

Genetic Divergence in Chickpea (*Cicer arietinum* L.) Genotypes under Normal and Late Planting

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Abstract Thirty eight chickpea (*Cicer arietinum* L.) genotypes were evaluated to explore the nature and magnitude of genetic divergence for yield and its contributing traits during *rabi* seasons under normal and late planting using Mahalanobis's D^2 Statistics. The data were recorded on thirteen important yield attributing traits from the genotypes raised in randomized complete block design (RCBD) under three replications. Highly significant differences existed among the genotypes tested for all the traits. Cluster analysis revealed wide range of diversity in the genotypes grouped in eleven and seven clusters in normal and late planting respectively. The characters like days to

pod initiation, days to maturity, 100-seed weight and harvest index, exhibited more contribution towards the genetic divergence under normal planting as compared to late planting. These traits should be considered as more important prior to any breeding program to develop heat stress tolerant variety. On the basis of inter and intra-cluster distance coupled with cluster means of different traits, the genotypes classified into clusters VI, X, VII, VIII under normal planting and clusters III, VII, VI and II under stress condition were found to be superior and may be utilized in breeding programs to obtain heterotic recombinants which may yield some transgressive segregants.

Keywords Chickpea, Genetic divergence, Mahalanobis's D^2 statistics, Cluster distance.

Introduction

Globally, chickpea (*Cicer arietinum* L.) is the third most important winter season legume. India is the largest chickpea producer accounting a share of about 70% in global chickpea production, with about 13.5 mha area, 13.1 mt production [1]. Distribution of chickpea in six states viz. Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh together contribute 91% of the production and 90% of the area of the country. Chickpea found in two categories 'desi' and 'kabuli'. The desi type contains small, angular, dark-brown seeds, while kabuli types comprise large, rams-head-shaped, light-brown

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Table 1. Distribution of chickpea genotypes in different clusters under normal and late planting.

| Cluster | Number of genotypes | | Genotypes | |
|---------|---------------------|------|--|--|
| | Normal | Late | Normal | Late |
| I | 16 | 26 | ICCV 7117, JG 14, ICCV 07102, ICCV 7118, JAKI 9218, ICCV 37, JG 11, JG 16, JG 130, JG 19, VISHAL, VAIBHAV, ICC 1882, ICCL 81248, ICCV 89314, JGK 1 | ICCV 7118, JAKI 9218, JG 11, JG 130, JGK 2, KAK-2, ICCV 7117, ICCV 06302, ICC 8474, N BeG 3, ICCV 2008-310, ICCV 2005-301, VIHAR, VISHAL, ICCV 07109, JGK 1X ICPK 4, GG 2, ICCV 07102, ICC37, JG 19, ICCV 07110, ICC 4958, ICCV 2006-302, JGK 1, ICCV 07105, JG 14 |
| II | | | 12 | 6 |
| III | 1 | 2 | MP JG 2003-115 | ICC 8950, JG 16 |
| IV | 1 | 1 | ICC 4495 | ICCV 2006-301 |
| V | 1 | 1 | ICC 8950 | MPJG 2003-115 |
| VI | 1 | 1 | ICC 6816 | ICC 1882 |
| VII | 1 | 1 | ICC 6874 | JGK 5 |
| VIII | 2 | – | ICCV 2008-310, ICCV 2005-301 | |
| IX | 1 | – | KAK 2 | |
| X | 1 | – | JGK 5 | |
| XI | 1 | – | ICCV 07105 | |

seeds. Currently, both types of chickpea have been rotationally cultivated in warm environments [2] with cereals due to changing climatic conditions and abiotic stresses, droughts and high temperature [3]. Heat stress is a severe constraint to chickpea production in certain regions due to a large shift in area of chickpea from cooler, long season environments to warm, short season environments and from northern to southern India therefore, area in late sown has been increased due to reduce winter period. Heat sensitivity in chickpea can reduce yields, product quality and lead to limited geographic adjustment [4]. Chickpea is highly sensitive to heat stress (32/20°C or higher as day/night temperatures) exposed during flowering and pod development stages [5]. The most practical adverse effects of heat stress on chickpea are reducing pollen viability, fertilization, seed development and decreasing harvest index [6], decreased plant height [7] and altering internal morphology of crop plants [8].

