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Stability Analysis of Asiatic Cotton (*Gossypium arboreum* L.) Genotypes with Respect to Seed Cotton Yield, GOT and Boll Weight under Multi Environmental Trials through GGE Biplot Analysis

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ABSTRACT

The GGE biplot is a useful visualization tool for accessing the performance of genotypes in different environments. In the present study, the 9 genotypes viz CISA 6-165, CISA 6-350, CISA 6-123, CISA 6-187, CISA 6-214, CISA 6-295, CISA 614-1, CISA 6-209, CISA 6-256 were tested under seven different environmental conditions. The genotypes were referred as G1 to G9, respectively. The seven different environmental conditions were cotton growing season 2010-11 to 2016-17 henceforth referred as E-1 to E-7, respectively. The aim of our study was to determine the stability of the genotypes in terms of seed cotton yield (SCY in kg/ha), Ginning Out Turn (GOT) and Boll Weight (g) under different environmental conditions through GGE Biplot stability analysis technique. In case of SCY all the environments formed only one mega environment (ME) for seed cotton yield. Only G1, G7, G8 and G9 were under the mega-environment performed better as compared to other genotypes but were not stable across the environments. Performance of a particular genotype was accessed by average environment coordination method and result showed that G7 was the highest performer followed by G8, G9 and G1. In case of GOT, two mega environments were formed and the genotypes G1, G5, G7 and G9 were better performers under E2, E4, E5, E6 and E7 (ME1). Other genotypes viz. G2, G3 and G6 were being best performer under ME2 (i.e. under E1 and E3) in term of GOT. The genotype G9 was best performer with higher average GOT and stability followed by G5 and G7. In case of Boll wt. the environments formed three mega environments in which G2, G3, G4 and G6 were best performer under ME1 (E3, E4, E6 and E7), G7 and G8 performed better under E1 and E2 (ME2) and G1 and G9 were better performer under E5 (ME3). The genotype G6 when placed on GGE biplot showed its higher average yield with better stability in terms of boll weight followed by G8 and G7. In conclusion, genotype G7 (CISA 614-1) for seed cotton yield, genotype G9 (CISA 6-256) for GOT and genotype G6 (CISA 6-295) for Boll weight may be used for further breeding program for specific trait improvement.

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INTRODUCTION

Cotton is the most important commercial and vital cash crop of India called as "White Gold", cultivated mainly for its fiber and other by-products important being the edible oil. India is the only country in world where all the four cultivated species of cotton (tetraploid and diploid) viz., *G. hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum* are grown from north to deep south. *G. hirsutum* covers more than 90% of acreage while the diploids the least, however, the diploids are relatively tolerant to biotic as well as abiotic stresses including less inputs as compared to *G. hirsutum* (Verma *et al*. 2020). *Desi* (Asiatic) or diploid cotton (*Gossypium arboreum* L., 2n = 26) has inherent ability to adapt adverse climatic conditions and well known for resistant to pests and diseases and its lint is of short staple length. They are still under cultivation in some part of India as farmers believe the sustainability of the yield in marginal soil and less management practices (Mehetre 2015). After the introduction of Bt cotton in India, there was significant decrease in area of *desi* (Asiatic) cotton. But there is a big demand of short staple length for denim and surgical purposes. As an alternative the diploid cotton, it may be taken if they are giving remuneration equal to or higher than *G. hirsutum*. Yield being a complex character and components which contribute towards high yield potential in cotton need careful study. The first step in successful breeding program is to select most desired and appropriate parents with better performance and stability. Concentrated breeding efforts are being made under All India Coordinated Research Project on Cotton (AICRP on Cotton) to release better yielding cultivars. Multi-location trials (MLTs) play a crucial role in the process of identification and release of improved and stable cultivars. However, often during the analysis of MLTs data genotype evaluation is limited on genotype main effects (G), while genotype × environment interactions (GEI) are ignored as noise, which is otherwise equally important (Yan and Tinker 2006). Various statistical models like analysis of variance (ANOVA), principal component analysis (PCA), and linear regression (LR) have been suggested over time to understand the complex GEI (Zobel *et al*. 1988, Yan and Kang 2003). Each procedure has its own advantages and disadvantages (Zobel *et al*. 1988, Wright 1971, Rakshit *et al*. 2012). Genotype (G) main effect plus GE interaction (GGE) Biplot analysis (Yan and Kang 2003) is a robust method to visualize and interpret MLT data graphically. Utility of GGE biplot in understanding GEI has been demonstrated in many crops (Rakshit *et al*. 2012, Rao *et al*. 2011). In plant breeding, multi environment trials are conducted to evaluate the performance of genotypes across the range of environments. GGE Biplot is a useful visualization tool for accessing the performance of genotypes in different environments. (Yan *et al*. 2003) For a GGE Biplot, the genotypes and environments are present in same plot provides information on the correlation between environments. The present study was aimed to access the stability of the genotypes in terms of seed cotton yield (SCY in kg/ha), Ginning Out Turn (GOT) and Boll weight (g) under different environmental situations through GGE biplot stability analysis technique.

