The Journal of Animal & Plant Sciences, 23(6): 2013, Page: 1733-1741
ISSN: 1018-7081

RELATIONSHIPS BETWEEN SEED YIELD AND OTHER PLANT TRAITS IN DESI AND KABULI CHICKPEA (*CICER ARIETINUM* L.) PARENTS AND THEIR MUTANTS DEVELOPED THROUGH INDUCED MUTATIONS

T. M. Shah and B. M. Atta

Nuclear Institute for Agriculture and Biology (NIAB), Jhang Road, Faisalabad, Pakistan
Corresponding Author Email: Shahge266@gmail.com

ABSTRACT

The correlations between seed yield and other plant traits of 79 genetically stable induced chickpea mutants of two desi (Pb2000 and C44), one kabuli (Pb-1) and one desi x kabuli introgression (CH40/91) were studied. At maturity seventeen different traits were measured in the replicated trial. The results indicated that yield was significantly correlated with primary branches, secondary branches, canopy width, pods per plant, hundred seed weight, biological yield and harvest index in all the four chickpea genotypes and their mutants. The results have suggested that in a chickpea breeding program aiming to break the yield barrier the selection criteria must include these traits for the development of improved germplasm and new cultivars.

Key words: Induced mutants, chickpea, Correlation coefficient analysis, morphological characteristics, positive and negative correlations

INTRODUCTION

Chickpea is ancient cultivated crop of South Asia, the Middle East and the South Africa that has grown for many years in these regions (Shah *et al.,* 2012, 2011). It is a rich source of proteins and provides best food for vegetarians (Yadav *et al*., 2007) especially for the poor people of South Asia, West Asia and South Asia (FAO, 2005). It contain about 16.4-31.2% proteins and 38.1-73.3% carbohydrates (Sehirali, 1988). Several medical organizations recommended that pulses may be used in our daily diet regularly (Leterme, 2002). Developing countries like Pakistan has facing problems of food insecurity and malnutrition which demanded to develop high yielding and multiple disease resistant chickpea varieties to meet the requirement of cheap vegetable protein in the country (Akhtar *et al.,* 2009). Creation of genetic variability followed by selection and screening of promising plants is the major thrust for this crop. Practically every mutant possesses pleiotropic effects on various agricultural economic traits and they are generally more important in the case of macro-mutations. These effects have to be checked in these mutants from the beginning and their performance must be evaluated, as ever since the economical value of a desirable mutant may finally depend on favorable or unfavorable characters connected with the mutant by linkage or pleiotropism.

The fundamental objective of chickpea breeding program is the improvement in the yield, its components and disease resistance of the crop. The direct selection for yield *per se* has low heritability thus resulting in narrow genetic increase, this has leaded the scientists to investigate for traits having close relationship with yield with higher heritabilities. The usefulness of mutations in weakening, strengthening or altering character association has been demonstrated by Tanaka and Takagi (1970) and Vilwan and Siddiq (1973) in rice, Shroff and Srinivasachar (1974) in cotton, Ibrahim and Sharaan (1974) and Morsi *et al*., (1977) in barley and Budak and Yildirim, (2002) in durum wheat. In legumes genetic variability and relationships between yield and other characters have been studied (Phadnis *et al*., 1970; Rani and Rao, 1981; Malik *et al*., 1983; Kharkwal, 2003; Momin and Misra, 2004), yet there is not much information available on the contribution of these characters in induced mutants of chickpea. The information obtained can be used to identify certain parameters that could be used as selection index in breeding chickpea genotypes with high yield potential.

In genetic systems several traits are coupled together in various different ways that can be simple or complex. This association response of different characters can be assessed through correlation analysis therefore this model can direct the yield assessment (Khan and Qureshi, 2001). Correlation between two characters in an ordinary population should be the composite of effects of selection, gene linkage and pleiotropy (Sakai and Suzuki, 1964). In the mutant and control populations, under similar selection pressure, any difference in the correlation coefficients between the two populations will be due to the effect of mutations on gene linkage and altered pleiotropic effect of newly mutated genes.

The aim of this study was to determine the relationships between plant traits and seed yield in parents and their induced mutants to identify the traits that could be included in the selection criteria for the

improvement of desi and kabuli chickpea.

MATERIALS AND METHODS

The plant material include four chickpea genotypes, viz. Pb2000, C44, Pb-1, CH40/91 and their 79 true breeding mutants. Genotype Pb2000 with 47 mutants; C44 with 20 mutants; Pb-1 with 6 mutants and CH40/91 with 6 mutants were grown in a randomized complete block design with three replications at NIAB, Faisalabad. The material was planted in a uniform and homogeneous field conditions in five row plots. Each row was 4 m in length and a distance of 15 cm was maintained between plants and 30 cm between rows. Observations were recorded on five randomly selected plants from each plot for 17 characters: PH, plant height (cm); PB, primary branches; SB, secondary branches; FLD, flowering duration; CW, canopy width (cm); RL, rachis length (mm); LL, leaf length (cm); DM, days taken to maturity; GH, growth habit; VG, vigor; PP, pods per plant; SPD, seed per pod; SPL, seed per plant; HSW, hundred seed weight (gm); BY, biological yield (gm); HI, harvest index and SY, seed yield (gm).

