 50% flowering (*r*=-0.166**).Seed yield per plant was positively correlated with branch number (*r*=0.235**), capitulum number (*r*=0.234**) and test weight (*r*=0.399**) while it was negatively correlated with days to 50% flowering (*r*=-0.189**). A critical analysis of direct and indirect effects in $F_{3:4}$ population indicated that test weight had the maximum direct positive effect (0.3031) on seed yield per plant followed by capitulum number (0.2167) and seed oil content (0.1428), which may be considered.

Keywords: Safflower populations, genetic correlation and path analysis

Introduction
Safflower (*Carthamus tinctorius* L.) is a traditional oilseed crop of India. Its seeds, flowers and foliage are economically important, which are exploited for extraction of cooking oil, natural dye and animal feed, respectively. Traditionally, safflower oil is considered of premium quality due to its high amount of polyunsaturated fatty acid (>70% linoleic acid). High oleic safflower oil (>30%) is also becoming more popular due to high stability and amenability for repeated uses. Carthamin, a natural dye, extracted from its brilliantly coloured flowers are used for coloring foods, cloths, preparation of cosmetics etc. Safflower foliage, seeds and seed meal after the extraction of oil are used as animal feeds (Li and Mundel, 1996). India is the second largest producer of safflower seeds in the world. India accounts for >30% (0.23 million ha) of area and >20 per cent (0.15 million tonnes) of global production (FAOSTAT, 2017) [7]. Maharashtra, Karnataka, Telangana and Andhra Pradesh are the major safflower growing states in India. Seed yield (~650 Kg/ha) and oil content (~30%) in the popular cultivars remain low, which are major concerns for increasing the profitability of safflower cultivation in India. Increase of seed yield and oil content in the cultivar would eventually lead to increase in oil yield, which would make safflower a commercially competitive crop for the farmers. High oil yield potential of cultivars can be realized when seed yield *per se* combines positively with seed morphological and biochemical traits. Therefore, genetic basis and the relationships of seed yield traits with seed morphological and biochemical traits is very essential to identify a combination of traits to be used for selection in breeding programmes.

Materials and Methods
In this study, a set of 184 $F_{2:3}$ genotypes produced from the cross: A-1 xEC-755675-1, which was developed and maintained at the ICAR-Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad was used. The field experiment of segregating population was conducted in an Augmented Randomized Complete Block Design (ARCBD) with check varieties (A-1 and EC-755673-1) at the ICRISAT farm of IIOR-ICAR, Patancheru, Hyderabad. The recommended packages of practices were followed to raise good crop.

Measurement of oil content was carried out at IIOR-ICAR, Rajendranagar, Hyderabad. The data were recorded on five competitive fertile plants from each family on seven characters *viz.*, plant height (cm), number of primary branches plant^{-1}, number of capitula plant^{-1}, number of seeds capitulum^{-1}, 100 seed weight (g), oil content (%) and seed yield plant^{-1} (g) except days to 50% flowering and days to maturity for which data was recorded on plot basis. The oil content (%) was measured on whole seeds (~ 20 g of sample) using nuclear magnetic resonance (NMR) spectroscopy as described by Yadav and Murthy (2016). The mean data of five observational plants from each family were used for statistical analysis, analysis of variance for experimental design as suggested by Snedecor and Cochran, 1967 [15] (Estimation of Correlation coefficients) and Wright, 1921 [19] (Estimation of direct and indirect effects).

Results and Discussion

The results of simple correlations among eight seed yield related traits (plant height, days to 50% flowering, branch number, capitulum number, seed number per capitula, seed yield per plant, test weight and seed oil content) in 179 families are presented in Table 1 and briefly discussed below.

