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Character association analysis in safflower (*Carthamus tinctorius* L.)

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Abstract
The present experiment was conducted at the experimental farm of All India Co-ordinated Research Project on Safflower, V.N.M.K.V., Parbhani during *rabi*, 2019 with a view to study the genotypic and phenotypic correlation and path analysis studies for yield and yield contributing traits in safflower. Sixty two safflower germplasm accessions along with 2 local checks *viz*., A-1, PBNS-12 were evaluated. Phenotypic and genotypic correlation of seed yield was positive and significant with plant height, number of primary and secondary branches per plant, number of effective capitula per plant, 100-seed weight, hull content. Thus these characters are the key yield contributing characters to be given selection pressure for improving yield. The result of path analysis indicated that the character number of primary branches, days to 50% flowering, number of secondary branches exerted the highest direct positive effect on seed yield per plant.

Keywords: Genotypic correlation, phenotypic correlation, path analysis, safflower and germplasm

1. Introduction
Safflower (*Carthamus tinctorius* L.) is an oilseed crop belonging to family *Compositae* or *Asteraceae*. Safflower is a diploid (2n=24) annual herbaceous crop which grows well in hot and dry climate. It is mainly cultivated for its seed, which is used to make edible oil and birdseed. Traditionally, it was grown for its flowers, used for colouring and flavoring food, fabric painting and for medicinal purposes. Safflower oil is rich in polyunsaturated fatty acids (Linoleic acid 78%) that helps to reduce blood cholesterol.
The germplasm possessing high genetic variability for quantitative traits is the basic material with plant breeder to initiate breeding programme while making selection. Therefore the appropriate knowledge of such interrelationship between seed yield and its contributing characters can significantly improve the efficiency of breeding programme. Association of characters influenced by a large number of genes is elaborated statistically by correlation coefficient. The method of partitioning the correlation into direct and indirect effects by path coefficient analysis suggested by Wright (1921) provides useful information on the relative merit of the traits in the selection criterion. The nature of association between seed yield and its components determine the appropriate trait to be used in indirect selection for improvement in the seed yield (Gopal *et al.* 2014) [10]. The core objective of current experiment was to find out the correlation or association of characters for yield and its contributing traits in safflower and to recognize the most important indirect selection criteria for genetic improvement of these characters.

2. Materials and Methods
The experimental material for the present study comprised of sixty two germplasm accessions along with two local checks *viz*., PBNS-12 and A-1 were evaluated in Randomized Block Design during *Rabi* 2019-20 at All India Co-ordinated Research Project on Safflower, V.N.M.K.V., Parbhani. Each accession was grown in single row of 5 m length with a spacing of 45 cm between rows and 20 cm between plants within a row. Recommended package of practices were followed to raise the good crop. Five plants at random from each row and replication were selected and labeled for recording observations and the mean of five plants was used for statistical analysis. The data were recorded for days to 50% flowering, days to maturity, plant height at maturity (cm), number of primary branches per plant, number of secondary branches per plant, number of effective capitula per plant, number of seeds per capitulum, 100- seed weight (g), seed yield per plant (g), hull content (%), oil content (%). In order to study the extent of association between different traits, the genotypic and phenotypic

simple correlation coefficients were worked out from the respective variances and covariances. The formulae as suggested by Johnson *et al*. (1995) [13] were used for calculating simple correlation coefficient as given below.

1. Genotypic correlation coefficient (rg_x)

$$rg_{xy} = \frac{Cov(g_x.g_y)}{\sqrt{\sigma^2 g_x.\sigma^2 g_y}}$$

Where

Cov ($g_{x.}g_y$) = Genotypic covariance between character x and y $\sigma^2 g_x$ and $\sigma^2 g_y$ = genotypic variance of character x and y, respectively.

Similarly,

2. Phenotypic correlation coefficient (rP_{xy})

$$rP_{xy} = \frac{Cov(P_x.P_y)}{\sqrt{\sigma^2 P_x.\sigma^2 P_y}}$$

Where

Cov ($P_{x.}P_y$) = Phenotypic covariance between characters x and y.

$\sigma^2 P_{x.}\sigma^2 P_y$ = Phenotypic variance of characters x and y, respectively.

Significance of correlation coefficient was determined from the Fisher and Yates table 'correlation coefficient' at 5 and 1 per cent level of significance. The r values were compared against (n-2) degrees of freedom.

The path analysis was performed to find out the direct and indirect effects of all the characters under study by the formula suggested by Dewey and Lu (1958).

3. Results and Discussion

Seed yield is a complex character and is dependent on number of component characters. Therefore, study of relationship of characters with each other and with seed yield become more important in crop improvement programme. Therefore, it is essential to find out relative contribution of each of the component character in yield for giving due weightage during selection. The result of current research revealed that phenotypic and genotypic characters associations are on par with each other signifying the less influence of environment (Table 1).

