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Correlation analysis between seed yield and yield contributing traits over the locations in genotypes of safflower (*Carthamus tinctorius* L.)

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Abstract
The present investigation is carried out for assessment of yield and yield contributing characters of safflower genotypes over four locations. Twelve genotypes were used in the field experiments, which were carried out at the AICRP on Safflower Parbhani, Oil Seeds Research Station in Latur, Agricultural Research Station in Badnapur, and Agricultural Research Station in Somnathpur. Thirteen morphological characters were studied for the observations. There was observed a positive correlation between yield and the test weight, the number of seeds per capitulum, the days to maturity, the number of seeds per capitulum, and the days to 50% flowering.

Keywords: Character association, correlation, environments, safflower, seed yield

Introduction
The botanical name for safflower is *Carthamus tinctorious* (L.), and it is also known as "karadi" in Marathi and "kusum" in Hindi. Safflower is a member of the Phanerogams division, the Angiosperm subdivision, the tribe Tubiflorae, and the family Asteraceae (Compositae). This genus contains 36 species, of which only *Carthamus tinctorious* (L.) (2n=24) is cultivated and used for oil production. The other species are all wild. Safflower is thought to have originated in three main regions: India, Irano-Afghanistan, and Ethiopia, according to Vavilov (1949) [14]. Wild species *C. palaestinus* is the progenitor of the weedy species *C. oxyacantha* and *C. percicus*. The cultivated species C. tinctorius is thought to have descended from these weedy species (Ashri and Knowles, 1960) [1]. The traditional purpose of the safflower crop is to produce seeds that can be used to make edible oil. Safflower has an oil content ranging from 25 to 37%, depending on the genotype, environment, and cultural practises. (Sargar *et al.*, 2021) [12] Thiamine and beta-carotene are vitamins, as are tocopherols, and minerals like Zn, Cu, Mn, and Fe found in safflower seeds (Phuduhudu, 2017) [10].
Safflower is an annual herbaceous thistle-like plant that is highly branched, 2 to 6 feet tall, and has numerous long, sharp spines on its leaves. Its flower head, or capitulum, is yellow or orange (rarely white to red), and its seeds, or achenes, are white, shiny, and smooth (Knowles, 1969) [6]. Safflower is primarily self-pollinated, but there has been a reported 28% cross-pollination rate, primarily through bees (Kadam and Patankar, 1942) [14]. Safflower petals are used to make herbal tea and have a variety of therapeutic and medicinal benefits. As a natural colouring agent, carthamin dye (obtained from petals) is frequently used. Salad and cooking herbs both use the tender leaves and shoots. Safflower oil is used in the production of paints, varnishes, and linoleum because it is high in PUFA (Linoleic acid 78%), which is crucial in lowering blood cholesterol levels. Safflower seed cakes with decorations are added to animal and poultry feed as a source of protein.
Correlation is a metric used to assess the mutual relationship between two variables. It acts as a gauge of how linearly and closely related two variables are. Studying correlations can help plant breeders better understand how the growth of one character will influence the concurrent growth of other characters. Character association research can be used to establish selection criteria for grain yield in parental lines so that the plants with the desired combination of characters can be successfully isolated (Kante *et al.*, 2022) [5]. Phenotypic correlation is the relationship between phenotypic values, and it can change as a result of environmental factors. The genomic correlation is the breeding value correlation. Therefore, understanding the relationships between various characters is crucial for creating a sound breeding programme (Shrotri *et al.*, 2021) [13].

Additionally, it helps in formulating the selection criteria for simultaneously enhancing a number of traits and economic yield.

Material and Methods

The current investigation was carried out at four locations: the AICRP on Safflower Parbhani, the Oilseeds Research Station Latur, the Agricultural Research Station Badnapur, and the Agricultural Research Station Somanathpur during the 2019 Rabi season. Nine safflower genotypes and three check varieties—PBNS-86, PBNS-12, and Sharda—were obtained from the AICRP on Safflower, Parbhani. Genotypes were sown at four different sites. At the AICRP's Safflower, Parbhani (E1), Oilseeds Research Station, Latur (E2), Agricultural Research Station, Badanapur (E3), and Agricultural Research Station, Somanathpur (E3) stations.

