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Genetic variability, path analysis and relationship among quantitative traits in chickpea (*Cicer arietinum* L.) genotypes

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Abstract
The present investigation was carried out in Randomized Complete Block Design (RCBD) with two replications during rabi season for three consecutive years from 2014-16 at Rajaula farm of Faculty of Agriculture, Mahatma Gandhi Gramodaya Vishwa Vidyalaya Chitrakoot (MGCGV), Satna (M.P.) to determine the extent of genetic variation, association and their interrelationship of yield with yield attributing traits among twenty chickpea genotypes. Assessment of genetic variability and association among the important economic traits along with understanding their direct and indirect effects over grain yield per plant are crucial for the choice of parents in the breeding program and selection strategy for improvement in yield and other traits. The results revealed high variability of most of the economically important traits. High GCV and PCV along with high heritability and genetic advance as percent of mean was reported for grain yield per plant, hundred seed weight, harvest index and biological yield per plant suggesting that these traits are good yield enhancing indices. The correlation and path analysis exhibited positive association and direct effects of harvest index, biomass per plant, hundred seed weight, number of seeds per plant and number of pods per plant on grain yield per plant indicating that the direct selection for these traits would improve the grain yield in chickpea.

Keywords: Genetic variability, correlation, path coefficient, yield traits, chickpea/gram

Introduction
Chickpea (*Cicer arietinum* L.) is one of the world's most important grain legumes. It is commonly known as Chana or Bengal gram (India and Pakistan), Garbanzo (Spain), Homes, Amaz (Arab world), Garo (Portugal), Shimbra (Ethiopia) and Nahud, Lablabi (Turkey) is believed to be one of the first legumes cultivated by humans (Loss *et al*., 1998) [13].
Chickpea seeds are major source of plant-based dietary protein (17-23%), carbohydrates (54-60%) and minerals such as phosphorus (340mg/100g), magnesium (140mg/100g), calcium (190mg/100g), iron (7mg/100g) and zinc (3mg/100g) (Singh *et al*., 2008) [20]. Chickpea is believed to be center of origin of chickpea is South East Turkeys and Syria. Chickpea is grown in semi-arid regions of the world for over hundreds of years, primarily in India, Pakistan and Middle East (Kumar and Abbo, 2001) [11]. Among legumes, chickpea ranks third in the cultivated area worldwide (FAO stat, 2017) [9]. Chickpea is currently grown at about 14.56 million hectares worldwide with the annual production of 14.78 million tons (FAO stat, 2017) [9]. The developing countries share more than 95% of the area, production and consumption of chickpea. In India chickpea is cultivated on 9.54 m ha area with an annual production of 9.08 Mt and productivity of 951 kg/ha (FAO stat, 2017) [9]. Madhya Pradesh covers 3.01 mha area with production of 3.35 Mt and productivity of 1115 kg/ha (MP Krishi statistics, 2015-16). The yield increase in India is low as compared to the world which needs to be increased through intense efforts on developing high yielding improved varieties along with ensuring its availability to the farmers through an active seed system. Genetic variability in a population is important for biodiversity because without variability, a population may fail to adapt to environmental changes and therefore, makes it more prone to extinction. The study of genetic variability including the important yield and yield attributing traits in chickpea is of utmost importance to judge its potential as base material for genetic improvement. Further direct selection for complex traits like seed yield is not effective. Knowledge of association of the simply inherited traits, which are less influenced by environment, is required to have sound selection criteria (Kumar Vinod and Bisen Rajani, 2016) [12]. This study was, therefore, carried out to determine the extent of genetic variation, association and their interrelationship of yield

attributing traits to yield among twenty chickpea genotypes with the specific objective to use suitable genetic parameters.

Materials and Methods

The present investigation was carried out with the major aim of to assess the genetic parameters and the association among the different economic traits of chickpea genotypes. The experiment was conducted in Randomized Complete Block Design (RCBD) with two replications during rabi season for three years from 2014-16 at Rahaula farm of Faculty of Agriculture, Mahatma Gandhi Gramodaya Vishwa Vidyalaya Chitrakoot (MGCGV), Satna (M.P.) situated at the latitude of 25.14° ´N, 80.85 ‘E, longitude and an altitude of 315 meter above the mean sea level. Four row trial with 4 m row length plots were planted with inter and intra-row spacing of 30 and 10 cm, respectively. Standard agronomic practices were adopted to raise a good crop. The recommended dose of nitrogen and phosphorus per hectare was applied at the time of sowing. Five healthy plants were randomly tagged in each plot to record data on various economic traits from each replication. The data collected from all the individual environments and combined across the environments were subjected to analysis of variance, and assessment of correlation and path analysis to estimate the direct and indirect effect of traits over pod yield.