MATERIALS AND METHODS

Field experiments were conducted at the research farm of ICAR-CICR, Regional Station, Sirsa, Haryana 125 055, India during *kharif* seasons from 2011 to 2017 to determine effects of different nine genotypes viz. CISA 6-165, CISA 6-350, CISA 6-123, CISA 6-187, CISA 6-214, CISA 6-295, CISA 614-1, CISA 6-209, CISA 6-256 under seven different environmental conditions. The genotypes were referred as G1 to G9, respectively. The seven different environmental conditions were cotton growing seasons viz. 2011 to 2017 henceforth referred as E-1 to E-7, respectively. The experiments were conducted using recommended package of practices in Randomized Block Design (RBD) and were replicated thrice. The plant geometry of 67.5 x 45 cm was maintained for all the crop seasons. Need based plant protection measures were taken as per local recommended package of practices. Picking was done thrice at full boll burst stage manually. Observations on boll weight were made on 05 randomly selected and tagged plants per plot. Seed cotton was cleaned and weighed from each plot for expressing seed cotton yield kg/ha. All the seed cotton samples were cleaned and ginned carefully in the laboratory for estimation of GOT % (ginning

Table 1. The detailed environmental conditions (2011 to 2017).

				Vegetative stage			
Years	2011 (E1)	2012 (E2)	2013 (E3)	2014 (E4)	2015 (E5)	2016 (E6)	201617 (E7)
T_{max}	40.49	38.09	40.01	37.02	40.11	40.90	41.42
T_{min}	24.56	23.00	23.85	22.96	23.81	24.10	24.48
T_{avg}	32.53	30.54	31.93	29.99	31.96	32.50	32.95
Avg rainfall	0.70	0.53	0.14	0.44	0.06	0.00	0.00
				Reproductive stage			
Years	2011 (E1)	2012 (E2)	2013 (E3)	2014 (E4)	2015 (E5)	2016 (E6)	2017 (E7)
T_{max}	37.91	38.58	37.35	37.96	36.05	37.70	37.00
T_{min}	27.83	28.78	28.22	27.98	26.65	27.96	26.94
T_{avg}	32.87	33.68	32.78	32.97	31.35	32.83	31.97
Avg rainfall	3.22	1.02	3.08	1.68	2.08	2.28	2.01
				Maturity phase			
Years	2011 (E1)	2012 (E2)	2013 (E3)	2014 (E4)	2015 (E5)	2016 (E6)	2017 (E7)
T_{max}	33.1	32.82	33.86	33.61	34.90	34.41	35.36
T_{min}	22.5	22.21	23.98	22.82	22.66	22.97	21.95
T_{avg}	27.8	27.52	28.92	28.18	28.78	28.69	28.66
Avg rainfall	2.9	2.41	0.58	2.25	0.23	0.96	1.65

outturn percentage). The different environments were defined by T_{max}, T_{min}, T_{avg}, and monthly average rainfall distribution at three phenological stages viz. vegetative phase, reproductive phase and maturity phase of cotton during the growing seasons. The detailed environmental conditions were presented in Table 1 and Fig. 1.

