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Correlation and path coefficient analysis for various quantitative traits in chickpea (C*icer arietinum* l.)

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Abstract
An experiment was conducted to study, the genetic association among 65 (50 F_1s + 15 Parents) treatments for 11 quantitative characters in which biological yield per plant, 100 seed weight, harvest index and pods per plant showed highly positive significant correlations with seed yield per plant in both timely and late sown environments. Whereas, Path analysis showed highly positive direct effects towards expression of seed yield per plant were displayed by biological yield per plant followed by harvest index and 100 seed weight in both timely and late sown environments. Highly positive indirect effects on seed yield per plant were exerted by biological yield per plant *via* 100 seed weight, pods per plant, plant height, primary branches per plant and days to 50 per cent flowering in both the environments. Significantly inter correlation among traits are useful in breeding programme for improvement of yield and its component traits.

Keywords: *Chickpea; Cicer arietinum L.; Correlation; Path analysis; Yield.*

Introduction
Pulses, also known as grain legumes, are a group of 12 crops that includes dry beans, dry peas, chickpeas, and lentils. They are high in protein, fibre, and various vitamins, amino acids, contain low fat, low sodium and no cholesterol. They also contribute to soil quality by fixing atmospheric nitrogen in the soil. They have emerged as the most important crop group which has been cultivated by human since ancient times. They have become very important in our daily diet. At least one of these pulses (dals) – chana (chickpea), mung, masur, tur, urad, is found in the menu of most of the Indian families every day. Over the years, India continues to be the largest producer and consumer of pulses in the world. In India total pulses are grown on an area of 8.39 m ha, with production of 7.06 mt and productivity of 840 kg/ha in (Anonymous, 2016). The major pulse crops grown in India are chana (chickpea), mung beans, urad, pigeon peas, dry peas and lentils. India grows a variety of pulse crops under a wide range of agro-climate conditions and is recognized globally as a major player in pulses contributing around 25-28% of the total global production.

Chickpea (Cicer arietinum L.) belongs to genus Cicer, tribe Cicereae, family Fabaceae, and subfamily Papilionaceae. It originated in south-eastern Turkey. Among pulse crops, chickpea occupies a premier position in respect of area and production in the world. Chickpea is a premier pulse crop of India covering 9.51 million hectares area and production contributing 8.83 million tones with the productivity of 929 kg/ha. The area, production and productivity of Utter Pradesh has been possessed 368.00 thousand ha, 164.00 thousand tones, 612.00 kg/ha respectively in year 2015-16 (Anonymous, 2016). Chickpea is the cheapest and most readily available source of protein (19.5%), fat (1.4%), carbohydrates (57-60%), ash (4.8%) and moisture (4.9-15.59%). It is called as poor man's meal (reported by Huisman and Vander Poel, 1994) and also helps to replenish soil fertility by fixing atmospheric N_2 via symbiosis. Despite its nutritional values and economic importance, chickpea production is relatively low in country; this is primarily due to poor genetic makeup of the cultivars available. Besides other reasons, the drought stress, poor management and biotic factors such as blight, wilt disease and pod borer are the major constraints to achieve potential yield. Yield is the major complicated traits that is an outcome of interaction of plant characters and is highly influenced by environmental changes. The direct selection of plant on the basis of seed yield may be misleading. Therefore, characters association and path analysis must be studied to understand the contribution of genotype and environment towards the final yield before selection of plant.

