Genetic divergence on chickpea (*Cicer arietinum* L.) genotypes grown under late sown conditions

ABSTRACT

In the current research, BG 372, Udai, and Pant G 186 were used as checks varieties along with 102 chickpea germplasm samples that revealed a wide range of variation for different characters. At the Narendra Deva University of Agriculture and Technology's Agronomy Research Farm in Narendra Nagar (Kumarganj), Ayodhya, the trial was carried out using Augmented Block Design. 11 quantitative characters, including days to 50% flowering, days to maturity, primary and secondary branches per plant, plant height (cm), pods per plant and seeds per pod, biological yield per plant (g), seed yield per plant (g), harvest index (%), and 100-seed weight(g), were observed . A statistical analysis of each character's genetics produced a variety of findings. Higher seed yield per plant was generated by genotypes GJG 1416, followed by BG 256, GJG 1416, PhuleG0819. Seed yield per plant exhibited positive and highly significant correlations with secondary branches per plant, pods per plant, seeds per pod, biological yield per plant, harvest index and 100-seed weight. The positive significant correlations of seed yield per plant were found with primary branches per plant and non-significant with plant height. It exhibited negative non-significant association with days to 50 per cent flowering and days to maturity. Path analysis identified biological yield per plant (g) and Harvest index important direct components for seed yield per plant. The characters identified above as important direct and indirect components merit due to consideration in the formulation of effective selection strategy in chickpea for developing high yielding varieties. The 11 clusters formed in divergence analysis contained genotypes of heterogeneous origin there by indicating no parallelism between genetic and geographic diversity. In this context, the maximum inter-cluster distance was recorded between cluster X and XI (12.201) followed by cluster III and XI (11.254), cluster VI and XI (11.125) and cluster VII and XI (10.875). Therefore, crosses between members of cluster separated by high inter-cluster distances are likely to throw desirable segregants.

Comment [A1]: Kindly reframe the whole paragraph and mention year and season of experiment.

Keywords: *Cicer arietinum* L, *Genetic divergence, Grain yield, Quantitative Characters*

INTRODUCTION

Chickpea is the third leading grain legume in the world and first in the South Asia. A pulse, also known as a "grain legume," is an annual leguminous crop that produces one to twelve seeds inside of a pod that can vary in size, shape and colour. With a 30% total area coverage and 40% of India's pulse output, chickpeas are a significant cool-season food legume pulse crop. It is a highly self-pollinated crop with a less than 1% outcrossing incidence. One cultivated species (*Cicer arietinum* L.) and 42 wild species make up the family Cicer. Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, Andhra Pradesh, and Gujarat account for more than 90% of the nation's total area dedicated to the production of chickpeas. In India, a total of 31.11 mha of pulses were produced, producing 24.51 million tonnes at a productivity of 788 kg/ha **(Anonymous, 2018)**. Based on the hypothesis that crosses involving divergent parents give higher chance of obtaining desirable segregants in the segregating generation, genetically diverse potential parents are chosen for use in hybridization programmes. To produce superior genotypes in the segregating generations, many researchers have stressed the need for parental diversity of the ideal magnitude (**Murty and Arunanchalam, 1966; Malhotra and Singh, 1971; Solh and Erskine, 1982; Balyan and Singh, 1986 and Gupta et al., 1966**). Therefore, efforts should be made to expand the use of already-existing diversity derived from the gathering of germplasm. Though the genetic studies in respect of germplasm evaluation, variability, correlation in chickpea are not more but most of these are based on testing of limited number of germplasm lines. Moreover, the results of the earlier studies of such aspects are relevant only for the materials and environments involved in the particular study and cannot be generalized**.**

Comment [A2]: Missing in the reference part

METHOD AND MATERIALS

Three well-known check varieties, Udai, Pant G186, and BG 372, were used in the experiment to assess the 105 different chickpea strains and varieties, including elite lines and land races. During Rabi 2017–18, the trial material was assessed at the Narendra Deva University of Agriculture and Technology's Agronomy Research Farm in Narendra Nagar, Kumarganj, Ayodhya (U.P.). During the experimental time, meteorological data were collected at temperatures ranging from 4.9 to 39.0 °C. Six blocks of equal size were placed throughout the experimental area. There were twenty entries including checks, in each block. Each treatment was planted in a single row that was 4 m long, with a 30 cm between rows and a 10 cm between rows spacing. On five randomly selected plants from each genotype in each replication we recorded data on eleven different quantitative characteristics, including plant height (cm), number of primary and secondary branches and pods and seeds per pod, the weight of 100 seeds (g), the number of days until 50% flowering, the number of days until maturity, biological yield per plant(g), harvest index(%) and seed yield per plant(g).