Statistical analysis

The data were used for statistical analysis using Genstat software (VSN International) for GGE biplot analysis and the results obtained were used for predicting results according to Yan (2014) and Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

The GGE biplot is a useful visualization tool for accessing the performance of genotypes in different environments. In GGE biplot, if first two Principal components (PCs) explains more than 60% of the total variation then the data were adequately summarized in the biplot (Yan *et al*. 2001). In GGE biplot the complex genotype x environment interactions (GEI) partitioned in different principal components (PCs) and the data are presented graphically against various PCs (%). In GGE biplot, a convex hull has been drawn by connecting the farthest genotype to form a polygon that consists all the genotypes. Sectors are also been added by drawing basis from the origin, perpendicular to each side of the convex hull. Finally eclipses have been drawn around the environments within the same sector to form mega environments (MEs). Genotypes that appear in the same sector as a particular environments are the best performers in that environment (Figs. 2a, 3a and 4a) (Yan and Tinker 2006). The mean performance of the genotypes and stability was accessed by using average environment combination (AEC) method (line with single arrow head in Figs. 2b, 3b and 4b) indicated its average yield, while dispersion of the genotype along the AEC ordinate is indication of stability (Rakshit *et al*. 2012). The greater the absolute length of the projection of a cultivar, the less stable it is across the environments (Figs. 2b, 3b and 4b). According to Kaya *et al*. (2006) in GGE biplot, an ideal genotype is high performer with high stability across environments which were denoted by the arrow head in the

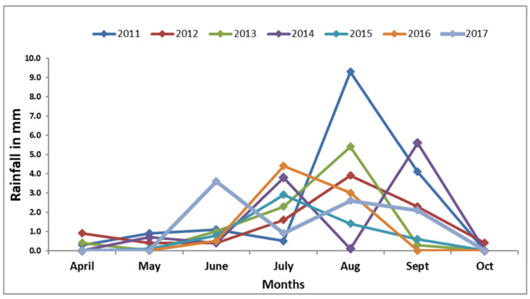

Fig. 1. Average monthly rainfall distribution for all the environments.

center of the concentric rings of the biplot (Figs. 2c, 3c and 4c). The ideal environment is denoted by the small arrow head in (Figs. 2e, 3e and 4e) at the center of the concentric rings having maximum representativeness as well a discrimination ability with highest vector length. The smaller the circle containing any particular environment the greater attributes it shows with ideal environment. In the present study genotype x environment interactions of nine genotypes under seven environments were analyzed in terms of Seed Cotton Yield (kg/ha), GOT and boll weight (g) to access the nature of performance and stability of the genotypes under various environments.

Seed cotton yield (kg/ha)

In GGE biplot if first two Principal components (PCs) explains more than 60% of the total variation then the data were adequately summarized in the biplot (Yan *et al*. 2000). In case of SCY the first PCs explained 91.08% of total variation. Fig. 2a depicted the GGE biplot summarizing the performance of genotypes under various environmental conditions. Here all the environmental conditions formed only one mega environmental (ME1). Only G1, G7, G8 and G9 were under the ME1 performed better as compared to other genotypes but were not stable across the environments (Fig. 2a). Average environment combination (AEC) method of predicting the mean performance of the genotypes and stability showed that the genotype G7 having smallest absolute length of projection (Fig. 2b). Thus, G7 was the highest performer followed by G8, G9 and G6 with medium stability across the environments. Fig. 2a also depicted that the E5, E6 and G1 were clustered together, so, the average performance of G1 was higher under the environmental conditions like E5 and E6. The same genotype G7 was closest to the ideal genotype denoted by small arrowhead in

