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Studies on phenotypic stability for yield and quality traits in brinjal (*Solanum melongena* L.)

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Abstract

The present investigation was carried out to study stability performance over three locations for fruit yield and its components using Line x Tester mating design. The crossing programme was carried out during late *kharif* season of 2019-2020. The evaluation of F₁ hybrids was done at three different locations in late *kharif* season 2020-2021. The experiment was conducted in Randomized Block Design (RBD) with three replications which included 40 genotypes comprising of 7 lines, 4 testers, their resultant 28 hybrids and one standard check GNRB-1. The analysis revealed that genotypes × environment (G×E) interactions were significant for most of the traits except plant height at final harvest, total number of branches plant⁻¹, fruit length, number of fruits plant⁻¹, fruit yield plant⁻¹, number of seeds fruit⁻¹ and TSS when tested against pooled error and pooled deviation. Among parents, NBL-117 and GNRB-1 showed above average stability and specifically adapted to unfavourable environment for total fruit yield ha⁻¹. Among crosses NBL-117 × Swarna Mani and NBL-117 × GNRB-1 exhibited their stability under unfavourable environments. The crosses NBL-117 × GAOB-2, NBL-117 × GOB-1 exhibited its suitability and stability under favourable environments. However, none of the genotypes were found to have average stability for total fruit yield ha⁻¹.

Keywords: Phenotypic, yield, traits in brinjal

Introduction

The goal of plant breeders has traditionally been to create genotypes that are more adaptable. Any plant breeding effort must now include the development of breeding lines through time and space in order to achieve this objective. Genotype x Environment (G x E) interaction has remained a major source of worry for plant breeders despite intensive testing and subsequent selection. A thorough knowledge of the genetic control of variability has been significantly hampered by the G x E interaction. This has made it very difficult to comprehend evolutionary trends and prevented the rationalisation of policy and practise in breeding for improved productivity in crucial crops. The capacity of the genotypes to maintain phenotypic stability may be impacted by the allelic balance of the genotypes to buffer against the environmental changes. Thus, before choosing desired genotypes in a plant breeding programme, a variety of candidate genotypes are often assessed in various conditions by conducting evaluation trials at various sites and over a variety of years. There is a G x E interaction when it comes to quantitative features like fruit production since different genotypes frequently behave differently in different environments. Such statistical interaction is caused by a change in the relative order of the genotypes or a change in the size of the genotype-environment differences. Progress from selection is also reduced due to effect of a large G x E interaction (Comstock and Moll, 1963) [3].

The G x E interaction assesses genetic differences in response to environmental changes. These interactions are a significant limiting factor in the estimation of variance components and the effectiveness of the selection procedure. Knowing the nature and relative magnitude of the various components of G x E interaction is critical when making decisions about breeding methods, selection programmes, and testing procedures in crop plants. (Baker, 1969) [1].

Material and Methods

Randomized block design with three replications was used for the evaluation of experimental material at three locations *i.e.*, Regional Horticulture Research Station, Navsari, Fruit Research Station, Gandevi and Hill Millet Research Station, Waghai to study phenotypic stability in brinjal during late *kharif* 2020.

Eleven parents which involve seven lines (females), four testers (males) and their 28 F_1 hybrids along with one commercial check (GNRB-1) were used as experimental material. Total 40 genotypes were used to study the phenotypic stability in the experiment.

With 10 plants per row and a spacing of 90 x 60 cm, each genotype was cultivated in a single row plot. To grow good crops during a specific crop season, advised cultural techniques were followed. On five randomly chosen competing plants, data were collected for yield and yield-related characteristics. The importance of genotype x environment interactions was determined using analysis of variance on the data. Stability parameters, regression (b_i) and deviation from regression (S^2d_i) were worked out by the methods suggested by Eberhart and Russell, 1966^[4].

Result and Discussion

The analysis of variance for genotype x environment interaction and stability parameters were estimated and are presented below for all fifteen characters. The mean squares due to genotypes including both parents and hybrids were highly significant for all the traits when tested against both pooled error and pooled deviation which depicted the presence of good amount of variation in the genetic material studied.

The analysis also indicated significant variation among the imposed environments for all the characters (except plant height at final harvest, fruit length, number of fruits plant⁻¹, total phenol content, TSS and total anthocyanin content) when tested against pooled error and pooled deviation. Similar results found by and Kachouli *et al.* (2019)^[5].

The mean squares due to $G \times E$ interactions were significant for most of the traits except plant height at final harvest, total number of branches plant⁻¹, fruit length, number of fruits plant⁻¹, fruit yield plant⁻¹, number of seeds fruit⁻¹ and TSS when tested against pooled error and pooled deviation. This indicated that genotypes interacted significantly in different environments for these traits. Concurrent results were revealed by Chaitanya and Reddy (2017)^[2] and Kumari *et al.* (2020)^[7]. The non-significance interaction of genotype x environment for remaining traits under study indicated that genotypes responded consistently over the environments for these traits.

The mean squares due to environment plus $G \times E$ interactions were significant for all traits when tested against pooled error and pooled deviations except plant height at final harvest, fruit length, number of fruits plant⁻¹, number of seeds fruit⁻¹ and TSS. It was further partitioned into three components i) Environments (Linear) ii) $G \times E$ (Linear) and iii) Pooled deviation ($G \times E$; Non-linear).

Significant values of mean square due to environments (linear) for all traits except plant height at final harvest, fruit length, number of fruits plant⁻¹ and TSS when tested against pooled error and pooled deviation indicated that environments differed considerably among different sowing dates and created ecosystems for these traits. The mean square values due to $G \times E$ (linear) were found to be significant for all the traits except plant height at final harvest, total number of branches plant⁻¹, fruit length, number of fruits plant⁻¹ and number of seeds fruit⁻¹ when tested against pooled error and pooled deviations which indicated that values for the regression line statistically differed and the variation in the performance of genotypes was due to regression of genotypes

on environmental indices and hence, performance of genotypes would be predictable. However, mean square values due pooled deviation were significant for all the traits except fruit length, 100-seed weight, total phenol content, Vitamin-C and total anthocyanin content against both pooled error and pooled deviation which suggested that the prediction of performance of genotypes over environment based on regression analysis for these traits might not be very reliable and lack of possibilities to predict the performance of genotypes across the environments for these characters. Similar results were found by Kachouli *et al.* (2019)^[5], Koundinya *et al.* (2019)^[6] and Siva *et al.* (2020)^[8].

However, relative magnitude of linear and non-linear components of $G \times E$ interaction would decide, whether the performance of a genotype for the character under consideration would be predictable or not. Since, when both linear and non-linear (pooled deviation) components of $G \times E$ interaction are significant, the magnitude of both the components need to be considered and greater magnitude of linear component [$G \times E$ (L)* > $G \times E$ (NL)*] suggests the linear response of genotypes to environmental index and thereby possibility for prediction of performance of genotypes over environments. Accordingly, three kinds of linear responses (b_i) viz., $b_i < 1$, $b_i = 1$ and $b_i > 1$ have been considered and interpreted as $b_i = 1$, average stability and widely adapted to different environments; $b_i > 1$ and significant, below average stability, increasing sensitivity to environmental changes and well adapted to favorable environment and $b_i < 1$ and significant, above average stability, greater tolerance to environmental changes; thereby genotype would have specific adaptability to poor environment.

In consideration to all above requirements and limitations, the stability parameters were worked out and interpreted. The stability parameters employed for identification of stable genotypes had high or low mean values than population mean as the character was of economic importance, a regression coefficient (b_i) equals to unity and its significant deviation from unity and a mean square deviation from linear regression coefficient statistically equal to zero (S^2d_i).

Stability Parameters

One of the most desirable properties of a genotype is stability performance for its wide adaptability. The stability parameters viz., mean performance, regression coefficient (b_i) and individual squared deviation from linear regression (S^2d_i) for parents as well as hybrids were estimated for fifteen traits to assess the stability over the environments as per Eberhart and Russell (1966)^[4] and the results are presented in Table. 1 to 3. The genotypes with higher mean values, regression coefficient value of unity ($b_i = 1$) and non-significant deviations from linear regression ($S^2d_i = 0$) were considered as stable for the trait and adaptable to varied environmental conditions studied in the present investigation. However, genotypes with a higher mean value and value of regression coefficient more than unity with non-significant deviation from linear regression were considered to be responsive and suitable for favourable environmental conditions. Further, the genotypes with higher mean values and regression coefficient less than unity or negative and non-significant deviations from linear regression were considered to be responsive and suitable for poor environmental conditions. Accordingly, the genotypes were classified as suitable for varied environmental

conditions. Trait wise results are described in subsequent paragraphs.

Days to 50% flowering

Perusal of data (Table 1) revealed that among the parents, GOB-1 (Mean = 64.00, $b_i = 0.38$ and $S^2d_i = -0.36$ NS) and GAOB-2 (Mean = 64.33, $b_i = 0.13$ and $S^2d_i = -0.35$ NS) showed desirable mean value than parental mean hence, these parents indicated above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent NBL-50 (Mean = 63.44, $b_i = -2.12$ and $S^2d_i = -0.51$ NS), registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses NBL-117 × GAOB-2, NBL-117 × GOB-1, BPG-3 × GNRB-1 and BPG-3 × GAOB-2 exhibited regression coefficient less than unity ($b_i < 1$) with lower (desirable) mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses *viz.*, NBL-50 × GAOB-2 and NBL-50 × GOB-1 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments.

According to Fig. 1, the genotypes or environments placed on left hand side of the vertical line possess less days to 50% flowering as compared to average and genotypes and environments placed on right hand side of vertical line possess more days. The genotypes G28, G27, G25, G8, G38, G30, G29, G37, G36, G26, G34, G5, G24, G21, G39, G6 and G4 possess less days to 50% flowering in increasing order while G1, G3, G35, G2, G23, G31, G33, G22, G7, G10, G20, G32, G15, G18, G9, G16, G17, G11, G12, G19, and G13 possess more days to 50% days to flowering in increasing order. The genotype G28 recorded less days to 50% flowering in all the environments and E_3 is most unstable environment among all the environments. The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig. 2 which also known as the IPCA 2 biplot. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G28 and G27 performed well in all three environments while G2 in E_1 , G11 and G12 in E_2 and E_3 performed poorly.