Name of genotypes

Sr. No.	Genotypes	Sr. No.	Genotypes
1	PBNS – 86 (check)	7	PBNS – 154
2	PBNS – 185	8	PBNS – 197
3	PBNS – 200	9	PBNS – 198
4	PBNS – 201	10	Sharda (check)
5	PBNS – 12 (check)	11	PBNS – 207
6	PBNS – 153	12	PBNS – 208

The experimental material was evaluated in Randomized Block Design (RBD) with three replications. Observations were recorded on thirteen yield and yield contributing characters. Analysis of variance location wise as per the method described by Panse and Sukhatme (1985) [8]. The phenotypic and genotypic correlation coefficient were computed by the formulae suggested by Falconer and Mackay (1964) [3] and elaborated by Dewey and Lu (1959) [2].

Result and Discussion

Analysis of variance revealed highly significant differences among the genotypes for all the characters examined. This illustrated the existence of quite variation in all the characters for successful selection in the material under study. The phenotypic correlation reveals the strength of the observed association between two characters. Given that it takes into account both inheritance and environmental factors, this does not give a true genetic picture of the relationship. Genotypic correlation provides an estimate of an inherent association between the genes controlling two characters when they are invariably and linearly connected. The underlying genetic mechanism causing this connection is either pleiotropy or complete linkage between the two characters. In order to create a successful selection strategy, genotypic correlation is therefore more significant. The focus of the current discussion is therefore solely on genotypic correlation coefficients. They could be useful in identifying important traits for crop improvement programmes like yield enhancement.

An analytical tool for assessing the degree of association between two characters who operated at the same time is the correlation coefficient. The breeder can determine the genetic make-up of an ideal variety and the relationship or correlation between the characters under consideration with the help of correlation studies. In this study, the yield and yield-contributing traits' phenotypic and genotypic correlation coefficients were calculated and are shown in Tables 1 to 4.

In all environments, seed yield per plant has a significant and positive correlation with days to 50% flowering, number of seed per capitulum, days to maturity, seed yield per plot and test weight, as shown in Tables 1 to 4. In E1 environment seed yield per plant recorded significant and positive association with days to 50% flowering (G = 0.4541, P = 0.3625), number of seed per capitulum (G = 0.9463, P = 0.4613) and seed yield per plot (G = 1.0065, P = 0.9712) at both levels. The association was significant and positive with days to maturity (G = 0.7513) at genotypic level only. Seed yield per plant was also exhibited positive but non-significant with number of capitula per plant (G= 0.2985, P = 0.0462), days to rosette period (G = 0.2162, P = 0.1243) and oil content (G = 0.0993, P = 0.0220) at both levels. Primary branches per plant (G = -0.5776, P = -0.4354) had significant but negative association at both levels. Test weight (G = -0.3479) had significant and negative association at genotypic level only. In E2 environment, seed yield per plant exhibited significant and positive association with days to 50% flowering (G = 0.7374, P = 0.4305) and seed yield per plot (G = 1.0030, P = 0.9971) at both levels. Seed yield per plant recorded positive association and significant at genotypic level only with days to maturity (G = 0.5965), primary branches per plant (G = 0.6455) and hull content (G = 0.5910). The character seed volume weight (G = 0.1271, P = 0.0693) had non-significant and positive association at both levels.