Comment [A3]: Reframe the sentence.its not conveying any meaning

Comment [A4]: Data was recorded on five randomly selected plants from each genotype in each replication for eleven

The standard statistical procedure were used for estimation of genetic parameters of variability, correlation, path and Genetic divergence among 144 genotypes including checks planted in augmented design was studied through Non-hierarchical Euclidean cluster analysis (**Beale, 1969; Spark, 1973).**

Comment [A5]: Missing in reference part

RESULT AND DISCUSSION.

Estimates of direct and indirect effects of different traits on seed yield per plant in path coefficient analysis using simple correlations are given in Table. The perusal of table revealed that the highest positive and substantial direct effects on seed yield per plant were exerted by biological yield per plant (0.618) followed by harvest index (0.512), pods per plant (0.098). Biological yield per plant (g) followed by Harvest index (%) , pods per plant, secondary branch per plant, seeds per pod, and 100 seed weight (g), demonstrated highly positive direct contribution to seed yield per plant. The available literatures have also identified these characters as major direct contributors to seed yield per plant in chickpea **(Renukadevi** and **Subbalakshmi, 2006; Singh 2007; Thakur** and **Sirohi, 2009; Yucel *et al.,* 2010, Ojha *et al.,* 2011, Singh** and **Shiva , 2012).** Highly indirect effects/indirect contributing characters for seed yield by the biological yield per plant (0.363) and harvest index(0.308) via pods per plant; biological yield per plant(0.203), harvest index (0.210) and pods per plant (0.045) via secondary branches per plant ; biological yield per plant(0.106) and harvest index (0.167) via pods per plant; biological yield per plant(0.250) and harvest index (0.254) via 100 seed weight.

Comment [A6]: Table is missing in the manuscript

Comment [A7]: Kindly reframe the paragraph

The indirect effects of pods per plant (0.363), 100 seed weight (0.250), harvest index (0.138), secondary branches per plant (0.203) and seeds per pod (0.106) via biological yield per plant; pods per plant (0.308), secondary branches per plant (0.210), 100-seed weight (0.254) and biological yield per plant (0.114), seeds per pod (0.167) and primary branches per plant (0.183) via harvest index; harvest index (0.059), biological yield per plant (0.057), primary branches per plant (0.037) and secondary branches per plant (0.045) via pods per plant showed high order positive indirect effects on seed yield

Other rest showed very less or negative indirect effects for seed yield .The above finding are broadly in agreement with report of (**Muhammad *et al.,* 2004, Singh *et al.,* 2004, Rao** and **Rao, 2005, Renukadevi** and **Subbalakshmi, 2006, Singh** and **Sindhu, 2008, Thakur** and **Sirohi,**

2009, Yucel *et al.*, 2010 and **Ojha *et al.*, 2011, Roy *et al.*, 2016.).**Whereas, harvest index (-0.038) via days to 50 per cent flowering; harvest index (-0.065) and biological yield per plant (-0.017) via days to maturity; primary branches per plant (-0.025) via secondary branches per plant; primary branches per plant (-0.018) via pods per plant; primary branches per plant (-0.017) via harvest index showed highly negative indirect effects on seed yield per plant. The estimates of indirect effects on the path coefficient were too low to be considered important. The residual factor effects (0.1696) were recorded positive.