Seed per pod (SPD) were obtained by dividing the total number of pods with total number of seeds per plant. Growth habit was recorded by using 1-5 scale; 1 = erect, 2 = semi-spreading, 3 = spreading, 4 = bushy, 5 = prostrate. Vigor was also rated on 1-5 scale; 1 being most vigorous and 5 the least. Harvest index was obtained by dividing seed yield with the biological yield and multiplying with 100. The correlation coefficient analysis was performed according to the methods proposed by Dewey and Lu, (1959).

RESULTS AND DISCUSSION

Mean values and standard error of 17 plant characters in Pb2000, C44, Pb-1, CH40/91 (controls) and their respective mutant populations are presented in Table 1. In mutants, wide range of variability existed both in the higher and lower direction for most of the characters under study. The mean standard error values were fairly high in Pb2000 mutants (5.10), C44 (4.51), Pb-1 (3.61), CH40/91 (5.79) compared to controls (2.55), (3.70), (2.94) and (3.55) respectively. The mean values and range of pods per plant and seeds per plant was increased in the mutants compared to respective controls. Kharkwal, (2000) reported increased variability for pods per plant in the induced mutants of chickpea. The wide range of variation in morphological characteristics of the mutant population offer immense scope for selecting plants with the desired changes.

Correlation Coefficient Analysis: The correlation coefficients among 17 characters in the control and respective mutant populations of Pb2000, C44, Pb-1 and, CH40/91 are presented in Table 2 – 5. The results have shown that relationship between the traits in the mutant populations are changed compared to the respective control populations. For example in Pb2000 mutants (Table 2), significant positive correlations were observed for plant height with rachis length (0.22), days to maturity (0.31) and vigor (0.26); Primary branches with leaf length (0.78) and growth habit (0.20); Secondary branches with leaf length (0.927) and growth habit (0.285); Canopy width with leaf length (0.856); Rachis length with seeds per plant (0.223); Leaf length with growth habit (0.298), pods per plant (0.877), seeds per pod (0.184), seeds per plants (0.896), hundred seed weight (0.859), biological yield (0.932), harvest index (0.772) and seed yield (0.952); Growth habit with vigor (0.429), pods per plant (0.371), hundred seed weight (0.235) and biological yield (0.204).

In C44 mutants (Table 3), significant positive correlations were observed between plant height and growth habit (0.28); Primary branches with days to maturity (0.38); Secondary branches with seeds per plant (0.88); Flowering duration with days to maturity (0.26). In Pb-1 (Table 4), significant positive correlations were observed in the mutants between plant height and vigor (0.656); Primary branches with rachis length (0.807); Secondary branches with rachis length (0.823); Canopy width with rachis length (0.918) and harvest index (0.868); Rachis length with leaf length (0,929), days to maturity (0.548), pods per plant (0.821), seeds per plant (0.758), hundred seed weight (0.878), harvest index (0.800) and seed yield (0.851); Days to maturity with pods per plant (0.549), seeds per pod (0.570), seeds per plant (0.608), hundred seed weight (0.566), biological yield (0.853) and seed yield (0.643).

In CH40/91 mutants (Table 5), significant positive correlations were observed between plant height and rachis length (0.61); Primary branches with vigour (0.62); Secondary branches with vigor (0.84) and hundred seed weight (0.883); Canopy width with vigor (0.749) and hundred seed weight (0.906); Leaf length with vigor (0.640) and hundred seed weight (0.863); Vigor with pods per plant (0.832), seeds per plant (0.727), hundred seed weight (0.717), biological yield (0.761), harvest index (0.622) and seed yield (0.808); Pods per plant with hundred seed weight (0.851); Seeds per plant with hundred seed weight (0.780); Hundred seed weight with biological yield (0.958), harvest index (0.510) and seed yield (0.897). In common beans there is considerable correlation between number of seeds per plant and number of pods per plant with grain yield (Salehi *et al.,* 2008).

In chickpea, plant height, number of pods per plant and number of seeds per plant have significant relationship with grain yield (Kobraee *et al*., 2010). Amjad *et al.* (2009) proposed that there is a significant relationship between plant yield with number of seeds per

pod and number of pods per plant. The results suggested that the existing relationships of yield components with yield could be improved further through mutation induction in such a way that the yielding ability is not altered. The increase in the correlation among traits may be utilized to enhance the rate of selection response in a primary trait (Moll and Stuber, 1974).

Significant negative correlations were observed in Pb2000 mutants between secondary branches and days to maturity (-0.22); Flowering duration with days to maturity (-0.32), growth habit (-0.54) and vigor (0.35); Leaf length with days to maturity (-0.17); Days to maturity with seeds per pod (-0.18), hundred seed weight (-0.272), biological yield (-0.271) and seed yield (-0.220). In C44 mutants, primary branches showed significantly negative correlation with growth habit (-0.350); Secondary branches with growth habit (-0.344); Flowering duration with rachis length (-0.273) and vigor (-0.571); Canopy width with growth habit (-0.619); Leaf length with growth habit (-0.446); Days to maturity with vigor (-0.259); Growth habit with pods per plant (-0.484), seeds per plant (-0.431), hundred seed weight (-0.522), biological yield (-0.514) and seed yield (-0.520). In Pb-1 mutants, days to maturity showed significantly negative correlation with growth habit (-0.664). In CH40/91 mutants, plant height showed significantly negative correlation with growth habit (0.598); Rachis length with growth habit (-0.527) and vigor (-0.491).