Simple correlation analysis was performed to understand relationships among seed yield traits in a population of $F_{3:4}$ progenies. Plant height showed no correlation with days to 50% flowering, branch number, capitulum number, seed number per capitula, seed yield per plant, test weight and seed oil content. However, several authors reported that plant height was positively associated with seed yield in safflower (Chaudhary, 1990; Kumar *et al*., 1982; Pascual-Villalobos and Alburquerque, 1996; Topal *et al.*, 2010) [5, 10, 13, 17]. Plant height showed positive correlation with days to maturity (r=0.22*) and oil content (r=0.26**) (Kurhade and Charjan, 2016) [11]. Days to 50% flowering was negatively correlated with seed yield per plant, test weight and seed oil content. Deshmukh (2009) [6] and Kurhade and Charjan (2016) [11] reported that days to 50% flowering had negative correlation with seed yield per plant. Branch number showed positive correlation with capitulum number (r=0.999**) and seed yield per plant (r=0.236**). It did not correlate with plant height, days to 50% flowering, seed number per capitulum, test weight and seed oil content.Chaudhary (1990) [5], Pascual-Villalobos and Alburquerque (1996) [13], Golkar *et al.* (2011) [8] and Kurhade and Charjan (2016) [11] observed positive correlation of branch number with seed yield per plant. Branch number showed positive correlation with capitulum number and seed yield per plant but did not correlate with plant height, days to 50% flowering, seed number per capitulum, test weight and seed oil content. Similar results were obtained for capitulum number. Bahmankar *et al.* (2014) [3], Golkar *et al.* (2011) [8], Kurhade and Charjan (2016) [11] and Pascual-Villalobos and Alburquerque (1996) [13] were also reported a strong association between capitulum number and seed yield per plant in safflower.Seed number per capitulum was negatively correlated with test weight and it did not show correlation with other traits. Negative correlation of seed number with test weight was reported by Arslan *et al.* (2007) [2], Chaudhary (1990) [5], Golkar *et al.* (2011) [8], Karimi *et al*. (2013), Khalili *et al.* (2013) [9], Kumar *et al.* (1982) [10], Kurhade and Charjan (2016) [11], Mozaffari *et al.* (2006) [12], Solanki *et al*. (1979) [16] and Topal *et al.* (2010) [17]. Test weight showed positive correlation with seed yield per plant and seed oil content while it was negatively correlated with days to 50% flowering and seed number per capitulum. Positive correlation of test weight with seed yield per plant was also observed by Solanki *et al*. (1979) [16], Chaudhary (1990) [5], Acharya *et al.* (1994) [1], Bidgoli *et al.* (2006) [4], Mozaffari *et al.* (2006) [12], Karimi *et al.* (2013) and Bahmankar *et al.* (2014) [3] in safflower. Seed oil content was positively correlated to test weight (r=0.203**) and negatively correlated with days to 50% flowering (r=-0.166**). It was not correlated with plant height, branch number, capitulum number, seed number and seed yield per plant. Vorpsi *et al.* (2010) [18] and Topal *et al.* (2010) [17] reported positive correlation of seed oil content with seed yield while Arslan *et al.* (2007) [2] and Ranga Rao *et al.* (1977) [14] reported negative correlation. Kurhade and Charjan (2016) [11] did not find correlation of seed oil content with seed yield in safflower.Seed oil content was positively correlated to test weight and negatively correlated with days to 50% flowering. Seed yield per plant was positively correlated with branch number, capitulum number and test weight while it was negatively correlated with days to 50% flowering. Positive correlation of capitulum number with seed yield remained consistent in both germplasm collection and segregating population while the correlation of days to 50% flowering, plant height, branch number, seed number per capitulum, test weight and oil content with seed yield were inconsistent.

A critical analysis of the results by path analysis revealed in Table 2 showed that test weight had the maximum direct positive effect (0.3031) on seed yield per plant followed by capitulum number (0.2167) and seed oil content (0.1428), which may be considered. Effects of other traits on seed yield were negligible, hence may not be informative.

Table 1: Correlation analysis among seed yield related traits in $F_{3:4}$ population in safflower

	DTF	PHT	BN	CN	SNC	SYP	TW
PHT	0.1154						
BN	-0.1438	-0.0836					
CN	-0.1405	-0.0822	0.9995**				
SNC	-0.0659	0.0135	0.0692	0.0687			
SYP	-0.1887**	0.0902	0.2355**	0.2345**	0.0958		
TW	-0.3031**	0.0831	0.0689	0.0651	-0.2166**	0.399**	

Critical values of correlation coefficients at 1 % and 5 % level of significance are 0.219 and 0.1665, respectively for n=179.DTF- Days to 50% flowering, PHT- Plant height, BN-Branch number, CN- Capitulum number, SNC- Seed number per capitulum, SYP-Seed yield per plant, TW- Test weight, OC- Seed oil content.

Table 2: Path analysis seed yield related traits in $F_{3:4}$ population of the cross: A-1 x EC-755673-1 in safflower

	DTF	PHT	CN	SNC	TW	OC	*r* with SYP
DTF	-0.0265	0.0089	-0.0303	-0.0107	-0.0923	-0.0258	-0.1767
PHT	-0.004	0.0583	-0.0195	0.0043	0.0075	0.0189	0.0655
CN	0.0037	-0.0052	0.2167	0.0111	0.0177	0.0041	0.2480
SNC	0.0019	0.0016	0.0159	0.1514	-0.0615	-0.0009	0.1083
TW	0.0081	0.0014	0.0127	-0.0307	0.3031	0.0432	0.3379
OC	0.0048	0.0077	0.0062	-0.001	0.0918	0.1428	0.2523
RESIDUE=0.8848							

Bold: Direct effects

DTF- Days to 50% Flowering, PHT- Plant Heigh, BN-Branch Number, CN- Capitulum Number, SNC- Seed Number per capitulum, SYP-Seed Yield per Plant, TW- Test Weight, OC- Seed oil content

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