Materials and Methods

A field experiment was conducted at Student's Instructional Farm, N.D.University of Agriculture and Technology, Kumarganj (Narendra Nagar), Faizabad, Uttar Pradesh, India during *Rabi* season 2013-2015 on 65 treatments (50 F_1s +15 Parents) in Randomized Block design with three replications and two environments i.e., Timely sown (E_1) and late sown (E_2). Each line was grown in one row of 4 meter length. Row to row and plant to plant spacing was kept 30 cm and 10 cm, respectively. On the basis of 5 randomly selected plants data were recorded in both the environments on primary branches per plant, secondary branches per plant, plant height (cm), pods per plant, seeds per pod, biological yield per plant (g), seed yield per plant (g), harvest index (%) and 100 seed weight (g) except days to 50% flowering and days to maturity which were recorded on plot basis. The correlation and path coefficients were estimated using raw and adjusted mean data. Correlation coefficients worked out as per Searle (1961) and path analysis as suggested by Dewey and Lu (1959). Data analysis was done using statistical software, Windostat ver.80 (Khetan 2015).

Results and Discussion

Correlation coefficients

Correlation coefficient provides symmetrical measurement of degree of association between two variables or characters help us in understanding the nature and magnitude of association among yield and yield components. Correlation coefficient was worked out at genotypic and phenotypic levels for different yield contributing characters in Chickpea (*Cicer arietinum* L.) genotypes are presented in Table 1 and 2, respectively. The genotypic correlation coefficients (Table- 1) revealed that seed yield per plant exhibited highly positive genotypic correlation with biological yield per plant (0.92 and 0.80), 100 seed weight (0.80 and 0.68), harvest index (0.61 and 0.48), pods per plant (0.50 and 0.62), primary branches per plant (0.30 and 0.07) and plant height (0.24 and 0.26) in both timely sown (E_1) and late sown (E_2) environments, respectively.

The phenotypic correlation coefficients presented in (Table-2) revealed that Seed yield per plant showed positive and highly significant correlation with biological yield per plant (0.903 and 0.798), 100 seed weight (0.780 and 0.636), harvest index (0.558 and 0.464) and pods per plant (0.459 and 0.537) in both environments *viz*., E_1 and E_2, respectively; Its positive and significant correlation was found with days to 50% flowering (0.288) in late sown environment (E_2), whereas, with secondary branches per plant (-0.239) it displayed negative and significant correlation in timely sown environment (E_1). The degree of inter-relationship was of highest magnitude between seed yield per plant and biological yield per plant followed by 100 seeds weight, harvest index (%) and pods per plant in both timely and late sown environments. These results are agreed with the earlier reports of Qurban *et al*., (2011), Ojha *et al.*, (2011), Singh and Shiva Nath (2012), Aycicek and Babagil (2013) and Indu Bala *et al*. (2015). Thus, these characters emerged as most important associates of seed yield per plant. Biological yield per plant, 100 seed weight, harvest index and pods per plant had strong positive associations with one another besides, having strong positive association with seed yield per plant in both timely and late sown environments. The occurrence of positive association at significant level of seed yield with most of its component traits and positive association between most of the yield components reveals less complex inter-relationship between yield and yield components. Such situation is favorable from breeding point of view because selection for one trait may bring correlated response for improvement of other traits which are positively associated with it. Most of the characters showed highly significant and positive correlations with seed yield except secondary branches per plant and seeds per pod in both the environments which showed non-significant and negative correlations.

Table 1: The estimates of genotypic correlation coefficient among 11 characters in Chickpea in E_1 and E_2.