Fruit diameter

Among the parents, GJB-3 (Mean = 6.02, $b_i = -0.95$ and $S^2d_i = -0.001$ NS) and GAOB-2 (Mean = 4.92, $b_i = -1.26$ and $S^2d_i = -0.000$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent IC-110662 (Mean = 4.80, $b_i = 1.17$ and $S^2d_i = -0.000$ NS) and GJB-2 (Mean = 4.82, $b_i = 3.88$ and $S^2d_i = -0.000$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses GJB-2 × GOB-1, GJB-2 × Swarna Mani, GJB-2 × GNRB-1, IC-110662 × GAOB-2, IC-110662 × Swarna Mani, IC-110662 × GNRB-1, NBL-117 × GAOB-2, NBL-117 × GOB-1 and NBL-117 × GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean

than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses *viz.*, GJB-3 × GAOB-2, IC-110662 × GOB-1, GJB-2 × GAOB-2, GJB-2 × Swarna Mani, GJB-2 × GOB-1, GJB-2 × GNRB-1 and BPG-3 × GAOB-2 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments (Table 1).

According to Fig. 3, the genotypes or environments placed on left hand side of the vertical line possess less and genotypes and environments placed on right hand side of vertical line possess high fruit diameter compared average. The genotypes G9, G31, G34, G30, G11, G35, G23, G24, G10, G22, G7, G6, G5, G12, G8 and G27 possess less fruit diameter in increasing order while G29, G38, G4, G1, G3, G2, G39, G16, G37, G15, G14, G17, G18, G19 and G32 possess high fruit diameter in decreasing order. The genotype G29 recorded high fruit diameter in all the environments and E_3 is most unstable environment among all the environments. The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig. 4. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G29 performed well in all three environments while G9 performed poorly in all three environments.

Fruit weight

Perusal of data (Table 1) revealed that, among the parents, GJB-3 (Mean = 6.02, $b_i = -0.95$ and $S^2d_i = -0.001$ NS) and GAOB-2 (Mean = 4.92, $b_i = -1.26$ and $S^2d_i = -0.000$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent IC-110662 (Mean = 4.80, $b_i = 1.17$ and $S^2d_i = -0.000$ NS) and GJB-2 (Mean = 4.82, $b_i = 3.88$ and $S^2d_i = -0.000$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses GJB-2 × GAOB-2, GJB-2 × Swarna Mani, GJB-2 × GNRB-1, IC-110662 × GOB-1, NBL-117 × GAOB-2, GJB-3 × GAOB-2 and BPG-3 × GAOB-2 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses *viz.*, GJB-3 × GNRB-1, IC-110662 × Swarna Mani, IC-110662 × GNRB-1, NBL-117 × GOB-1, NBL-117 × Swarna Mani and NBL-117 × GNRB-1 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments.

According to Fig. 5, the genotypes or environments placed on left hand side of the vertical line possess less fruit weight and genotypes and environments placed on right hand side of vertical line possess high fruit weight. The genotypes G31, G11, G5, G30, G6, G7, G22, G10, G9, G8, G12, G35, G24 and G13 possess less fruit weight in increasing order while G3, G4, G38, G29, G39, G14, G2, G17, G32, G18 and G33 possess high fruit weight in decreasing order. E_3 is most unstable environment among all the environments. The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig. 6. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype.

According to this figure, G3 performed well in all three environments while G31 performed poorly in all three environments.

100 seed weight (mg)

From the data (Table 2) it is revealed that, among the parents, NBL-50 (Mean = 3.91, $b_i = 0.64$ and $S^2d_i = -0.001$ NS) AB-8/5 (Mean = 3.94, $b_i = 0.89$ and $S^2d_i = -0.001$ NS) and GAOB-2 (Mean = 4.05, $b_i = 0.28$ and $S^2d_i = -0.001$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent GJB-3 (Mean = 3.83, $b_i = 2.37$ and $S^2d_i = 0.000$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses NBL-117 \times GAOB-2, AB-8/5 \times Swarna Mani, AB-8/5 \times GOB-1 and NBL-50 \times GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses NBL-50 \times Swarna Mani, NBL-50 \times GAOB-2 GJB-3 \times GNRB-1, GJB-3 \times Swarna Mani and GJB-3 \times GOB-1 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments.

According to Fig. 7, the genotypes or environments placed on left hand side of the vertical line possess less 100 seed weight and genotypes and environments placed on right hand side of vertical line possess high 100 seed weight. The genotypes G8, G29, G9, G5, G2, G30, G31, G7, G4, G1, G10, G11, G3, G35 and G38 possess less 100 seed weight in increasing order while G34, G21, G24, G23, G22, G16, G17, G14, G28, G37, G27, G28, G39 and G25 possess high 100 seed weight in decreasing order. E_3 is most unstable environment among all the environments.

The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig. 8. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. G9 performed well in E_1 , G8 and G29 in E_2 G8 in E_3 while G34 performed poorly in E_1 and E_3 and G21 in E_2 .

Total fruit yield (t ha⁻¹)

Among parents, NBL-117 (Mean = 34.72, $b_i = 0.94$ and $S^2d_i = -0.49$ NS) and GNRB-1 (Mean = 33.70, $b_i = 0.95$ and $S^2d_i = -0.52$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent NBL-50 (Mean = 27.79, $b_i = 3.06$ and $S^2d_i = -0.49$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment (Table 2).

Among crosses NBL-117 \times Swarna Mani and NBL-117 \times GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses NBL-117 \times GAOB-2, NBL-117 \times GOB-1 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments.

According to Fig. 4.9, the genotypes or environments placed on left hand side of the vertical line possess less total yield (t ha⁻¹) and genotypes and environments placed on right hand side of vertical line possess total yield (t ha⁻¹). The genotypes G9, G34, G36, G2, G37, G14, G15, G13, G31, G1, G12, G28, G3, G21, G38 and G16 possess less total yield (t ha⁻¹) in increasing order while G35, G28, G25, G26, G39, G30, G5 and G7 possess high total yield (t ha⁻¹) in decreasing order. E_3 is most unstable environment among all the environments.

The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig.10. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G35 in E_1 , G27 in E_2 and E_3 performed well while G9 in E_1 , G2 in E_2 and G36 in E_3 performed poorly.

Total phenol content (mg 100 g⁻¹)

Among parents, GJB-3 (Mean = 0.77, $b_i = -1.01$ and $S^2d_i = -0.001$ NS), GJB-2 (Mean = 1.44, $b_i = -0.89$ and $S^2d_i = -0.001$ NS), GAOB-2 (Mean = 2.10, $b_i = -1.09$ and $S^2d_i = -0.001$ NS) and GNRB-1 (Mean = 1.64, $b_i = -3.89$ and $S^2d_i = -0.001$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent IC-110662 (Mean = 1.34, $b_i = 2.27$ and $S^2d_i = -0.001$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment. Among crosses NBL-50 \times GAOB-2, GJB-2 \times Swarna Mani, GJB-2 \times GNRB-1, BPG-3 \times GAOB-2, BPG-3 \times Swarna Mani, NBL-117 \times GAOB-2, NBL-117 \times Swarna Mani and NBL-117 \times GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The crosses NBL-50 \times GOB-1, NBL-50 \times GNRB-1, GJB-2 \times GAOB-2, GJB-2 \times GOB-1, BPG-3 \times GNRB-1 and NBL-117 \times GOB-1 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments (Table 2).

According to Fig. 11, the genotypes or environments placed on left hand side of the vertical line possess less total phenol content (mg 100 g⁻¹) and genotypes and environments placed on right hand side of vertical line possess total phenol content (mg 100 g⁻¹). The genotypes G3, G2, G9, G1, G15, G11, G12, G10, G16, G13, G31, G14, G32 and G37 possess less total phenol content (mg 100 g⁻¹) in increasing order while G36, G39, G30, G6, G38, G5, G33, G8, G19, G22, G18, G24, G17, G23, G28, G34, G7 and G26 possess high total phenol content (mg 100 g⁻¹) in decreasing order. E_3 is most unstable environment among all the environments.

The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig. 12. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G3 performed well in all three environments while G36 performed poorly in all three environments.

Vitamin-C (mg 100 g⁻¹)

Among parents, NBL-50 (Mean = 12.90, $b_i = 0.51$ and $S^2d_i = -0.12$ NS), AB-8/5 (Mean = 12.75, $b_i = 0.68$ and $S^2d_i = -0.12$ NS),

NS), GAOB-2 (Mean =15.21, $b_i = 0.30$ and $S^2d_i = -0.12$ NS) and GNRB-1 (Mean = 12.59, $b_i = 0.02$ and $S^2d_i = -0.12$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent IC-110662 (Mean = 13.54, $b_i = 1.78$ and $S^2d_i = -0.12$ NS), BPG-3 (Mean = 12.67, $b_i = 1.41$ and $S^2d_i = -0.12$ NS) and NBL-117 (Mean = 13.23, $b_i = 3.04$ and $S^2d_i = -0.07$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses GJB-3 × GAOB-2, GJB-3 × GOB-1, NBL-50 × GNRB-1, NBL-50 × GAOB-2, IC-110662 × GAOB-2, IC-110662 × GOB-1, GJB-2 × GNRB-1, BPG-3 × GAOB-2, BPG-3 × GOB-1, NBL-117 × GAOB-2, NBL-117 × Swarna Mani, NBL-117 × GOB-1 and NBL-117 × GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The BPG-3 × GNRB-1 and BPG-3 × Swarna Mani exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments (Table 3).

According to Fig.13, the genotypes or environments placed on left hand side of the vertical line possess less vitamin-C (mg 100 g⁻¹) and genotypes and environments placed on right hand side of vertical line possess vitamin-C (mg 100 g⁻¹). The genotypes G38, G37, G6, G29, G7, G4, G9, G33 and G2 possess less vitamin-C (mg 100 g⁻¹) in increasing order while G36, G21, G23, G22, G24, G32, G35, G28, G28, G14 and G27 possess high vitamin-C (mg 100 g⁻¹) in decreasing order. E₃ is most unstable environment among all the environments. The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig.14. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G36 performed well in all three environments while G38 performed poorly in all three environments.

Total anthocyanin content (mg 100 g⁻¹)

Among parents, NBL-50 (Mean = 80.77, $b_i = -0.28$ and $S^2d_i = -0.05$ NS), IC-110662 (Mean =81.57, $b_i = -0.12$ and $S^2d_i =$

0.01 NS), BPG-3 (Mean= 87.50, $b_i = 0.45$ and $S^2d_i = -0.06$ NS), NBL-117 (Mean = 80.37, $b_i = 0.22$ and $S^2d_i = -0.06$ NS) and GAOB-2 (Mean =88.68, $b_i = -2.60$ and $S^2d_i = 0.16$ NS) showed above average stability and specifically adapted to unfavorable environment with mean value in desirable direction, b_i value less than unity and non-significant S^2d_i values. The parent AB-8/5 (Mean = 86.26, $b_i = 3.94$ and $S^2d_i = -0.07$ NS) registered mean values in desired direction along with b_i value more than unity and non-significant S^2d_i values hence, had below average stability and specifically adapted to favourable environment.