The change in the direction of correlation coefficients indicated breakage of relationship between the characters in the mutant populations. In Pb2000, the association of plant height with primary branches, canopy width, growth habit, pods per plant, hundred seed weight; Rachis length with leaf length was significantly positive in the control population but correlations decreased significantly in the mutant population. A shift from negative to significant positive correlation in the mutants of Pb2000 was observed between plant height and days to maturity, vigor; Primary branches with leaf length; Canopy width with seeds per plant; Rachis length with growth habit; Leaf length with growth habit, seeds per pod; Pods per plant with hundred seed weight, biological yield and seed yield.

In C44 control population, the significantly positive association was observed between plant height and primary branches, secondary branches, canopy width, rachis length. Leaf length, seeds per pod and hundred seed weight; Primary branches with rachis length and harvest index; Canopy width with harvest index; Rachis length with leaf length; leaf length with harvest index; Growth habit with vigor; Seeds per plant with harvest index; Harvest index with seed yield. All these correlations decreased significantly in the mutant population. A shift from negative to significant positive correlation in the mutants of C44 was observed between primary branches and days to maturity; Vigor with biological yield.

In Pb-1, the association of plant height with primary branches, secondary branches, canopy width, leaf length, seeds per plant, harvest index and seed yield; Flowering duration with vigor was significantly positive in the control population, but it decreased significantly in the mutant population. In Pb-1 mutants, a shift from negative to significant positive correlation was observed between days to maturity and primary branches, secondary branches, canopy width, rachis length, leaf length, pods per plant, seeds per plant, hundred seed weight, biological yield and seed yield.

In the control population of CH40/91, the plant height was positively correlated with secondary branches, canopy width, leaf length, pods per plant, biological yield and seed yield; Primary branches and harvest index; Growth habit with seeds per pod, but these correlations decreased significantly in the mutant population. In CH40/91 mutants, a shift from negative to significant positive correlation was observed between primary branches and vigor; Hundred seed weight with primary branches, secondary branches, canopy width, leaf length, pods per plant, seeds per pod, biological yield harvest index and seed yield; Vigor with pods per plant, seeds per plant, biological yield, harvest index and seed yield.

Reversed correlations were obtained by Shroff and Srinivaschar, (1974) when one mean remained static and the other shifted in the positive or negative direction. The cases of alterations in the relationships appear due to the effects of mutagens in breaking or strengthening the linkage of genes. Thus the present findings support the view that mutagenic treatments could alter the mode of relationships between any two characters, apart from generating variability (Rao and Siddiq, 1976).

Table 1: Mean and standard error (SE) of different plant characteristics in Pb2000, C44, Pb-1, CH40/91 and its mutants in M_3 generation

Plant traits[1]	Pb2000		C44		Pb-1		CH40/91	
	Mean± SE		Mean± SE		Mean± SE		Mean± SE	
	CONTROL	MUTANTS	CONTROL	MUTANTS	CONTROL	MUTANTS	CONTROL	MUTANTS
PH	73.7±0.98	67.4±7.05*	64.7±1.10	83.0±4.57**	67.6±1.04	90.2±7.46**	75.0±0.92	73.8±4.39 NS
PB	6.6±0.40	5.3±0.69NS	5.5±0.81	5.6±0.58 NS	6.1±0.64	5.4±0.52 NS	6.0±0.92	5.3±0.46 NS
SB	48.0±3.64	37.6±6.13**	41.9±4.91	30.1±3.93**	50.0±4.34	27.7±3.06**	61.3±6.42	30.0±4.57**
FLD	14.0±0.81	13.3±2.31 NS	14.4±0.81	13.9±1.56 NS	10.0±0.81	10.3±0.81 NS	15.1±0.64	12.8±1.21 NS
CW	47.0±2.77	51.6±4.34 NS	44.2±5.32	53.2±4.80*	47.9±2.54	55.1±5.43*	81.1±6.82	62.4±5.61**
RL	53.8±1.68	52.1±6.47 NS	60.6±4.45	63.6±5.03 NS	55.0±4.97	51.3±6.42 NS	65.8±2.49	63.3±6.36 NS
LL	65.0±2.37	56.3±5.26*	71.9±5.38	68.9±6.88 NS	65.2±4.62	64.2±6.30 NS	78.8±2.89	78.8±5.66 NS
DM	174.3±1.79	162.3±3.87**	172.5±1.56	171.2±3.01 NS	166.8±2.02	164.2±2.72 NS	172.7±1.27	173.1±1.91 NS
GH	6.1±0.17	4.3±1.10 NS	2.3±0.17	2.8±0.75 NS	2.3±0.12	1.4±0.23 NS	2.3±0.12	2.5±0.29 NS
VG	04.5±0.29	3.6±0.81 NS	5.2±0.17	3.5±0.92 NS	5.3±0.17	4.2±0.69 NS	4.5±0.75	3.0±0.81 NS
PP	72.4±5.61	99.1±13.87**	73.2±7.51	87.3±12.08**	83.3±8.44	102.7±9.48**	83.9±6.99	104.6±17.98**
SPD	1.8±0.06	1.8±0.12 NS	1.9±0.06	1.9±0.12 NS	1.7±0.06	1.8±0.12 NS	1.9±0.06	1.9±0.12 NS
SPL	129.5±9.25	150.6±17.69**	129.0±17.28	131.7±19.25 NS	126.9±12.95	152.3±8.32**	154.8±12.95	165.4±31.97**
HGW	25.8±0.58	20.2±1.85*	22.4±0.46	24.0±1.85 NS	15.7±0.23	22.6±2.43*	24.7±0.46	25.8±1.79 NS
BY	63.1±5.20	53.9±6.30*	53.9±6.18	47.2±5.72*	38.6±3.01	43.6±2.08*	58.1±8.73	52.2±6.42*
HI	53.6±3.01	55.7±3.64 NS	51.3±2.31	63.0±2.02**	51.5±2.02	51.8±3.35 NS	52.8±2.14	61.6±3.76*
SY	34.2±4.68	30.4±5.14 NS	27.9±4.39	29.7±3.64 NS	20.0±2.08	22.6±2.02 NS	31.1±5.84	32.4±5.20 NS
Mean SE	**2.55**	**5.10**	**3.70**	**4.51**	**2.94**	**3.61**	**3.55**	**5.79**