The genetic divergence existing in 105 chickpea germplasm collections was studied by employing Non-hierarchical Euclidean cluster analysis for 11 quantitative characters. These genotypes were grouped in 11 different clusters. The pseudo F-test revealed that eleven clusters arrangement was the most appropriate for this material. Therefore, the 105 genotypes were accepted to be grouped in 11 different non-overlapping clusters. (**Narayana** and **Reddy, 2001, Jeena** and **Arora, 2002, Raval** and **Dobariya, 2004, Jeena *et al.*, 2005, Gumber *et al.*, 2006; Lokere *et al.*, 2007; Dwevedi** and **Lal, 2009; Sreelakshmi *et al.*, 2010** and **Yadav *et al.*, 2010**). The distribution of 105 chickpea accessions in to 11 clusters is given in **Table-1**

Comment [A8]: Missing in reference part

Table 1: Clustering pattern of 105 chickpea genotypes on the basis of Non-hierarchical Euclidean cluster analysis of eleven character

Cluster number	Number of genotypes	Genotypes
I	21	RSG 881,BG 3003, H 11- 41, JG 36, PhuleG0819, IPC 2012-98, RVIG 34, RVSSG 4, IPC 2008-92, RVSSG 10, RVSSG 42, JG 2016-43, RS2011-16, RAG 888, H 11-58, PhuleG13116, BG256, BG3021, JG 37, RVSSG 2, RVSSG 9.
II	2	IPC 2008-69, H 07-157.
III	15	IPC 2010-69, IPC 2011-138, H 12-36, IPC 2010-134, H 09-90, H 08-75, H 09-19, Vijay, PBC 570, H 08-13, H 08-18, BG 3027, RG 2011-02, JG 2016-45, RKG 13-380.
IV	37	RVSSG 5, PhuleG0818, RVSSG45, H 08-18,IPC 97-72, GJG 08820, PhuleG0408, KDG 94-4, RVSSG 41, H 04-09, RSG 957, PhuleG0151, IPC 2004-5, H 06-62, IPC2007-28, IPC 2013-33, IPC 1014, H 08-25, GJG 1209, IPC 2011-141, IPC 0907, GJG0921, GJG 1001, PhuleG0609-15, HIR 55, PhuleG21207, IPC 2006-126, PhuleG12110, GJG 0810, BG 3031, GJG 1403, PhuleG625-6, IPC 07-56, H 04-49, PhuleG0405.
V	2	H 13-03,GJG 0809
VI	15	PhuleG0805, H 10-05, IPC 07-56, H 09-9, IPC 2010-62, DC 16-1, H 12-29, H 12-36, EC 442406, H 13-36, JG 2016-9605, JG 2016-44, GJG 1010, H 10-22, UDAI.
VII	3	IPC 2006-127, H 06-6, GJG 1114
VIII	1	PANT G 186
IX	2	IPC 2010-127, GJG 1416
X	6	RVSSG 1, JG 38, IPC 2013-21,BG 372,PDG 84-16,H 12-1
XI	1	GJG 1208

Table -2: Estimates of average intra and inter cluster distance for 11clusters in chickpea germplasm

Cluster number	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	**2.364**	3.304	3.504	3.657	4.693	4.411	4.597	4.101	5.545	7.187	10.445
II		**2.448**	4.045	3.678	5.190	5.168	3.698	4.948	5.552	7.301	10.805
III			**1.998**	3.885	4.547	3.387	6.349	5.459	6.683	8.645	11.254
IV				**2.631**	3.952	3.789	4.840	4.363	4.356	7.723	10.811
V					**3.011**	4.324	6.083	4.130	4.074	7.727	10.792
VI						**2.602**	6.459	4.633	5.991	8.873	11.125
VII							**2.651**	4.084	4.547	6.248	10.875
VIII								**0.000**	3.940	6.624	10.505
IX									**2.043**	6.147	10.640
X										**1.589**	12.201
XI											**0.000**

Note: Bold figures indicate intra cluster distance.

