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Stability and diversity analysis of economic traits of in different genotypes of chickpea/gram (*Cicer arietinum* L.) in Chitrakoot region

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Abstract
Assessment of genetic diversity, stability, 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. Therefore, the present investigation entitled "Stability and diversity analysis of economic traits of in different genotypes of chickpea'' was carried out with the major aim of to assess the genetic parameters, genetic diversity, the association among the different economic traits, and to assess the stability of chickpea genotypes. The experiment was conducted in Randomized Complete Block Design (RCBD) with two replications during rabi season for three consecutive years from 2014-16at Rajaula farm of Faculty of Agriculture, Mahatma Gandhi Gramodaya Vishwa Vidyalaya Chitrakoot (MGCGV), Satna (M.P.). The results revealed high variability of most of the economically important traits. Genotypes, Ujjawala, KAK 2, PG 0517, HK 1 and Shubhra recorded with superior and stable yield performance across the environments that can be used as a parent in future breeding programs. 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. 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. Pooled analysis of variance revealed significant genotypic, environment and genotype × environment interaction (GEI) variances for all the traits indicating the influence of environmental factors on the expression of different economically important traits. Diversity analysis revealed grouping of genotypes into 4 to 5 clusters at individual environment and six clusters across the environment with highest contribution of hundred seed weight (53.68%) followed by number of nodes per plant (11.05%), biomass yield per plant (7.37%), grain yield per plant (6.84%) and number of pods per plant (6.32%) towards total genetic divergence. The present study concluded significant variation among the genotypes for different important economic traits with the identification of promising stable genotypes that can be used as a parent in breeding programs.

Keywords: 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).

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). 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). It is an annual, self-pollinating, diploid pulse crop with a genome size of ~738 Mbp (Varshney *et al*., 2013). This annual legume is a significant contributor to agricultural sustainability through nitrogen fixation and as a rotation crop allowing the diversification of agricultural production systems (Gan *et al*., 2006).

Among legumes, chickpea ranks third in the cultivated area worldwide (FAO stat, 2017). Chickpea is currently grown at about 14.56 million hectares worldwide with the annual production of 14.78 million tons (FAO stat, 2017). The developing countries share more than 95% of the area, production and consumption of chickpea. It is grown mainly in South East Asian countries with significant cultural, religious and nutritional value. India is the largest chickpea producer accounting a share of about 70% in global chickpea production.

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). Distribution of chickpea in six states viz., Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh together contribute 91% of the total production and 90% area of the country. 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 chickpea production in India is increased by 77% since 2000 which is largely due to increase in 55% chickpea cultivation area. However, only 14% increase in yield has been achieved during this period (Fig 1). Since 2000, production of chickpea across the world has increased by 84% owing to combined effect of increase in area by 43% and yield by 28%. 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.

The expansion of irrigation facilities in northern India has led to replacement of chickpea with wheat and mustard in larger areas which has resulted in reduction of chickpea area from 3.2 m ha to 1.0 m ha in northern states. Whereas it has increased from 2.6 mha to 4.3 mha in central and southern states of India during the past three decades. Thus, there has been shift in chickpea area from cooler long duration, highly productive environment to warm, short duration, rainfed and less productive environment. In these situations, to achieve the targeted production, a two prolonged strategy involving horizontal expansion through crop diversification and productivity enhancement by strategic research is required (Gaur *et al*., 2012). Besides the above-mentioned facts of replacement of chickpea area with other crops, an increasing trend of the area, production and productivity can be seen in last one and a half decades.

Estimation of genetic divergence and characterization of genotypes helps breeders to select parents in their breeding programme to create new variability, development of superior cultivars and different populations for various genetic studies of economically important traits. Yield depends on many component traits that influence yield either jointly or singly and either directly or indirectly through other related characters. Selection for yield on the basis of per se performance alone may not be effective as that based on the component traits associated with it. Hence, information on nature and extent of association between traits could be helpful in improving multiple traits and to formulate selection strategies in a breeding program.

The yield is often influenced by a number of traits such as hundred seed weight, number of pods per plant, harvest index, days to maturity and plant height etc. The knowledge on relationship among the traits and its direct or indirect effects on economic yield also helps breeders to make sound breeding and selection strategy for selection of individuals in early generations to enhance genetic gains. Therefore, the present investigation has been planned to assess the association among the economic important traits and their direct and indirect effect on grain yield in chickpea.