*****Mean value is significantly different at P≥ 0.05 from respective controls

**Mean value is highly significantly different at P≥ 0.01 from respective controls

NS non significant

[1] PH, plant height (cm); PB, primary branches; SB, secondary branches; FLD, flowering duration; CW, canopy width (cm); RL, rachis length (mm); LL, leaf length (cm); DM, days taken to maturity; GH, growth habit; VG, vigor; PP, pods per plant; SPD, seed per pod; SPL, seed per plant; HSW, hundred seed weight (gm); BY, biological yield (gm); HI, harvest index and SY, seed yield (gm).

Table: 2 Correlation coefficient values among various plant characteristics in chickpea genotype Pb2000 and its mutants in M_3 generation

		PH	PB	SB	FLD	CW	RL	LL	DM	GH	VG	PP	SPD	SPL	HSW	BY	HI
PH	a	1.00															
	b	1.00															
PB	a	0.78**	1.00														
	b	0.09	1.00														
SB	a	0.71**	0.82**	1.00													
	b	-0.13	0.77**	1.00													
FD	a	0.24	0.12	0.05	1.00												
	b	-0.10	0.12	0.10	1.00												
CW	a	0.82**	0.75**	0.75**	0.24	1.00											
	b	0.08	0.68**	0.77 **	0.04	1.00											
RL	a	0.04	-0.22	-0.11	0.01	0.05	1.00										
	b	0.22**	-0.08	0.07	-0.12	0.11	1.00										
LL	a	0.05	-0.05	0.19	-0.18	0.20	0.7**	1.00									
	b	-0.01	0.78**	0.93**	0.08	0.86**	0.11	1.00									
DM	a	-0.11	0.02	-0.02	0.16	-0.07	-0.39**	-0.25	1.00								
	b	0.31**	-0.06	-0.22*	-.32**	-0.14	0.02	-0.17*	1.00								
GH	a	0.30*	0.17	0.17	0.07	0.28*	-0.36**	-0.21	0.21	1.00							
	b	0.08	0.20*	0.29**	-0.54**	0.20**	0.28**	0.30**	0.01	1.00							
VG	a	-0.01	-0.11	-0.06	0.30*	0.13	0.27	0.21	0.17	0.12.	1.00						
	b	0.26**	0.04	-0.03	-0.35**	0.12	0.07	0.05	-0.02	0.43**	1.00						
PP	a	0.73**	0.78**	0.81**	0.14	0.84**	-0.05	0.16	-0.01	0.19	0.05	1.00					
	b	0.01	0.71**	0.91**	-0.09	0.78**	0.07	0.88**	-0.05	0.37**	0.02	1.00					
SPD	a	-0.48**	-.56**	-0.58**	-0.19	-0.31*	0.01	-0.20	-0.12	-0.08	0.12	-0.48**	1.00				
	b	0.09	0.05	0.14	0.03	0.17*	0.23**	0.18*	-0.18*	0.15	0.041	0.07	1.00				
SPL	a	0.68**	0.75**	0.88**	0.10	0.75**	-0.12	0.09	0.02	0.31*	0.01	0.81**	-0.43**	1.00			
	b	-0.04	0.69**	0.90**	-0.07	0.78**	0.10	0.90**	-0.05	0.31**	0.04	0.95**	0.08	1.00			
HSW	a	0.62**	0.76**	0.85**	0.13	0.66**	-0.22	0.02	0.08	0.22	-0.06	0.80**	-0.50**	0.94**	1.00		
	b	0.04	0.72**	0.88**	0.08	0.77**	-0.02	0.86**	-0.27**	0.24	0.02	0.83**	0.18*	0.78**	1.00		
BY	a	0.66**	0.70**	0.85**	0.13	0.74**	-0.12	0.11	-0.03	0.28	0.04	0.81**	-0.38**	0.97**	0.93**	1.00	
	b	-0.02	0.78**	0.91**	0.15	0.87**	0.05	0.93**	-0.27**	0.21*	0.05	0.84**	0.19*	0.84**	0.92**	1.00	
HI	a	0.64**	0.69**	0.83**	0.10	0.68**	-0.17	0.06	0.08	0.32*	0.01	0.74**	-0.48**	0.96**	0.91**	0.92**	1.00
	b	-0.15	0.53**	0.80**	0.06	0.61**	0.11	0.77**	-0.072	0.28**	-0.03	0.72**	0.04	0.78**	0.62**	0.64**	1.00
SY	a	0.65**	0.69**	0.85**	0.11	0.73**	-0.12	0.11	0.001	0.31*	0.04	0.79**	-0.40**	0.98**	0.92**	0.99**	0.97**
	b	-0.07	0.77**	0.96**	0.13	0.84**	0.05	0.95**	-0.220**	0.26**	0.03	0.88**	0.14*	0.90**	0.90**	0.96**	0.83**

