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Path Analysis and Relationship Among Quantitative Traits in Chickpea (*Cicer arietinum* L.)

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Abstract: Phenotypic and genotypic variances, heritability in broad sense (h^2), genetic advance (GA), correlation and path coefficient analyses were conducted for yield and yield components in 30 genotypes of chickpea under rainfed conditions. Medium to high genetic variance was observed for days to flowering, maturity, secondary branches and 100-seeds weight, whereas for other characters, low to medium heritability (broad sense) was observed along with low to high genetic advance. Improvement of these traits through direct selection could be limited from germplasm used in the present study. Days to flowering, days to maturity and 100-seed weight exhibited high heritability coupled with high genetic advance, hence crop improvement through these traits could be possible by simple selection. It was concluded that to improve grain yield emphasis should be given on development of chickpea cultivars with higher seed weight and biological yield. To break undesirable linkage of biological yield Vs harvest index and grain yield Vs harvest index, bi-parental mating among selective parents is suggested for further improvement. Both correlation and path analyses indicated that pods per plant and 100-seed weight were potent contributors to grain yield through direct effects. Seven elite accessions which produced higher grain yield than both the checks were selected and suggested for further evaluation under various ecological zones for adaptation.

Key words: Association, correlation coefficient, direct and indirect effects, gram

Introduction

Chickpea is an ancient cultivated plant, domesticated during early age of civilization and being cultivated throughout the world. Its nomenclature in different countries is well documented as, gram, chickpea, hommos, chana, chieting vetch, nakhud, nakhut, kicher, pois chice, garbanzo, etc. (Malik, 1994). Chickpea probably originated in South-eastern Turkey and old Sanskrit names and carbonized seeds indicate the presence of chickpea on the India sub-continent as early as 2000 BC (Savithri, 1976). It is fifth most important among legumes in the world and being cultivated on more than 12 million hectares with annual production of 8 million tones. In Pakistan, it is cultivated on an area of 971,000 hactares with annual production of 564,000 tones with national average of 581 kg ha^{-1}. Our national average is very low as compared to its potential and yield obtained by other chickpea growing countries, and only one third of the potential is harvested (Ghafoor *et al*., 1997).

The extent of genetic variation is a pre-requisite in any crop improvement and yield is an end product of many field crops. Independent variables influence yield directly or indirectly and they are inter-related in a complex way (Singh *et al*., 1995). In a biological system most of the traits are associated with each other by simple or complex paths and to investigate the actual path for improving yield potential is the task of breeders. Correlation analysis provides information on associated response of plant characters and therefore, leads to a directional model for yield prediction (Khan and Qureshi, 2001). Character association is very important study that has been conducted in chickpea using different material by Malik *et al.* (1988) Gull (1995) Bakhsh *et al.* (1998). Path coefficient analysis quantifies the inter-relationship among different variables keeping yield as dependant. The present studies were under-taken to find out inter-relationships among various quantitative traits and to investigate the most important traits contributing towards grain yield in chickpea.

Materials and Methods

Twenty eight accessions of chickpea along with two chickpea (Punjab 91 and Paidar 91) were evaluated for agronomic traits under field conditions at National Agricultural Research Centre, Islamabad, Pakistan (33.40°N and 73.07°E). The germplasm accessions were collected from three districts of Punjab (Khushab, Layyah and Bhakkar) and these were selfed to ensure homozygousity for two years prior to evaluation during 1999. The experiment was planted during winter season of 1999 in randomized complete block design (RCBD) in four replications. Two rows of 4 meter length for each genotype in each replicate were planted with 10 cm intra-row spacing, whereas inter-row distance was kept 50 cm. Pesticides and fungicides were sprayed to save the crop from infestation of pests and *Asochyta rabiei*. For evaluation, data were recorded following descriptors for chickpea (IBPGR, 1985). The data for days to flowering and maturity were recorded on line basis at 50% of flowering and 90% pod maturity and each genotype was represented by single value. Other quantitative data, i.e., plant height, primary and secondary branches, pods, grain yield (g) and biological yield (g) were recorded on ten plants sampled randomly. Seed weight was recorded after counting 100 seeds in grams and harvest index was determined as economic yield expressed in percentage over total biomass. The data recorded were analyzed for simple statistics, i.e., mean, standard deviation, variance and broad sense heritability. Broad sense heritability was estimated as a ratio between genotypic and phenotypic variance (Singh and Chowdhry, (1979). Correlation coefficients were calculated as followed by Al-Jibouri *et al.* (1958) whereas path coefficient analysis was conducted according to Dewey and Lu (1959).

