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Stability Analysis of Yield and its Components of Brinjal using Eberhart and Russell Model

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ABSTRACT: Brinjal is one of the most important vegetable belonging to the family *Solanaceae*. With the ongoing erratic climate change events, the brinjal fruit yield has been affected to that extent where farmers are facing heavy economic loss. Now, it is imperative to identify stable brinjal genotypes that can perform across various environments without compromising yield. However, conducting a stability analysis is not always straight forward as the environmental conditions can fluctuate drastically. By comparing more than one stability model the selection of a stable genotype will be more reliable. Hence, a study was conducted across three environments to assess the yield performance of thirty-six brinjal genotypes. Eberhart and Russell model of stability analysis was employed which has been proved to be a reliable model and to support the findings of this model, Lewis phenotypic stability has been included. The study revealed that the genotypes ICO-427008, ICO-334660 and CO_2 were relatively stable and can be further used as parents to develop a more robust stable genotype. These identified genotypes could pave way introducing high performing brinjal varieties into the market.

Keywords: G×E, Environments, Yield loss, stability factor.

INTRODUCTION

Brinjal (*Solanum melongena* L., 2n=24) belongs to the Angiospermic family 'Solanaceae' and it is an often-cross pollinated crop with cross pollination reported as high as 48% (Madhavi *et al*., 2015). China is the world's leading eggplant producer with over half of eggplant acreage, followed by India which accounts for roughly one quarter of total world's production. Overall, Asia accounts for about 94 percent of the world eggplant area with about 92 percent of world output (FAO, 2010). The eggplant is well adapted to grow under high rainfall and high temperatures, as well as under dry conditions with irrigation. Eggplant has moderate amounts of dietary fibre, vitamins, and micronutrients and it contributes to the diet of people in developing countries when other vegetables are in short supply. Due to its low calorie (24kcal/100g) and high potassium content (200mg/100g), it is suitable for diabetes, hypersensitive and obese patients.

There are umpteen number of commercially grown varieties and hybrids available in the market released by both public and private sector. However, a genotype possessing considerably high yield potential coupled with stable performance in different environments has great value for its adaptation on large scale and in plant breeding programme (Mehta *et al.*, 2011; Raj *et al.*, 2019). Moreover, there is an utmost need for development of high yielding stable varieties and hybrids for specific environments and seasons (Vadodaria *et al.*, 2009). Genotype and environmental interaction play a significant role for any such productive gain. Selection of suitable and stable crop varieties has received much attention by the breeders as an advance approach in increasing crop production. A stable variety/hybrid is desirable for obtaining uniform crop yield over a wide range of agro-climatic situations. Stability in productivity is a major and it is important to identify brinjal genotypes capable of performing well across the environments (Sofiya & Raj, 2021). Study of stability parameters is useful to measure adaptability and stability of crop cultivars, which can be used to identify genotypes suitable for different environments from season to season. Genotype × Environment interaction is expected to play an important role in the performance of genotypes under diverse environmental conditions, besides their individual effect. Among various other stability models, Eberhart and Russell (1966) model is the predominantly used one. Krishna *et al.* (2022) studied mango cultivars and found Mallika to be the most stable variety using Eberhart and Russell model. Raj *et al.* (2019) utilized the same model and identified AU-101 as a stable hybrid under unfavourable conditions. Sara *et al.* (2021) studied thirty-three pearl millet genotypes for stability using the same model- and found AUBH-15 to be stable hybrid for yield. Mehta *et al.* (2011) studied seven long brinjal varieties and found that IBWI-2007-1 to be stable under irrigated conditions. Sivakumar *et al.* (2017) studied thirty four brinjal genotypes and found four brinjal hybrids to be stable for fruit yield per plant. Studied fifty five brinjal genotypes identified Pusa Uttam and Pusaupkar to be stable over four different environments. Siva *et al.* (2020) studied a total of thirty brinjal genotypes and found four hybrids to be stable across environment for fruit yield and its components.