Among crosses NBL-50 × GAOB-2, NBL-50 × GOB-1, NBL-50 × GNRB-1, AB-8/5 × GAOB-2, AB-8/5 × GOB-1, AB-8/5 × GNRB-1, AB-8/5 × Swarna Mani, IC-110662 × GNRB-1, IC-110662 × GOB-1, BPG-3 × GAOB-2, BPG-3 × GOB-1, NBL-117 × Swarna Mani, NBL-117 × GOB-1 and NBL-117 × GNRB-1 exhibited regression coefficient less than unity ($b_i < 1$) desirable mean than population mean and non-significant S^2d_i indicated their stability under unfavorable environments. The NBL-50 × Swarna Mani, IC-110662 × GAOB-2, IC-110662 × Swarna Mani, BPG-3 × GNRB-1, BPG-3 × Swarna Mani and NBL-117 × GAOB-2 exhibited regression coefficient greater than unity ($b_i > 1$) with desirable mean value indicated its suitability and stability under favorable environments (Table 3).

According to Fig. 15, the genotypes or environments placed on left hand side of the vertical line possess less total anthocyanin content (mg 100 g⁻¹) and genotypes and environments placed on right hand side of vertical line possess total anthocyanin content (mg 100 g⁻¹). The genotypes G29, G3, G2, G1, G37, G33, G38, G19, G18, G17, G20 and G39 possess less total anthocyanin content (mg 100 g⁻¹) in increasing order while G10, G9, G24, G21, G11, G36, G22, G12, G34, G23, G31, G6, G16, G13 and G7 possess high total anthocyanin content (mg 100 g⁻¹) in decreasing order. E₃ is most unstable environment among all the environments.

The performance of PC1 and PC2 scores for 40 genotypes and 3 environments is indicated in Fig.16. The origin of the graph which lies at zero on the x-axis and y-axis represented the most stable genotypes as compared to another genotype. According to this figure, G10 performed well in all three environments while G3 performed poorly in all three environments.

Table 1: Stability parameters for days to 50 % flowering, fruit diameter and fruit weight for parents and hybrids in brinjal

Genotypes	Days to 50 % flowering					Fruit diameter (cm)					Fruit weight (g)				
	Mean	b_i	$b_i = 0$	$b_i = 1$	S^2d_i	Mean	b_i	$b_i = 0$	$b_i = 1$	S^2d_i	Mean	b_i	$b_i = 0$	$b_i = 1$	S^2d_i
G1	66.44	0.73			0.74	5.25	6.03	**	++	0.009*	57.76	0.35	**	++	-0.06
G2	66.66	0.26			0.12	5.05	-0.06		++	-0.001	63.69	1.49	*		0.22*
G3	66.44	0.37	**	++	-0.50	5.14	-1.85	**	++	-0.001	83.08	1.82			0.84**
G4	66.22	1.27			2.88*	5.40	-2.97	**	++	-0.003	81.33	1.33	**		0.06
G5	65.33	1.14			0.85	4.38	4.12	**	++	-0.000	30.25	1.12	**		-0.03
G6	66.11	2.48	**	+	0.94	4.39	-1.26	**	++	-0.001	30.96	0.48			0.07
G7	67.55	2.37	**	++	-0.45	4.37	2.01	**	+	0.000	31.03	0.51	*		-0.03
G8	62.11	-2.33		+	6.75**	4.41	1.96	**	++	-0.001	34.09	-0.15		++	-0.06
G9	68.55	2.23	**		1.63*	3.88	1.01			0.002	33.28	0.12		+	0.05
G10	67.77	3.23	**	++	1.02	4.25	1.56	**	++	0.000	33.26	0.44			-0.02
G11	69.11	2.11	**	++	0.09	4.17	3.64	**	+	0.006*	29.92	0.32			0.08
G12	69.11	2.36	**	++	0.11	4.40	8.03			0.083**	34.34	1.32	**		0.07
G13	69.55	2.46	*		4.75**	4.85	0.43			0.001	46.02	-0.11	**	++	-0.07
G14	68.55	2.12	**	++	-0.46	4.88	2.01	**	+	0.000	66.09	-0.17	**	++	-0.07
G15	68.44	2.98	**	++	0.99	4.94	0.44	**	++	-0.001	55.05	1.35	**	++	-0.07
G16	68.55	1.73	*		1.56*	5.01	-1.60	**	++	-0.000	58.63	1.25	**		-0.01
G17	68.66	1.62	**	++	-0.40	4.86	2.61	**	++	0.001	62.79	0.24		++	-0.02
G18	68.44	0.62	**	++	-0.50	4.82	2.92	**	++	0.001	61.65	-0.14			0.86**

G19	68.55	1.50	**	++	-0.47	4.82	4.03	**	+	0.010*	59.29	-0.16			0.20
G20	67.77	0.39			2.54*	4.85	2.25	*		0.003	57.89	0.23	**	++	-0.06
G21	66.00	-0.35		+	1.02	4.78	2.33	**	++	-0.000	59.09	0.73	**		-0.04
G22	67.33	-0.25	**	++	-0.51	4.28	3.89	**	++	-0.000	32.70	1.99	**	++	0.07
G23	66.88	-0.24		++	-0.43	4.19	0.21			0.006*	33.80	1.34			0.38*

Table 1: Stability parameters for days to 50 % flowering, fruit diameter and fruit weight for parents and hybrids in brinjal (Contd...2)

Genotypes	Days to 50 % flowering					Fruit diameter (cm)					Fruit weight (g)				
	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i
G24	65.77	0.50			-0.24	4.23	-3.14	*	++	0.009*	39.17	1.71	**	++	0.00
G25	61.66	-2.98	**	++	0.39	4.72	0.94	**		-0.001	51.24	0.98	**		-0.01
G26	64.44	-0.61		++	0.44	4.90	0.40		+	-0.001	55.03	1.42	**	++	-0.07
G27	60.44	-1.45			8.87**	4.55	1.86	**	++	-0.001	53.51	1.54	**	++	-0.07
G28	59.00	-0.57			13.19**	4.91	-1.89	*	++	0.001	50.31	2.01	**	++	0.06
Hybrid mean	66.48					4.67					49.40				
Parents (Female)															
G29	64.00	2.21			6.01**	6.02	-0.95	**	++	-0.001	75.89	-0.46			0.71*
G30	63.44	2.12	**	++	-0.51	4.15	-2.05		++	0.005*	30.74	0.98			0.36*
G31	67.11	3.22	**	+	3.72*	3.93	2.00	**		0.000	28.37	1.13			0.21*
G32	67.88	2.35	*		3.02*	4.80	1.17	**		-0.000	61.98	-0.40		+	0.36*
G33	67.11	1.97			3.48*	4.82	3.88	**	++	-0.000	51.65	0.99			0.46*
G34	65.11	1.10			1.88*	4.13	1.10			0.001	55.79	10.47	*		30.68**
G35	66.55	2.48	**		1.67*	4.18	-0.57		++	-0.000	37.19	1.46	**	++	-0.06
Male															
G36	64.33	0.13			-0.35	4.92	-1.26	*	++	-0.000	57.01	-0.14		++	-0.06
G37	64.00	0.38			-0.36	4.96	-3.66	*	++	0.009*	57.88	0.40	**	++	-0.04
G38	62.22	-0.35			1.77*	5.58	-3.02			0.017**	77.69	1.44	*		0.30*
G39	66.11	2.24	**	++	-0.37	5.05	1.60	**	++	-0.001	69.59	1.24	**		0.10
Parental mean	65.26					4.78					54.89				
Standard check															
G40	60.11	-1.60		+	2.88*	5.03	1.55	**	++	0.008*	71.25	-0.55			0.02
Population mean	66.13	1.00				4.70	1.00				51.02	1.00			

*, ** Significant at 5 % and 1 % probability levels, respectively when b_i = 0
 +, ++ Significant at 5 % and 1 % probability levels, respectively when b_i = 1

Table 2: Stability parameters for 100 seed weight, total fruit yield and total phenol content for parents and hybrids in brinjal

Genotypes	100 seed weight (mg)					Total fruit yield (t ha-1)					Total phenol content (mg 100 g-1)				
	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i
G1	4.03	3.67			0.008*	22.63	-0.33	**	++	-0.52	0.76	2.88	**	++	-0.001
G2	3.90	2.86	**	+	-0.006	21.71	0.20			3.32*	0.74	3.35			0.003
G3	4.05	1.60	**		-0.001	23.50	2.35			0.66	0.71	3.13	**	+	-0.001
G4	3.96	2.14	**	++	-0.001	22.58	1.03	**		-0.52	0.79	4.46	**	++	-0.001
G5	3.88	2.81	**	++	-0.001	25.79	1.36	*		-0.25	1.50	-0.28			-0.000
G6	4.12	6.64	**	++	-0.001	24.55	0.45			0.14	1.53	3.15	**	++	-0.001
G7	3.94	2.06	**	+	-0.000	25.40	-0.58		++	-0.32	1.28	-6.88			0.005*
G8	3.80	-1.50	**	++	-0.001	24.55	0.26			-0.42	1.39	2.33	*		-0.001
G9	3.83	4.36			0.037**	20.02	-5.88			10.83**	0.75	3.23	**	++	-0.001
G10	4.04	-0.42		++	-0.001	22.40	0.37	**	++	-0.51	22.40	0.37	**	++	-0.51
G11	4.05	-0.03			-0.000	23.54	0.75			0.60	0.78	8.82	**	++	-0.000
G12	4.11	0.91			-0.000	22.96	0.61	**		-0.48	0.77	6.20	**	++	-0.000
G13	4.11	0.87			-0.000	22.40	-0.66		+	-0.20	0.77	3.00			-0.000
G14	4.12	0.06			-0.001	21.95	-1.61		+	0.22	0.81	5.70	**	++	-0.001
G15	4.11	1.02			-0.000	22.11	1.73	**	+	-0.45	0.83	1.84			-0.001
G16	4.16	-0.07			-0.000	24.65	1.43	*		-0.27	0.77	4.74	**	+	-0.000
G17	4.14	0.95	**	++	-0.001	24.21	2.66	**	++	-0.46	0.80	6.25	**	++	-0.000
G18	4.11	0.51			-0.000	22.86	1.07	*		-0.36	1.30	2.10			0.000
G19	4.11	0.86	**		-0.001	22.80	1.46	**		-0.41	1.33	1.31			-0.001
G20	4.13	0.24			-0.001	23.16	1.47	**		-0.41	1.37	-6.10	**	++	-0.001
G21	4.27	0.48			-0.000	24.10	1.83	**	++	-0.52	1.28	-0.69		+	-0.001
G22	4.21	4.60	**	++	-0.001	24.77	3.91	**	++	-0.15	1.24	0.54			-0.001
G23	4.22	1.70	*		0.000	22.95	0.55			0.13	1.33	-0.56			0.000