Characters / Environment		DF	DM	PH	PB	SB	PPP	SPP	100 SW	BYP	HI	SYP
DF	E_1	1.000	0.259*	0.099	0.358**	0.100	0.442**	-0.432**	-0.122	0.031	-0.037	0.001
	E_2	1.000	-0.108	0.409**	0.099	0.028	-0.040	-0.043	0.325**	0.209	0.205	0.313**
DM	E_1		1.000	0.154	0.169	-0.334**	0.085	-0.187	0.274*	0.140	0.276*	0.223
	E_2		1.000	0.171	0.266*	0.440**	0.103	-0.156	-0.053	0.078	-0.244*	-0.053
PH	E_1			1.000	0.050	-0.061	-0.000	-0.180	0.351**	0.221	0.195	0.242*
	E_2			1.000	0.168	0.318**	0.137	-0.150	0.241*	0.246*	0.056	0.259*
PB	E_1				1.000	0.068	0.363**	-0.305**	0.146	0.305**	0.122	0.302**
	E_2				1.000	0.267*	0.174	-0.117	-0.033	0.050	0.077	0.074
SB	E_1					1.000	0.045	0.180	-0.367**	-0.213	-0.252*	-0.290*
	E_2					1.000	0.214	0.599**	-0.363**	0.089	-0.229	-0.050
PPP	E_1						1.000	-0.240*	-0.038	0.527**	0.169	0.500**
	E_2						1.000	0.327**	-0.109	0.604**	0.154	0.621**
SPP	E_1							1.000	-0.444**	-0.353**	0.084	-0.270*
	E_2							1.000	-0.764**	-0.161	-0.168	-0.242*
100 SW	E_1								1.000	0.720**	0.535**	0.805**
	E_2								1.000	0.460**	0.449**	0.676**
BYP	E_1									1.000	0.250*	0.923**
	E_2									1.000	-0.123	0.804**
HI	E_1										1.000	0.609**
	E_2										1.000	0.481**
SYP	E_1											1.000
	E_2											1.000

Traits: DF=Days to 50% flowering, **DM**=Days to maturity, **PH**=Plant height (cm), **PB**=Primary branches plant^{-1}, **SB**=Secondary branches plant^{-1}, **PPP**=Number of pods plant^{-}1, **SPP**=Number of seeds pod^{-1}, **100 SW**= 100 seed weight (g), **BYP**=Biological Yield plant^{-1} (g), **HI**=Harvest index (%) and **SYP**=Seed yield plant^{-1} (g). ***, ** Significant at 5 and 1 per cent probability level, respectively.**

Table 2: The estimates of phenotypic correlation coefficient among 11 characters in Chickpea in E_1 and E_2.

Characters / Environment		DF	DM	PH	PB	SB	PPP	SPP	100 SW	BYP	HI	SYP
DF	E_1	1.000	0.259*	0.092	0.247*	0.098	0.390**	-0.161	-0.118	0.053	-0.021	0.022
	E_2	1.000	-0.065	0.369**	0.096	0.037	-0.031	-0.014	0.307**	0.182	0.193	0.288*
DM	E_1		1.000	0.156	0.098	-0.297*	0.068	-0.070	0.257*	0.147	0.221	0.213
	E_2		1.000	0.132	0.142	0.294*	0.100	-0.098	-0.048	0.081	-0.205	-0.035
PH	E_1			1.000	0.080	-0.062	0.005	-0.039	0.328**	0.206	0.142	0.222
	E_2			1.000	0.082	0.228*	0.101	-0.088	0.224	0.211	0.046	0.221
PB	E_1				1.000	0.080	0.271*	-0.065	0.105	0.200	0.114	0.208
	E_2				1.000	0.197*	0.116	-0.002	-0.020	0.016	0.094	0.062
SB	E_1					1.000	0.040	0.109	-0.328**	-0.157	-0.225	-0.239*
	E_2					1.000	0.187	0.360**	-0.316**	0.080	-0.146	-0.013
PPP	E_1						1.000	-0.233*	-0.036	0.476**	0.177	0.459**
	E_2						1.000	-0.105	-0.080	0.513**	0.130	0.537**
SPP	E_1							1.000	-0.247*	-0.105	0.066	-0.054
	E_2							1.000	-0.506**	-0.014	-0.032	-0.044
100 SW	E_1								1.000	0.679**	0.486**	0.780**
	E_2								1.000	0.426**	0.410**	0.636**
BYP	E_1									1.000	0.181	0.903**
	E_2									1.000	-0.151	0.798**
HI	E_1										1.000	0.558**
	E_2										1.000	0.464**
SYP	E_1											1.000
	E_2											1.000