The regression model of stability has been widely used in many annual crops; however, the literature is still limited for brinjal. Also, in a geographical point of view, the available studies on brinjal are mainly conducted in North India and more assessment of environmental effects on brinjal fruit yield under South Indian conditions is also a necessity. Considering the above points this study was designed to study the brinjal genotypes thar are having stable performance for yield and its components throughout the year in different environments.

MATERIALS AND METHODS

The present investigation was conducted in three different locations *viz.,* experimental farm in the Department of Genetics and Plant Breeding, garden land farm in the Department of Agronomy of Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu and experimental farm in Virudhachalam, Tamil Nadu. The experimental materials for this study comprised of thirty-six brinjal genotypes obtained from the National bureau of plant genetic resources (NBPGR) and some land races and released varieties (Table 1). Seeds of the 36 genotypes and land races were sown in raised nursery beds. The seedings are ready for transplanting within 4-6 weeks of planting when they attain a height of 15cm with 2-3 true leaves with the spacing of 60cm between rows and 60cm between plants. The experiment was carried out in randomized block design with three replications. Fifteen plants per replication were maintained for each genotype. Recommended agronomic practices and need based plant production measures were carried out.

The observations were recorded on five traits *viz.*, fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant. The data was subjected to Eberhart and Russell (1966) model of stability analysis and the phenotypic stability was determined by Lewis (1954) stability factor. The statistical analysis was carried out using TNAUSTAT software.

Table 1: List of 36 Brinjal accessions and their sources.

Genotype code	Genotypes	Source
G_1	ICO-216794	NBPGR, New Delhi
G_2	IC0-354749	NBPGR, New Delhi
G_3	ICO-355370	NBPGR, New Delhi
G_4	ICO-361838	NBPGR, New Delhi
G_5	ICO-382352	NBPGR, New Delhi
G_6	ICO-382587	NBPGR, New Delhi
G_7	ICO-411485	NBPGR, New Delhi
G_8	ICO-422586	NBPGR, New Delhi
G_9	ICO-427008	NBPGR, New Delhi
G_{10}	ICO-427029	NBPGR, New Delhi
G_{11}	ICO-545862	NBPGR, New Delhi
G_{12}	Ven yutha round brinjal	Tamil Nadu, India
G_{13}	Namakkal brinjal	Tamil Nadu, India
G_{14}	Udumalai samba brinjal	Tamil Nadu, India
G_{15}	Green round brinjal	Tamil Nadu, India
G_{16}	Cvksirukkaraisivappu brinjal	Tamil Nadu, India
G_{17}	Vellore mullu brinjal	Tamil Nadu, India
G_{18}	ICO-373485	.NBPGR, New Delhi
G_{19}	ICO-334660	NBPGR, New Delhi
G_{20}	ICO-336474	NBPGR, New Delhi
G_{21}	ICO-329327	NBPGR, New Delhi
G_{22}	ICO-345590	NBPGR, New Delhi
G_{23}	ICO-383119	NBPGR, New Delhi
G_{24}	ICO-394902	NBPGR, New Delhi
G_{25}	ICO-344674	NBPGR, New Delhi
G_{26}	Dindigul brinjal	Tamil Nadu, India
G_{27}	Udha brinjal	Tamil Nadu, India
G_{28}	Brinjal thorn	Tamil Nadu, India
G_{29}	Whitish blue stripped	Tamil Nadu, India
G_{30}	AU	Tamil Nadu, India
G_{31}	Palur-1	Tamil Nadu, India
G_{32}	Palur-2	Tamil Nadu, India
G_{33}	Arkakusumakar	Tamil Nadu, India
G_{34}	Local (mullu brinjal)	Tamil Nadu, India
G_{35}	Udavai green brinjal	Tamil Nadu, India
G_{36}	CO_2	Tamil Nadu, India