Field survey of farmers demonstrated better yield of chickpea in warmer environments than bean, cowpea, green gram and maize in Kenya [9]. According to

these results and performance of the whole plant on field, new germplasm of chickpea identified and developed against heat stress using different sowing dates and temperature (normal and late seasons) at ICRISAT [10]. Several early maturing heat tolerant chickpea genotypes were distinguished suitable for semi-arid environments and concluded that these early maturing genotypes showed minimum grain yield loss varied from 10 to 15% for each rising 1°C above optimal temperature. A diverse group of chickpea materials screened to assess genetic variability for heat tolerance in heat stressed (late sown) and non-

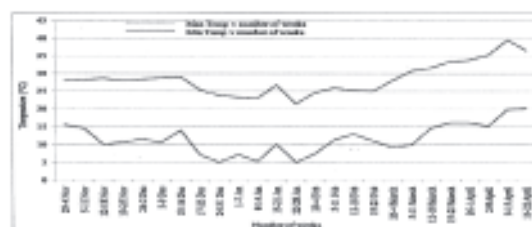
**Fig. 1.** Weekly average of maximum and minimum temperature of during crop season at JNKVV, Jabalpur.

Table 2. Inter and intra cluster D^2 values for different clusters in normal planting.

| Cluster | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
|---------|--------|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| I | 332.71 | 695.16 | 550.06 | 623.59 | 604.41 | 1064.33 | 674.05 | 1220.27 | 821.94 | 1340.12 | 993.73 |
| II | | 419.53 | 1225.93 | 1032.48 | 1593.94 | 2364.10 | 1667.28 | 772.56 | 753.32 | 928.02 | 1841.38 |
| III | | | 0.00 | 771.40 | 490.63 | 828.18 | 760.04 | 1261.24 | 1225.51 | 1321.71 | 487.87 |
| IV | | | | 0.00 | 335.71 | 898.63 | 697.41 | 903.24 | 1920.20 | 2278.54 | 881.25 |
| V | | | | | 0.00 | 268.67 | 301.15 | 1774.82 | 2005.76 | 2594.42 | 607.20 |
| VI | | | | | | 0.00 | 729.06 | 2714.34 | 2386.49 | 3174.73 | 1306.15 |
| VII | | | | | | | 0.00 | 2290.78 | 1925.32 | 2856.11 | 467.94 |
| VIII | | | | | | | | 0.00 | 1750.87 | 1048.71 | 1765.83 |
| IX | | | | | | | | | 0.00 | 731.73 | 2219.05 |
| X | | | | | | | | | | 0.00 | 2373.57 |
| XI | | | | | | | | | | | 0.00 |

stressed (optimally sown) environments along with yield attributing traits of chickpea were associated with grain yield under heat stress [6]. Field screening under same stress presser condition is a powerful tool for evaluation of germplasm and to be utilized effectively in the breeding program to develop new crop varieties for heat stress prone areas. Thus, the present study was conducted to identify and evaluate the high yielding chickpea promising lines with genetic divergence among the genotypes for different traits under normal and heat stress environment. This promising material will be helpful for the evolution of high yielding and heat tolerant agronomically superior varieties of chickpea.

Materials and Methods

Thirty eight chickpea promising lines including twenty seven desi and eleven kabuli were evaluated under normal planting and late planting during *rabi* season of 2012-13 with two different dates following randomized completely block design (RCBD) with three replications. The research was conducted at Seed Breeding Farm, Department of Plant Breeding and Genetics, JKKVV, Jabalpur under All India Coordinated Research Project on Chickpea (AICRP on chickpea). Each genotype was planted in a two row plots with four meter length and inter and intra-row spacing maintained at 30 and 10 cm respectively. This region has subtropical to semi-arid climate where the temperature varied from 4.0°C (minimum) in January to 42°C (maximum) in May (Fig. 1). All the recommended cul-

tural practices were adopted to maintain a healthy crop growth under rainfed conditions. Data regarding yield and thirteen attributing traits were recorded when 50% plants started to produce flowers in the plot. Multivariate analysis was done as per Mahalanobis's D^2 statistics [11] and the genotypes were grouped into different clusters following Tochers's method [12] using Window Stat 9.1 version software.