Table 3: Cluster means for 11 clusters in chickpea germplasm

Number of cluster	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Pods per plant	Seeds Per Pod	100-seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Seed yield per plant (g)
I	76.333	133.714	38.852	1.562	4.652	27.471	1.219	16.442	12.655	36.397	4.579
II	78.500	134.500	41.300	1.200	3.800	25.800	1.100	22.355	16.940	35.345	5.955
III	77.467	134.267	34.547	1.227	4.013	14.787	1.087	16.031	11.816	26.623	3.146
IV	67.595	123.892	34.303	1.335	4.286	19.538	1.162	20.741	12.237	36.433	4.436
V	64.500	122.500	37.300	1.200	3.500	15.400	1.700	16.745	14.210	31.415	4.455
VI	65.867	121.800	35.520	1.293	3.953	17.640	1.027	15.001	11.557	24.723	2.877
VII	70.667	126.667	34.867	1.400	4.733	35.467	1.133	21.160	20.750	41.067	8.417
VII	64.000	119.000	27.800	1.400	4.600	33.600	1.400	12.910	17.870	33.460	5.980
IX	58.000	115.000	42.300	1.400	5.500	22.000	1.600	20.995	17.315	41.805	7.250
X	73.333	126.000	44.167	3.117	8.133	26.500	1.700	20.620	26.773	32.508	8.682
XI	67.000	125.000	345.00	1.200	4.600	32.200	1.400	13.240	13.110	42.940	5.630

The highest number of genotypes appeared in cluster IV, which contains 37 genotypes. Cluster I and cluster III, cluster VI each with 21 and 15 genotypes respectively. The estimates of intra and inter-cluster distance for eleven clusters are presented in **Table-2**

The highest intra-cluster value was found for cluster V (3.011) followed by cluster VII (2.651), cluster IV (2.631), cluster VI (2.602), cluster II (2.448) cluster I (2.364) and cluster IX (2.043) while the lowest value was recorded in cluster XI (0.000) and cluster VIII (0.000) followed by cluster X (1.589) and cluster III (1.998). The maximum inter-cluster distance was recorded between cluster X and XI (12.201) followed by cluster III and XI (11.254), cluster VI and cluster XI (11.125). Inter-cluster distances between cluster VII and XI (10.875), cluster II and XI (10.805), cluster IX and XI (10.640), cluster VIII and cluster XI (10.505) were also of high order. The minimum inter-cluster distance was observed between cluster I and II (3.304) followed by cluster III and VI (3.387), cluster I and IV (3.657), cluster II and cluster VI (3.678) and cluster II and cluster VII (3.698). **Jeena *et al.* (2005), Naghavi** and **Jahansouz (2005), Srivastava *et al.* (2005), Gumber *et al.* (2006), Patel *et al.* (2006), Sindhu *et al.*(2006), Dubey *et al.* (2007), Lokere *et al.* (2007), Dwevedi** and **Lal (2009), Sial *et al.* (2010), Sreelakshmi *et al.* (2010), Yadav *et al.* (2010)** and **Ojha *et al.* (2011), Kumar *et al.*, 2013, Jakhar *et al.* 2016)** The mean performance of clusters for 11 characters is presented in **Table-3**

Comment [A9]: Missing in reference part

Comment [A10]: Missing in reference part

Comment [A11]: Relate them with results

The genotypes of cluster IX were earlier flowering ($\bar{X}$ = 58 days) followed by cluster V (($\bar{X}$ = 65 days). While, genotypes of cluster II were late in flowering ($\bar{X}$ = 79 days) followed by cluster III ($\bar{X}$ = 78 days) and cluster I (76 days).

The entries represented in cluster IX ($\bar{X}$ =115 days) was comparatively early maturing followed by cluster VIII ($\bar{X}$ = 119 days), while genotypes in cluster II were late in maturity ($\bar{X}$ = 135 days) followed by cluster III ($\bar{X}$ = 134 days) and cluster I ($\bar{X}$ =134 days).

The highest and lowest cluster means for plant height at maturity was observed for cluster XI ($\bar{X}$ =345 cm) and cluster VIII ($\bar{X}$ = 27.28 cm), respectively. Cluster X ($\bar{X}$ = 44.16 cm) and cluster IX ($\bar{X}$ = 42.30 cm) was another clusters which contained mostly tall stature genotypes.

