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# Selecting Stable Chickpea Genotypes under Rainfed Cultivation using GGE Biplot Analysis

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## ABSTRACT

**Background:** Large environmental influence has been observed on grain yield in rainfed chickpea resulting in higher yield instability. Besides per se performance, stability of chickpea genotypes is a key trait for assured yield under rainfed cultivation. The present study evaluates chickpea advanced breeding lines for stability of grain yield and its components.

**Methods:** A set of 27 chickpea (*Cicer arietinum* L.) advanced breeding lines and three check varieties (JAKI 9218, JG 16, RSG 888) were evaluated for phenological and yield performance under three different environments under rainfed cultivation during 2019-20. The data was subjected to ANOVA and GGE Biplot analysis.

**Result:** The first two principal components of the GGE Biplot explained about 80.13% of the total variation in multi-environment trial. The which won where/what biplot indicated that the genotype IPC17-78 performed well at Bhopal and Kanpur location followed by IPC15-12, IPC17-04 and IPC17-35. At Dharwad genotype IPC19-226 performed well followed by IPC19-220, IPC17-53, IPC19-222 and IPC18-63. Based on Mean vs Stability function of GGE Biplot analysis, chickpea genotype IPC17-369 was the most stable and high yielding genotype followed by IPC17-78 and IPC17-53. Genotypes IPC17-35 and IPC17-54 were more stable but had lesser yield potential. In the "Discrimitiveness vs representativeness" biplot, all the environments plotted at far distance from biplot origin indicating that they were all able to discriminate between genotypes; however, Kanpur and Bhopal were the most discriminating locations.

**Key words:** Chickpea, GGE Biplot, Stability.

## INTRODUCTION

Chickpea is the major pulse crop grown in India contributing 46.62% of total pulse production during 2020-21 (DAC and FW, 2021). There is continuous growth in chickpea production and productivity in the country for the past decade reaching an all-time high of 11.99 million tonnes in 2020-21. However, there is a huge difference in productivity level in different states in the country. Higher productivity has been recorded in Gujarat (1568 kg/ha) and Madhya Pradesh (1417 kg/ha) while low productivity has been recorded in Bihar (730 kg/ha) and Karnataka (782 kg/ha) (Anonymous, 2020). Many factors affect chickpea yield in the country including rainfed cultivation on marginal soil, biotic and abiotic stresses, low input and other management *etc* (Dixit, 2021). This leads to large environmental influence on the yield levels leading to instability over locations and years. In India, chickpea is cultivated almost in all parts of the country mainly as a rainfed crop (68% area) (Anonymous, 2019). Development of resilient varieties of chickpea adapted to rainfed cultivation is the most important breeding goal in the country. This requires a thorough understanding of the environmental influence on the performance of a genotype as large G×E interaction often clouds the performance of potential genotypes (Hasan and Deb, 2017). In breeding trials, the Genotype × Environment (G×E) interaction is often studied with the help of different stability models like Eberhart and Russel Model (1966), AMMI model (Kumar *et al.,* 2020; Rao and Prabhakaran, 2005) *etc*. Recently graphical analysis using biplots have been followed which provides for easy understanding of the Genotype and Genotype × Environment interaction in multi-environment trials (Yan and Tinker, 2006). In the GGE biplot method, selection of cultivars with yield stability is based on both the effect of the genotype and the G×E (Yan *et al*., 2000) and has extensively been used in selecting suitable chickpea genotypes (Farshadfar *et al*., 2012, 2013). Many workers have studied genotypes x environment interaction in chickpea in multi-environmental trial for identifying stable genotypes in their respective environments (Hajivand *et al*., 2020; Desai *et al*., 2016; Bakhsh *et al*., 2011; Tilahun *et al*., 2015; Yadav *et al.,* 2014; Yucel and Mart, 2014; Hamayoon *et al*., 2011). In the present study, an attempt has been made to evaluate chickpea advanced breeding lines for stability of grain yield and its components following genotype main effect (G) and

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genotype by environment interaction (GE) Biplot analysis under three different environments under rainfed cultivation in India.