Table 2: Stability parameters for 100 seed weight, total fruit yield and total phenol content for parents and hybrids in brinjal (Contd...2)

Genotypes	100 seed weight (mg)					Total fruit yield (t ha-1)					Total phenol content (mg 100 g-1)				
	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i
G24	4.26	1.83	**	++	-0.001	23.25	1.22	**		-0.51	1.30	2.04			-0.001
G25	4.04	-0.37	*	++	-0.001	33.67	1.12	**		-0.48	1.26	-1.19		++	-0.001
G26	4.08	-1.02	**	++	-0.001	32.30	4.52	**	++	0.67	1.24	3.23			0.000
G27	4.09	-1.47		++	-0.000	34.54	-0.18			0.68	1.25	-2.71	*	++	-0.000
G28	4.10	-0.62		+	-0.000	33.69	0.84	**	++	-0.51	1.28	-1.65			-0.000
Hybrid mean	4.07					24.75					1.09				
Parents (Female)															
G29	3.83	2.37	*		0.000	23.19	2.36	*		0.36	0.77	-1.01	**	++	-0.001
G30	3.91	0.64			-0.001	27.79	3.06	**	++	-0.49	1.60	-1.37			0.006
G31	3.94	0.89	**		-0.001	22.43	0.79			-0.38	0.82	1.89			0.000
G32	4.12	0.51	**	++	-0.001	23.21	1.05			0.03	1.34	2.27	**		-0.001
G33	4.13	0.29	**	++	-0.001	23.48	0.46			0.07	1.44	-0.89	**	++	-0.001
G34	4.27	1.58	**	++	-0.001	20.67	1.72			0.05	1.28	-2.88			0.005*
G35	4.06	-1.15	*	++	-0.001	34.72	0.94	**	++	-0.49	1.25	-1.32			0.000
Male															
G36	4.05	0.28		++	-0.001	20.89	0.66	**	++	-0.51	2.10	-1.09			-0.001
G37	4.10	-0.71			0.000	21.90	-0.37			5.84**	0.98	3.96			0.001
G38	4.06	0.75			-0.001	24.22	4.23	*		1.88*	1.53	-2.08			0.008*
G39	4.09	0.17			-0.000	33.70	0.95	**	++	-0.52	1.64	-3.89	**	++	-0.001
Parental mean	4.05					25.10					1.30				
Standard check															
G40	4.08	-0.32			-0.001	33.20	-1.49	**	++	0.13	1.60	-0.59		+	-0.001
Population mean	4.06	1.00				27.55	1.00				1.16	1.00			

*, ** Significant at 5 % and 1 % probability levels, respectively when b_i = 0

+, ++ Significant at 5 % and 1 % probability levels, respectively when b_i = 1

Table 3: Stability parameters for vitamin-C and total anthocyanin content for parents and hybrids in brinjal

Genotypes	Vitamin-C (mg 100 g-1)					Total anthocyanin content (mg 100 g-1)				
	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i
G1	12.77	0.39			-0.08	23.10	0.01		++	-0.06
G2	12.71	-0.74	**	++	-0.13	22.68	-0.20		++	-0.05
G3	12.31	-0.21		++	-0.13	21.85	3.07			0.03
G4	11.90	-0.40		++	-0.12	22.46	0.33			-0.04
G5	12.78	0.56			-0.12	79.23	-0.17		++	-0.05
G6	11.46	15.56	**	++	-0.04	82.26	0.60	**	++	-0.06
G7	11.76	1.41	**	++	-0.13	76.62	4.01	**	++	-0.06
G8	12.73	0.54	*		-0.12	81.05	0.03		++	-0.06
G9	11.98	0.57	**	++	-0.12	91.28	0.56			-0.04
G10	12.34	1.15	**	++	-0.13	93.77	-1.38		++	-0.04
G11	12.37	0.23		++	-0.12	88.48	-0.37	*	++	-0.06
G12	12.34	-0.21	*	++	-0.13	87.84	0.27			-0.05
G13	12.90	0.80			-0.11	84.51	1.46	**		-0.06
G14	13.03	-0.59		+	-0.11	81.79	0.65	**	+	-0.06
G15	12.62	0.85			-0.12	82.75	1.60			0.09
G16	12.53	1.75			-0.07	84.61	-0.06			-0.05
G17	12.49	0.33		++	-0.13	61.47	2.33	**	++	-0.06
G18	12.27	0.94	**		-0.12	59.34	-1.12	**	++	-0.05
G19	12.60	0.07			-0.09	58.65	0.20			-0.05
G20	12.74	0.66	**		-0.12	63.29	1.62	**		-0.06
G21	14.25	0.67	**		-0.12	89.27	-0.84	*	++	-0.05
G22	14.08	0.56			-0.11	88.14	-2.46			0.17
G23	14.25	2.75	**	+	-0.10	86.92	2.53			0.45*
G24	13.73	3.24	**	++	-0.13	89.35	2.82	**	++	-0.06
G25	12.92	0.78	**		-0.12	83.48	1.22			-0.05
G26	12.87	0.78	**	++	-0.13	84.13	-0.75		++	-0.05
G27	12.78	0.05		+	-0.12	81.08	-0.01		++	-0.06
G28	13.11	-0.08		++	-0.13	80.75	0.68			-0.05
Hybrid mean	12.73					72.50				

Table 3: Stability parameters for vitamin-C and total anthocyanin content for parents and hybrids in brinjal for parents and hybrids in brinjal (Contd...2)

Genotypes	Vitamin-C (mg 100 g-1)					Total anthocyanin content (mg 100 g-1)				
	Mean	b _i	b _i = 0	b _i = 1	S ² d _i	Mean	b _i	b _i = 0	b _i = 1	S ² d _i
Parents (Female)										
G29	11.54	-0.86	**	++	-0.12	21.14	-1.14			0.29*
G30	12.90	0.51	**	++	-0.12	80.77	-0.28			-0.05
G31	12.75	0.68			-0.12	86.26	3.94	**	++	-0.07
G32	13.54	1.78	**	++	-0.12	81.57	-0.12			0.01
G33	12.29	0.58			-0.10	56.43	0.56			-0.01
G34	12.67	1.41	**		-0.12	87.50	0.45			-0.06
G35	13.23	3.04	*		-0.04	80.37	0.22		++	-0.06
Male										
G36	15.21	0.30			-0.12	88.68	-2.60			0.16
G37	10.82	-0.06		++	-0.12	36.84	0.32			-0.04
G38	9.93	-0.10			-0.10	57.21	-2.57			0.39*
G39	12.59	0.02		++	-0.12	63.90	5.81	**	++	-0.05
Parental mean	12.50					67.33				
Standard check										
G40	12.56	0.16		++	-0.13	71.62	-0.71			-0.05
Population mean	12.67	1.00				71.06	1.00			

*, ** Significant at 5 % and 1 % probability levels, respectively when b_i = 0
 +, ++ Significant at 5 % and 1 % probability levels, respectively when b_i = 1

Genotypes:

- | | | | |
|---------------------------------|-------------------------------------|-----------------------------------|-------------------------|
| G1- GJB-3 × GAOB-2 | G11- AB-8/5 × Swarna Mani | G21- BPG-3 × GAOB-2 | G31- AB-8/5 |
| G2- GJB-3 × GOB-1 | G12- AB-8/5 × GNRB-1 | G22- BPG-3 × GOB-1 | G32- IC-110662 |
| G3- GJB-3 × Swarna Mani | G13- IC-110662 × GAOB-2 | G23- BPG-3 × Swarna Mani | G33- GJB-2 |
| G4- GJB-3 × GNRB-1 | G14- IC-110662 × GOB-1 | G24- BPG-3 × GNRB-1 | G34- BPG-3 |
| G5- NBL-50 × GAOB-2 | G15- IC-110662 × Swarna Mani | G25- NBL-117 × GAOB-2 | G35- NBL-117 |
| G6- NBL-50 × GOB-1 | G16- IC-110662 × GNRB-1 | G26- NBL-117 × GOB-1 | G36- GAOB-2 |
| G7- NBL-50 × Swarna Mani | G17- GJB-2 × GAOB-2 | G27- NBL-117 × Swarna Mani | G37- GOB-1 |
| G8- NBL-50 × GNRB-1 | G18- GJB-2 × GOB-1 | G28- NBL-117 × GNRB-1 | G38- Swarna Mani |
| G9- AB-8/5 × GAOB-2 | G19- GJB-2 × Swarna Mani | G29- GJB-3 | G39- GNRB-1 |
| G10- AB-8/5 × GOB-1 | G20- GJB-2 × GNRB-1 | G30- NBL-50 | G40- GNRB-1 |