The seed yield per plant recorded significant and positive association with the number of secondary branches (0.953), number of effective capitula per plant (0.596), hull content (0.444), 100-seed weight (0.299) and plant height (0.265) at genotypic level. The phenotypic correlation of the character seed yield per plant recorded significant and positive association with number of secondary branches (0.910), number of primary branches (0.899), number of effective capitula (0.579), hull content (0.339) and plant height (0.253). The character oil content (-0.365) showed negative and significant association. The character which had non-significant but positive association with days to maturity (0.016), number of seeds per capitulum (0.087) and days to 50% flowering (0.117) at genotypic level. The character oil content (-0.240) showed negative but significant correlation with seed yield per plant. The characters which showed non-significant but positive association with days to maturity (0.018), number of seeds per capitulum (0.095), and days to 50% flowering (0.113) at phenotypic level.

Phenotypic and genotypic correlation of seed yield was positive and significant with plant height, number of primary and secondary branches per plant, number of effective capitula per plant, 100-seed weight, hull content. Plant height showed positive and significant correlation with the seed yield. Similar results were found by Murat and Vahdettin (2004) [23], Arslan B. (2007) [4], Ahmadzadeh *et al*. (2008) [3], Kurhade and Charjan. (2011) [15], El Lattief (2012) [9], Behnam *et al*. (2012) [6], Ahmadzadeh (2013) [1], Sirel and Aytac (2016) [20], Sundargirwar *et al*. (2015) [21], Dambal and Patil (2016) [8], Pavithra *et al*. (2016) [18], Talebi and Abhari (2016) [22], Arzu *et al*. (2018) [5].

For number of effective capitula per plant number of branches per plant had positive and significant association with seed yield. Similar results were found by Murat and Vahdettin (2004) [23] Arslan (2007) [4], Dambal and Patil (2016) [8], Pavithra *et al*. (2016) [18], Jadhav *et al*. (2018) [12], for effective capitula per plant, Hajghani *et al*. (2009) [11], Omidi *et al*. (2009) [16], Kurhade and Charjan. (2011) [15], El Lattief (2012) [9]. 100- seed weight found positive and significant association with seed yield per plant. Similar results were obtained by Omidi *et al*. (2009) [16], El Lattief (2012) [9]. However days to 50% flowering, days to maturity and no. of seeds per capitulum had non-significant and positive association with seed yield per plant in both genotypic and phenotypic correlation studies.

The values of correlation coefficient indicate simply the nature and extent of relationship present among the pairs of traits. The direct and indirect effects of various grain yield characters on grain yield both at genotypic and phenotypic levels are presented in (Table-2). The path analysis indicated that the character number of primary branches per plant, days to 50% flowering, number of secondary branches per plant exerted the highest direct positive effect on seed yield per plant. Hence, for the improvement of grain yield these characters must be considered in a direct selection criterion. Similar findings for the character number of secondary branches per plant were reported by Reddy *et al.* (2004) [19], Kamran and Ali (2006) [14], Pavithra *et al*. (2016) [18]. The character days to maturity, plant height, number of effective capitula per plant, hull content and oil content had direct negative effect on seed yield per plant. Ahmadzadeh *et al.*, (2012) [2] who found negative direct effect of days to maturity and positive direct effect of days to 50% flowering on seed yield in safflower. The characters days to 50% flowering (-0.052), days to maturity (-0.049), and plant height (-0.014) showed negative and non-significant indirect effect on seed yield per plant.

In conclusion, from the result of present investigation it can be concluded that plant height, number of primary and secondary branches per plant, number of effective capitula per plant, 100-seed weight, hull content. Thus these characters are the key yield contributing characters through which high yielding genotypes of safflower may be selected for future hybridization programme.

Table 1: Phenotypic correlation (PC) and genotypic correlations (GC) between seed yield and yield contributing traits in safflower genotype

