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Study of correlation and path coefficient analysis for some quantitative traits in chickpea (*Cicer arietinum* L.)

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Abstract
An experiment was conducted to study, the genetic association among 76 (60 F_1s + 16 Parents) treatments for 11 quantitative characters in which Seed yield per plant showed positive and highly significant correlation with biological yield per plant, number of seeds per pod, harvest index, 100 seed weight and pods per plant in both environments. Path coefficient analysis revealed highly positive direct effects towards expression of seed yield per plant were displayed by number of seeds per pod followed by 100 seed weight, harvest index and number of pods per plant in both environments. Highly positive indirect effects on seed yield per plant were exerted by biological yield per plant via number of seeds per pod, 100 seed weight, pods per plant, harvest index and plant height; seeds per pod via biological yield per plant and harvest index; harvest index via 100 seed weight and biological yield per plant 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. 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) [1]. 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) [1]. 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 N2 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 2014-2016 on 76 treatments (60 F1s +16 Parents) in Randomized Block design with three replications and two environments i.e., Timely sown (E1) and late sown (E2). 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) [4] and path analysis as suggested by Dewey and Lu (1959) [3]. 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 phenotypic correlation coefficients presented in (Table- 1) revealed that Seed yield per plant showed positive and highly significant correlation with biological yield per plant (0.950 and 0.845), number of seeds per pod (0.801 and 0.782), harvest index (0.558 and 0.464), 100 seed weight (0.513 and 0.519) and pods per plant (0.323 and 0.330) in both environments viz., E1 and E2, respectively, while its positive and significant correlation was found with days to plant height (0.239 and 0.282) in both E1 and E2, whereas, days to 50% flowering (-0.095 and-0.280) and days to maturity (-0.962 and -0.385) displayed highly negative and significant correlation in both timely and late sown environments. Remaining characters were also found positive but having non-significant correlations. 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) [6], Ojha *et al*., (2011) [5], Singh and Shiva Nath (2012) [7-9], Aycicek and Babagil (2013) [8] and Indu Bala *et al*. (2015) [11]. Thus, these characters emerged as most important associates of seed yield per plant. 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.

Table 1: The estimates of genotypic correlation coefficient among 11 characters in chickpea in E1 and E2

Characters / Environment		Days to 50 % flowering	Days to maturity	Plant height (cm)	Primary Branches/ Plant	Secondary Branches/ Plant	Pods / plant	Seeds per pod	100 seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Grain yield per plant (g)
Days to 50 % flowering	E_1 (TS)	1.000	1.153	-0.072	-0.165	-0.129	0.165	-0.253	-0.197	-0.199	-0.010	-0.159
	E_2 (LS)	1.000	0.703	-0.004	0.373	0.038	-0.013	-0.295	-0.377	-0.248	-0.406	-0.346
Days to maturity	E_1 (TS)		1.000	-0.211	-0.368	-0.159	0.037	-0.257	-0.513	-0.302	-0.319	-0.361
	E_2 (LS)		1.000	0.013	0.444	0.100	-0.040	-0.398	-0.415	-0.334	-0.532	-0.482
Plant height (cm)	E_1 (TS)			1.000	0.074	0.228	-0.0004	0.360	0.181	0.400	0.177	0.392
	E_2 (LS)			1.000	0.067	0.096	0.346	0.296	0.054	0.499	0.262	0.407
Primary Branches/ Plant	E_1 (TS)				1.000	0.901	0.159	0.143	0.004	0.091	0.179	0.082
	E_2 (LS)				1.000	-0.460	-0.114	-0.462	-0.081	-0.378	-0.602	-0.571
Secondary Branches/ Plant	E_1 (TS)					1.000	0.312	0.218	0.095	0.245	0.112	0.232
	E_2 (LS)					1.000	0.078	0.045	-0.152	-0.078	0.083	-0.008
Pods per plant	E_1 (TS)						1.000	-0.047	-0.032	0.355	-0.001	0.328
	E_2 (LS)						1.000	-0.061	-0.008	0.539	0.130	0.335
Seeds per pod	E_1 (TS)							1.000	0.174	0.793	0.624	0.827
	E_2 (LS)							1.000	0.215	0.573	0.873	0.817
100 seed weight (g)	E_1 (TS)								1.000	0.534	0.257	0.526
	E_2 (LS)								1.000	0.523	0.512	0.565
Biological yield / plant (g)	E_1 (TS)									1.000	0.412	0.993
	E_2 (LS)									1.000	0.619	0.907
Harvest index (%)	E_1 (TS)										1.000	0.573
	E_2 (LS)										1.000	0.909
Grain yield per plant (g)	E_1 (TS)											1.000
	E_2 (LS)											1.000