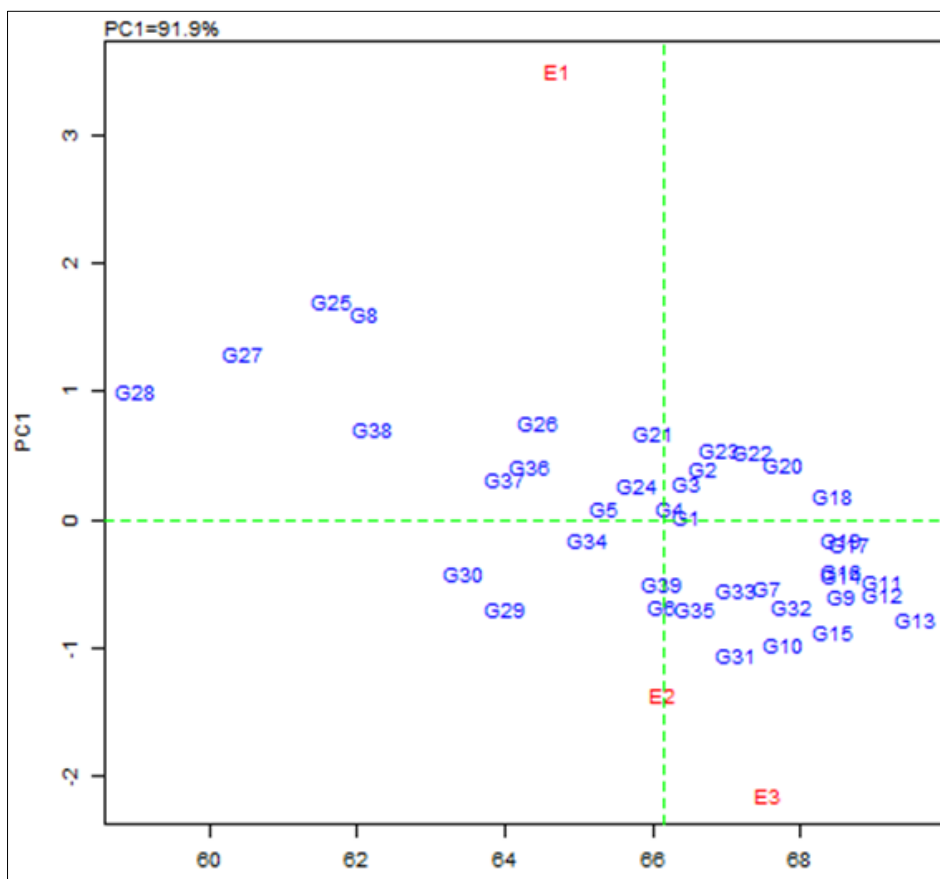


Fig 1: AMMI 1 (Mean vs PC1) biplot for days to 50% flowering

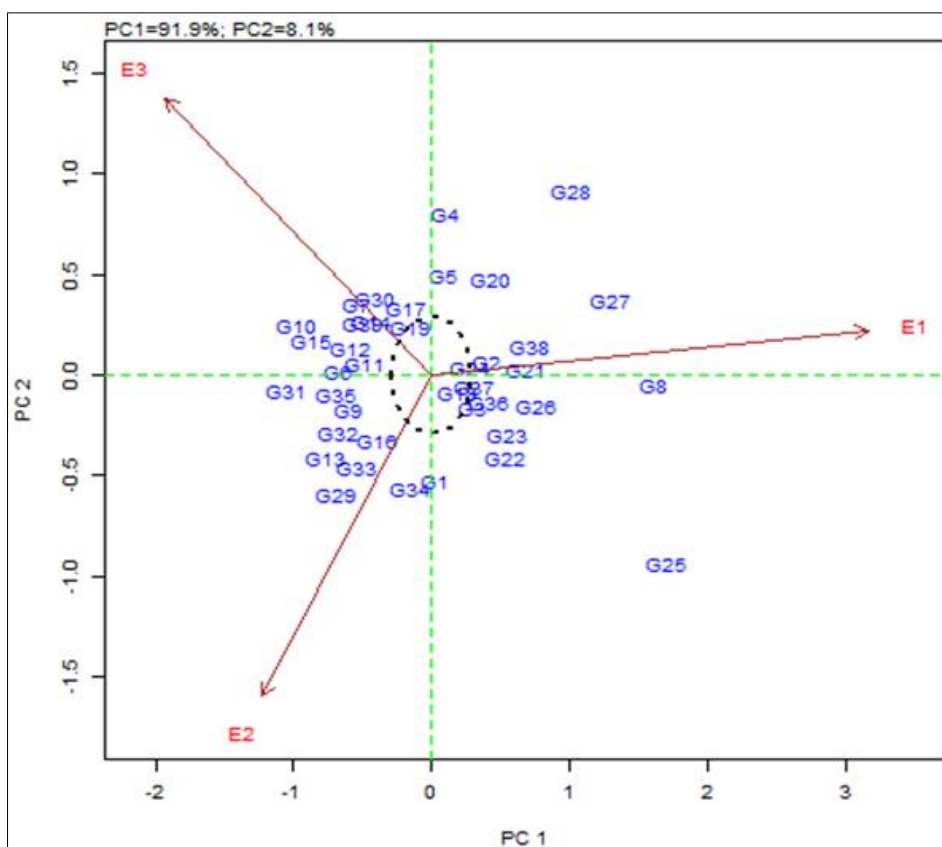


Fig 2: AMMI 1 (PC1 vs PC2) biplot for days to 50% flowering

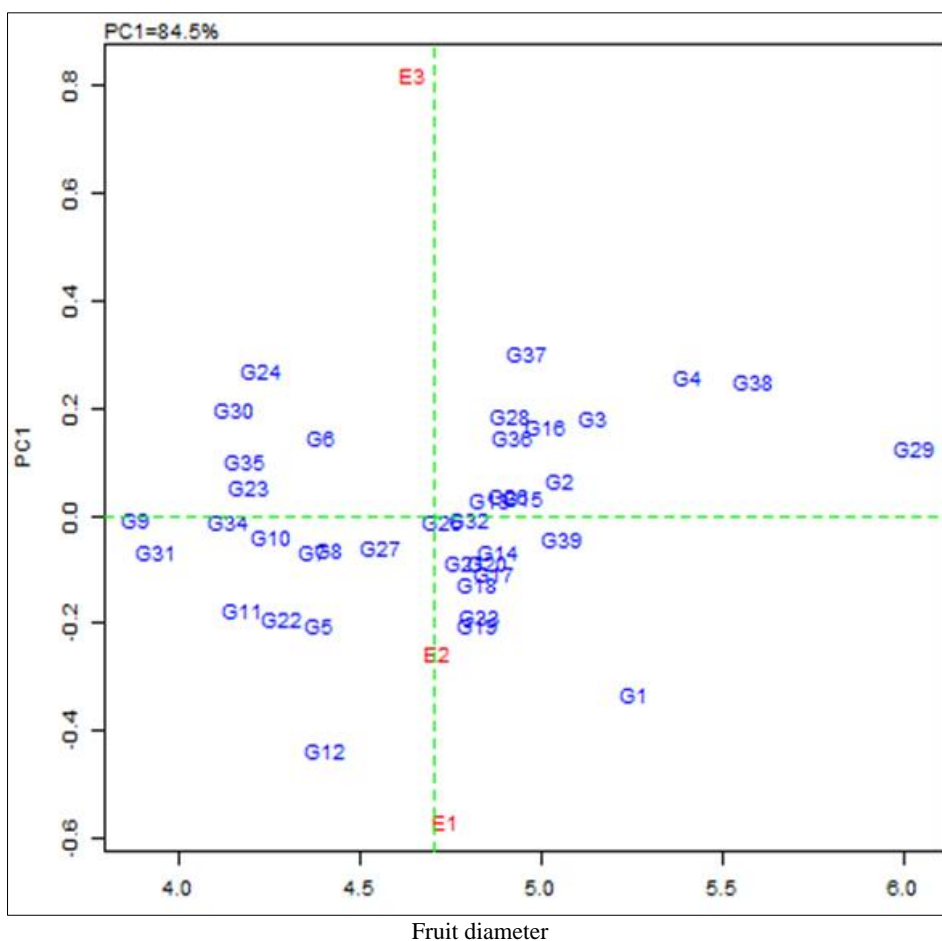


Fig 3: AMMI 1 (Mean vs PC1) biplot for fruit diameter

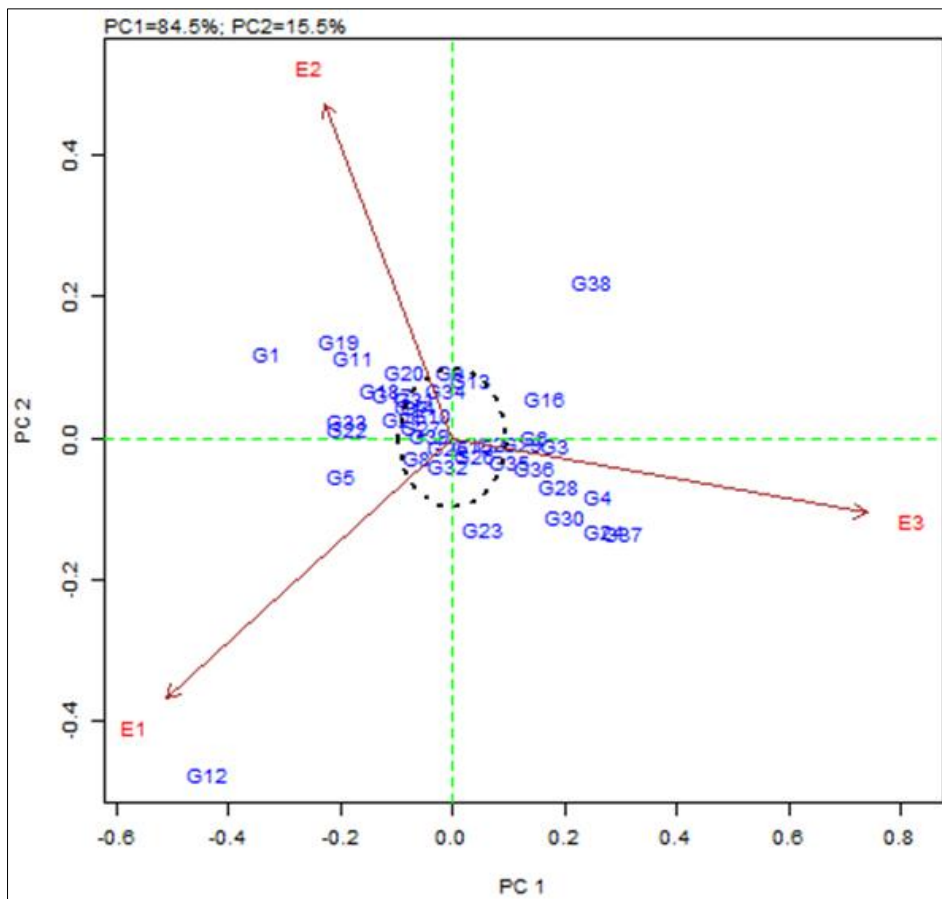


Fig 4: AMMI 1 (PC1 vs PC2) biplot for fruit diameter

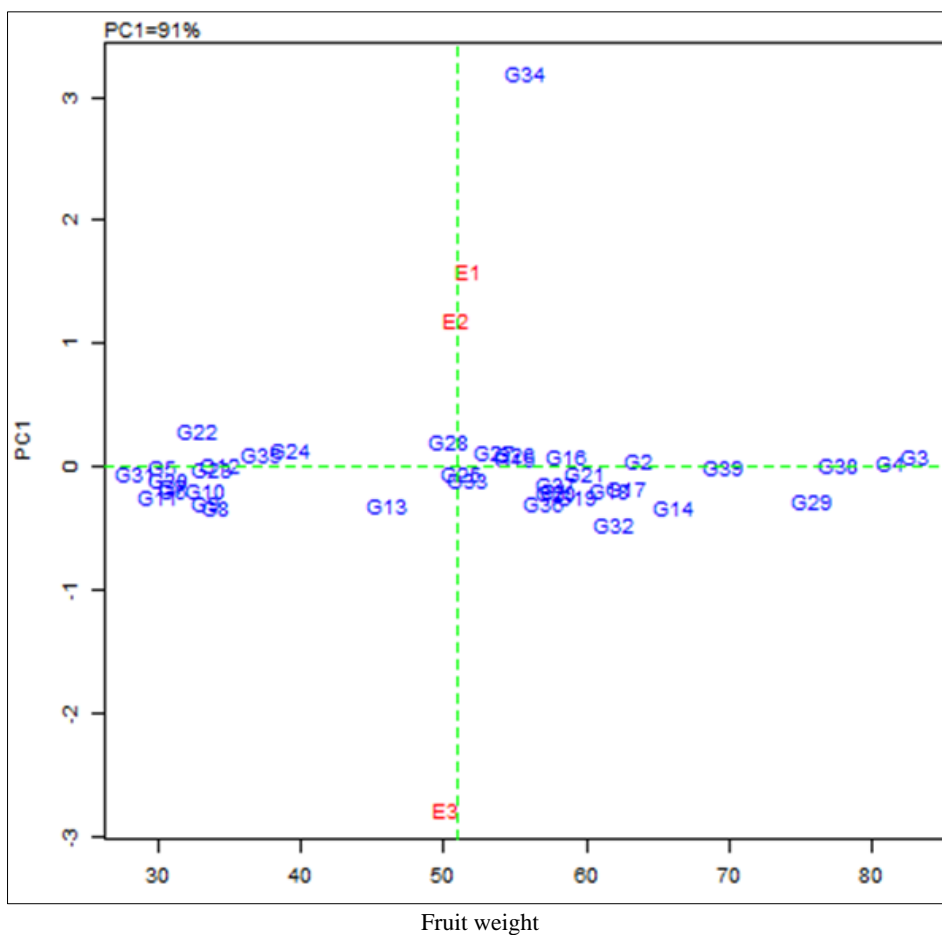


Fig 5: AMMI 1 (Mean vs PC1) biplot for fruit weight

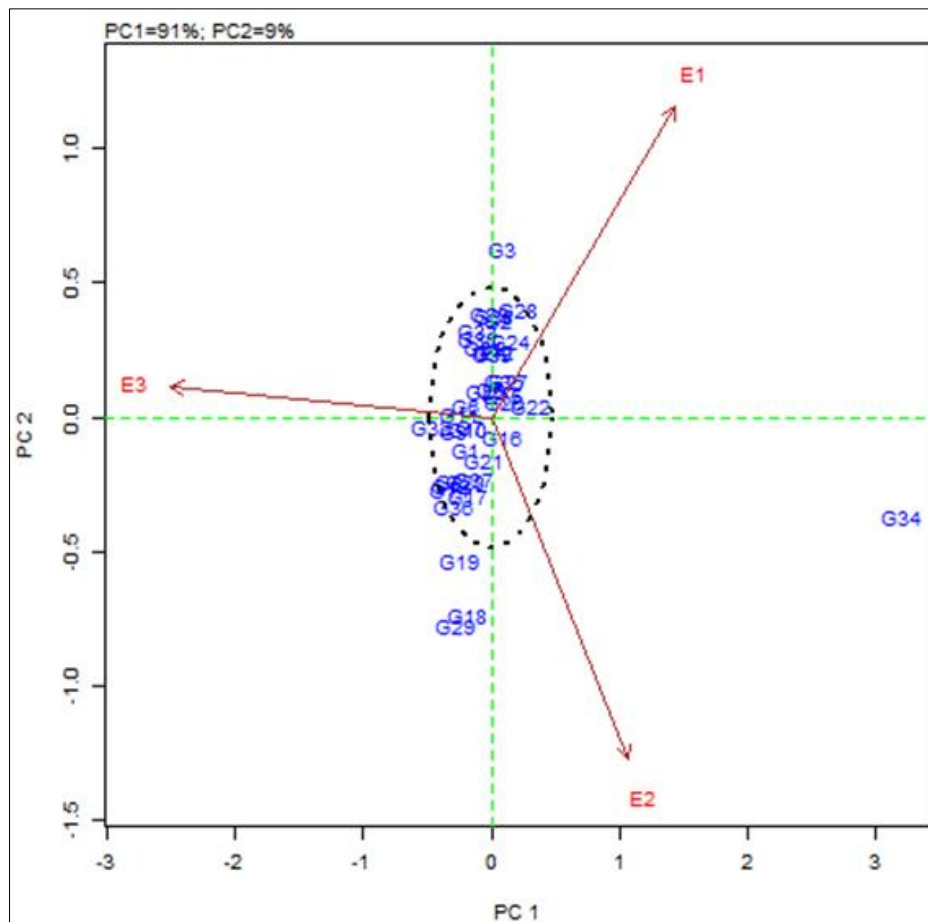


Fig 6: AMMI 1 (PC1 vs PC2) biplot for fruit weight