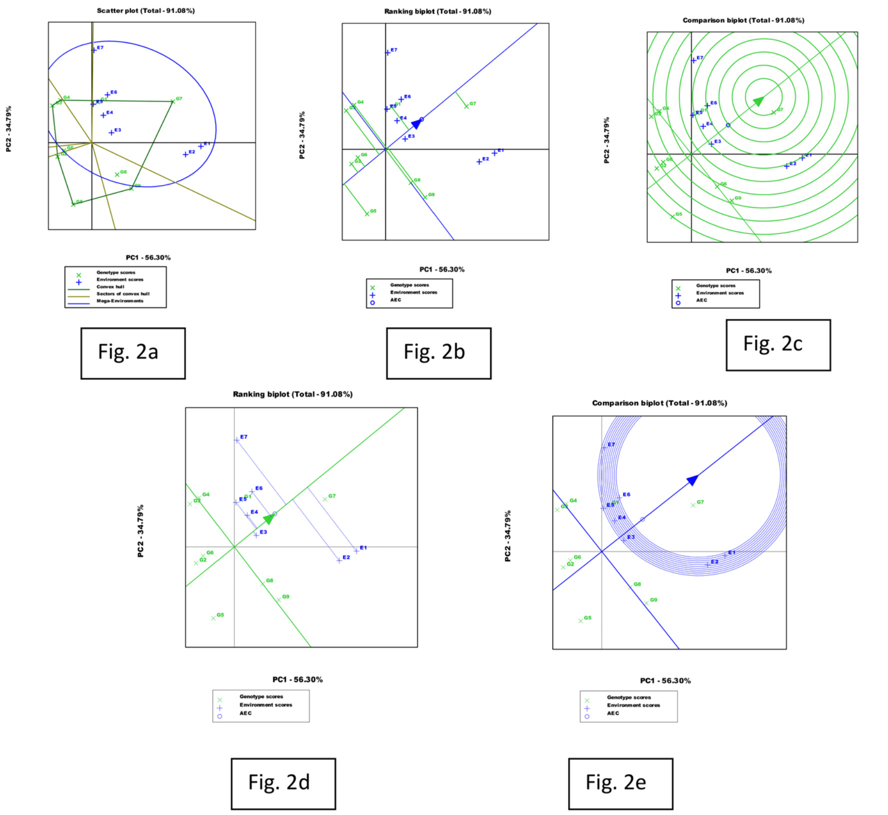

Fig. 2. GGE biplots for seed cotton yield, a: mega environments, b: stability of genotypes, c: ranking of genotypes relative to an ideal genotype, d: ranking of environments based on highest performing genotypes, e: ranking of environments based on discriminating ability and representativeness.

Fig. 2c. The genotype G7 marked top among nine genotypes tested for seed cotton yield under various seven environments followed by genotype G1. The ease with which genotypes could be identified using GGE biplot cannot be exercised from mean date table. The similar observations were made by Dehghani *et al*. (2006) in Barley. In seven environments, G7 recorded above average performance with best performance under environment E1 and E2 followed by under environments E7, E6, E5, E4 and E3 (Fig. 2d). Similar observations were recorded in peanut by Tolessa *et al*. (2013). For SCY, the ideal environment was denoted by the small arrow head in (Fig. 2e) at the center of the concentric rings. The smaller the circle containing any particular environment the greater attributes it shows with ideal environment. Here the environment 6 (E6) showed more attributes with ideal environment followed by E1 and E2. Our result was in accordance with the observations made by Mortazavian *et al*. (2014) in Barley and Kaya *et al*. (2006) in bread wheat. Under environmental conditions E1, the atmospheric temperature varied from 24.560C to 40.490C with an average of 32.530C, 27.830C to 37.910C with an average of 32.870C and 22.50C to 33.10C with an average of 27.80C at the time of vegetative, reproductive and maturity phase, respectively and the growing season also experienced a well distributed rainfall throughout the growing season with a peak rainfall in the month of August. It can be concluded that to improve the production of seed cotton yield the breeders can select the environmental situations like E1 (Table 1).