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 2) revealed that highly positive and substantial direct effects on the expression of seed yield per plant were exerted

by biological yield per plant (0.801 and 0.782) followed by seeds per pod (0.0.513 and 0.0.519), harvest index (0.437 and 0.862), 100 seed weight (0.513 and 0.519), and number of pods per plant (0.323 and 0.330) in both environments, respectively. Whereas, highly positive indirect effects on seed yield per plant were found of biological yield per plant via 100 seed weight (0.3459 and 0.3214), pods per plant (0.2533 and 0.4220) and plant height (0.1063 and 0.1719); 100 seed weight via biological yield per plant (0.2930 and 0.0833), harvest index (0.2180 and 0.0813) and plant height (0.1429 and 0.0437); harvest index via 100 seed weight (0.1164 and 0.2129) in both E1 and E2, respectively; and remaining traits contributed very less or negative indirect effects on seed yield per plant in both environments. Path analysis at phenotypic level (Table 3) revealed that highly positive direct effects towards expression of seed yield per plant were displayed by number of seeds per pod (0.6744 and 0.1239) followed by 100 seed weight (0.4798 and 0.0.0799), harvest index (0.3295 and 0.5329) and number of pods per plant (0.3397 and 0.0108) in both environments viz., E1 and E2, respectively; whereas, secondary branches per plant (0.3838) and days to maturity (0.1416) in E1 and biological yield per plant (0.4824) in E2 also showed highly positive direct effect on seed yield per plant. Whereas, highly positive indirect effects on seed yield per plant were exerted by biological yield per plant via number of seeds per pod (0.4736 and 0.2314), 100 seed weight (0.2853 and 0.2081), pods per plant (0.1938 and 0.2285), harvest index (0.1481 and 0.2507) and plant height (0.1314 and 0.1634); seeds per pod via biological yield per plant (0.2188 and 0.1212) and harvest index (0.1206 and 0.2003); harvest index via 100 seed weight (0.0318 and 0.1718) and biological yield per plant (0.0360 and 0.1994) in both the environments, respectively. Whereas remaining traits contributed very less or negative indirect effects on seed yield per plant in both the 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) [5], Singh and Shiva Nath (2012) [7-9], Aycicek and Babagil (2013) [8], Indu Bala *et al*. (2015). Vaghela *et al*. (2009) [10] and Ojha *et al*., (2011) [5]. The residual effect was found 0.0034 (E1) and 0.0887 (E2) at genotypic level and 0.2071 (E1) and 0.2315 (E2) at phenotypic level represent some more associated components that are contributing towards seed yield.