## MATERIALS AND METHODS

The material for the present study comprised of 27 chickpea (*Cicer arietinum* L.) advanced breeding lines and three check varieties (JAKI 9218, JG 16, RSG 888) (Table 1). The material was grown at three locations *viz*., IIPR, Kanpur (Uttar Pradesh), IIPR-RS, Bhopal (Madhya Pradesh) and IIPR RRC, Dharwad (Karnataka) under rainfed cultivation during 2019-20. These locations represent three different chickpea growing zones namely North East Plain Zone (Kanpur), Central Zone (Bhopal) and Dharwad (South Zone). The material was grown in a randomized block design with three replications. In each replication, four rows of a variety were planted in 4m row with row to row spacing of 30 cm and plant to plant spacing of 10 cm. Observations were recorded on days to 50% flowering, days to maturity and yield (kg/ha). The data was subjected to analysis of variance (ANOVA) for testing the significance of variation due to these traits as described by Gomez and Gomez (1984). Mean values were calculated and compared using F-test at 5% level of significance. The genotype main effect and genotype by environment interaction (GGE) Biplot analysis was performed on mean of these traits among the 30 chickpea breeding lines over 3 environments using statistical software R, versions 2.15 (2013). The GGE biplots were constructed from the first two principal components (PC1 and PC2) that were derived by subjecting mean values to singular value decomposition utilizing statistical package "GGEBilotGUI" (Frutos *et al*. 2014). For testing the mean performance and stability of genotype, the biplots were drawn using Mean vs Stability function with no scaling (Scale = 0), Tester Centered G + GE (Centering = 2) with genotype focused (Row metric preserving) singular-value partitioning (SVP = 1). For testing the environments, the Discriminativeness vs Representativeness function was utilized with no scaling (Scale = 0), tester centered G + GE (Centering = 2) with environment focused (Column metric preserving) singular-value partitioning (SVP = 2).

**Table 1:** Description of breeding lines and checks with pedigree.

| Entry | Pedigree | Remarks |
|---|---|---|
| IPC 15-12 | IPC 2009-50/IPC 2007-88 | Advanced breeding line |
| IPC 16-136 | ILWC 21/IPC 2008-57 | Advanced breeding line |
| IPC 17-04 | JG 16/IPC 2008-57 | Advanced breeding line |
| IPC 17-102 | WR 315/IPC 2010-116 | Advanced breeding line |
| IPC 17-114 | IPC 208-57/ICC 1164 | Advanced breeding line |
| IPC 17-139 | DCP 92-3/ICCV 96-30 | Advanced breeding line |
| IPC 17-16 | IPC 2008-57/ICC 1205 | Advanced breeding line |
| IPC 17-174 | IPC 2008-57/ILWC 245 | Advanced breeding line |
| IPC 17-20 | JG 315/JG 2003-14-16 | Advanced breeding line |
| IPC 17-256 | IPC 2008-57/ILWC 245 | Advanced breeding line |
| IPC 17-35 | JG 315/JG 2003-14-16 | Advanced breeding line |
| IPC 17-369 | IPC 2009-50/IPC 2009-35 | Advanced breeding line |
| IPC 17-377 | IPC 20006-11/ICC 96030 | Advanced breeding line |
| IPC 17-47 | IPC 2009-50/ICCV 14778 | Advanced breeding line |
| IPC 17-53 | JG 315/JG 2003-14-16 | Advanced breeding line |
| IPC 17-54 | IPC 2008-57/ICC 1205 | Advanced breeding line |
| IPC 17-78 | IPC 2008-57/PA 1108 | Advanced breeding line |
| IPC 18-48 | ILWC 21/IPC 2008-57 | Advanced breeding line |
| IPC 18-63 | IPC 2010-59/IPC 2008-57 | Advanced breeding line |
| IPC 19-219 | ICC4958/JG 11//JG 16/ICCV 97105 | Advanced breeding line |
| IPC 19-220 | ICC 4958/JG 16//JAKI 9218//ICCV 00108 | Advanced breeding line |
| IPC 19-221 | BG 256/WR 315 | Advanced breeding line |
| IPC 19-222 | JG 14/ICCV 96836 | Advanced breeding line |
| IPC 19-223 | ICC 4958/ICCV 00108//JG 11/JG 130 | Advanced breeding line |
| IPC 19-226 | JG 11/ICC 4958 | Advanced breeding line |
| IPC 19-228 | IPC 2006-11/ICC 96030 | Advanced breeding line |
| IPC 19-229 | KWR 108/ICC 4958 | Advanced breeding line |
| JAKI 9218 (ch) | ICCV 37/GW 5/7//ICCV 107 | Released variety |
| JG 16 (ch) | ICCC4 × ICCV 10 | Released variety |
| RSG 888 (ch) | RSG 44 ×E 100 Y | Released variety |