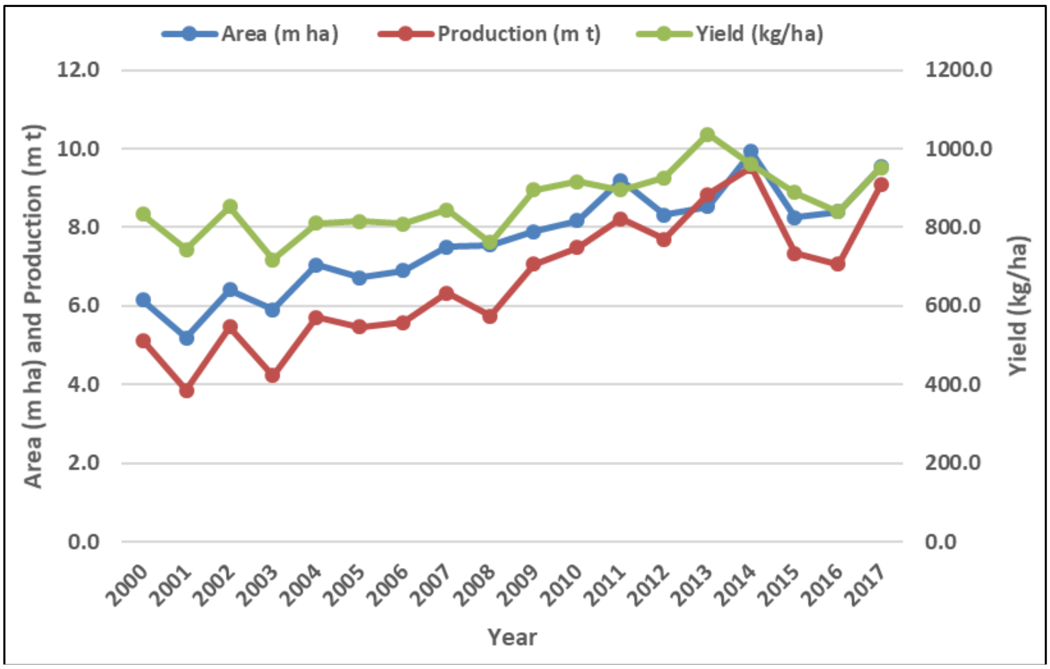

Fig 1: Trend of area, production and productivity of chickpea in India during last 15 year (2000-2017)

Materials and methods

The present investigation was carried out with the major aim of to assess the genetic parameters, genetic diversity, the association among the different economic traits, and to assess the stability of chickpea genotypes. The experiment was conducted in Randomized Complete Block Design (RCBD) with two replications during rabi season for three years from 2014 to16 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 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 (r_g=35 and r_p=23), number of pods per cluster (r_g=21 and r_p=16), number of primary branches (r_g=88 and r_p=56), number of pods per plant (r_g=74 and r_p=59), number of seeds per plant (r_g=67 and r_p=54), hundred seed weight (r_g=90 and r_p=82), biomass per plant (r_g=90 and r_p=84) and harvest index (r_g=68 and rp=69). Biomass yield per plant was significantly positively associated with plant height (r_g=42 and r_p=21), number of nodes per plant (r_g=26 and r_p=18), number of primary branches per plant (r_g=79 and r_p=52), number of pods per plant (r_g=79 and r_p=55), number of seeds per plant (r_g=80 and r_p=54) and hundred seed weight (r_g=89 and r_p=83) at genotypic and phenotypic level. Harvest index was significant positively associated with number of primary branches per plant (r_g=64 and r_p=32), number of pods per plant (r_g=23 and r_p=35), hundred seed weight (r_g=53 and r_p=42) and biomass per plant (r_g=28 and r_p=22). The number of pods per plant was significant positively associated with plant height (r_g=45 and r_p=17), number of nodes per plant (r_g=60 and r_p=44), number of primary branches per plant (r_g=51 and r_p=27), seeds per plant (r_g=92 and r_p=86) (Table 1).

Table 1: 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

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)

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 2).

Table 2: Direct and indirect effects of different traits on grain yield per plant estimated through path analysis during Rabi 2014-15

Traits	PH	NNPP	NBPP	NPPC	NPOdsPP	NSPPlant	NSPPod	HSW	HI	BIOMPP
PH	0.040	-0.025	-0.014	-0.024	-0.508	0.608	-0.145	-0.012	0.157	0.324
NNPP	0.012	-0.083	0.002	0.004	-0.525	0.444	0.115	0.006	0.084	0.162
NBPP	0.012	0.003	-0.045	0.005	-0.237	0.328	-0.133	-0.050	0.399	0.519
NPPC	0.013	0.005	0.003	-0.074	-0.034	-0.106	0.170	-0.002	0.121	0.065
NPOdsPP	0.024	-0.052	-0.013	-0.003	0.847	0.801	0.018	-0.021	0.152	0.510
NSPPlant	0.025	-0.038	-0.015	0.008	-0.703	0.965	-0.315	-0.019	0.147	0.486
NSPPod	0.010	0.016	-0.010	0.021	0.025	0.502	-0.606	-0.004	0.047	0.089

HSW	0.008	0.008	-0.037	-0.003	-0.288	0.299	-0.036	0.616	0.304	0.697
HI	0.012	-0.013	-0.034	-0.017	-0.246	0.270	-0.055	-0.036	0.525	0.324
BIOMPP	0.016	-0.017	-0.029	-0.006	-0.534	0.579	-0.067	-0.053	0.210	0.810
Residual effect	0.001									

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)

Discussion

Yield is a complex polygenictrait 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) [11]. 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) [5]; Babbar *et al*. (2012) [6]; Naveed *et al*. (2012) [10] and Malik *et al*. (2014) [9]. 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) [7] 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) [13, 1, 9]. 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, 19]

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) [12]. 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) [8]; Arshad *et al*. (2004) [4]; (Ali *et al*. 2009), and Borate and Dalvi (2010) 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) [4] and Talebi *et al*. (2007) [14] 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) [2].

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.

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