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	0.300**	0.023	-0.063	-0.089	0.144*	-0.142*	-0.112	-0.117	0.108	-0.095
	E_2	1.000	0.666**	-0.027	-0.014*	-0.052	-0.038	-0.228**	-0.287**	-0.206**	-0.287**	-0.280
DM	E_1		1.000	0.128	0.018	-0.015	0.004	-0.076	-0.167*	-0.112	-0.077	-0.962
	E_2		1.000	0.0004	-0.067	0.026	-0.056	-0.318**	-0.293**	-0.270**	-0.407**	-0.385
PH	E_1			1.000	0.145*	0.160*	0.023	0.228**	0.114	0.236**	0.005	0.239
	E_2			1.000	0.140*	0.241**	0.318**	0.200**	0.111	0.361**	0.199**	0.282
PB	E_1				1.000	0.529**	0.099	0.085	0.003	0.096	0.069	0.058
	E_2				1.000	0.269**	0.038	0.116	0.073	0.111	0.141*	0.136
SB	E_1					1.000	0.274**	0.203**	-0.079	0.225**	0.086	0.209
	E_2					1.000	0.073	0.025	-0.030	-0.001	0.033	0.005
PPP	E_1						1.000	-0.044	-0.016	0.341**	0.022	0.323
	E_2						1.000	-0.058	0.017	0.505**	0.127	0.330
SPP	E_1							1.000	0.165*	0.770**	0.042**	0.801
	E_2							1.000	0.196**	0.511**	0.845**	0.782
100 SW	E_1								1.000	0.502**	0.229**	0.513
	E_2								1.000	0.460**	0.477**	0.519
BYP	E_1									1.000	0.260**	0.950
	E_2									1.000	0.554**	0.845
HI	E_1										1.000	0.437
	E_2										1.000	0.862
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 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	-0.1306	-0.1507	0.0095	0.0216	0.0169	-0.0216	0.0330	0.0258	0.0260	0.0013	-0.1599
	E_2	0.0638	0.0449	-0.0003	0.0238	0.0024	-0.0009	-0.0188	-0.0241	-0.0158	-0.0259	-0.3467
DM	E_1	0.1634	0.1416	-0.0300	-0.0521	-0.0225	0.0053	-0.0365	-0.0727	-0.0428	-0.0453	-0.3617
	E_2	-0.0105	-0.0149	-0.0002	-0.0066	-0.0015	0.0006	0.0060	0.0062	0.0050	0.0080	-0.4899
PH	E_1	-0.0006	-0.0019	0.0089	0.0007	0.0020	0.0000	0.0032	0.0016	0.0036	0.0016	0.3921
	E_2	-0.0002	0.0004	0.0345	0.0023	0.0033	0.0119	0.0102	0.0019	0.0172	0.0091	0.4073
PB	E_1	0.0669	0.1490	-0.0303	-0.4046	-0.3647	-0.0646	-0.0581	-0.0016	-0.0368	-0.0728	0.0826
	E_2	-0.0510	-0.0607	-0.0092	-0.1366	0.0629	0.0156	0.0632	0.0111	0.0516	0.0822	-0.5711
SB	E_1	-0.0498	-0.0611	0.0878	0.3459	0.3838	0.1199	0.0837	-0.0367	0.0941	0.0430	0.2329
	E_2	-0.0025	-0.0065	-0.0063	0.0298	-0.0648	-0.0051	-0.0029	0.0099	0.0051	-0.0054	-0.0085
PPP	E_1	0.0562	0.0126	-0.0001	0.0543	0.1061	0.3397	-0.0162	-0.0109	0.1208	-0.0005	0.3286

	E_2	-0.0001	-0.0004	0.0037	-0.0012	0.0008	0.0108	-0.0007	-0.0001	0.0058	0.0014	0.3358
SPP	E_1	-0.1706	-0.1737	0.2433	0.0968	0.1471	-0.0321	0.6744	0.1179	0.5353	0.4210	0.8274
	E_2	-0.0366	-0.0493	0.0367	-0.0573	0.0056	-0.0077	0.1239	0.0267	0.0711	0.1083	0.8178
100 SW	E_1	-0.0950	-0.2463	0.0873	0.0020	-0.0459	-0.0154	0.0839	0.4798	0.2566	0.1233	0.5264
	E_2	-0.0302	-0.0332	0.0044	-0.0065	-0.0122	-0.0007	0.0172	0.0799	0.0418	0.0410	0.5653
BYP	E_1	0.0013	0.0020	-0.0026	-0.0006	-0.0016	-0.0023	-0.0052	-0.0035	-0.0066	-0.0027	0.9932
	E_2	-0.1199	-0.1613	0.2408	-0.1824	-0.0378	0.2601	0.2767	0.2525	0.4824	0.2987	0.9073
HI	E_1	-0.0011	-0.0333	-0.0185	0.0188	0.0117	-0.0001	0.0651	0.0268	0.0429	0.1042	0.5731
	E_2	-0.1595	-0.2088	0.1031	-0.2364	0.0326	0.0511	0.3431	0.2013	0.3431	0.3926	0.9099

