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Correlation and path analysis studies in chickpea (*Cicer arietinum* L.) grown in phosphorus deficiency soil

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Abstract
Association and path coefficient analysis were done with 104 chickpea genotypes over two seasons and two locations to find out correlation among traits and to find out the direct and indirect effects of other agronomical traits on seed yield. The present study was conducted during *rabi* 2015-16 and *rabi* 2016-17. Correlation studies indicated that seed yield per plant and shoot phosphorus concentration were exhibited stable positive association with number of primary branches per plant, number of secondary branches per plant, number of pods per plant, plant biomass and harvest index at genotypic and phenotypic levels. This indicates the importance of these traits in selection for yield. The path analysis thus revealed that days to first flowering, days to maturity, plant height, number of primary branches, number of pod per plant, number of seeds per pod, hundred seed weight, plant biomass, harvest index and shoot phosphorus concentration had positive direct effect on seed yield per plant indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of chickpea.

Keywords: Chickpea genotypes, seed yield, shoot phosphorus concentration, correlation and path analysis

Introduction
Chickpea has been taken under cultivation in India from ancient times. It is the most important pulse crop of India contributing to about 40% of domestic pulse production and it is a rich source of protein (17-20%). There has been an impressive growth in area, production and productivity of chickpea in India during the past decade. In India, Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Andhra Pradesh, Karnataka, Chhattisgarh, Bihar and Jharkhand are major chickpea producing states contributing more than 95% of the total chickpea production. In West Bengal, average chickpea productivity is comparatively higher than national average. But, in areas where soil is acidic and P availability is low, reduced crop growth as well as yield is noticed (Dutta and Bandyopadhyay, 2009) [1]. This gap could be due to susceptibility of this crop to the phosphorus deficiency. Fohse *et al.* (1991) [3] reported that phosphorus use efficiency has large variation among species. For instance, barley is generally less P efficient than maize and rice. It also shows considerable genetic variation within species (Hammond *et al.*, 2009) [4], which is the basis for further improvement by breeding. However, breeding for phosphorus use efficiency is likely to be a complicated process due to the complexity of the trait and the influence of the environment. The present research was conducted to find out other important traits through association analysis and direct and indirectly involve in the improving of seed yield of chickpea under low input conditions

Materials and Methods
The present study was conducted with 104 (including 4 checks) chickpea genotypes in *Augmented Randomized Complete Block Design* (Federer, 1956) [2] during *rabi* season of 2015-16 and 2016-17 at two different locations *viz*., Regional Research Sub Station, Sekhampur, Birbhum, West Bengal (Red laterite zone) and District Seed Farm, 'AB' block, Kalyani, Nadia (New Alluvial Zone), West Bengal, India. In the experiment, recommended agronomical and plant protection practices were adopted for better crop growth. Each genotype was grown in row length of 2.5m and spacing between plants 10 cm and row to row distance was 30 cm. Rice was

the preceding crop at both the sites before chickpea sowing. Observations were recorded as per the DUS guidelines of chickpea, on the basis of five randomly selected plants in each genotype for various yield and yield attributing traits. The statistical analysis was performed by using R software.

Results and Discussion

Association between shoot phosphorus concentration and other agronomical characters

Association analysis is an important biometrical tool for formulating the selection index, as it reveals the strength of relationship among the group of characters. Present study, phenotypic and genotypic correlation coefficients between shoot phosphorus concentration and other agronomical traits were estimated and are mentioned in the table 1 and 2.

Shoot phosphorus concentration showed significant and positive association with seed yield plant^{-1}, harvest index, plant biomass, number of pods plant^{-1}, number of secondary branches plant^{-1} and number of primary branches plant^{-1} and significant negative association with days to 1st flowering, days to 50% flowering and days to maturity at genotypic and phenotypic level indicating that the genotypes having high phosphorus acquisition recorded higher seed yield per plant. Similar results were obtained by Zhou *et al.* (2016) [9] in soya bean.

seed yield plant^{-1} showed significant and positive association with number of number of primary branches plant^{-1}, number of secondary branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 100 seed weight, plant biomass, harvest index and shoot phosphorus concentration at both genotypic and phenotypic levels which suggested that selection for seed yield per plant based on these traits is beneficial. These results are conformity with Samyuktha *et al.* (2017) [6] and Kobraee *et al.* (2010) [5] where they have reported that the number of pods plant^{-1}, number of seeds pod^{-1}, number of seeds plant^{-1} and 100 seed weight showed a highly significant positive association with single plant yield. Whereas, Yadav *et al.* (2012) [8] reported positive association of 100 seed weight with single plant yield.