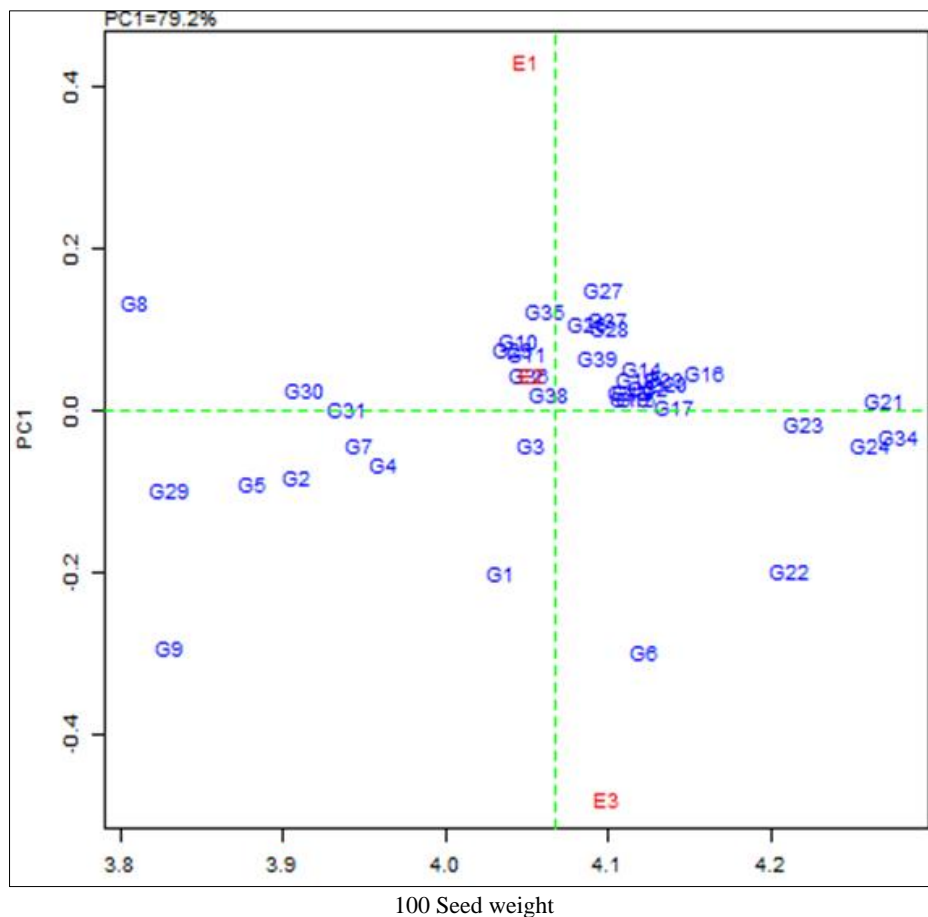


Fig 7: AMMI 1 (Mean vs PC1) biplot for 100 Seed weight

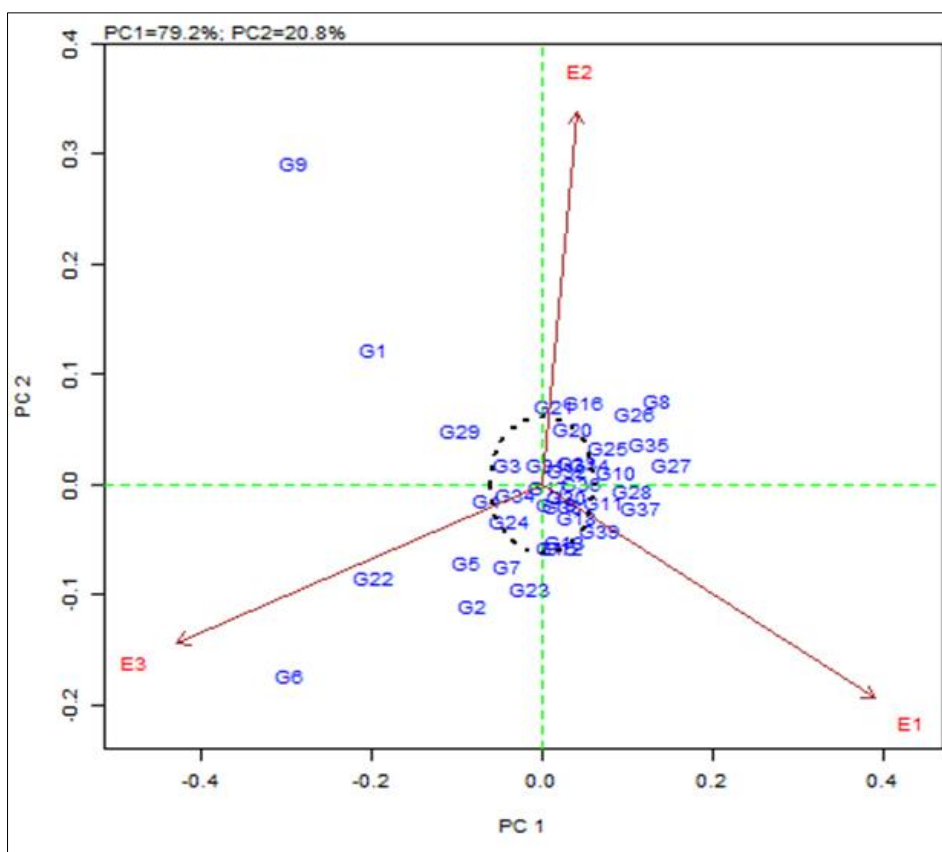


Fig 8: AMMI 1 (PC1 vs PC2) biplot for 100 Seed weight

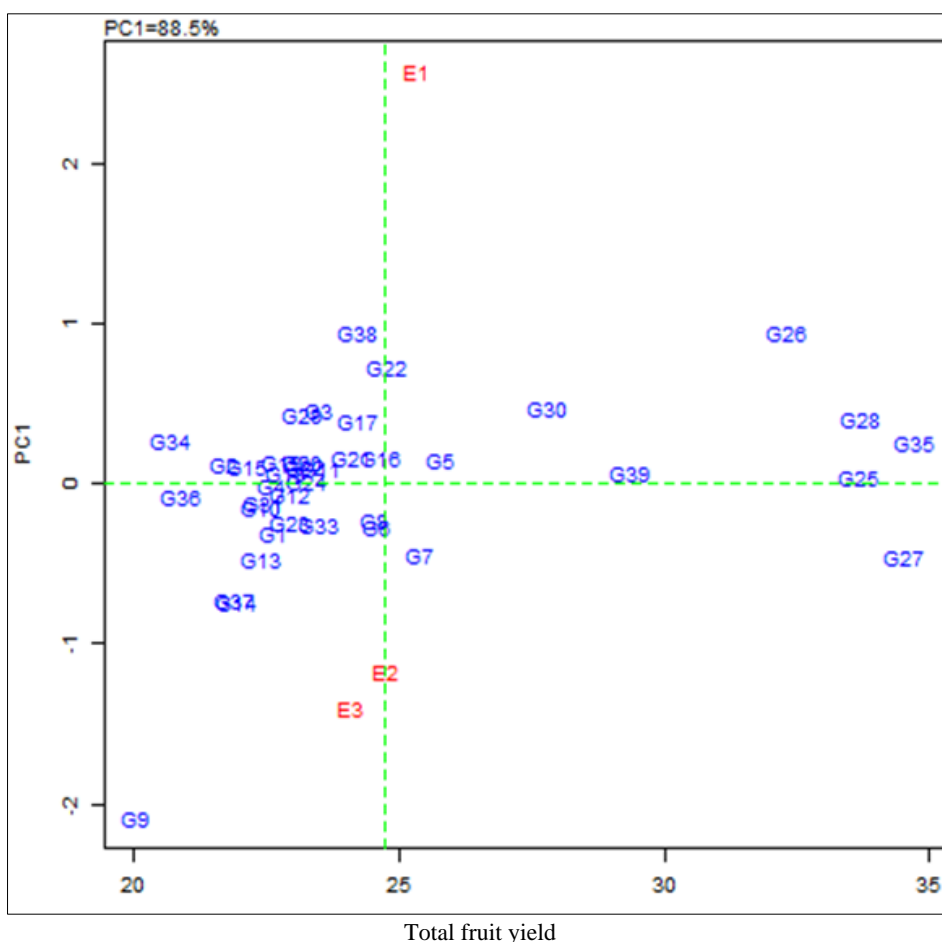


Fig 9: AMMI 1 (Mean vs PC1) biplot for total fruit yield

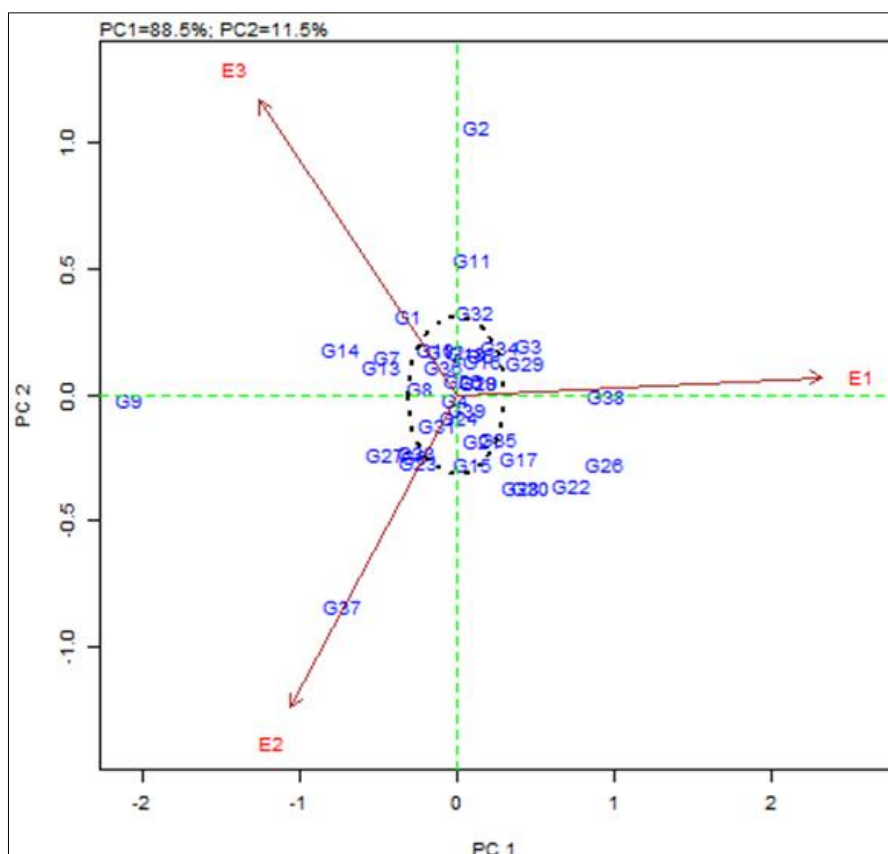


Fig 10: AMMI 1 (PC1 vs PC2) biplot for total fruit yield

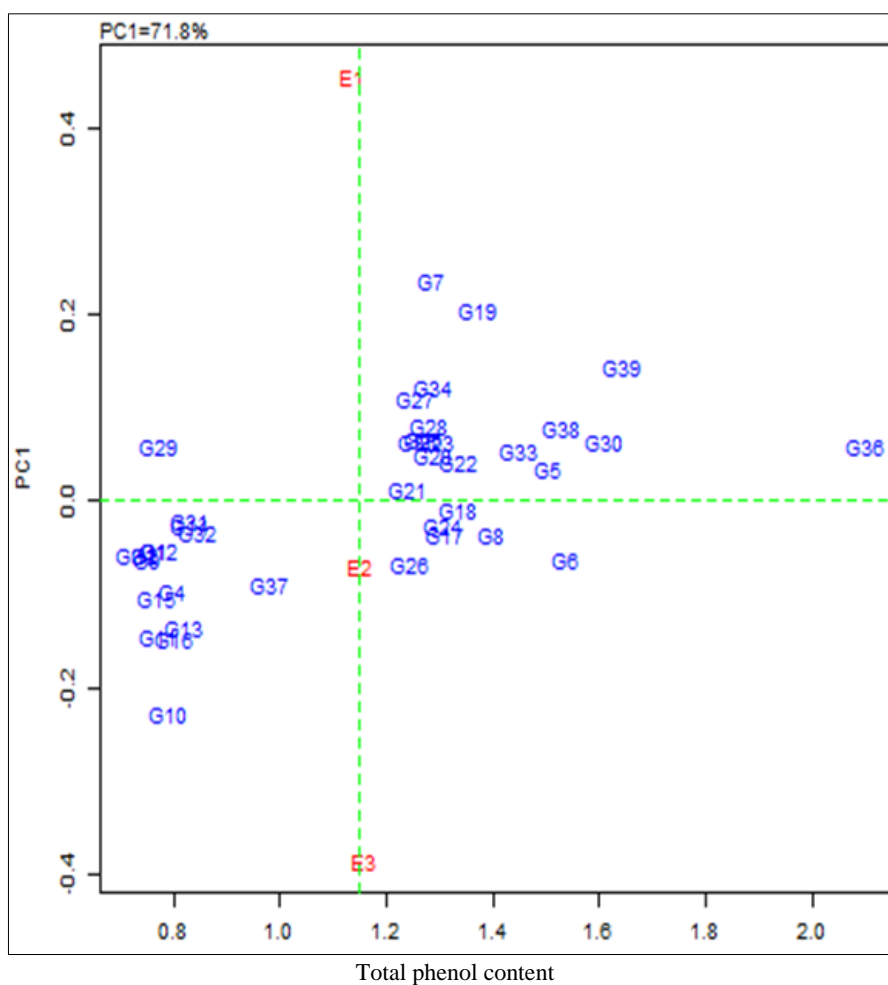


Fig 11: AMMI 1 (Mean vs PC1) biplot for total phenol content

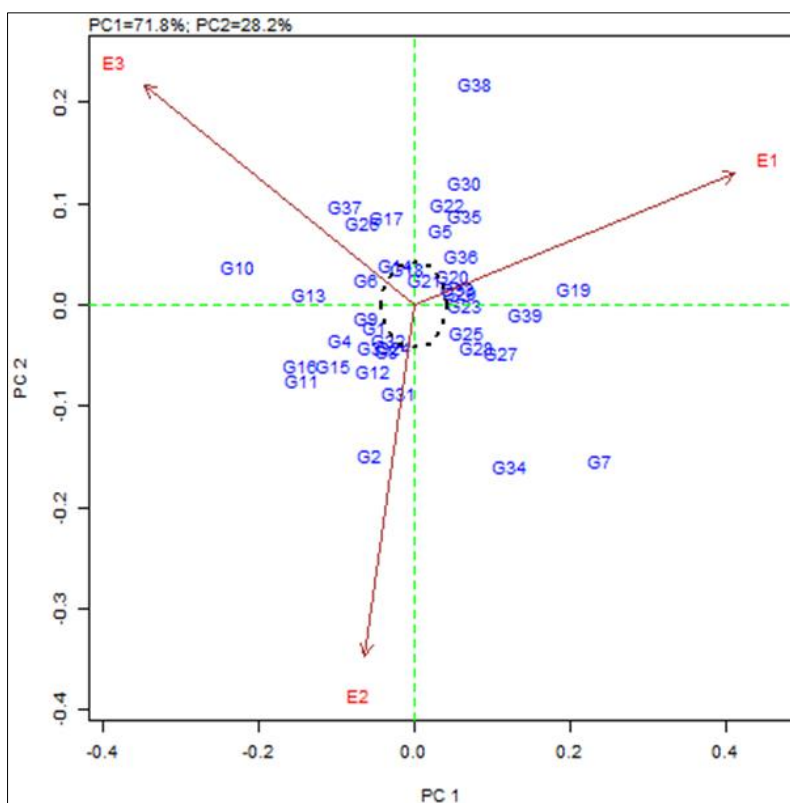