Results and Discussion

Significant differences were observed for all the thirteen characters among the thirty eight chickpea genotypes classified into eleven (normal planting) and seven clusters (late planting). Correspondingly Verma et al. [13] grouped 108 genotypes into eight clusters in normal planting and nine clusters under late planting showing an important role of the nature and magnitude of genetic divergence in the formation of successful breeding programs. The characters viz. days to 50% flowering (0.28%), plant height (1.99%), seeds per pod (0.85%) and number of seed yield (3.41) exhibited more contribution towards the genetic divergence under normal planting as compared to late planting whereas only four traits like days to pod initiation (0.57%), days to maturity (1.14%), 100-seed weight (40.97%) and harvest index (33.43%) revealed higher contribution towards to the genetic divergence under late planting in contrast to normal planting (Fig. 2). Maximum contributing to genetic divergence was recorded for harvest index (33.3%) and 100 seed

Table 3. Inter and intra cluster D^2 values for different cluster under late planting.

| Cluster | I | II | III | IV | V | VI | VII |
|---------|--------|--------|--------|---------|--------|---------|---------|
| I | 255.05 | 452.36 | 663.39 | 352.31 | 366.26 | 814.72 | 911.73 |
| II | | 200.36 | 561.08 | 701.15 | 428.40 | 514.65 | 1426.85 |
| III | | | 33.65 | 1273.18 | 868.31 | 860.42 | 2530.00 |
| IV | | | | 0.00 | 465.20 | 835.83 | 549.40 |
| V | | | | | 0.00 | 1099.76 | 852.71 |
| VI | | | | | | 0.00 | 2225.15 |
| VII | | | | | | | 0.00 |

weight (40.97%) under normal and the late planting respectively, whereas days to flower initiation and days to 50% flowering showed minimum contribution under normal (0.28%) and late condition (0.28 and 0.14% respectively). No contribution towards genetic divergence showed by the characters viz. days to pod initiation, days to maturity, number of primary and secondary branches per plant in normal planting and plant height, number of primary and secondary branches under late planting (Fig. 2). Samocha et al. [14] reported that highly variable and unpredictable environment like high temperature may select genotypes suitable for local adaptation that can promote genetic divergence. Some specifically regional adaptive processes can give rise to quantitatively detectable traits that become complicated for genetic investigation when more than one environment is considered [15]. Since the gene expression may vary with change of environment [16]. Screening parents belonging to the maximum divergent clusters are expected to manifest maximum heterosis in crossing and wide variability in genetic architecture [17].

As the D^2 values represent the index of genetic diversity among the cluster, it would be more appropriate to make cross between genotypes separated by high estimates of statistical distance [18]. Understanding of genetic divergence within the cluster (intra-cluster) and between the various clusters (inter-cluster) indicates the divergence among the genotypes falling within particular cluster and genotypes of different clusters (Table 1). This indicates that the presence of wide diversity among the tested genotypes. Under both environments, cluster I comprised maximum genotypes, whereas clusters III, IV, V, VI, VII, X and X included only single genotype. The average intra and inter cluster D^2 values are presented

in Tables 2 and 3 under normal and late planting respectively. The intra cluster distance was highest in cluster II ($D^2=419.53$) and cluster I ($D^2=255.05$) under normal and late planting respectively, which indicates the presence of more variability within these clusters. Similar result has been reported by earlier reporters [19, 20]. Darshanlal and Singh [21] grouped chickpea genotypes in different clusters formed studying the traits viz. plant height, yield per plant, number of primary and secondary branches per plant, seeds per pod, total number of pods per plant were the main yield contributing characters to genetic divergence in chickpea. The maximum inter cluster distance was observed between the cluster VI and cluster X ($D^2=3174.73$) in normal as well as cluster III and cluster VII ($D^2=2530.00$) in late environmental condition which revealed that these clusters were genetically more divergent from each other. The lowest inter cluster distance was found between cluster V and cluster VII ($D^2=301.15$) in normal and between cluster I and cluster IV ($D^2=352.31$) in late condition which indicated that genotypes of these clusters were not genetically diverse. Thus, crossing of genotypes from

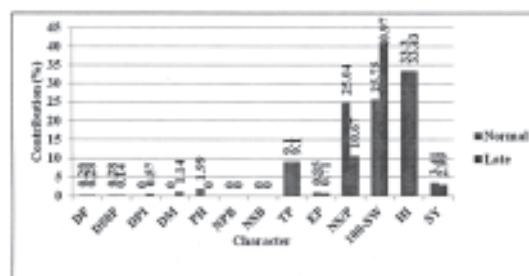
**Fig. 2.** Contribution of different characters toward clustering in chickpea genotypes under normal and late planting.