a = control b = mutants

Table: 3 Correlation coefficient values among various plant characteristics in chickpea genotype C44 and its mutants in M_3 generation

		PH	PB	SB	FLD	CW	RL	LL	DM	GH	VG	PP	SPD	SPL	HSW	BY	HI
PH	a	1.00															
	b	1.00															
PB	a	0.98**	1.00														
	b	0.21	1.00														
SB	a	0.98**	0.97**	1.00													
	b	0.09	0.72**	1.00													
FD	a	-0.06	-0.16	-0.04	1.00												
	b	0.20	-0.06	-0.08	1.00												
CW	a	0.97**	0.94**	0.97**	0.02	1.00											
	b	0.00	0.64**	0.80**	-0.20	1.00											
RL	a	0.76**	0.79**	0.75**	-0.13	0.73**	1.00										
	b	0.14	0.03	-0.17	-0.27*	-0.01	1.00										
LL	a	0.90**	0.84**	0.88**	-0.06	0.91**	0.59**	1.00									
	b	0.02	0.59**	0.85**	-0.25	0.89**	0.01	1.00									
DM	a	-0.43	-0.45	-0.44	0.07	-0.35	-0.56*	-0.35	1.00								
	b	0.22	0.38**	0.07	0.26*	-0.07	-0.11	-0.09	1.00								
GH	a	0.15	0.16	0.16	-0.020	0.15	-0.01	-0.01	0.35	1.00							
	b	0.28*	-0.35**	-0.34**	0.06	-0.62**	0.03	-0.45**	-0.05	1.00							
VG	a	-0.45	-0.45	-0.41	0.27	-0.40	-0.43	-0.41	0.65**	0.47*	1.00						
	b	-0.22	0.23	0.23	-0.57**	0.12	0.07	0.17	-0.26*	0.11	1.00						
PP	a	0.97**	0.95**	0.94**	-0.08	0.92**	0.78**	0.87**	-0.50*	0.09	-0.48*	1.00					
	b	-0.04	0.54**	0.87**	-0.11	0.89**	-0.05	0.89**	-016	-0.49**	0.23	1.00					
SPD	a	-0.25	-0.19	-0.24	0.06	-0.35	-0.13	-0.22	-0.09	-0.15	0.11	-0.19	1.00				
	b	-0.00	0.15	0.02	-0.02	-0.03	-0.19	-0.03	0.23	-0.17	-0.02	-0.13	1.00				
SPL	a	0.92**	0.91**	0.88	-0.12	0.84**	0.75**	0.80**	-0.56*	0.05	-0.52*	0.98**	-0.12	1.00			
	b	0.06	0.68**	0.88**	-0.04	0.85**	-0.05	0.85**	-0.11	-0.43**	0.24	0.91**	-0.05	1.00			
HSW	a	0.79**	0.80**	0.80**	0.01	0.72**	0.64**	0.67**	-0.56*	0.08	-0.40	0.79**	0.14	0.75**	1.00		
	b	0.09	0.76**	0.89**	-0.03	0.86**	-0.14	0.83**	0.05	-0.52**	0.14	0.85**	0.13	0.94**	1.00		
BY	a	0.91**	0.89**	0.88**	-0.11	0.84**	0.72**	0.83**	-0.56*	0.06	-0.46*	0.97**	-0.14	0.98**	0.78**	1.00	
	b	-0.04	0.63**	0.93**	-0.11	0.87**	-0.15	0.87**	-0.07	-0.52**	0.27*	0.94**	0.015	0.91**	0.91**	1.00	
HI	a	0.74**	0.78**	0.66**	-0.13	0.66**	0.65**	0.55*	-0.39	-0.01	-0.55*	0.78**	-0.03	0.83**	0.53*	0.70**	1.00
	b	-0.22	0.11	-0.08	0.06	0.04	-0.14	0.03	0.06	-0.04	-0.07	-0.01	0.00	0.05	-0.01	-0.14	1.00
SY	a	0.91**	0.91**	0.87**	-0.14	0.83**	0.74**	0.79**	-0.55*	0.06	-0.51*	0.98**	-0.10	1.00**	0.76**	0.98**	0.82**
	b	-0.11	0.66**	0.90**	-0.09	0.88**	-0.19	0.87**	-0.05	-0.52**	0.25	0.93**	0.03	0.93**	0.91**	0.97**	0.12