Traits: DF=Days to 50% flowering, **DM**=Days to maturity, **PH**=Plant height (cm), **PB**=Primary branches plant^{-1}, **SB**=Secondary branches plant^{-1}, **PPP**=Number of pods plant^{-}1, **SPP**=Number of seeds pod^{-1}, **100 SW**= 100 seed weight (g), **BYP**=Biological Yield plant^{-1} (g), **HI**=Harvest index (%) and **SYP**=Seed yield plant^{-1} (g). ***, ** Significant at 5 and 1 per cent probability level, respectively.**

Path coefficient analysis

Path coefficient analysis measure the direct influence of one variable upon the other and permits separation of correlation coefficient into component of direct and indirect effects. Partitioning of total correlations into direct and indirect effects provide actual information on contribution of characters and thus forms the basis for selection to improve the yield of plant population. Path analysis at genotypic level (Table 3) revealed that highly positive and substantial direct effects on the expression of seed yield per plant were exerted by biological yield per plant (0.4803 and 0.6978) followed by 100 seed weight (0.4068 and 0.1808), harvest index (0.2171 and 0.4736), pods per plant (0.2561 and 0.1378) and seeds per pod (0.1215 and 0.0293) in both the environments, respectively. Path analysis at phenotypic level (Table 4) revealed that highly positive direct effects towards expression of seed yield per plant were displayed by biological yield per plant (0.6897 and 0.7923) followed by harvest index (0.3295 and 0.5329) and 100 seed weight (0.1733 and 0.1085) in both environments *viz*., E_1 and E_2, respectively; while the rest of the characters contributed very less or negative direct effects on seed yield per plant in both environments. These characters have also been reported as major direct contributors towards seed yield in chickpea. These results are agreed with the earlier reports of Ojha *et al.*, (2011), Singh and Shiva Nath (2012), Aycicek and Babagil (2013) and Indu Bala *et al*. (2015).

Highly positive indirect effects on seed yield per plant were exerted by biological yield per plant *via* 100 seed weight (0.4686 and 0.3375), pods per plant (0.3287 and 0.4067), plant height (0.1426 and 0.1675), primary branches per plant (0.1384 and 0.0131) and days to 50 per cent flowering (0.0371 and 0.1445) in both the environments respectively. Whereas 100 seed weight *via* biological yield per plant (0.1178 and 0.0462) and harvest index *via* 100 seed weight (0.1602 and 0.2185) in both E_1 and E_2 environments, respectively. The remaining traits contributed very less or negative indirect effects on seed yield per plant in both the environments. These results agree with the earlier reports of Vaghela *et al.* (2009) Ojha *et al.*, (2011), Singh and Shiva Nath (2012), and Aycicek and Babagil (2013). The residual effect was found 0.0034 (E_1) and 0.0887 (E_2) at genotypic level and 0.1387 (E_1) and 0.1050 (E_2) at phenotypic level represent some more associated components that are contributing towards seed yield.

Table 3: Genotypic direct and indirect effect of yield components characters on seed yield in Chickpea in E_1 and E_2.

Characters / Environment		DF	DM	PH	PB	SB	PPP	SPP	100 SW	BYP	HI	SYP
DF	E_1	-0.0152	-0.0039	-0.0015	-0.0054	-0.0015	-0.0067	0.0066	0.0019	-0.0005	0.0006	0.0017
	E_2	0.0251	-0.0027	0.0103	0.0025	0.0007	-0.0010	-0.0011	0.0082	0.0053	0.0052	0.3132
DM	E_1	-0.0048	-0.0185	-0.0029	-0.0031	0.0062	-0.0016	0.0035	-0.0051	-0.0026	-0.0051	0.2239
	E_2	-0.0010	0.0090	0.0015	0.0024	0.0040	0.0009	-0.0014	-0.0005	0.0007	-0.0022	-0.0536
PH	E_1	-0.0026	-0.0040	-0.0258	-0.0013	0.0016	0.0000	0.0047	-0.0091	-0.0057	-0.0050	0.2421
	E_2	-0.0049	-0.0020	-0.0119	-0.0020	-0.0038	-0.0016	0.0018	-0.0029	-0.0029	-0.0007	0.2596
PB	E_1	0.0088	0.0041	0.0012	0.0244	0.0017	0.0089	-0.0075	0.0036	0.0075	0.0030	0.3020