Results and Discussion

Genetic variance, phenotypic variance, heritability and genetic advance presented in the Table 1 revealed high proportion of genetic variation for days to flowering, days to maturity, secondary branches and 100-seed weight. The range for days to flowering, days to maturity and number of primary branches was low, but due the adaptation of chickpea to Thall desert, the crop duration does not matter due to sole crop culture (Gull, 1995). For other characters, considerable range of the means was observed that indicated the scope of selection from these genotypes for crop improvement. Medium to high genetic variance was observed for days to flowering, maturity, secondary branches and 100-seed weight, whereas for other characters, low to medium heritability (broad sense) was observed. Improvement of these traits through simple selection might be limited from germplasm used in the present study. For the characters like, days to flowering, days to maturity and 100-seed weight, high heritability coupled with high genetic advance revealed the presence of additive gene effects, hence crop improvement through these improvement traits could be possible through simple selection (Ghafoor *et al.*, 2000). Genetic advance along with heritability estimates gives an indication for gene-action and the characters with high heritability coupled with high genetic advance are supposed to be controlled additively, hence could be exploited through simple selection. Chickpea breeders should consider heritability estimates along with genetic advance because h^2 alone is not a good indicator of the amount of usable genetic variability (Ghafoor *et al.*, 1998).

Correlation coefficient analysis: The results regarding genotypic, phenotypic and environmental correlation coefficient given in the Table 2 revealed that the genotypic correlation’s were slightly higher than phenotypic ones for most of the characters, exhibiting high degrees of genetic association among traits under consideration. The environmental correlation coefficients were not much important in most of the cases except five combinations, i.e., primary branches Vs secondary branches, pods Vs biological yield, pods Vs grain yield biological yield Vs grain yield where it was positive and biological yield Vs harvest index where it was negative. The significant environmental correlation indicated environmental influence which is quite expected in a crop like chickpea (Malik and Tufail, 1984). The experiment was conducted under rainfed condition and hence environments played important role to determine correlation among characters, therefore, these results could only be valid for selection under rainfed conditions. Days to flowering exhibited significantly positive correlation with primary branches (0.5687), whereas negative with plant height (-0.5505), pods per plant (-0.7241) and harvest index (-0.8992). Short duration cultivars could be selected to improve the yield potential from present material. Days to maturity gave positive correlation with primary branches (0.7097) and harvest index (0.5097), whereas plant height had significant positive correlation with biological yield and negative with primary branches. 100-seed weight showed significant association with biological yield and grain yield. Grain yield was positively correlated with all the characters, except harvest index where it was significant, whereas it was insignificant negative with days to flowering and secondary branches. Genetic improvement in chickpea is mainly focused on grain yield by the breeders of the country (Bakhsh *et al.*, 1998). Grain yield is a complex character which is the final product of many (some known and others unknown) independent variables. In the present study, grain yield was positively associated with biological yield and 100-seed weight but negatively with harvest index. To improve grain yield emphasis should be given on development of chickpea cultivars with higher seed weight and biological yield. The genotypes with low grain yield and high biological yield consequently produced low harvest index and this important combination, high biological yield and harvest index could be attained using bi-parental mating to break unwanted linkage for further improvement of the crop. Positive correlation of grain yield with branches, pods and

Table 1: Basic statistics for 30 genotypes of chickpea evaluated during 1999

	σ^2 g	σ^2 p	h^2	GA
Days to flowering	3.41	5.08	0.67	2.62
Days to maturity	6.27	8.83	0.71	3.65
Plant height (cm)	44.70	108.36	0.41	7.43
Primary branches	0.10	0.41	0.23	0.26
Secondry branches	1.48	2.65	0.56	1.57
Pods per plant	19.57	90.75	0.22	3.55
100-seeds weight (g)	2.24	2.44	0.92	2.48
Biological yield (g)	31.38	92.84	0.34	5.63
Grain yield (g)	7.82	18.08	0.43	3.18
Harvest indes (%)	9.15	20.34	0.45	3.51