a = control b = mutants

Table: 4 Correlation coefficient values among various plant characteristics in chickpea genotype Pb-1 and its mutants in M_3 generation

		PH	PB	SB	FLD	CW	RL	LL	DM	GH	VG	PP	SPD	SPL	HSW	BY	HI
PH	a	1.00															
	b	1.00															
PB	a	0.96**	1.00														
	b	0.18	1.00														
SB	a	0.97**	0.97**	1.00													
	b	0.39	0.87**	1.00													
FD	a	0.23	0.13	0.16	1.00												
	b	0.29	0.03	0.26	1.00												
CW	a	0.89**	0.91**	0.89**	0.14	1.00											
	b	0.24	0.92**	0.93**	0.26	1.00											
RL	a	0.52	0.45	0.57	0.03	0.38	1.00										
	b	0.36	0.81**	0.83**	0.24	0.92**	1.00										
LL	a	0.97**	0.95**	0.98**	0.22	0.89**	0.53	1.00									
	b	0.38	0.88**	0.94**	0.27	0.98**	0.93**	1.00									
DM	a	-0.71*	-0.66*	-0.60*	-0.48	-0.60*	-0.50	-0.58*	1.00								
	b	0.34	0.65**	0.60**	0.33	0.65**	0.55*	0.64**	1.00								
GH	a	0.59*	0.52	0.48	0.36	0.38	0.21	0.55	-0.64*	1.00							
	b	-0.32	-0.28	-0.27	-0.45	-0.33	-0.20	-0.32	-0.67**	1.00							
VG	a	-0.03	-0.12	-0.12	0.68*	-0.12	-0.41	-0.11	-0.18	0.25	1.00						
	b	0.66**	-0.34	-0.01	0.31	-0.27	-0.29	-0.14	0.01	-0.23	1.00						
PP	a	0.93**	0.96**	0.98**	0.05	0.91**	0.53	0.97**	-0.52	0.43	-0.22	1.00					
	b	0.64**	0.70**	0.89**	0.36	0.83**	0.82**	0.91**	0.55*	-0.25	0.19	1.00					
SPD	a	-0.29	-0.21	-0.28	0.09	-0.13	-0.36	-0.27	0.25	-0.44	0.07	-0.19	1.00				
	b	0.04	0.07	-0.04	0.24	0.03	-0.00	0.01	0.57*	-0.22	-0.03	-0.04	1.00				
SPL	a	0.89**	0.93**	0.95**	-0.04	0.89**	0.52	0.95**	-0.45	0.37	-0.28	0.99**	-0.14	1.00			
	b	0.28	0.80**	0.93**	0.29	0.89**	0.76**	0.92**	0.61**	-0.29	0.03	0.87**	-0.00	1.00			
HSW	a	0.82**	0.87**	0.89**	-0.04	0.91**	0.42	0.89**	-0.4	0.38	-0.22	0.93**	-0.12	0.95**	1.00		
	B	0.48*	0.79**	0.94**	0.38	0.93**	0.88**	0.97**	0.57*	-0.29	0.04	0.96**	-0.05	0.93**	1.00		
BY	a	0.81**	0.88**	0.89**	0.07	0.88**	0.37	0.89**	-0.39	0.30	-0.26	0.94**	0.01	0.96**	0.93**	1.00	
	B	0.48*	0.55*	0.65**	0.37	0.56*	0.47	0.59*	0.85**	-0.46	0.28	0.63**	0.47	0.66**	0.60**	1.00	
HI	a	0.71*	0.68*	0.74**	-0.19	0.56	0.52	0.71*	-0.28	0.44	-0.09	0.74**	-0.38	0.74**	0.71*	0.53	1.00
	B	0.11	0.78**	0.84**	0.12	0.87**	0.80**	0.87**	0.25	-0.08	-0.27	0.73**	-0.34	0.82**	0.84**	0.19	1.00
SY	a	0.86**	0.92**	0.94**	0.01	0.86**	0.46	0.93**	-0.39	0.38	-0.20	0.98**	-0.12	0.99**	0.96**	0.96**	0.76**
	B	0.38	0.88**	0.98**	0.28	0.95**	0.85**	0.97**	0.64**	-0.32	-0.03	0.91**	-0.03	0.96**	0.96**	0.67**	0.85**

a = control b = mutants

Table: 5 Correlation coefficient values among various plant characteristics in chickpea genotype CH40/91 and its mutants in $_3$ generation