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	-0.0199	-0.0060	-0.0005	0.0013	0.0018	-0.0029	0.0028	0.0022	0.0023	-0.0022	-0.0958
	E_2	0.0098	0.0066	-0.0003	-0.0014	-0.0005	-0.0004	-0.0022	-0.0028	-0.0020	-0.0028	-0.2806
DM	E_1	0.0089	0.0295	0.0038	0.0005	-0.0004	0.0001	-0.0022	-0.0049	-0.0033	-0.0023	-0.0962
	E_2	-0.0105	-0.0157	0.0000	0.0011	-0.0004	0.0009	0.0050	0.0046	0.0042	0.0064	-0.3858
PH	E_1	0.0005	0.0027	0.0213	0.0031	0.0034	0.0005	0.0049	0.0024	0.0050	0.0001	0.2390
	E_2	0.0009	0.0000	-0.0339	-0.0047	-0.0082	-0.0108	-0.0068	-0.0038	-0.0122	-0.0068	0.2828
PB	E_1	0.0034	-0.0010	-0.0079	-0.0540	-0.0286	-0.0054	-0.0046	-0.0002	-0.0052	-0.0037	0.0583
	E_2	-0.0007	-0.0003	0.0007	0.0051	0.0014	0.0002	0.0006	0.0004	0.0006	0.0007	0.1364
SB	E_1	-0.0006	-0.0001	0.0011	0.0038	0.0072	0.0020	0.0015	-0.0006	0.0016	0.0006	0.2098
	E_2	0.0004	-0.0002	-0.0019	-0.0021	-0.0079	-0.0006	-0.0002	0.0002	0.0000	-0.0003	0.0052
PPP	E_1	0.0213	0.0007	0.0035	0.0147	0.0405	0.1417	-0.0065	-0.0025	0.0504	0.0033	0.3237
	E_2	-0.0031	-0.0045	0.0251	0.0030	0.0058	0.0789	-0.0046	0.0014	0.0399	0.0100	0.3304
SPP	E_1	-0.0404	-0.0216	0.0650	0.0241	0.0579	-0.0126	0.2842	0.0471	0.2188	0.1206	0.8015
	E_2	-0.0541	-0.0754	0.0475	0.0275	0.0061	-0.0138	0.2368	0.0465	0.1212	0.2003	0.7824
100 SW	E_1	-0.0172	-0.0256	0.0174	0.0005	-0.0122	-0.0026	0.0253	0.1527	0.0767	0.0351	0.5133
	E_2	-0.02660	-0.0272	0.0103	0.0068	-0.0028	0.0017	0.0182	0.0927	0.0427	0.0443	0.5191
BYP	E_1	-0.0666	-0.0642	0.1344	0.0546	0.1282	0.1938	0.4376	0.2853	0.5682	0.1481	0.9506
	E_2	-0.0934	-0.1224	0.1634	0.0502	-0.0005	0.2285	0.2314	0.2081	0.4522	0.2507	0.8459
HI	E_1	0.0149	-0.0107	0.0007	0.0096	0.0120	0.0030	0.0587	0.0318	0.0360	0.1382	0.4379
	E_2	-0.1034	-0.1467	0.0718	0.0510	0.0121	0.0457	0.3042	0.1718	0.1994	0.3597	0.8622

Residual Factors = 0.2071 (E_1) and 0.2315 (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, number of seeds per pod, 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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