Results

The pooled analysis of variance revealed highly significant differences among the genotypes for all the eleven characters studied except plant height, thus indicating the existence of sufficient genetic variability among the existing collection and scope for further improvement (Kumar Vinod and Bisen Rajani, 2016) [12]. Coefficient of variation provides a relative measure of variance among the different traits. The value of phenotypic coefficient of variation was found to higher than genotypic coefficient of variation for characters *viz*., hundred seed weight followed by grain yield per plant, biomass yield per plant, number of branches per plant, number of seeds per plant, number of pods per plant, harvest index, number of pod per cluster, number of nodes per plant, plant height and number of seeds per pod.

High heritability was recorded for the characters grain yield per plant, hundred seed weight and biomass yield per plant, whereas harvest index and number of nodes per plant showed moderate heritability [Table-1]. The highest genetic advance as percentage of mean was recorded for hundred seed weight, grain yield per plant, biomass per plant, number of branches per plant and harvest index. Moderate genetic advance was recorded for number of nodes per plant, number of pods per plant and number of seeds per plant. Low genetic advance was recorded for plant height, number of seeds per pod and number of pods per cluster [Table-1].

High heritability coupled with high genetic advance for grain yield per plant, hundred seed weight and biomass yield per plant indicating lesser influence of environment in expression of these characters and presence of additive gene action, hence amenable for simple selection and useful in further population improvement.

Table 1: Parameters of genetic variability for yield and yield related traits in chickpea genotypes

Characters	GCV	PCV	h^2 (Broad sense) %	Genetic advance as % of mean
PH	6.93	15.23	21	6.49
NNPP	11.65	16.02	53	17.45
NBPP	20.29	30.98	43	27.39
NPPC	6.21	17.09	13	4.65
NPOdsPP	12.73	21.67	35	15.4
NSPPlant	13.37	24.6	30	14.98
NSPPod	4.86	11.74	17	4.15
HSW	44.85	45.87	96	90.36
BIOMPP	25.1	27.38	84	47.38
HI	14.32	19.99	51	21.12
GYPP	32.59	37.1	77	58.96

The understanding on association among the traits at genotypic and phenotypic level helps breeders to design a sound breeding strategy. Grain yield per plant had significant positive genotypic and phenotypic association with plant height (rg = 0.35 and rp = 0.23), number of pods per cluster (rg = 0.21 and rp = 0.16), number of primary branches (rg = 0.88 and rp = 0.56), number of pods per plant (rg = 0.74 and rp = 0.59), number of seeds per plant (rg = 0.67 and rp = 0.54), hundred seed weight (rg = 0.90 and rp = 0.82), biomass per plant (rg = 0.90 and rp = 0.84) and harvest index (rg = 0.68 and rp = 0.69). Biomass yield per plant was significantly positively associated with plant height (rg = 0.42 and rp = 0.21), number of nodes per plant (rg = 0.26 and rp = 0.18), number of primary branches per plant (rg = 0.79 and rp = 0.52), number of pods per plant (rg = 0.79 and rp = 0.55), number of seeds per plant (rg = 0.80 and rp = 0.54) and hundred seed weight (rg = 0.89 and rp = 0.83) at genotypic and phenotypic level. Harvest index was significant positively associated with number of primary branches per plant (rg = 0.64 and rp = 0.32), number of pods per plant (rg = 0.23 and rp = 0.35), hundred seed weight (rg = 0.53 and rp = 0.42) and biomass per plant (rg = 0.28 and rp = 0.22). The number of pods per plant was significant positively associated with plant height (rg = 0.45 and rp = 0.17), number of nodes per plant (rg = 0.60 and rp = 0.44), number of primary branches per plant (rg = 0.51 and rp = 0.27), seeds per plant (rg = 0.92 and rp = 0.86) (Table 2).