Ginning out turn (GOT)

In case of GOT, the first two PCs explained 73.12% of total variation and two mega environments were formed. The environments formed two mega envi-

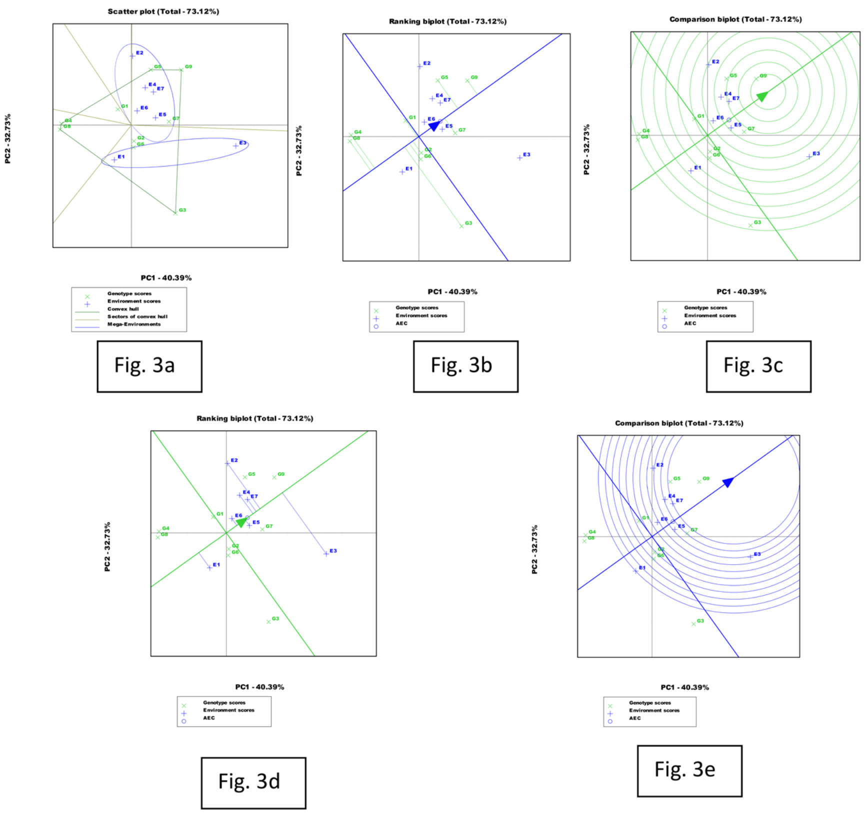

Fig. 3. GGE biplots for ginning out turn, a: mega environments, b: stability of genotypes, c: ranking of genotypes relative to an ideal genotype, d: ranking of environments based on highest performing genotypes, e: ranking of environments based on discriminating ability and representativeness.

ronments consisted of E1 and E3 under ME1 and E2, E4, E5, E6 and E7 under ME2. The genotypes G1, G5, G7 and G9 were better performers under ME1 and genotypes G2, G3 and G6 were better performers under ME2 in terms of GOT (Fig. 3a). The genotype G9 showed smallest absolute length of dispersion along the AEC coordinate. Thus, G9 was the highest performer with better stability followed by G5 and G7. But, the stability of the genotypes G7 and G9 can be marked similarly in terms of GOT (Fig. 3b). The same genotype G9 was close to the ideal genotype denoted by single arrow head in Fig. 3c marked top for ginning out turn among nine genotypes tested under various seven environments. The genotype G9 also recorded above average performance with best performance under E3, followed by under E2, E7, E4, E5 and E6 (Fig. 3d). In terms of GOT, the ideal environment was denoted by the small arrow head in Fig. 3e at the center of between concentric rings having maximum representativeness as well as discrimination ability. Here the concentric rings containing E7 showed none attributes with ideal environments followed by E4 and E5 (Fig. 3e). Under environmental conditions E3, the atmospheric temperature varied from 23.85°C to 40.01°C with an average of 31.39°C, 28.22°C to 37.35°C with an average of 32.78°C and 23.98°C to 33.86°C with an average of 28.92°C at the time of vegetative, reproductive and maturity phase, respectively, and the growing season also experienced a well distributed rainfall throughout with a peak rainfall in the month of August. It can be concluded that to improve the ginning out turn the breeders can select the environmental situations like E3 (Table 1).