Table 4. Cluster mean for yield and yield contributing traits of chickpea genotypes under normal planting.

| Characters | Cluster I | Cluster II | Cluster III | Cluster IV | Cluster V | Cluster VI | Cluster VII | Cluster VIII | Cluster IX | Cluster X | Cluster XI |
|--|-----------|------------|-------------|------------|-----------|------------|-------------|--------------|------------|-----------|------------|
| Days to flower initiation | 38.58 | 37.25 | 37.00 | 37.00 | 38.67 | 46.00 | 47.67 | 33.50 | 35.00 | 35.67 | 36.00 |
| Days to 50% flowering | 50.29 | 47.00 | 47.33 | 50.33 | 50.33 | 59.00 | 62.33 | 39.67 | 41.67 | 42.33 | 50.00 |
| Days to pod initiation | 62.54 | 59.36 | 57.33 | 62.67 | 65.67 | 71.00 | 70.33 | 51.50 | 53.33 | 63.00 | 62.00 |
| Days to maturity | 112.54 | 109.64 | 107.00 | 113.33 | 116.33 | 121.33 | 120.00 | 102.17 | 103.67 | 101.67 | 111.67 |
| Plant height (cm) | 42.34 | 45.75 | 65.27 | 39.07 | 40.07 | 37.30 | 36.07 | 57.85 | 39.50 | 60.10 | 50.23 |
| Number of primary branches per plant | 2.63 | 2.50 | 3.00 | 2.67 | 3.00 | 2.67 | 3.00 | 2.67 | 2.33 | 3.00 | 2.00 |
| Number of secondary branches per plant | 10.96 | 9.72 | 10.67 | 8.67 | 10.33 | 9.67 | 11.67 | 11.00 | 7.67 | 7.67 | 8.67 |
| Total number of pods per plant | 57.69 | 48.48 | 65.00 | 75.67 | 75.00 | 93.33 | 53.00 | 63.50 | 35.67 | 44.67 | 44.33 |
| Effective pods per plant | 42.22 | 35.43 | 41.33 | 67.00 | 65.00 | 84.33 | 44.33 | 50.50 | 24.00 | 33.00 | 34.33 |
| Number of seeds per pod | 1.03 | 0.87 | 1.26 | 1.14 | 1.23 | 1.25 | 1.32 | 1.04 | 0.84 | 0.96 | 1.55 |
| 100-seed weight (g) | 25.03 | 34.02 | 26.83 | 16.23 | 13.77 | 14.10 | 13.03 | 38.13 | 36.37 | 55.07 | 20.40 |
| Harvest index (%) | 49.40 | 39.59 | 56.17 | 37.67 | 51.13 | 61.60 | 48.83 | 32.13 | 57.07 | 51.63 | 46.37 |
| Seed yield per plant (g) | 10.92 | 12.16 | 19.33 | 12.97 | 10.37 | 14.37 | 6.77 | 15.73 | 20.00 | 14.03 | 11.47 |

these clusters may not produce higher amount of heterotic expression in the F_1 's and wide range of variability in subsequent segregating (F_2) populations. The selection of parents should also consider the special advantages of each cluster and each genotype within a cluster depending on specific objectives of hybridization [22, 23]. In general the present study revealed the presence of significant genetic variability among the tested genotypes. Thus, there is an opportunity to improve yield through hybridization of genotypes from different clusters and subsequent selection from segregating advanced generations.