In E3 environment seed yield per plant showed significant and positive association with days to 50% flowering (G = 0.6034, P = 0.4047), days to maturity (G = 0.8702, P = 0.3942) and seed yield per plot (G = 1.0024, P = 0.9883) at both levels. Seed yield per plant had significant and positive association with days to rosette period (G = 0.7166), test weight (G = 0.8181), oil content (G = 0.4414) and hull content (G = 0.4533) at genotypic level only. Number of capitula per plant (G = - 0.6991, P = -0.3921) had significant but negative association at both levels. In E4 environment, seed yield per plant revealed positive association and significant with seed yield per plot (G = 0.9927, P = 0.9893) at both levels. Seed yield per plant had significant and positive association with plant height (G = 0.3460), number of primary branches per plant (G = 0.8629) and hull content (G = 0.5229) at genotypic level only. Number of seed per capitulum (G = -0.4349, P = -0.3531) had significant but negative association both levels. Seed yield per plant had significant and negative association at genotypic level only with days to maturity (G = -0.3470), number of capitula per plant (G = -1.2945) test weight (G = -0.5522) and oil content (G = -0.4161). These findings are close agreement with Naik *et al.*, (2009) [7] and Yadav *et al.*, (2017) [15].

In other correlation studies it is observed that, days to 50% had positive correlation with days to maturity, seed yield per plot, rosette period and oil content in E2 and E3 environment, whereas, in E1 and E4 environment similar trend were not observed but had positive correlation with number of seed per capitulum, seed volume weight, seed yield per plot in E1 environment and days to maturity in E4 environment. Days to maturity had positive correlation with days to rosette period, seed yield per plot, capitula per plant in E2 and E3 environment, whereas, E1 environment was positively correlated with oil content, seed volume weight and seed yield per plot.

Table 1: Estimation of phenotypic and genotypic correlation coefficient under E1 environment in safflower (Parbhani)

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	primary branches/plant	Number of capitula/plant	Number of seeds/capitulum	Days to rosette period	Test weight (g)	Oil Content (%)	Hull content (%)	Seed volume weight (g/lit)	Seed yield/ Plot (g)	Seed yield/ plant (g)
Days to 50% flowering	G	1	0.8439**	-0.2533	-0.1206	-0.2396	0.7526**	-0.5257**	-0.4441**	0.2551	-0.4298**	0.4724**	0.4714**	0.4541**
	P	1	0.3213	-0.2107	-0.0794	-0.0237	0.3645 *	-0.3199	-0.2826	0.1729	-0.2773	0.3436 *	0.4101 *	0.3625*
Days to maturity	G		1	0.1827	0.3215	-0.2059	0.3152	0.0979	-0.5951**	0.3611*	-0.2104	0.6573**	0.7267**	0.7513**
	P		1	0.1794	0.1777	0.0685	0.1225	-0.0763	-0.3166	0.1459	-0.1310	0.2747	0.0722	0.0739
Plant height (cm)	G			1	0.3744*	0.4155*	0.1109	-0.1952	-0.3542*	-0.4457**	0.6351**	0.0457	-0.3096	-0.3222
	P			1	0.1874	0.3475 *	-0.0074	-0.1207	-0.2165	-0.3398 *	0.3143	0.0625	-0.2989	-0.3495*
Primary branches/plant	G				1	-0.1212	-0.7546**	0.1837	0.1750	0.1336	0.2040	0.6898**	-0.5739**	-0.5776**
	P				1	0.0990	-0.3116	0.0539	0.1159	-0.0907	0.0288	0.3544 *	-0.4599 **	-0.4354**
No. of capitula/ plant	G					1	0.6878**	0.2818	-0.4325**	-0.5627**	0.7780**	-0.2336	0.2236	0.2985
	P					1	-0.0632	-0.0112	-0.0606	-0.4851**	0.5859 ***	0.0459	0.0067	0.0462
No. of seed/ Capitulum	G						1	-0.7756**	-0.4489**	-0.6599**	0.5541**	0.4303**	0.9862**	0.9463**
	P						1	-0.0786	-0.1578	-0.1679	0.0283	0.0652	0.5007 **	0.4613**
Days to rosette period	G							1	0.1360	-0.1321	0.0659	0.0479	0.1298	0.2162
	P							1	-0.0479	0.0327	-0.0194 -	0.0580	0.1579	0.1243
Test weight (g)	G								1	-0.1785	0.1393	-0.0340	-0.3692*	-0.3479*
	P								1	-0.1459	0.1590	0.0555	-0.1996	-0.1410
Oil content (%)	G									1	0.9010**	-0.1990	0.0613	0.0993
	P									1	0.5639 **	-0.1402	0.0363	0.0220
Hull content (%)	G										1	0.2924	-0.1527	-0.1017
	P										1	0.2280	-0.0479	0.0076
Seed volume weight (g/lit)	G											1	0.0869	0.1180
	P											1	0.0006	-0.0494
Seed yield/plot (g)	G												1	1.0065**
	P												1	0.9712**
Seed yield/plant (g)	G													1
	P													1