Fig 12: AMMI 1 (PC1 vs PC2) biplot for total phenol content

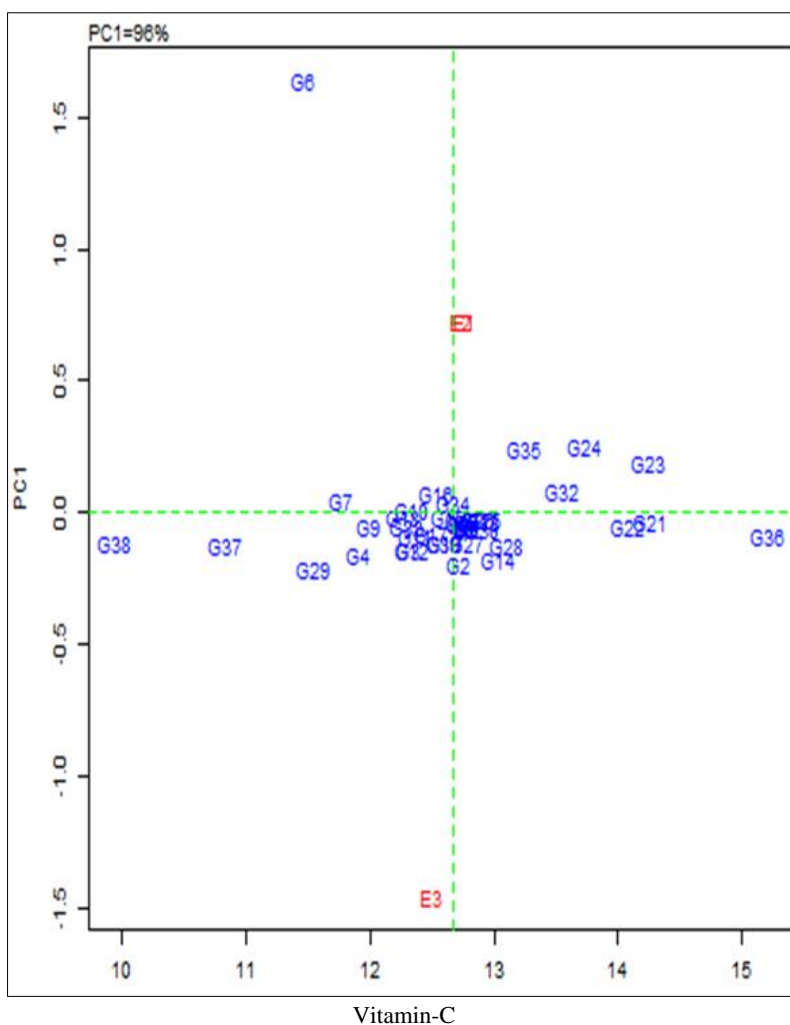


Fig 13: AMMI 1 (Mean vs PC1) biplot for Vitamin-C

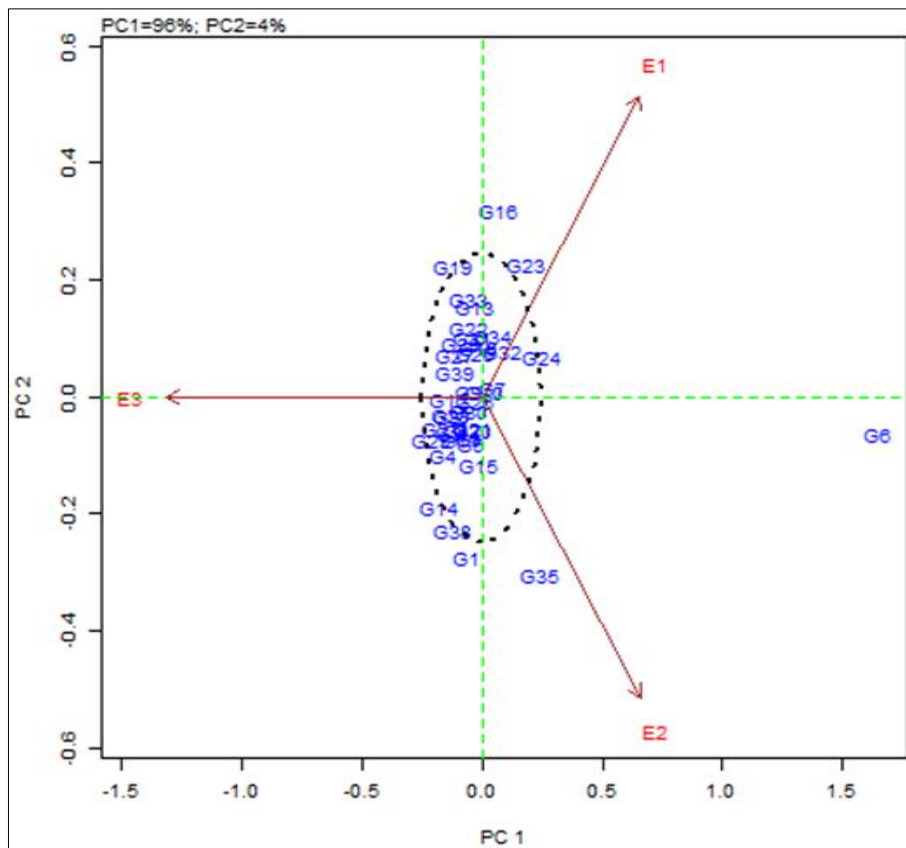


Fig 14: AMMI 1 (PC1 vs PC2) biplot for Vitamin-C

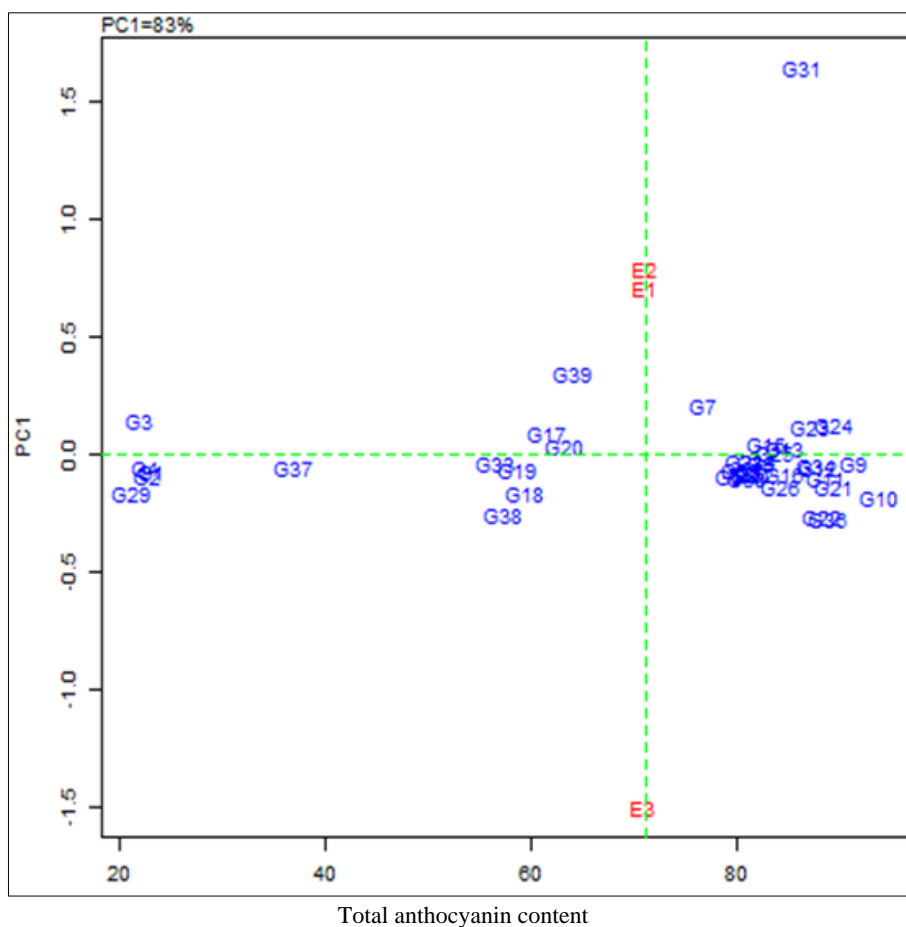


Fig 15: AMMI 1 (Mean vs PC1) biplot for total anthocyanin content

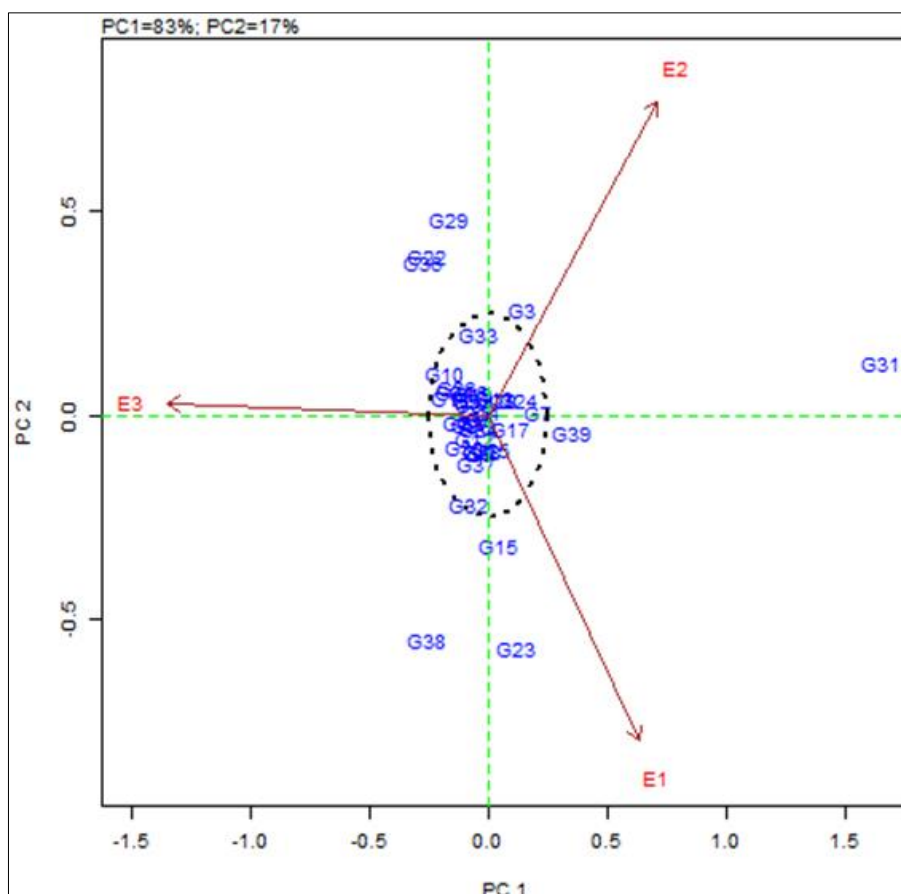


Fig 16: AMMI 1 (PC1 vs PC2) biplot for total anthocyanin content

Conclusion

In the breeding programme, NBL-117 and GNRB-1 could be favoured as parents since they displayed above average stability and are anticipated to produce acceptable transgressive segregants in subsequent generations. Between the crosses, NBL-117 x Swarna Mani and NBL-117 x GNRB-1 showed above average stability for total fruit output ha⁻¹. Such crossings can either be utilised through heterosis breeding or they also have the potential to produce attractive transgressive segregants in the segregating generations, which plant breeders can handle using the pedigree approach to create high yielding and stable varieties of brinjal.

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