σ^2g- genotypic variance, σ^2p- phenotypic variance, σ^2h- heritability (broad sense), GA- genetic advance at 10% selection differential

Table 2: Genotypic correlation among ten quantitative traits in chickpea

		DF	DM	PH	PBR	SBR	P/P	SW	BY	GY
DM	r_G	0.1218								
	r_P	0.0368								
	r_E	-0.1527								
PH	r_G	-0.5505**	-0.3419							
	r_P	-0.2426	-0.1950							
	r_E	0.1064	-0.0242							
PBR	r_G	0.5687**	0.7097**	-0.6098**						
	r_P	0.2870	0.2277	0.0223						
	r_E	0.1261	-0.1254	0.3127						
SBR	r_G	0.2240	0.9120**	-0.0800	0.4986*					
	r_P	0.0134	0.2888	0.0218	0.4315*					
	r_E	-0.0985	0.0233	0.0564	0.4218*					
P/P	r_G	-0.7241**	0.1988	0.9325**	-0.5589**	-0.2000				
	r_P	-0.0507	0.0068	0.3371	0.0468	0.0884				
	r_E	0.1291	-0.0532	0.2835	0.1196	0.1134				
SW	r_G	-0.1770	0.0902	0.1254	0.1406	0.2336	0.2179			
	r_P	-0.1449	0.0764	0.0809	0.0677	0.0844	0.0455			
	r_E	-0.0095	0.1996	0.1232	0.0640	0.0466	0.0605			
BY	r_G	-0.0732	-0.2198	0.9411**	-0.3561	-0.2473	0.8112**	0.6710**		
	r_P	-0.0807	-0.1247	0.3090	0.1924	0.1416	0.5290**	0.1565		
	r_E	-0.1195	-0.1557	0.1755	0.2721	0.1789	0.5020*	0.0931		
GY	r_G	-0.3280	0.0719	0.7880**	-0.3029	-0.1422	0.8345**	0.7044**	0.09121**	
	r_P	-0.1030	-0.0282	0.3679	0.1563	0.1620	0.6616**	0.2464	0.8690**	
	r_E	-0.0172	-0.0978	0.2662	0.2519	0.2058	0.6376**	0.1191	0.8603**	
HI	r_G	-0.8992**	0.5097*	-0.6249**	-0.5512**	0.0878	-0.9881**	0.177	-0.8058**	-0.8511**
	r_P	0.0069	0.1928	-0.0425	-0.1937	-0.0323	0.0440	0.0296	-0.4851*	-0.0699
	r_E	0.2779	0.2211	0.0319	-0.1679	-0.0398	0.0862	-0.0187	-0.4600*	-0.0211

DF-days to flowering, DM-days to maturity, PH-plant height (cm), PBR-primary brancher per plant, SBR-secodary brancher per plant, P/P-pods/plant, SW-100-seeds weight (g), BY-biological yield/plant (g), GY-grain yield plant (g)

Table 3: Direct (parenthesis) and indirect effect of independent variables with dependent variable (grain yield). The last shows genotypic correlations of independent variables with grain yield