RESULTS AND DISCUSSION

The join regression analysis indicated that the variance due to genotype was significant for all the traits suggesting the presence of genetic variability among the genotypes under study (Table 2). The variances due to environment were also significant for all the five traits indicating that these traits were highly influenced by all the three locations. The variance due to G × E and E + (G × E) were also significant for all the traits inferring the differential response of the brinjal genotypes in different locations and when tested against pooled deviation it indicated that the genotypes differed widely among themselves. The E + (G × E) interaction was only significant for yield per plant against pooled error which indicated the distinct nature of seasons and G × E interactions in the phenotypic expression of the genotypes for this particular trait. High magnitude of the environment (linear) effect in comparison to Genotype × Environment (linear) for yield per plant was observed, which may be responsible for high variation to the trait in different locations. Similar observations for yield per plant was also observed by Chaitanya and Reddy (2021); Bora *et al*. (2011).

Table 2: Analysis of variance by Eberhart and Russell model.

Sources	df	MSS				
		Fruit length (cm)	**Fruit girth (cm)**	**Number of fruits per plant**	**Average fruit weight (g)**	**Fruit yield per plant (kg)**
Genotypes	35	27.08**	18.00**	4770.06**	192.57**	0.67**
Environments	2	7.08**	5.50**	432.95**	316.37**	1.54**
G ´ E	70	2.51**	0.89**	66.24**	21.86	0.07**
E + (G ´ E)	72	2.63	1.02	76.42	30.04	0.11**
Environment (Linear)	1	14.15*	10.99**	865.90**	632.73**	3.07**
Genotype ´ Environment (Linear)	35	2.82	0.83	45.01	14.35	0.08

Once the Genotype × Environmental interaction was found to be significant, the next step was to identify the stable genotypes that interacted the least with environments giving a near consistent performance. The genotype is found to be stable based on non-significant deviation from regression coefficient, mean values and a regression coefficient value equal to unity. Thus, depending on the character, a genotype with high or low mean (desirable mean depends on the character), unity in regression coefficient and non-significant deviation from regression were considered as widely adapted and stable genotype. Above and below average stability is based on greater than unity b_i and lesser than unity b_i, respectively.

The deviation from regression were non-significant and regression coefficient were around the unity for genotype G_5 and more than unity in G_4, G_8, G_{13}, G_{30}, G_{31}, G_{34}, G_{35} indicating above average stability, whereas greater than unity was observed in G_1, G_3, G_{10}, G_{12}, G_{15}, G_{17}, G_{20}, G_{28}, G_{33} indicating below average stability for fruit length (Table 3a and 3b).

Table 3a: Stability parameters for five quantitative traits.