The highest number of primary branches per plant was found in cluster X ($\overline{X}$ = 3.117). Cluster II ($\overline{X}$ = 1.200), Cluster V ($\overline{X}$ = 1.200) and Cluster XI ($\overline{X}$ = 1.200) appears to possesses genotypes having very low number of primary branches per plant.

The genotypes with high number of secondary branches per plant was concentrated in cluster X ($\overline{X}$ = 8.133) followed by cluster IX ($\overline{X}$ = 5.500). Cluster V ($\overline{X}$ = 3.500) appears to possesses genotypes having very low number of secondary branches per plant.

The highest cluster mean for number of pods per plant was observed for cluster VII ($\overline{X}$ = 35.467) followed by cluster VIII ($\overline{X}$ = 33.600) and cluster XI ($\overline{X}$ = 32.200) while genotypes for lowest number of pods per plant was concentrated in cluster III ($\overline{X}$ = 14.787).

The genotypes representing the maximum cluster mean for number of seeds per pod was present in cluster V ($\overline{X}$ = 1.700) and cluster X ($\overline{X}$ = 1.700) while lowest number of seeds per pod were observed in cluster VI ($\overline{X}$ = 1.027).

The genotypes with highest 100-seed weight was found in cluster II ($\overline{X}$ = 22.355 g) followed by cluster VII ($\overline{X}$ = 21.160 g), cluster IX ($\overline{X}$ = 20.995) and cluster IV ($\overline{X}$ = 20.741). Lowest 100 seed weight was observed in cluster VIII ($\overline{X}$ = 12.910 g) followed by cluster XI ($\overline{X}$ = 13.24 g) .

The biological yield per plant was highest among the genotypes of cluster II ($\overline{X}$ = 81.456 g) followed by cluster X ($\overline{X}$ = 80.459 g). The lowest biological yield was observed in cluster IV ($\overline{X}$ = 53.711 g).

The highest cluster mean for harvest index was observed for cluster XI ($\overline{X}$ =42.940%) followed by cluster IX ($\overline{X}$ = 41.805 %) and cluster VII ($\overline{X}$ = 41.067 %), while lowest harvest index was observed in cluster VI($\overline{X}$ = 24.723 %).

The highest cluster mean for seed yield per plant was observed in case of cluster X ($\overline{X}$ = 8.682 g) followed by cluster VII ($\overline{X}$ = 8.417 g).

Conclusion:

Path analysis identified biological yield per plant (g) and harvest index important direct components for seed yield per plant. The characters identified above as important direct and indirect components merit due to consideration in the formulation of effective selection strategy in chickpea for developing high yielding varieties. The Non-hierarchical Euclidean cluster analysis grouped 105 genotypes included checks into eleven clusters. This indicated presence of substantial genetic diversity in the evaluated germplasms. The highest intra-cluster distance which was observed in case of cluster V (3.011), followed by cluster VII (2.651), while the lowest value was recorded in case of cluster XI (0.000) and cluster VI (6.520) followed by cluster X (1.589). The maximum inter cluster distance was found between cluster I and XI (10.445) followed by VIII and XI (10.505). The minimum inter-cluster distance was observed between I and II (3.304) followed by cluster III and VI (3.387). The eleven clusters formed in divergence analysis contained genotypes of heterogenic origin there by indicating no parallelism between genetic and geographic diversity. Therefore, crosses between the members of cluster separated by high inter cluster distance, are likely to throw desirable segregants. In this context, cluster XI had very high inter-cluster distance from remaining ten clusters, but cluster XI have moderate to poor mean performance for some characters.

Comment [A12]: Reframe the sentence

References:

Balyan, H.S. and Singh, S. (1986 a). Character association in Lentil. LENS News letter, **13** (1): 1-3.

Beale, E.M.L. (1969). Euclidean cluster analysis. A paper contributed to 37th session of the International Statistical Institute.

Dwevedi, K. K. and Lal, G. M. (2009). Assessment of genetic diversity of cultivated chickpea (*Cicerarietinum* L.).*Asian Journal of Agricultural Sciences*.**1** (1): 7-8.

Gumber, R.K.; Singh, S.; Rathore, P.; Singh, K. and Verma, P.K. (2006). Multivariate analysis over environments of multiple disease resistant lines of chickpea.*Legume Res.*,**29** (1): 48-52.