## RESULTS AND DISCUSSION

### Analysis of variance

The effect due to genotypes and environment was significant for days to 50% flowering, days to maturity and yield (Table 2). This indicated that the performance was affected by differences among genotypes as well as environments under which these genotypes are grown. The interaction effect among genotypes and environments was significant for all the traits. Thus, the genotypes respond differentially under different environments for yield and related traits indicating that no set pattern of response could be obtained in these cases making it imperative to find out optimum environment for each genotype. Similar findings have been reported by Dhuria and Babbar (2021) in diverse elite *kabuli* chickpea lines for phenological and yield related traits.

### GGE biplot analysis

The first two principal components (PC1 and PC2) of the GGE Biplot, derived from subjecting environment centered values of yield and associated traits due to GGE to singular value decomposition explained about 96.72% of the total variation of days to 50% flowering; 91.65% of the total variation of days to maturity and 80.13% of the total variation of yield in multi-environment trial (Fig 1). This indicated that the GGE biplot adequately explains the variation in days to 50% flowering, days to maturity and yield in the multi-environmental trial to derive reasonable conclusions.

### Mean performance and stability of genotypes across locations

The performance and stability of a genotype can be visualized graphically in GGE Biplots by utilizing the average environment coordination (AEC) method (Yan and Kang, 2002). The line passing through Biplot origin and marker for average environment is termed AEC abcissa (AECa) and it points toward higher mean value. The perpendicular line to AEC passing through the Biplot origin is termed as AEC ordinates and points to greater variability (poor stability) in either direction.

For days to 50% flowering and days to maturity, the best genotypes would be having earliest flowering and maturity and the highest stability. Graphically, the genotype showing highly stable for days to 50% flowering and days to maturity should show higher negative projection on AECa and it should be located closer to the AECa *i.e.* its projection on AECa should be closed to zero (Yan, 2001). Based on Mean vs Stability function of GGE Biplot analysis, chickpea genotypes IPC 19-219 followed by IPC 19-222 and IPC 17-102 showed early maturity with moderate stability. The line IPC 19-220 showed moderate earliness with high stability (Fig 2). These lines are derived through hybridization of early maturing donors like JG 11, JG 16, JG 14, JAKI 8218, ICC 1205 *etc* that contributed to earliness. These can be utilized as donors for transferring earliness to agronomically superior lines. The genotypes IPC 2017-369, IPC 2017-78 and IPC 2017-53 exhibited high yield with moderate stability. The genotypes IPC 2017-35 and IPC 2017-54 exhibited moderate yield with high stability. These lines possess stress resistant parents in their pedigree. The parents IPC 2008-57 and IPC 2009-50 are early maturing and cold tolerant line; ICC 1205 possess heat tolerance; WR 315 possess fusarium wilt resistance; JG 2003-14-16 possess dry root

**Table 2:** Analysis of variance for yield and associated traits in 30 chickpea lines evaluated at 3 environments in India.

| Source of variation | d. f. | Mean sum of square | | |
|---|---|---|---|---|
| | | Days to 50% flowering | Days to maturity | Yield (kg/ha) |
| Replication | 2 | 63.53 $^{NS}$ | 24.41 $^{NS}$ | 109110 $^{NS}$ |
| Environment (E) | 2 | 621.88** | 3393.14** | 2648637** |
| Genotype (G) | 29 | 333.95** | 390.42** | 399425** |
| G × E | 58 | 54.77** | 94.54** | 323177** |
| Error | 178 | 22.35 | 23.51 | 49868 |

$^{NS}$ : Non-significant, ** : Significant at P=0.01.