Genotypes	Fruit length			Fruit girth			Number of fruits per plant		
	Mean (cm)	**b_i**	**S^2d_i**	**Mean (cm)**	**b_i**	**S^2d_i**	**Mean**	**b_i**	**S^2d_i**
G_1	6.45	-0.4	-0.07	5.5	0.53	0.44*	106.12	-0.37	15.30**
G_2	16.28	3.8	1.27**	2.93	0.64	-0.03	51.02	1.25	13.68**
G_3	8.95	0.33	0.03	6.46	0.72	0.54**	92.15	1.4	130.90**
G_4	7.59	1.64	-0.08	5.84	0.65	0.24	138.37	-1.1	8.95**
G_5	6.91	1.12	-0.05	6.65	-0.03	-0.08	116.91	3.09	81.86**
G_6	8.24	0.24	0.31*	3.42	1.63	-0.01	81.97	0.71	-0.45
G_7	11.15	0.83	1.56**	9.58	-1.56	1.92**	149.4	2.37	6.31**
G_8	6.98	2.45	-0.01	4.7	1.26	0.25*	58.37	1.24	4.22*
G_9	13.06	1.66*	-0.08	3.03	0.47	-0.07	35.09	-0.56	7.11**
G_{10}	7.06	0.03	0.01	7.8	0.79	0.33*	118.51	1.2	17.50**
G_{11}	14.84	5.42	0.90**	3.28	1.87	-0.06	72.62	1.43	2.46
G_{12}	9.21	0.36	-0.08	2.99	1.72	0.68**	107.5	3.87	104.09**
G_{13}	10.1	2.72	0.1	4.9	2.39	0.16	38.18	-1.18	10.22**
G_{14}	13.31	3.92	0.54**	3.49	1.61	1.83**	33.89	0.84	2.85
G_{15}	6.83	-0.83	0.15	3.07	-0.43	-0.05	35.61	0.33	0.24
G_{16}	11.72	1.28	0.55**	3.25	1.82	0.02	39.81	1.06	8.12**
G_{17}	6.38	0.42	0.02	4.29	2.18	0.01	45.72	1.21	0.53
G_{18}	6.81	1	1.67**	4.59	-0.58	0.33*	110.76	1.8	140.07**
G_{19}	10.88	0.51	0.51**	6.27	1.7	0	115.44	2.78	22.20**
G_{20}	9.21	0.82	0.19	8.08	1.76	-0.06	138.58	2.26	1797.95**
G_{21}	10.81	1.84	0.79**	9.3	1.48	0.05	56.6	0.42	10.35**
G_{22}	14.57	0.56	1.10**	3.15	2.47	0.71**	123.27	3.45	5.79*
G_{23}	12.4	-7.17	1.44**	8.47	-1.27*	-0.08	19.63	0.65	7.87**
G_{24}	9.35	2.28	2.08**	2.85	1.92	0.31*	36.73	1.41*	-1.03
G_{25}	7.25	0.64	0.62**	7.15	1.4	1.36**	34.07	0.67	1.68
G_{26}	10.48	-1	0.50**	4.01	2.71	0.17	123.79	-2.03	153.47**
G_{27}	11.6	0.61	1.47**	3.44	1.69	0.24	113.8	2.79	30.97**
G_{28}	10.38	-0.07	-0.06	7.25	1.64	-0.08	43.94	0.99	-0.19
G_{29}	11.78	-3.88*	-0.05	2.74	0.76	1.02**	35.76	0.5	-0.66
G_{30}	11.6	4.88	0.16	9.23	-2.8	2.02**	51.04	1.23	90.47**
G_{31}	11.79	8.03	0	8.87	6.92*	-0.07	63.02	2.37	96.99**
G_{32}	11.71	4.94	23.66**	9.45	-1.2	7.19**	83.27	-0.25	106.97**
G_{33}	5.07	0.35	-0.08	2.17	1.03	-0.03	33.66	0.95	6.17**
G_{34}	13.08	-1.68	-0.01	9.15	-0.69	0.44*	146.1	0.12	46.07**
G_{35}	17.8	-2.82	3.12	5.76	1.05	0.59**	75.13	-1.72	9.35**
G_{36}	11.85	1.12	0.50**	8.88	-1.14	10.15**	39.18	0.81	85.86**

Table 3b: Stability parameters for five quantitative traits.