Sr. No.	Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of effective capitula per plant	Number of seeds per Capitulum	100- seed weight (g)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
1.	Days t50% flowering	PC	1.000	0.954**	0.521**	0.114	0.140	0.125	0.272**	- 0.068	0.025	0.508 **	0.113
		GC	1.000	0.976**	0.492**	0.061	0.132	0.134	0.292**	- 0.063	- 0.236**	0.397**	0.117
2.	Days to maturity	PC		1.000	0.456**	0.045	0.035	0.088	0.290 **	- 0.065	- 0.002	0.533 **	0.018
		GC		1.000	0.399**	- 0.052	0.005	0.080	0.314**	- 0.067	- 0.402**	0.374**	0.016
3.	Plant height (cm)	PC			1.000	0.293 **	0.245**	0.395 **	0.457 **	- 0.034	- 0.023	0.239**	0.253**
		GC			1.000	0.270**	0.238**	0.414**	0.473**	- 0.039	- 0.254**	0.112	0.265**
4.	Number of primary branches / plant	PC				1.000	0.873 **	0.603 **	0.115	0.319 **	0.349 **	- 0.188 *	0.899**
		GC				1.000	0.930**	0.672**	0.091	0.336**	0.314**	- 0.471**	1.003
5.	Number of secondary branches/ plant	PC					1.000	0.508 **	0.049	0.254 **	0.362**	- 0.206 *	0.910**
		GC					1.000	0.552**	0.047	0.259**	0.421**	- 0.356**	0.953**
6.	Number of effective capitula/plant	PC						1.000	0.348**	0.270 **	0.130	- 0.110	0.579**
		GC						1.000	0.362**	0.332**	0.147	- 0.194*	0.596**
7.	Number of seeds/ capitulum	PC							1.000	- 0.065	0.028	- 0.000	0.095
		GC							1.000	- 0.071	0.000	- 0.024	0.087
8.	100- seed weight (g)	PC								1.000	0.279**	- 0.274**	0.269**
		GC								1.000	0.382**	- 0.385**	0.299**
9.	Hull content (%)	PC									1.000	- 0.274**	0.339**
		GC									1.000	- 1.243	0.444**
10.	Oil content (%)	PC										1.000	-0.240**
		GC										1.000	- 0.365**
11.	Seed yield / plant (g)	PC											1.000
		GC											1.000

Table 2: Path analysis direct (diagonal) and indirect effects of yield contributing character on grain yield in safflower genotypes

Sr. No	Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	Number of primary branches per plant	Number of secondary branches per plant	Number of effective capitula per plant	Number of seeds per capitulum	100- seed weight (g)	Hull content (%)	Oil content (%)	Seed yield per plant (g)
1	Days to 50% flowering	P	0.151	0.144	0.078	0.017	0.021	0.019	0.041	-0.010	0.003	0.077	0.113
		G	0.589**	0.575**	0.290**	0.036	0.078	0.079	0.172	-0.037	-0.139	0.234**	0.117
2	Days to maturity	P	-0.118	-0.123	-0.056	-0.005	-0.004	-0.010	-0.036	0.008	0.000	-0.066	-0.066
		G	-0.480**	-0.492**	-0.196*	0.026	-0.002	-0.039	-0.155	0.033	0.198*	-0.184*	0.016
3	Plant height (cm)	P	-0.016	-0.014	-0.032	-0.009	-0.007	-0.012	-0.014	0.001	0.0007	-0.007	0.253**
		G	-0.056	-0.045	-0.114	-0.030	-0.027	-0.047	-0.053	0.004	0.029	-0.012	0.265**
4	Number of primary branches/ plant	P	0.047	0.019	0.122	0.415**	0.363**	0.250**	0.047	0.132	0.145	-0.078	0.899**
		G	0.050	-0.043	0.221*	0.816**	0.759**	0.549**	0.074	0.274**	0.257**	-0.384**	1.003
5	No. of secondary branches/ plant	P	0.069	0.017	0.121	0.430**	0.493**	0.251**	0.024	0.125	0.178*	-0.101	0.910**
		G	0.026	0.001	0.048	0.188*	0.202*	0.111	0.009	0.052	0.085	-0.072	0.953**
6	Number of effective capitula/ plant	P	0.010	0.007	0.032	0.049	0.042	0.082	0.028	0.022	0.010	-0.009	0.579**
		G	-0.012	-0.007	-0.037	-0.060	-0.049	-0.089	-0.032	-0.029	-0.013	0.017	0.596**
7	Number of seeds/ capitulum	P	0.0009	0.0009	0.001	0.0004	0.0002	0.001	0.003	-0.0002	0.0001	0.0000	0.095
		G	0.020	0.022	0.033	0.006	0.003	0.025	0.070	-0.005	0.000	-0.001	0.087
8	100-seed weight	P	0.001	0.001	0.0009	-0.007	-0.006	-0.006	0.001	-0.024	-0.006	0.006	0.269**
		G	-0.0006	-0.0006	-0.0004	0.003	0.002	0.003	-0.0006	0.008	0.003	-0.003	0.299**
9	Hull content (%)	P	-0.0003	0.0000	0.0003	-0.003	-0.004	-0.001	-0.0003	-0.003	-0.011	0.003	0.339**
		G	0.033	0.056	0.035	-0.044	-0.058	-0.020	-0.0001	-0.053	-0.139	0.173*	0.444**
10	Oil content (%)	P	-0.032	-0.034	-0.015	0.012	0.013	0.007	0.0000	0.017	0.017	-0.064	-0.240**
		G	-0.052	-0.049	-0.014	0.061	0.046	0.025	0.003	0.050	0.163	-0.131	-0.365**

Residual effect of Phenotypic Correlation (PC) = 0.342, Residual effect of Genotypic Correlation (GC) =0.125

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