Table 2: Estimation of phenotypic and genotypic correlation coefficient under E2 environment in safflower (Latur)

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	primary branches/plant	Number of capitula/plant	Number of seeds/capitulum	Days to rosette period	Test weight (g)	Oil Content (%)	Hull content (%)	Seed volume weight(g/lit)	Seed yield/ Plot (g)	Seed yield/ plant (g)
Days to 50% flowering	G	1	1.0133**	-0.0252	0.2308	0.5523**	-0.0557	0.4773**	-0.2394	-0.1080	0.3448*	0.4168*	0.7358**	0.7374**
	P	1	0.8381**	-0.0696	0.1798	0.3140	0.0222	0.3648*	-0.1252	0.0645	0.2515	0.2178	0.4246**	0.4305**
Days to maturity	G		1	-0.1001	0.1486	0.4147*	-0.0947	0.5763**	-0.1803	0.0403	0.0882	0.1256	0.5976**	0.5965**
	P		1	-0.1491	0.0304	0.2933	-0.0454	0.4914**	-0.0883	0.1748	0.0697	0.0411	0.3189	0.3144
Plant height (cm)	G			1	0.5521**	0.5810**	0.6683**	0.2056	0.4931**	-0.4143*	-0.1947	0.1508	-0.2629	-0.2649
	P			1	0.1969	0.3672*	0.4579**	0.0205	0.3348*	-0.3199	-0.2590	0.0183	0.0382	0.0429
Primary branches/plant	G				1	0.0703	0.4711**	0.1750	-0.4061*	0.0489	0.0238	0.6776**	0.6324**	0.6455**
	P				1	-0.0657	0.1946	0.2066	-0.2118	-0.0334	0.1122	0.2071	0.0720	-0.0759
No. of	G					1	0.3561*	0.4798**	0.4018*	-0.0323	0.0289	0.3875*	0.0450	0.0589

capitula/ plant	P					1	0.2994	0.3449*	0.3577*	0.0412	0.0516	0.3492*	-0.0541	-0.0424
No. of seed/ Capitulum	G						1	0.0069	-0.2025	-0.0906	-0.7410**	0.3008	0.0131	-0.0310
	P						1	-0.1006	-0.1146	-0.0022	-0.3855*	0.1264	-0.0170	-0.0170
Days to rosette period	G							1	-0.0110	0.4212*	0.0772	-0.0410	0.1697	0.1808
	P							1	-0.0011	0.3272	0.0164	0.0530	-0.0158	-0.0256
Test weight (g)	G								1	-0.4803**	0.0789	-0.4687**	-0.3202	-0.2983
	P								1	-0.2915	0.1269	-0.3124	-0.2665	-0.2478
Oil content (%)	G									1	-0.5105**	-0.0236	-0.2300	-0.2583
	P									1	-0.2839	-0.0614	-0.1448	-0.1264
Hull content (%)	G										1	0.4035*	0.5676**	0.5910**
	P										1	0.1629	0.2355	0.2613
Seed volume weight (g/lit)	G											1	0.0978	0.1271
	P											1	0.0875	0.0693
Seed yield/plot (g)	G												1	1.0030**
	P												1	0.9971**
Seed yield/plant (g)	G													1
	P													1

Table 3: Estimation of phenotypic and genotypic correlation coefficient under E3 environment in safflower (Badnapur)