Gupta, A.; Sinha, M.K.; Mani, V.P. and Dube, S.D. (1966).Classification and genetic diversity in lentil germplasm. *LENS News letter, **23** (1/2): 10-14.*

Jeena, A.S. and Arora, P.P. (2002).Path analysis in relation to selection in chickpea.*Agril. Sci. Digest*, **22** (2): 132-133.

Jeena, A.S.; Arora, P.S. and Upreti, M.C. (2005).Path coefficient analysis for increasing yield of chickpea.*BhartiyaKrishiAnusandhanPatrika*, **20** (1): 32-35.

Lokere, Y.A.; Patil, J.V. and Chavan, U.D. (2007).Genetic analysis of yield and quality traits in *kabuli* chickpea. *J. Food Legumes.***20** (2): 147-149.

Malhotra, R.S. and Singh, K.B. (1971).Multivariate analysis in blackgram (*Phaseolusmungo*Roxb.).*Indian J. agric. Sci*., **41**: 757-760

Muhammad, A.; Bakhsh, A. and Abdul, G. (2004).Path coefficient analysis in chickpea(*Cicerarietinum* L.).*Pakistan J. Botany*, **36** (1): 75-81.

Murty, B.R. and Arunachalam, V. (1966). The nature and divergence in relation to breeding system in some crop plants. *Indian J. Genet*., **26**: 188-198.

Narayana, H.S. and Reddy, N.S. (2001).Genetic divergence in chickpea.*J. of Res*. in chickpea (*Cicerarietinum* L.). *Legume Res*., **28** (4): 250-255.*ANGRAU*, **28** (4): 31-32.

Ojha, VinaySankar; Shiva Nath and Singh, Ranjeet.(2011). Correlation and Path analysis in chickpea (*Cicerarietinum* L.). *Progressive Research.*, **6** (1):66-68.

Rao, C.M. and Rao, Y.K. (2005). Association and path analysis under four environments in chickpea.*Legume Res*., **28** (4): 272-275.

Raval, L.J. and Dobariya, K.L. (2004). Assessment of genetic divergence in chickpea (*Cicerarietinum*L.).*Annals of Agricultural Res.,***25** (1): 30-34.

Renukadevi, P. and Subbalakshmi, B. (2006).Correlation and path coefficient analysis in chickpea.*Legume Res*., **29** (3): 201-204.

Roy, A.; Ghosh, S. and Kundagrami, S. (2016).Genetic approach and biometrical association of yield attributing traits in chickpea (*Cicerarietinium*L.).*International Journal of Science and Research.***5**(7):2208-2212

Singh, A.K. and Arora, P.P. (2004). Genetic diversity analysis in chickpea.*Agriculture and Biological Res.*, **20** (2): 150-155.

Singh, Amandeep and Sindhu, J. S. (2008).Correlation and path analysis in chickpea under different environments. *J. Food Legumes.,***21**(2) *: 145-148.*

Singh, AmrendraPratap and Shiva Nath (2012). Genetic diversity among the germplasm for selection of parents for hybridization programme in chickpea. *Progressive Research*, 7 (2): 256-258.

Singh, N. P. Ram Krishna, Yadav Renu and Rajendra Kumar (2007) Unravelling chickpea divergence for selection of parents for development of mapping populations.*Advances in Plant Sciences*.**20** (2): 629-631.

Sreelakshmi, C.; Shivani, D. and Kumar, C. V. S. (2010) Genetic divergence, variability and character association studies in bengal gram (*Cicerarietinum* L.). *Electronic Journal of Plant Breeding*.**1** (5): 1339-1343.

Thakur, S.K. and Sirohi, A. (2009).Correlation and path coefficient analysis in chickpea (*Cicerarietinum*L.) under different seasons. *Legume Res.*, **32** (1): 51-54.

Yadav, A. K.; Mishra, S. B.; Singh, S. S. and MadhuriArya (2010) Character association and genetic divergence study in chickpea (*Cicerarietinum* L.). *Environment and Ecology*.**28** (2B): 1276-1280.