The traits *viz.*, days 1st flowering, days to 50% flowering, days to maturity, plant height and pod bearing height at both genotypic and phenotypic level showed a significant negative association with seed yield plant^{-1}. Though early flowering accessions produce reduced yield than the late flowering ones, it is desirable in case of arid and semiarid conditions under which majority of chickpea is grown, using the available soil moisture and also escape from the biotic and abiotic stresses that occurs during the late growing season. Hence evolving early flowering genotypes coupled with high yield remains a key objective in chickpea breeding programmes. But this negative association with yield could be compensated by adopting appropriate breeding methods like bi parental mating or diallel selective mating. In this study it was observed that, in general, genotypic correlation coefficients were of higher magnitude than the phenotypic correlation coefficients. The correlation study indicated that number of primary branches per plant, number of secondary branches per plant, number of pods per plant, number of seeds per pod, hundred seed weight, plant biomass, harvest index and shoot phosphorus concentration were in positive and significant association with yield per plant at both phenotypic and genotypic levels. This indicates the importance of these traits in selection for yield.

Table 1: Genotypic correlation coefficients between yield and its component characters in chickpea

Character	DFF	D50F	DM	PH	PBH	NPB	NSB	NPP	NSP	HSW	PB	HI	P	SYP
DFF	1.000	0.980**	0.604**	0.357**	0.493**	0.015	-0.223*	-0.223**	-0.172**	-0.107	0.379**	-0.675**	-0.331**	-0.355**
D50F		1.000	0.654**	0.359**	0.499**	-0.001	-0.260**	-0.254**	-0.229**	-0.090	0.362**	-0.709**	-0.334**	-0.395**
DM			1.000	0.520**	0.503**	0.149	-0.183*	-0.377**	-0.388**	0.354**	0.127**	-0.317**	-0.187**	-0.182**
PH				1.000	0.911**	0.044	-0.359**	-0.514**	-0.586**	0.542**	0.283**	-0.282**	-0.016	-0.116*
PBH					1.000	-0.017	-0.398**	-0.398**	-0.507**	0.278**	0.186*	-0.467**	-0.063	-0.326**
NPB						1.000	0.788**	0.589**	0.119*	0.176**	0.755**	0.639**	0.446**	0.850**
NSB							1.000	0.884**	0.621**	-0.310**	0.991**	0.626**	0.561**	0.939**
NPP								1.000	0.423**	-0.606**	0.552**	0.464**	0.515**	0.610**
NSP									1.000	-0.532**	0.166**	0.338**	-0.022	0.372**
HSW										1.000	-0.047	0.246**	0.036	0.159**
PB											1.000	0.265**	0.334**	0.548**
HI												1.000	0.406**	0.943**
P													1.000	0.456**
SYP														1.000

*- Significant at 5 per cent level of significance, **- Significant at 1 per cent level of significance.

DFF- Days to first flowering, D50F- Days to 50% flowering, DM - Days to maturity, PH- Plant height (cm), PBH- Pod bearing height (cm), NPB- Number of primary branches per plant, NSB- Number of secondary branches per plant, NPP- Number of pods per plant, NSP- Number of seeds per pod, HSW -Hundred seed weight (g), PB - Plant biomass (g), HI-Harvest index, P- Shoot phosphorus concentration (%) and SYP- Seed yield per plant (g).

Table 2: Phenotypic correlation coefficients between yield and its component characters in chickpea

Character	DFF	D50F	DM	PH	PBH	NPB	NSB	NPP	NSP	HSW	PB	HI	P	SYP
DFF	1.000	0.891**	0.445**	0.233**	0.329**	-0.066	-0.072	-0.090	-0.080	-0.076	0.029	-0.195**	-0.216**	-0.158**
D50F		1.000	0.498**	0.232**	0.353**	-0.025	-0.074	-0.093	-0.132**	-0.057	0.046	-0.212*	-0.215**	-0.171**
DM			1.000	0.258**	0.269**	0.058	-0.090	-0.065	-0.227**	0.230**	0.090	-0.077	-0.110*	0.061
PH				1.000	0.553**	0.014	-0.039	-0.212**	-0.342**	0.359**	0.077	-0.095	0.004	-0.059
PBH					1.000	-0.040	-0.151**	-0.176**	-0.321**	0.215**	0.130**	-0.210*	-0.029	-0.156**
NPB						1.000	0.575**	0.422**	0.059	0.070	0.210**	0.356**	0.253**	0.514**
NSB							1.000	0.553**	0.238**	-0.126**	0.160**	0.465**	0.240**	0.601**
NPP								1.000	0.131**	-0.345**	0.116*	0.489**	0.295**	0.593**
NSP									1.000	-0.444**	0.048	0.202**	-0.025	0.258**
HSW										1.000	-0.020	0.151**	0.029	0.127**

PB											1.000	-0.290**	0.131**	0.220**
HI												1.000	0.227**	0.821**
P													1.000	0.321**
SYP														1.000

*- Significant at 5 per cent level of significance, **- Significant at 1 per cent level of significance.