	E_2	-0.0020	-0.0055	-0.0035	-0.0206	-0.0055	-0.0036	0.0024	0.0007	-0.0010	-0.0016	0.0740
SB	E_1	-0.0025	0.0084	0.0015	-0.0017	-0.0250	-0.0011	-0.0045	0.0092	0.0054	0.0063	-0.2905
	E_2	0.0005	0.0086	0.0062	0.0052	0.0194	0.0042	0.0117	-0.0071	0.0017	-0.0045	-0.0501
PPP	E_1	0.1133	0.0219	-0.0001	0.0931	0.0116	0.2561	-0.0617	-0.0097	0.1351	0.0434	0.5009
	E_2	-0.0055	0.0142	0.0189	0.0240	0.0296	0.1378	0.0452	-0.0151	0.0833	0.0213	0.6215
SPP	E_1	-0.0525	-0.0228	-0.0219	-0.0371	0.0220	-0.0292	0.1215	-0.0540	-0.0430	0.0102	-0.2700
	E_2	-0.0013	-0.0046	-0.0044	-0.0034	0.0176	0.0096	0.0293	-0.0224	-0.0047	-0.0049	-0.2429
100 SW	E_1	-0.0499	0.1114	0.1429	0.0597	-0.1494	-0.0155	-0.1808	0.4068	0.2930	0.2180	0.8058
	E_2	0.0589	-0.0096	0.0437	-0.0061	-0.0657	-0.0199	-0.1382	0.1808	0.0833	0.0813	0.6760
BYP	E_1	0.0153	0.0673	0.1063	0.1469	-0.1027	0.2533	-0.1700	0.3459	0.4803	0.1205	0.9238
	E_2	0.1459	0.0545	0.1719	0.0354	0.0622	0.4220	-0.1126	0.3214	0.6978	-0.0862	0.8049
HI	E_1	-0.0082	0.0599	0.0424	0.0267	-0.0548	0.0368	0.0183	0.1164	0.0545	0.2171	0.6090
	E_2	0.0974	-0.1155	0.0268	0.0366	-0.1085	0.0731	-0.0800	0.2129	-0.0585	0.4736	0.4812

Residual Factors = 0.0034 (E_1) and 0.0887 (E_2)

Traits: DF=Days to 50% flowering, **DM**=Days to maturity, **PH**=Plant height (cm), **PB**=Primary branches plant^{-1}, **SB**=Secondary branches plant^{-1}, **PPP**=Number of pods plant^{-}1, **SPP**=Number of seeds pod^{-1}, **100 SW**= 100 seed weight (g), **BYP**=Biological Yield plant^{-1} (g), **HI**=Harvest index (%) and **SYP**=Seed yield plant^{-1} (g).

Table 4: Phenotypic direct and indirect effect of yield component characters on grain yield in Chickpea in E_1 and E_2.