The mean value of the 13 quantitative characters in each cluster was presented in Tables 4 and 5. Among the clusters in normal planting, sixteen genotypes which included eight released varieties (JAKI 9218, JG 11, JG 16, JG 130, JG 19, VISHAL, VAIBHAV and JGK 1) formed Cluster I. Similarly, Cluster II comprised twelve genotypes including three released varieties (JGK 2, VIHAR and NBeG 3), whereas cluster III, IX and X contained only one released variety (MP-JG 2003–115, KAK 2 and JGK 5 respectively). Correspondingly, Temesgen et al. [24] reported that group of seven chickpea genotypes which include one released variety made Cluster V under normal planting. Under late planting, twenty six genotypes which included twelve released varieties in Cluster I,

whereas Cluster II (VAIBHAV), V (MPJG 2003–115) and VII (JGK 5) consisted of only one released variety. The highest cluster mean values were recorded for genotype ICC 6816 of cluster VI for characters days to pod initiation (71.00), days to maturity (121.33), total number of pods (93.33), number of effective pods per plant (84.33), harvest index (61.60) and seed yield per plant (14.37). The lowest cluster mean values were setimated in cluster VIII, for days to flower initiation (33.50), days to 50% flowering (39.67), days to pod initiation (51.50), harvest index (32.13) under normal planting, whereas under late planting, the highest mean value was recorded in genotypes ICC 8950 and JG 16 of cluster III for the characters days to flower initiation (40.33), days to 50% flowering (45.67), days to pod initiation (50.17), days to maturity (79.83), harvest index (53.8). The lowest cluster mean values for different traits like days to flower initiation (30.00), days to 50% flowering (34.00), days to pod initiation (38.00), days to maturity (67.67) and number of number of primary branches per plant (2.33) were found in cluster V. Cluster VI had highest cluster mean value for total number of pods (90.00) and number of effective pods per plant (63.67).

Conclusion

Cluster analysis revealed the wide range of diversity in the genotypes grouped in eleven clusters in nor-

Table 5. Cluster mean for yield and yield contributing traits of chickpea genotypes under late planting.

| Characters | Cluster I | Cluster II | Cluster III | Cluster IV | Cluster V | Cluster VI | Cluster VII |
|--|-----------|------------|-------------|------------|-----------|------------|-------------|
| Days to flower initiation | 35.97 | 38.61 | 40.33 | 34.67 | 30.00 | 36.67 | 31.67 |
| Days to 50% flowering | 40.69 | 43.78 | 45.67 | 39.33 | 34.00 | 40.67 | 36.0 |
| Days to pod initiation | 45.49 | 49.44 | 50.13 | 43.67 | 38.00 | 46.33 | 44.00 |
| Days to maturity | 75.22 | 79.33 | 79.83 | 73.00 | 67.67 | 77.33 | 74.00 |
| Plant height (cm) | 39.56 | 37.69 | 36.88 | 39.87 | 46.97 | 37.70 | 42.53 |
| Number of primary branches per plant | 2.68 | 2.78 | 2.67 | 3.00 | 2.33 | 2.67 | 2.67 |
| Number of secondary branches per plant | 9.17 | 8.83 | 9.17 | 10.00 | 9.33 | 9.00 | 6.67 |
| Total number of pods | 43.55 | 51.33 | 47.50 | 66.67 | 39.00 | 90.00 | 24.67 |
| Effective pods per plant | 34.54 | 39.72 | 41.50 | 59.00 | 31.00 | 63.67 | 19.00 |
| Number of seeds per pod | 1.03 | 1.11 | 1.39 | 1.03 | 1.33 | 0.74 | 0.87 |
| 100-seed weight (g) | 28.94 | 17.49 | 15.28 | 37.23 | 26.17 | 15.47 | 45.43 |
| Harvest index (%) | 42.15 | 34.20 | 53.80 | 38.03 | 30.57 | 43.88 | 24.77 |
| Seed yield per plant (g) | 9.22 | 6.48 | 5.68 | 14.13 | 9.13 | 11.27 | 9.73 |

mal planting and seven clusters in late planting. On the basis of inter-cluster distance and cluster mean values, the genotypes of cluster VI, X, VII, VIII in normal planting, whereas III, VII, VI and II in late planting were found superior may be utilized in breeding programs for obtaining heterotic recombinants which may yield some transgressive segregants. The characters viz. number of effective pods per plant, seeds per pod, harvest index and 100-seed weight, which contributes more towards yield under late planting that exhibited heat stress condition should be given prime importance in breeding of heat tolerance.

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