DFF- Days to first flowering, D50F- Days to 50% flowering, DM - Days to maturity, PH- Plant height (cm), PBH- Pod bearing height (cm), NPB- Number of primary branches per plant, NSB- Number of secondary branches per plant, NPP- Number of pods per plant, NSP- Number of seeds per pod, HSW -Hundred seed weight (g), PB - Plant biomass (g), HI-Harvest index, P- Shoot phosphorus concentration (%) and SYP- Seed yield per plant (g).

Path coefficient analysis

Upon for assessment of apparent relationship between dependent and independent characters, it is necessary to partition the direct and indirect effects of each character on yield to understand the nature of association at genotypic and phenotypic level. As a guideline for interpretation of the results of path analysis, the following broad points as suggested by (Singh and Chaudhary, 1977) [7] has been found. If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and a direct selection through this trait will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection. Under the circumstances where correlation coefficient may be negative but the direct effect is positive and high, a restricted simultaneous selection model is to be followed i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect. If correlation coefficient is negative and direct effect is also negative, then the selection based on that character has to be dropped.

So, in the present study direct and indirect effects of different traits on seed yield per plant were estimated through path analysis at phenotypic and genotypic levels and are presented in table 3 and 4.

Direct and indirect effects of shoot phosphorus concentration on seed yield

Shoot phosphorus concentration showed low and positive direct effect on seed yield per plant at genotypic level and negligible and positive direct at phenotypic level. At genotypic level, it exhibited negligible and positive indirect effect on seed yield per plant through number of primary branches, number of secondary branches, number of pods per plant, hundred seed weight, plant biomass, harvest index and negligible and negative indirect effect via days to first flowering, days to 50 per cent flowering, days to maturity, plant height, pod bearing height and number of seeds per pod. At phenotypic level, this trait showed negligible and positive indirect effect on seed yield per plant through plant height, number of primary branches, number of secondary branches, number of pods per plant, hundred seed weight plant biomass and harvest index and negligible and negative indirect effect on seed yield per plant through days to first flowering, days to 50 per cent flowering, days to maturity, pod bearing height and number of seeds per pod. At both genotypic and phenotypic levels this trait showed positive and significant association with seed yield per plant. The positive direct effect of this trait and its positive association with seed yield per plant reveals its true relationship with yield and direct selection for this trait will be rewarding.

The path analysis thus revealed that days to first flowering, days to maturity, plant height, number of primary branches, number of pod per plant, number of seeds per pod, hundred seed weight, plant biomass, harvest index and shoot phosphorus concentration had positive direct effect on seed yield per plant indicating that direct selection based on these traits may be helpful in evolving high yielding varieties of chickpea. The residual effect of path analysis in the present study was low (0.141 at genotypic level and 0.276 at phenotypic level), which indicated that the traits included in the study were sufficient enough to explain their pattern of interaction on yield.

Table 3: Direct (Diagonal) and indirect genotypic effects of different characters towards seed yield.

Character	DFF	D50F	DM	PH	PBH	NPB	NSB	NPP	NSP	HSW	PB	HI	P
DFF	0.195	0.191	0.118	0.069	0.096	0.003	-0.043	-0.043	-0.033	-0.021	0.074	-0.131	-0.064
D50F	-0.275	-0.280	-0.183	-0.101	-0.140	0.001	0.073	0.071	0.064	0.025	-0.101	0.199	0.094
DM	0.017	0.019	0.029	0.015	0.014	0.004	-0.005	-0.011	-0.011	0.010	0.004	-0.009	-0.005
PH	0.246	0.248	0.359	0.691	0.630	0.030	-0.248	-0.355	-0.405	0.374	0.196	-0.195	-0.011
PBH	-0.350	-0.354	-0.358	-0.648	-0.711	0.012	0.283	0.283	0.361	-0.198	-0.132	0.332	0.045
NPB	0.011	0.001	0.107	0.031	-0.012	0.715	0.564	0.421	0.085	0.126	0.540	0.457	0.319
NSB	0.071	0.082	0.058	0.113	0.126	-0.249	-0.316	-0.280	-0.197	0.098	-0.317	-0.198	-0.177
NPP	0.118	0.134	0.199	0.272	0.210	-0.311	-0.467	0.528	-0.223	0.320	-0.292	-0.245	-0.272
NSP	-0.006	-0.008	-0.014	-0.022	-0.019	0.004	0.023	0.016	0.037	-0.020	0.006	0.012	-0.001
HSW	0.079	0.066	-0.260	-0.399	-0.205	-0.129	0.229	0.447	0.392	0.736	0.035	-0.181	-0.027
PB	0.107	0.103	0.036	0.080	0.053	0.214	0.284	0.156	0.047	-0.013	0.283	0.075	0.095
HI	-0.518	-0.544	-0.243	-0.216	-0.358	0.490	0.480	0.356	0.259	0.189	0.203	0.767	0.311
P	-0.050	-0.050	-0.028	-0.002	-0.009	0.067	0.084	0.077	-0.003	0.005	0.050	0.061	0.150
SYP (g)	-0.355**	-0.395**	-0.182**	-0.116*	-0.326**	0.850**	0.939**	0.610**	0.372**	0.159**	0.548**	0.943**	0.456**