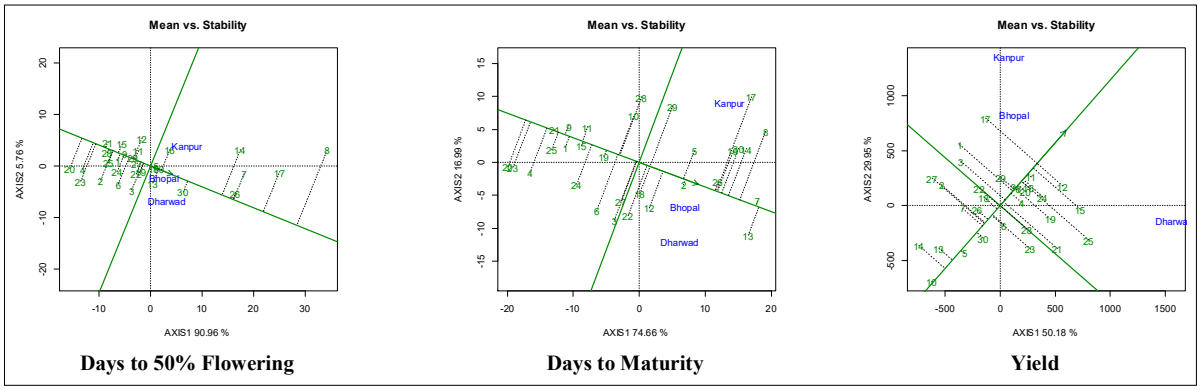



**Fig 1:** GGE biplot of the combined analysis for days to 50% flowering, days to maturity and yield showing mean vs stability.

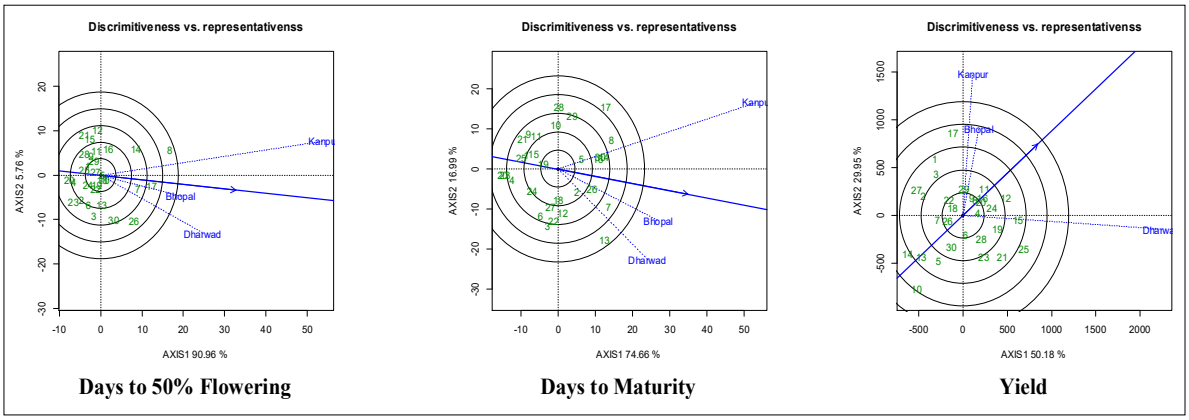



**Fig 2:** GGE biplot of the combined analysis for days to 50% flowering, days to maturity and yield showing discrimitiveness vs representativeness of environments.

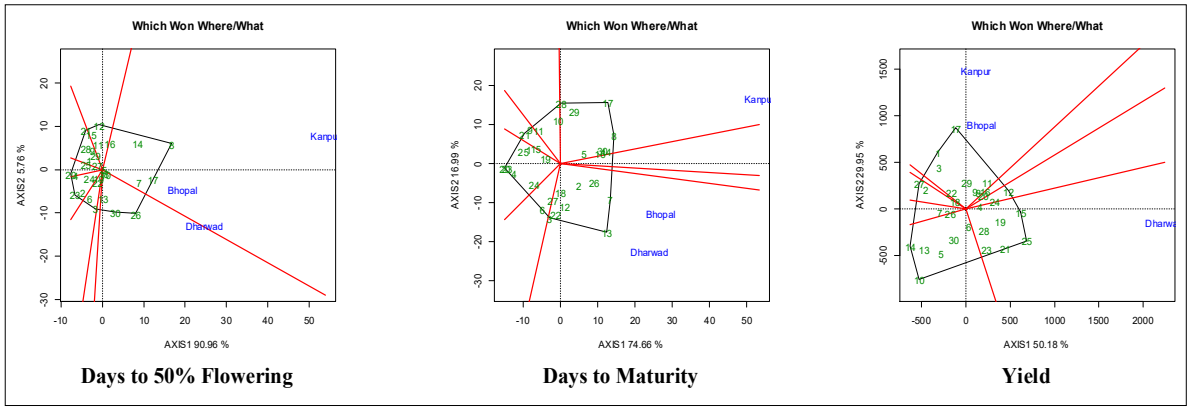



**Fig 3:** GGE biplot of the combined analysis for days to 50% flowering, days to maturity and yield showing which won where/what plots.

rot tolerance. Expression of higher yield and stability of these lines is a manifestation of positive interaction among earliness and biotic and abiotic stress tolerance which is crucial under rainfed cultivation of chickpea (Yücel, 2020; Maphosa *et al*., 2020; Mohammeda *et al*., 2017). These lines can be promoted for coordinated evaluation under AICRP for release as variety and can also be used as donors for yield and stability.