		PH	PB	SB	FLD	CW	RL	LL	DM	GH	VG	PP	SPD	SPL	HSW	BY	HI
PH	a	1.00															
	b	1.00															
PB	a	0.63*	1.00														
	b	0.50*	1.00														
SB	a	0.96**	0.96**	1.00													
	b	0.22	0.87**	1.00													
FD	a	0.21	0.21	0.44	1.00												
	b	-0.22	-0.33	-0.30	1.00												
CW	a	0.97**	0.97**	0.98**	0.34	1.00											
	b	0.24	0.85**	0.91**	-0.23	1.00											
RL	a	0.29	0.29	0.16	-0.39	0.25	1.00										
	b	0.61**	-0.13	-0.23	0.23	-0.16	1.00										
LL	a	0.76**	0.76**	0.79**	0.39	0.79**	-0.09	1.00									
	b	0.12	0.77**	0.81**	-0.28	0.95**	-0.27	1.00									
DM	a	-0.19	-0.19	-0.28	-0.42	-0.27	0.17	-0.34	1.00								
	b	0.19	0.29	0.36	0.08	0.18	0.26	0.10	1.00								
GH	a	-0.03	-0.03	0.06	0.12	-0.06	-0.44	-0.00	-0.14	1.00							
	b	-0.60**	-0.29	-0.14	-0.33	-0.16	-0.53*	-0.04	-0.28	1.00							
VG	a	-0.16	-0.16	-0.15	0.08	-0.25	-0.00	-0.08	-0.06	0.06	1.00						
	b	-0.13	0.62**	0.84**	-0.09	0.75**	-0.49*	0.64**	0.09	-0.13	1.00						
PP	a	0.98**	0.98**	0.95**	0.20	0.92**	0.25	0.71**	-0.13	0.12	-0.15	1.00					
	b	0.04	0.75**	0.86**	-0.13	0.97**	-0.30	0.94**	0.07	-0.13	0.83**	1.00					
SPD	a	0.29	0.29	0.31	-0.06	0.29	-0.01	0.18	-0.31	0.76**	-0.28	0.41	1.00				
	b	-0.30	0.03	-0.14	0.05	-0.14	-0.24	-0.13	-0.19	0.08	0.00	-0.07	1.00				
SPL	a	0.92**	0.92**	0.85**	0.04	0.83**	0.27	0.63*	-0.07	0.21	-0.22	0.97**	0.5	1.00			
	b	-0.05	0.66**	0.76**	-0.09	0.93**	-0.29	0.95**	-0.00	-0.06	0.73**	0.98**	-0.06	1.00			
HSW	a	-0.48	-0.48	-0.49	-0.19	-0.51	0.06	-0.49	0.44	-0.10	0.20	-0.46	-0.30	-0.43	1.00		
	b	0.36	0.91**	0.88**	-0.41	0.91**	-0.29	0.86**	0.04	-0.09	0.72**	0.85**	-0.14	0.78**	1.00		
BY	a	0.96**	0.97**	0.93**	0.20	0.89**	0.26	0.68*	-0.05	0.08	-0.14	0.99**	0.33	0.96**	-0.36	1.00	
	b	0.19	0.86**	0.90**	-0.36	0.95**	-0.37	0.95**	0.10	-0.04	0.76**	0.93**	-0.12	0.88**	0.96**	1.00	
HI	a	0.93**	0.93**	0.89**	0.12	0.88**	0.37	0.63*	-0.30	0.16	-0.09	0.91**	0.46	0.87**	-0.45	0.90**	1.00
	b	-0.10	0.38	0.61**	0.08	0.66**	-0.03	0.64**	0.13	-0.08	0.62**	0.72**	-0.27	0.72**	0.51*	0.60*	1.00
SY	a	0.97**	0.97**	0.92**	0.16	0.89**	0.30	0.65*	-0.08	0.11	-0.15	0.99**	0.39	0.97**	-0.39	0.99**	0.92**
	b	0.10	0.78**	0.91**	-0.24	0.95**	-0.28	0.93**	0.14	-0.07	0.81**	0.95**	-0.19	0.92**	0.90**	0.95**	0.80**

a = control b = mutants

Conclusion: The results indicated that yield was significantly correlated with primary and secondary branches, canopy width, pods per plant, hundred seed weight, biological yield and harvest index in all the four chickpea genotypes and mutants. The results have suggested that due consideration should be given to these characters in the selection of promising plants in the chickpea breeding program. It is concluded that improvement of grain yield in chickpea is linked with these traits and hence suggested that these parameters should be an integral part of effective selection criteria leading to yield enhancement in chickpea.

Acknowledgement: Statistical assistance provided by Mr. G. R. Tahir, DCS (Rtd.) and Mr. M. Akram, ARO is greatly acknowledged.

REFERENCES

Akhtar, KP., T.M. Shah, B.M. Atta, M. Dickinson, J. Hodgetts, R. A. Khan, S. Hameed, and M. A. Haq (2009). Symptomatology, etiology and transmission of chickpea phyllody disease in Pakistan. J. Plant Path. 91 (3), 711-715.