Residual effect=0.141

DFF- Days to first flowering, D50F- Days to 50% flowering, DM - Days to maturity, PH- Plant height (cm), PBH- Pod bearing height (cm), NPB- Number of primary branches per plant, NSB- Number of secondary branches per plant, NPP- Number of pods per plant, NSP- Number of seeds per pod, HSW -Hundred seed weight (g), PB - Plant biomass (g), HI-Harvest index, P- Shoot phosphorus concentration (%) and SYP- Seed yield per plant (g).

Table 4: Direct (Diagonal) and indirect phenotypic effects of different characters towards seed yield.

Character	DFF	D50F	DM	PH	PBH	NPB	NSB	NPP	NSP	HSW	PB	HI	P
DFF	0.038	0.034	0.017	0.009	0.012	-0.002	-0.003	-0.003	-0.003	-0.003	0.001	-0.007	-0.008
D50F	-0.025	-0.028	-0.014	-0.007	-0.010	0.001	0.002	0.003	0.004	0.002	-0.001	0.006	0.006
DM	0.017	0.019	0.039	0.010	0.010	0.002	-0.003	-0.002	-0.009	0.009	0.003	-0.003	-0.004
PH	0.001	0.001	0.002	0.006	0.003	0.001	0.001	-0.001	-0.002	0.002	0.001	-0.001	0.001
PBH	-0.005	-0.006	-0.004	-0.009	-0.016	0.001	0.002	0.003	0.005	-0.003	-0.002	0.003	0.001
NPB	-0.002	-0.001	0.002	0.001	-0.001	0.036	0.021	0.015	0.002	0.003	0.008	0.013	0.009
NSB	-0.004	-0.004	-0.005	-0.002	-0.009	0.034	0.059	0.033	0.014	-0.007	0.009	0.028	0.014
NPP	-0.010	-0.010	-0.007	-0.023	-0.019	0.047	0.061	0.110	0.014	-0.038	0.013	0.054	0.033
NSP	-0.007	-0.011	-0.020	-0.030	-0.028	0.005	0.021	0.011	0.087	-0.039	0.004	0.018	-0.002
HSW	-0.007	-0.005	0.020	0.031	0.019	0.006	-0.011	-0.030	-0.038	0.087	-0.002	0.013	0.002
PB	0.012	0.019	0.038	0.032	0.054	0.088	0.067	0.049	0.020	-0.008	0.418	-0.121	0.055
HI	-0.159	-0.172	-0.063	-0.077	-0.171	0.289	0.378	0.397	0.164	0.123	-0.236	0.812	0.185
P	-0.007	-0.007	-0.003	0.001	-0.001	0.008	0.007	0.009	-0.001	0.001	0.004	0.007	0.031
SYP	-0.158**	-0.171**	0.061	-0.059	-0.156**	0.514**	0.601**	0.593**	0.258**	0.127**	0.220**	0.821**	0.321**

Residual effect =0.276

DFF- Days to first flowering, D50F- Days to 50% flowering, DM - Days to maturity, PH- Plant height (cm), PBH- Pod bearing height (cm), NPB- Number of primary branches per plant, NSB- Number of secondary branches per plant, NPP- Number of pods per plant, NSP- Number of seeds per pod, HSW -Hundred seed weight (g), PB - Plant biomass (g), HI-Harvest index, P- Shoot phosphorus concentration (%) and SYP- Seed yield per plant (g).

Conclusion

Based on the results of correlation and path analysis, the present study it was revealed that major emphasis should be laid on selection process with number of primary branches, number of pods per plant, number of seeds per plant, hundred seed weight, plant biomass, harvest index and shoot phosphorus concentration and there should be economic balance among these traits to get higher seed yield per plant.

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