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	primary branches/plant	Number of capitula/plant	Number of seeds/capitulum	Days to rosette period	Test weight (g)	Oil Content (%)	Hull content (%)	Seed volume weight (g/lit)	Seed yield/ Plot (g)	Seed yield/ plant (g)
Days to 50% flowering	G	1	0.8788**	0.1885	0.4871**	-0.5534**	0.1993	0.3277	0.3197	0.4836**	0.1069	-0.0549	0.6481**	0.6034**
	P	1	0.4276**	0.2012	0.2871	-0.3249	0.2379	0.3083	0.1146	0.3462*	-0.0993	-0.0004	0.4208*	0.4047*
Days to maturity	G		1	0.2678	0.2405	-0.6807**	-0.2351	0.4624**	0.8184**	-0.0032	-0.1190	0.1703	0.9870**	0.8702**
	P		1	0.1428	0.0682	-0.2091	0.0109	0.1934	0.2348	-0.0855	0.1100	-0.1491	0.4069*	0.3942*
Plant height (cm)	G			1	-0.0513	-0.3561*	0.8081**	0.1956	0.1763	-0.0780	-0.3810*	-0.2339	-0.0504	-0.0343
	P			1	-0.0500	-0.2364	0.4277**	0.1748	0.0322	0.0151	-0.1270	-0.1256	-0.0868	-0.0924
Primary branches/plant	G				1	-0.1342	-0.1532	-0.3546*	0.3495*	0.2520	0.4316**	-0.6311**	0.1963	0.2224
	P				1	0.0649	0.0026	-0.1829	0.1151	0.0670	0.1103	-0.3198	-0.0413	-0.0630
No. of capitula/ plant	G					1	0.2165	-0.4536**	-0.4581**	-0.6330**	0.9142**	0.5885**	-0.6325**	-0.6991**
	P					1	0.1502	-0.1795	-0.4252**	-0.5659**	0.2404	0.2338	-0.3880*	-0.3921*
No. of seed/ Capitulum	G						1	0.0444	-0.7294**	0.3312*	-0.2559	0.1652	-0.3023	-0.2866
	P						1	0.0699	-0.3271	0.0776	-0.0563	0.0665	-0.0272	-0.0193
Days to rosette period	G							1	0.2542	0.0619	-0.1764	0.7680**	0.7111**	0.7166**
	P							1	0.0732	-0.0210	-0.1617	0.5319**	0.2760	0.2837
Test weight (g)	G								1	-0.3666*	0.3602*	-0.3801*	0.8189**	0.8181**
	P								1	-0.1423	0.3300*	-0.0762	0.2820	0.2828
Oil content (%)	G									1	0.7111**	-0.4512**	0.3780*	0.4414**
	P									1	0.3713*	-0.1489	0.1875	0.2167
Hull content (%)	G										1	0.1673	0.5000**	0.4533**
	P										1	-0.0159	-0.0554	-0.0632
Seed volume weight (g/lit)	G											1	0.1457	0.0817
	P											1	0.0409	0.0569

Seed yield/plot (g)	G												1	1.0024**
	P												1	0.9883**
Seed yield/plant (g)	G													1
	P													1

Table 4: Estimation of phenotypic and genotypic correlation coefficient under E4 environment in safflower (Somnathpur)