Characters / Environment		DF	DM	PH	PB	SB	PPP	SPP	100 SW	BYP	HI	SYP
DF	E_1	-0.0101	-0.0026	-0.0009	-0.0025	-0.0010	-0.0040	0.0016	0.0012	-0.0005	0.0002	0.0229
	E_2	0.0143	-0.0009	0.0053	0.0014	0.0005	-0.0004	-0.0002	0.0044	0.0026	0.0028	0.2881
DM	E_1	-0.0013	-0.0050	-0.0008	-0.0005	0.0015	-0.0003	0.0004	-0.0013	-0.0007	-0.0011	0.2137
	E_2	-0.0009	0.0144	0.0019	0.0021	0.0042	0.0015	-0.0014	-0.0007	0.0012	-0.0030	-0.0356
PH	E_1	-0.0019	-0.0032	-0.0205	-0.0016	0.0013	-0.0001	0.0008	-0.0067	-0.0042	-0.0029	0.2229
	E_2	-0.0022	-0.0008	-0.0060	-0.0005	-0.0014	-0.0006	0.0005	-0.0013	-0.0013	-0.0003	0.2212
PB	E_1	-0.0008	-0.0003	-0.0003	-0.0034	-0.0003	-0.0009	0.0002	-0.0004	-0.0007	-0.0004	0.2082
	E_2	-0.0010	-0.0015	-0.0009	-0.0104	-0.0021	-0.0012	0.0000	0.0002	-0.0002	-0.0010	0.0629
SB	E_1	-0.0011	0.0034	0.0007	-0.0009	-0.0114	-0.0005	-0.0012	0.0037	0.0018	0.0026	-0.2392
	E_2	0.0001	0.0008	0.0006	0.0005	0.0027	0.0005	0.0010	-0.0008	0.0002	-0.0004	-0.0135
PPP	E_1	0.0386	0.0068	0.0005	0.0268	0.0040	0.0988	-0.0231	-0.0036	0.0471	0.0175	0.4595
	E_2	-0.0023	0.0076	0.0077	0.0088	0.0141	0.0754	-0.0080	-0.0061	0.0387	0.0098	0.5374
SPP	E_1	-0.0099	-0.0043	-0.0024	-0.0040	0.0067	-0.0143	0.0611	-0.0151	-0.0065	0.0041	-0.0540
	E_2	-0.0007	-0.0046	-0.0042	-0.0001	0.0170	-0.0050	0.0472	-0.0239	-0.0007	-0.0015	-0.0445
100 SW	E_1	-0.0205	0.0446	0.0569	0.0182	-0.0570	-0.0063	-0.0429	0.1733	0.1178	0.0843	0.7801
	E_2	0.0334	-0.0052	0.0243	-0.0023	-0.0343	-0.0088	-0.0549	0.1085	0.0462	0.0445	0.6362
BYP	E_1	0.0371	0.1014	0.1426	0.1384	-0.1087	0.3287	-0.0730	0.4686	0.6897	0.1251	0.9035
	E_2	0.1445	0.0642	0.1675	0.0131	0.0636	0.4067	-0.0114	0.3375	0.7923	-0.1197	0.7985
HI	E_1	-0.0071	0.0729	0.0470	0.0379	-0.0742	0.0584	0.0220	0.1602	0.0598	0.3295	0.5589
	E_2	0.1031	-0.1096	0.0250	0.0503	-0.0780	0.0695	-0.0173	0.2185	-0.0805	0.5329	0.4641

Residual Factors = 0.1387 (E_1) and 0.1050 (E_2)

Traits: DF=Days to 50% flowering, **DM**=Days to maturity, **PH**=Plant height (cm), **PB**=Primary branches plant^{-1}, **SB**=Secondary branches plant^{-1}, **PPP**=Number of pods plant^{-}1, **SPP**=Number of seeds pod^{-1}, **100 SW**= 100 seed weight (g), **BYP**=Biological Yield plant^{-1} (g), **HI**=Harvest index (%) and **SYP**=Seed yield plant^{-1} (g).

Conclusion

On the basis of results, it can be concluded that whatever may be the characters chosen for increasing the seed yield the selecting plant types must have high biological yield per plant, harvest index, 100 seed weight and pods per plant. These traits showed positive direct effect along with significant and positive association with seed yield except others due to some biotic and abiotic factors. Therefore, these traits are likely to be successfully employed for the selection of high yielding chickpea genotypes or using as donor parent in breeding programme to improve yield and its related component.

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