Amjad M.A., N.N. Nausherwan, A. Amjad, M. Zulkiffal and M. Sajjad (2009). Evaluation of selection criteria in *Cicer arietinum* L. using correlation coefficients and path analysis. Aust. J. Crop Sci., 3(2): 65-70.

Budak, N. and M.B. Yildirim (2002). Heritability, correlation and genetic gains obtained in the populations of Ege 88 and Kunduru durum wheats irradiated with gamma rays. Cereal Res. Commun., 30(1/2): 47-53.

Dewey, J.R. and K.H. Lu. (1959). A correlation and path coefficient analysis of crested wheat grass seed production. Agron. J., 51:515-518.

F.A.O. (2005). Year Book. Food and Agriculture Organization of the United Nations.

Ibrahim, A.F. and A.N. Sharaan (1974). Variability of character expression in barley M_3 and M_4 bulk populations after seed irradiation with gamma-rays. Z. Pflazucht 72:212-225.

Khan, M.R. and A.S. Qureshi (2001). Character correlation and path analysis of the variation induced by gamma rays in M_2 of chickpea (*Cicer arietinum*). Proc. Pakistan Acd.Sci., 38:19-24.

Kharkwal, M.C. (2000). Induced mutations in chickpea (*Cicer arietinum* L.) IV. Types of macromutations induced. Indian J. Gen. and Pl. Breed. 60(3):305-320.

Kharkwal, M.C. (2003). Induced mutations in chickpea (*Cicer arietinum* L.). VI. Significance of induced altered correlations. Indian J. Genet., 63(3): 219-224.

Kobraee S, K. Shamsi, B. Rasekhi and S. Kobraee (2010). Investigation of correlation analysis and relationships between grain yield and other quantitative traits in chickpea (*Cicer arietinum* L.). African J. Biotech. 9(16): 2342-2348.

Leterme, P. (2002). Recommendations by health organizations for pulse consumption. British J. Nutri. 88: 239–242.

Malik, B.A., S.A. Hussain, A.M. Haqqani and A.H. Chaudhary (1983). Genetic variability in mungbean (*Vigna radiata*). Pakistan J. Agric. Res. 4:171-173.

Moll, R.H. and C.W. Stuber (1974). Quantitative genetics. Empirical results relevant to plant breeding. Adv. Agron. 26:279-313.

Momin, B.W., and R.C. Misra 2004. Induced variability, character association and path-coefficient analysis in mutant cultures of greengram. Envir. and Ecol. 22(3): 608-611.

Morsi, L.R., R.A. Abo-Elenein and I.M. Mahmood (1977). Studies on the induction of new genetic variability for quantitative traits by gamma-rays and N-nitroso-N-methyl urethane in barley. Egyptian J. Genet. Cytol. 6:244-258.

Phadnis, B.B., A.P. Ekbote and S.S. Ainchwar (1970). Path coefficient analysis in gram (*Cicer arietinum* L.). Indian J. Agric. Sci. 40:1016-1031.

Rani, Y.U. and J.S. Rao, (1981). Path analysis of yield components in blackgram. Indian J. Agric. Sci. 51:378-381.

Rao, G.M. and E.A. Siddiq (1976). Studies on the induced variability for amylose contents with references to yield components and protein characteristics in rice. Environ. Exp. Bot. 16: 177-188.

Sakai, K.I. and A. Suzuki (1964). Induced mutations and pleiotropy of genes responsible for quantitative traits in rice. Radiat. Bot. 4:141-151.

Salehi M., M. Tajik and A.G. Ebadi (2008). The Study of Relationship between Different Traits in Common Bean with multivariate statistical methods. American - Erusion J. Agric. Environ. Sci., 3(6): 806-809.

Şehirali, S. 1988. Yemeklik Dane Baklagiller. A.Ü. Ziraat Fakültesi Yayınları: 1089, Ankara, 435 s.

Shah,T.M., B.M. Atta, M.A. Haq and J.I. Mirza (2011). Induced genetic variability in chickpea (*Cicer arietinum* L.). IV.Spectrum of morphological mutations Pakistan J. Bot. 43(4): 2039-2043.

Shah,T.M., B.M. Atta, M.A Haq and J.I. Mirza (2012). Radio sensitivity of various chickpea genotypes In M_1 generation II-Field studies. Pakistan J. Bot., 44(2): 631-634

Shroff, V.N. and D. Srinivasachar (1974). Effect of mutagens on the association between the various traits in cotton. Indian J. Genet. Pl. Breed. 34A:85-87.

Tanaka, S. and Y. Takagi (1970). Protein contents of rice mutants. Proc. FAO/IAEA Symp. on Improving Plant Proteins by Nuclear Techniques, IAEA, Vienna. pp. 55-61.

Vilwan, S. and E.A. Siddiq 1973. Study on the mutational manipulation of protein characters in rice. Theor. Appl. Genet. 43:276-280.

Yadav, S.S., R.J. Redden, W. Chen and B. Sharma 2007. "Chickpea Breeding and Management". *CABI*, p.101.