Table 2: Genotypic and phenotypic correlation among agronomic traits of 20 genotypes evaluated across the environments

Traits	PH	NNPP	NBPP	NPPC	NPOdsPP	NSPPlant	NSPPod	HSW	BIOMPP	HI	GYPP
Genotypic correlation											
PH	1.00	0.01	0.67	0.21	0.45	0.40	0.00	0.48	0.42	0.06	0.35
NNPP		1.00	-0.13	0.12	0.60	0.67	0.27	-0.02	0.26	-0.05	0.21

NBPP			1.00	-0.11	0.51	0.44	-0.08	0.95	0.79	0.64	0.88
NPPC				1.00	0.00	0.08	0.26	-0.21	-0.08	-0.01	-0.03
NPOdsPP					1.00	0.92	-0.10	0.52	0.79	0.23	0.74
NSPPlant						1.00	0.31	0.48	0.80	0.09	0.67
NSPPod							1.00	-0.07	0.09	-0.29	-0.10
HSW								1.00	0.89	0.53	0.90
BIOMPP									1.00	0.28	0.90
HI										1.00	0.68
GYPP											1.00
Phenotypic correlations											
PH	1.00	0.08	0.24**	0.03	0.17*	0.20**	0.09	0.21**	0.21**	0.15*	0.23**
NNPP		1.00	0.08	0.06	0.44***	0.39***	0.00	-0.03	0.18*	0.00	0.16*
NBPP			1.00	-0.09	0.27***	0.24**	-0.01	0.65***	0.52***	0.32***	0.56***
NPPC				1.00	0.05	0.04	0.01	-0.09	-0.03	0.09	0.02
NPOdsPP					1.00	0.86***	-0.04	0.32***	0.55***	0.35***	0.59***
NSPPlant						1.00	0.46	0.27***	0.53***	0.29***	0.54***
NSPPod							1.00	-0.02	0.08	-0.01	0.03
HSW								1.00	0.83***	0.42***	0.82***
BIOMPP									1.00	0.22*	0.84***
HI										1.00	0.69***
GYPP											1.00

The data collected from three different individual environments were subjected to path analysis to understand the direct and indirect effects of different yield contributing traits on grain yield per plant across the environments. The results of path coefficient analysis revealed that all traits, except plant height, number of pods per cluster and number of seed per pod exhibited positive direct effects on grain yield per plant. Among the traits, harvest index (0.694) followed by biomass per plant (0.640), hundred seed weight (0.375), number of seeds per plant (0.292) and number of pods per plant (0.257) reported maximum direct effects on grain yield per plant. Apart from direct effect, harvest index reported positive indirect effect on grain yield through hundred seed weight (0.528) followed by number of pods per plant (0.347) and biomass yield per plant (0.208). Similarly, the indirect effect of biomass yield per plant was maximum through hundred seed weight (0.384) followed by number of pods per plant (0.301), number of primary branches per plant (0.275). Plant height and number of nodes per plant had negligible direct effects and indirect effects through other characters (Table 3).

Table 3: Direct and indirect effects of different traits on grain yield per plant estimated through path analysis across the environments

Traits	PH	NNPP	NBPP	NPPC	NPOdsPP	NSPPlant	NSPPod	HSW	HI	BIOMPP
PH	-0.017	0.002	0.013	-0.052	0.017	0.023	0.000	-0.018	0.174	0.147
NNPP	-0.001	0.041	0.003	0.014	0.025	-0.064	-0.001	0.003	0.146	-0.006
NBPP	-0.006	0.003	0.141	-0.014	0.017	-0.029	0.000	-0.057	0.430	0.275
NPPC	-0.003	-0.002	0.002	-0.286	0.020	0.266	0.001	-0.008	-0.007	0.147
NPOdsPP	-0.005	0.018	0.012	-0.100	0.257	-0.006	-0.001	-0.023	0.347	0.301
NSPPlant	0.001	0.009	0.004	0.261	0.001	0.292	-0.002	-0.003	0.167	-0.026
NSPPod	0.000	0.002	0.000	0.011	0.003	-0.041	-0.014	0.003	0.014	-0.019
HSW	-0.004	-0.002	0.031	-0.029	0.018	-0.012	0.001	0.375	0.528	0.384
HI	-0.004	0.009	0.026	0.003	0.029	-0.070	0.000	-0.057	0.694	0.192
BIOMPP	-0.004	0.000	0.018	-0.066	0.027	0.012	0.000	-0.045	0.208	0.640
Residual effect	0.003	Direct effect on main diagonal (Bold figure)								