Variables	Days to flowering	Days to maturity	Plant height	Primary brancher	Secondary branches	Pods per plant	100-seed weight	Biological yield	Harvest indes	g_G with grain yield
Days to flowering	(-0.4438)	-0.1477	0.8294	-0.4247	0.2768	-1.3934	-0.2155	0.0788	1.1121	-0.3280
Days to maturity	-0.0541	(-1.2127)	0.5150	-0.5300	1.1269	0.3825	0.1098	0.2366	-0.5022	0.0719
Plant height	0.2444	0.4146	(-1.5065)	0.4554	-0.0988	1.7942	0.1527	-1.2835	0.6157	0.7880
Primary branches	-0.2524	-0.8607	0.9187	(-0.7467)	0.616	-1.0755	0.1712	0.3833	0.5431	-0.3029
Secondary branches	-0.0994	-1.1059	0.1205	-0.3723	(1.2356)	-0.3848	0.2845	0.2662	-0.0865	-0.1422
Pods per plant	0.3214	-0.2411	-1.4048	0.4174	-0.2471	(1.9242)	0.2654	-1.1458	1.1742	1.0638
100-seed weight	0.0785	-0.1093	-0.1889	-0.1050	0.2887	0.4193	(1.2177)	-0.7222	-0.1744	0.7044
Biological yield	0.03525	0.2666	-1.7964	0.2659	-0.3056	2.0482	0.8170	(-1.0764)	0.7939	1.0458
Harvest index	0.5010	-0.6181	0.9414	0.4116	0.1085	-2.2933	0.2155	0.8674	(-0.9852)	-0.8511

Table 4: Performance of chickpea genotypes selected on the basis of evaluation during 1999

Genotypes	DF	DM	PH	Pods	SW	GY	HI
52984	123	171	73.3	39.5	22.17	18.35	56.53
52983	123	174	62.5	42.2	20.84	19.15	50.64
52981	125	177	66.9	37.0	22.40	19.15	53.77
52979	123	174	65.3	46.0	23.98	20.05	57.00
52978	124	174	64.6	38.6	21.11	18.75	52.08
52975	122	178	59.6	39.9	22.57	19.95	54.31
52974	121	174	66.5	39.1	23.52	19.50	53.48
C-44	124	176	66.5	38.8	23.52	19.35	54.36
Paidar-91	124	174	66.9	37.7	16.98	11.95	56.52
F.RATIO(V)	9.13**	10.78**	3.80**	2.09*	242.1**	4.05**	4.27**
F.RATIO(R)	9.21**	0.57ns	1.96ns	12.63**	149.5**	6.75**	6.00**
CD1	1.81	2.24	11.17	14.08	0.009	6.30	7.81
CD2	2.39	2.96	14.76	18.61	0.011	8.33	10.33

DF-Days to 50% flowering, DM-days to 90% maturity, PH-Plant height (cm), Pods-number of pods/plant, SW-100-seed weight, GY-Grain yield/plant (g), HI-Harvest indes (%). * Significant at 0.05 ** Highly significant at 0.001

seed weight has already been reported by Gull, 1995 and Bakhsh *et al.* (1998) that indicated the consistency of these associations in chickpea, hence could be exploited for crop improvement.

Path coefficient analysis: The genotypic correlation coefficients were partitioned into direct and indirect effects by various yield contributing characters (Table 3). The path coefficient analysis was carried out in this study to utilize a complete represent of the causal factors involved in determining the end product i.e., grain yield. The direct effects exhibited by secondary branches, pods and 100-seed weight were positive, whereas all the other characters gave negative direct effects. The highest direct effect of 1.9242 was exhibited by pods per plant and it was followed by secondary branches (1.2356) and 100-seed weight (1.2177). 100-seed weight and pods per plant also exhibited significant positive association with grain yield, hence could more confidently be exploited for crop improvement.

In the present study conducted under rainfed conditions indicated that pods per plant and 100-seed weight had the maximum contribution in determining grain yield, the ultimate product in chickpea under rainfed conditions. Further it was observed that high indirect contribution was exhibited via secondary branches and harvest index by most of the yield components, hence these two traits along with pods per plant and 100-seed weight are suggested to be given emphasis while selecting high yielding chickpea cultivars for rainfed conditions. Correlation and path coefficient analyses indicated that pods per plant and 100-seed weight were potent contributors to grain yield through direct effects. Although biological yield had significant association but exhibited negative direct effects, whereas Singh *et al.* (1995) reported high direct effects by biological yield, pods per plant and 100-seed weight. The contradiction for biological yield may be related to the experimental conditions as present study was conducted under rainfed conditions. On the basis of performance, seven accessions produced higher grain yield than both the checks, hence were selected for further evaluation under a wide range of environmental conditions (Table 4).

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