Characters		Days to 50% flowering	Days to maturity	Plant height (cm)	primary branches/plant	Number of capitula/plant	Number of seeds/capitulum	Days to rosette period	Test weight (g)	Oil Content (%)	Hull content (%)	Seed volume weight (g/lit)	Seed yield/ Plot (g)	eed yield/ plant (g)
Days to 50% flowering	G	1	1.0410**	-0.0027	-0.0218	-0.3700*	-0.5359**	0.2964	-0.4099*	-0.1429	-0.6150**	-0.0839	0.0687	0.2008
	P	1	0.6133***	-0.0402	0.0090	-0.1042	-0.2852	0.2621	-0.2081	-0.1186	-0.3626 *	-0.0776	0.0710	0.1486
Days to maturity	G		1	-0.5799**	-0.3410*	-0.0840	-0.3245	0.2841	-0.1039	-0.3063	-0.4745**	-0.2625	-0.4165*	-0.3470*
	P		1	0.0544	-0.2700	-0.0262	-0.2202	0.1167	0.0300	-0.0461	-0.2971	-0.0279	-0.0250	0.0227
Plant height (cm)	G			1	-0.1178	0.1575	0.5582**	0.0891	-0.1236	0.6174**	0.2007	-0.0858	0.3247	0.3460*
	P			1	-0.3736 *	-0.1079	0.1436	0.0797	-0.0467	0.3218	-0.0531	0.0242	-0.0114	0.0019
Primary branches/plant	G				1	-0.8400**	-0.1115	0.1447	-0.3562*	-0.2409	0.1935	0.3166	0.8413**	0.8629**
	P				1	-0.1061	-0.0375	0.1541	-0.2378	-0.2670	0.1399	0.2091	0.3123	0.3051
No. of capitula/ plant	G					1	0.3050	-0.2699	1.0606**	-0.1189	0.2767	0.3245	-1.2703**	-1.2945**
	P					1	0.0579	-0.1924	0.3783 *	0.0229	-0.0073	0.1953	-0.1387	-0.1669
No. of seed/ Capitulum	G						1	0.0179	0.0554	0.1737	0.3276	0.3040	-0.3510	-0.4349**
	P						1	0.0073	-0.0066	-0.0358	0.3343 *	0.0942	-0.3437 *	-0.3531*
Days to rosette period	G							1	-0.4150*	0.4202*	-0.9133**	-0.3397*	-0.1173	-0.0703
	P							1	-0.1960	0.2691	-0.3469 *	-0.1109	-0.0765	-0.0415
Test weight (g)	G								1	-0.3105	0.3534*	-0.1004	-0.4813**	-0.5522**
	P								1	-0.2451	0.2028	-0.0453	-0.2235	-0.2317
Oil content (%)	G									1	-0.5171**	-0.0796	-0.3795*	-0.4161*
	P									1	-0.2761	-0.0999	0.0550	0.0421
Hull content (%)	G										1	0.4437**	0.6816**	0.5229**
	P										1	0.3009	0.1394	0.1017
Seed volume weight (g/lit)	G											1	0.2498	0.2065
	P											1	0.3297 *	0.2995
Seed yield/plot (g)	G												1	0.9927**
	P												1	0.9893**
Seed yield/plant (g)	G													1
	P													1

Plant height had positive correlation with number of primary branches per plant, number of capitula per plant and hull content in E1 and E2 environment, whereas, seed per capitula had positively correlated in E3 and E4 environment. Primary branches had positive correlation with seed volume weight in E1 and E2 environment, however seed yield per plot had positively correlated in E2 and E4 environment. In E3 environment positive correlation with test weight and hull content. Number of capitula per plant had positive correlation with hull content in E1 and E3 environment, whereas, capitula per plant had positive correlation with test weight in E2 and E4 environment. Day to rosette period had positive correlation with oil content in E2 and E4 environment, while in E3 environment days to rosette period had positive correlation with seed volume weight and seed yield per plot. Test weight had positive correlation with hull content in E3 and E4 environment. Hull content had positive correlation with seed yield per plot in E2, E3 and E4 environment. Oil content had positive correlation with hull content in E1 and E3 environment. In one or more environments, the rest of the characters are positively correlated.

The present results of significant positive correlation between yield and yield contributing characters such as days to maturity, primary branches per plant, plant height, number of capitula per plant, number of seeds per capitulum, test weight and hull content are in agreement with the findings of Pavitra (2016) [9] and Yadav (2017) [15] and Purkaystha and Srivastava (2020) [11]. These characters are showing significant positive correlation with yield, it indicated that direct selection of genotypes for crop improvement on the basis of component trials.

Conclusion

The presented investigation revealed that, the seed yield per plant recorded significant and positive association with Number of seed per capitulum, day to 50% flowering, days to maturity and test weight, which are considered as important yield components of seed yield over four locations. These yield components could be used in any future safflower breeding programme for yield improvement. Hence, higher yield could be obtained by exerting selection pressure over any of these traits.

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