Discussion

Yield is a complex polygenic trait governed by a large number of genes and is greatly influenced by environmental factors. Yield can be improved by effecting indirect selection for its contributing traits, which have high heritability and strong association with yield (Nunes *et al.*, 2011) [17]. The information on the interrelationship among economically important traits is also useful to decide breeding procedure for improvement in these traits and to achieve desired combination of traits in future genotypes. The evaluation of correlation among the traits across the environments confirms the true association among the pair of traits which indicates that the strategy can be deployed across the location. Grain yield per plant had significant positive genotypic and phenotypic association with plant height, number of pods per cluster, number of primary branches, number of pods per plant, number of seeds per plant, hundred seed weight, biomass per plant and harvest index. The positive association of grain yield per plant with other yield contributing traits reported in earlier studies of Babbar and Patel (2005) [6]; Babbar *et al*. (2012); Naveed *et al*. (2012) [16] and Malik *et al*. (2014) [14]. The concluded positive significant association of seed yield with biological yield, pod weight per plant, number of pods per plant, number of seeds per plant, hundred seed weight and harvest index. Dar *et al*. (2012) [8] observed significant positive correlation of seed yield per plant with pods per plant, branches per plant and number of seeds per pod.

Plant biomass, pod number, filled pod number and seed number per plant were positively correlated with seed yield in several other studies (Pandey *et al*. 2013; Aarif *et al*. 2014; Mishra and Babbar, 2014, Malik *et al*. 2014) [1, 14, 15, 19]. The positive significant association of biomass yield per plant was observed with plant height, number of primary branches per plant, number of pods per plant, number of seeds per plant and hundred seed weight at genotypic and phenotypic level.

The findings are in accordance with the findings of earlier studies (Thakur and Sirohi, 2009; Akhtar *et al*. 2011 and Malik *et al*. 2014) [3, 14, 22].

The knowledge of direct and indirect influence of yield contributing characters on the ultimate end product yield in any crop is of prime importance in selecting high yielding genotypes. Residual effect was low (0.003) which measures the effects of those variable not included in the study was negligible, hence indicating the number of characters chosen for the study was appropriate. The results revealed that all the traits, except plant height, number of pods per cluster and number of seed per pod exhibited positive direct effects on grain yield per plant indicating that the selection for these traits will directly reward for selection in grain yield per plant. The findings are in accordance with the results of earlier studies of Paliwal *et al*. (1987). [18]. Harvest index followed by biomass per plant, hundred seed weight, number of seeds per plant and number of pods per plant reported maximum direct effects on grain yield per plant. Similar findings were earlier reported by Jeena and Arora (2002) [10]; Arshad *et al*. (2004) [5]; (Ali *et al*. 2009) [4], and Borate and Dalvi (2010) [7] where they concluded that these traits can be considered as selection criterion for yield enhancement.

Apart from direct effect, harvest index reported the positive indirect effect on grain yield through hundred seed weight followed by number of pods per plant and biomass yield per plant indicating that these traits will be useful for making indirect selection for higher yield through selecting harvest index. Similarly, the indirect effect of biomass yield per plant was maximum through hundred seed weight followed by number of pods per plant and number of primary branches per plant on grain yield per plant indicating that the grain yield can be increased through making selection for the traits. Arshad *et al*. (2004) [5] and Talebi *et al*. (2007) [21] also reported indirect effect of different yield contributing traits via harvest index and biological yield per plant which can be used of selection of higher grain yield in chickpea.

The path analysis showed that the maximum positive direct effects contributing to grain yield per plant was exhibited by harvest index, biomass per plant, hundred seed weight, number of seeds per plant and number of pods per plant which implies that direct selection for these traits would improve the single plant yield (Agarwal *et al*., 2018).

Conclusion

The present investigation attempted to understand the association among the economically important traits and to identify the traits with the highest direct and indirect effects on yield across the environments. The study has identified superior genotypes which can be used as parent in future breeding programs. The correlation and path analysis exhibited highest positive direct effects of harvest index, biomass per plant, hundred seed weight, number of seeds per plant and number of pods per plant on grain yield per plant indicating that the direct selection for these traits would improve the grain yield in chickpea. The present study concluded that the association among the traits and their direct and indirect effects over grain yield per plant can be used for defining the selection strategy for chickpea improvement.

Abbreviations

PH- Plant height (cm); NNPP- Number of Nodes per plant; NBPP- Number of branches per plant; NPPC - Number of pod per cluster; NPodsPP- Number of pods per plant; NSPPlant- Number of seeds per plant; NSPPod- Number of seeds per pod; HSW- 100 Seed weight (g); BIOMPP- Biomass per plant (g); HI- Harvest Index (%); GYPP- Grain Yield per plant (g).

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