Boll weight

In case of boll weight 71.77% of total variation was explained by first two PCs. The environments formed

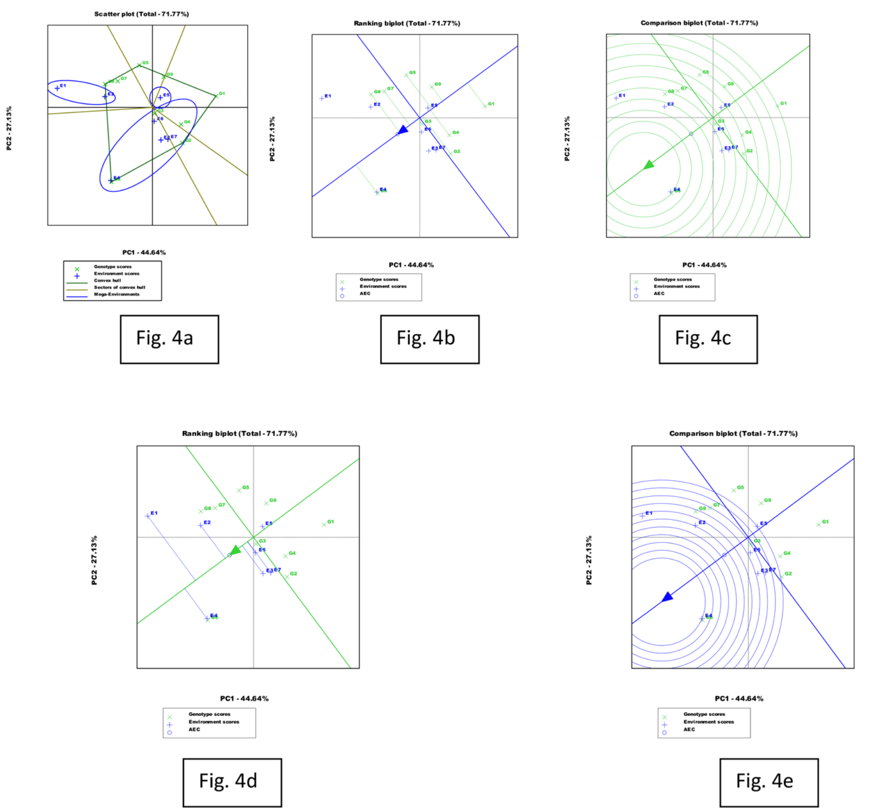

Fig. 4. GGE biplots for boll weight, a: mega environments, b: stability of genotypes, c: ranking of genotypes relative to an ideal genotype, d: ranking of environments based on highest performing genotypes, e: ranking of environments based on discriminating ability and representativeness.

3 mega environments viz. ME1, ME2 and ME3. Genotypes G2, G3, G4 and G6 were better performer under ME1, G7 and G8 performed better under ME2 and G1 and G9 were better performer under ME3 (Fig. 4a). Average environment combination (AEC) method of predicting the mean performance of the genotypes and stability showed the genotype G6 having above average performance among a the genotype in terms of boll wt followed by G8 and G7 (Fig. 4b). Genotype G6 and E4 were clustered together in Fig. 4b showed its best performance under E4. The same genotype G6 was close to our ideal genotype denoted by single arrow head in Fig. 4c, showed its above average performance across the environments with best performance under E4 followed by under E1, E3 and E2 (Fig. 4d). The ideal environments were denoted by the small arrow head in Fig. 4e at the center of the concentric rings in terms of boll weight. Here smaller circle containing the environment E4 showed more attributes with ideal environments followed by E1 and E2. Under environmental conditions E4, the atmospheric temperature varied from 22.96°C to 37.02°C with an average of 29.99°C, 27.98°C to 37.96°C with an average of 32.97°C and 22.82°C to 33.61°C with an average of 28.18°C at the time of vegetative, reproductive and maturity phase, respectively, and the growing season also experienced a well distributed rainfall throughout with a peak rainfall in the month of September. It can be concluded that to improve the boll weight the breeders can select the environmental situations like E3 (Table 1).

CONCLUSION

Thus, it can be concluded that the genotype G7 (CISA 614-1) for seed cotton yield under environmental conditions like E1, genotype G9 (CISA 6-256) for GOT under environmental conditions like E3 and genotype G6 (CISA 6-295) for boll weight under environmental conditions like E4 can be used for further breeding program for specific trait improvement.

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