### Evaluation of environments

In the "Discrimitiveness vs representativeness" biplot, the length of environmental vector acts as a measure of discriminating ability of an environment (Fig 2). All the environments plotted at far distance from Biplot origin indicate that they were all able to discriminate between genotypes. However, they vary in their vector length indicating difference in their discriminating ability. For days to 50% flowering and days to maturity, Kanpur was the most discriminating location followed by Dharwad and Bhopal. For yield, Dharwad was the most discriminating followed by Kanpur and Bhopal location. All the locations formed small angle with AECa and were most representative of the average environment. However, Bhopal location was most representative followed by Kanpur and Dharwad of the average environment for all the traits. Test environments that are discriminative but non-representative are useful for selecting specifically adapted genotypes in target environments. Non discriminating test environments are less useful as they provide little discriminating information about the genotypes. Thus, Kanpur and Dharwad location were suited for selecting region specific adapted genotypes. The cosine of angle between two environment vectors approximates the correlation between them. If the angle between two environment axis is less than 90,°the correlation is positive while an angle more than 90° indicates negative correlation between environments. Presence of right angle between two environment axis indicates absence of correlation. Most of the angles were acute (<90°) indicating positive correlation among test environments. For days to 50% flowering and maturity, the angle between all the locations were acute (<90°) indicating positive correlation. This was expected as phenological traits are highly heritable and do not show differential response to environments. Thus, there will be no cross-over genotypes for these traits *i.e*., the variation in flowering and maturity duration of genotypes at each location will be relative to each other. For yield, the

angle between Kanpur and Bhopal was acute (<90°), while angle between both Kanpur- Dharwad and Bhopal-Dharwad was nearly 90°. Thus, there was no correlation between yield of genotypes observed at Dharwad with either Kanpur or Bhopal.

**Which won where and mega environment identification**

The which when where graph provides a polygon view of the biplot by first joining the farthest genotypes and subsequently perpendicular lines are drawn from the origin of each biplot to each side of the polygon, separating the biplot into several sectors or mega-environments. For days to 50% flowering, all three locations were grouped together as one mega environment (Fig 3). For days to maturity, Bhopal and Dharwad formed one mega-environment while Kanpur formed a separate environment. This was expected as crop in Kanpur location in North India has usually longer maturity duration while that in Central (Bhopal) and Southern States (Dharwad) show relatively early maturity. For yield, Kanpur and Bhopal locations formed one mega environment while Dharwad was grouped as separate environment. Thus, the genotype performance in Kanpur and Bhopal locations was similar despite the difference in maturity duration. This is due to better per unit time growth and productivity of chickpea in Central India as compared to that in North India conditions. Among genotypes, IPC 2017-78 performed well in Kanpur and Bhopal while IPC 2019-226 performed well in Dharwad. These genotypes can be promoted for evaluation in State adoptive trials for state release. Naveed *et al.* (2016) have followed similar approach to identify location specific genotypes of chickpea.

## CONCLUSION

The present study estimates the stability of chickpea advanced reeding lines under rainfed cultivation in multi-environment trial using GGE Biplot analysis. The which won where/what biplot indicated that the genotype IPC17-78 performed well at Bhopal and Kanpur location followed by IPC15-12, IPC17-04 and IPC17-35. At Dharwad genotype IPC19-226 performed well followed by IPC19-220, IPC17-53, IPC19-222 and IPC18-63. Based on Mean vs Stability function of GGE Biplot analysis, chickpea genotype IPC17-369 was the most stable and high yielding genotype followed by IPC17-78 and IPC17-53. Genotypes IPC17-35 and IPC17-54 were more stable but had lesser yield potential. Based on "Discrimitiveness vs representativeness" biplot, Kanpur and Bhopal were identified as the most discriminating locations while Dharwad was least discriminating. The study provides useful insight into GGE Biplot analysis for identifying best performing chickpea breeding lines at each location and most stable lines across locations.

**Conflict of interest**

All authors declared that there is no conflict of interest.

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