Genotypes	Average fruit weight			Fruit yield per plant		
	Mean (g)	b_i	S^2d_i	Mean (kg)	b_i	S^2d_i
G_1	10.78	0.45	-11.52	1.15	1.95	0
G_2	47.47	3.04	-0.43	2.42	2.98	0
G_3	17.37	0.95	-15.11	1.57	1.06	0.06**
G_4	15.31	0.27	-18.13	2.46	0.57	0
G_5	12.69	1.15	-18.13	1.46	2.84	0.02*
G_6	14.68	1.11	-17.3	1.2	1.70*	-0.01
G_7	11.23	0.83	15.57	1.63	3.49	0.06**
G_8	14.3	1.45	-16.68	1.04	1.85	0.01
G_9	36.02	3.26	-16.46	1.64	1.18	0.01
G_{10}	13.51	1.14	-18.36	1.69	0.49	0.02*
G_{11}	18.37	1.55	-18.26	1.5	0.84	-0.01
G_{12}	11.52	0.66	-12.3	0.98	0.51	0.08**
G_{13}	11.63	1.1	-14	0.96	1.2	0.06**
G_{14}	17.05	1.02	2.95	0.78	0.3	-0.01
G_{15}	20.92	1.87	5.12	0.89	1.05	0.10**
G_{16}	7.14	0.59	-15.18	0.58	0.33*	-0.01
G_{17}	11.4	1	-13.42	0.73	-0.22	0
G_{18}	15.11	1.67	-17.16	1.37	1.97	0.02
G_{19}	15.85	0.33	-16.3	1.69	1.25	0
G_{20}	9.25	0.29	-17.76	1.8	2.51	0.38**
G_{21}	15.74	1.06	-16.71	0.96	0.83	0.15**
G_{22}	8.58	0.12	-17.32	0.73	0.59	0
G_{23}	21.59	0.5	-16.9	0.53	0.12*	-0.01
G_{24}	13.05	1.25	-9.05	1.25	1.94	0
G_{25}	12.55	1.36	13.54	0.49	0.32	0
G_{26}	13.79	1.71	33.56	1.35	0.16	0
G_{27}	12.52	0.12	-14.08	1.51	0.36	0
G_{28}	8.11	0.38	-15.82	0.9	0.86	0.14**
G_{29}	23.6	0.42	-12.98	1.42	0.33	0.03*
G_{30}	17.3	0.92	-17.59	1.05	1.12	0.16**
G_{31}	32.79	3.72	753.92**	0.95	0.22	0.14**
G_{32}	17.29	-0.53	-17.08	1.25	-0.37	0.26**
G_{33}	10.44	0.07	-15.05	0.54	0.67*	-0.01
G_{34}	15.43	0.41	-17.78	1.66	-0.28	0.01
G_{35}	18.45	-0.11	-17.72	1.43	-0.15	0.04*
G_{36}	18.16	0.88	-13.44	1.21	1.41	0

The genotype G_{28} were found to be above average stability due to regression coefficient more than unity for fruit girth and non-significant deviation from regression. For number of fruits per plant, the genotypes G_{17} and G_{28} exhibited non-significant deviation from regression and regression coefficient were found to be equal to unity indicating stable performance. For average fruit weight, the genotypes G_5, G_6, G_{10}, G_{13}, G_{14}, G_{17}, G_{21}, G_{24}, G_{25} had non-significant deviation from regression and equal to unity for regression coefficient indicating stable performance across environments. For fruit yield per plant, the deviation from regression were non-significant and the regression coefficient were found to be around the unity for the genotype G_9, G_{19}, G_{36} indicating their stable performance Similar studies were also conducted to identify stable genotypes for fruit yield per plant, average fruit weight and fruit length by Sivakumar *et al.* (2017); Siva *et al.* (2020); Chaudhari *et al.* (2015); Suneetha *et al.* (2006); Mehta *et al.* (2011) in brinjal.

The criterion for identifying a genotype with less fluctuation due to environment in characters is by measuring the ratio between the high mean in any environment and the low mean in any environment. This is the simple measure of the phenotypic stability of a genotype. The stability factor nearing a ratio of 1.00 indicated the maximum phenotypic stability (Table 4). The genotypes G_4, G_{10}, G_{12}, G_{17}, G_{23}, G_{26}, G_{29}, G_{34}, G_{35} showed around unity stability factor for fruit yield per plant. The genotypes G_5, G_{22}, G_{28} with poor adaptability according to regression model showed around unity stability factor for three characters *viz.*, fruit length, fruit girth, average fruit yield per plant. Almost all the genotypes showed maximum phenotypic stability for character fruit length.

Table 4: Stability factors for five quantitative traits.

Genotypes	Fruit length (cm)	Fruit girth (cm)	Number of fruits per plant	Average fruit weight (g)	Fruit yield per plant (kg)
G_1	0.9435	1.1634	0.971	1.4248	2.1286
G_2	1.216	1.2282	1.2039	1.5048	1.6518
G_3	1.042	1.1681	1.1386	1.2895	1.2036
G_4	1.2132	1.15	0.9492	1.0837	1.0846
G_5	1.1487	1.001	1.2213	1.7349	2.2957
G_6	1.008	1.3165	1.063	1.4954	1.8117
G_7	1.0404	0.9669	1.1191	1.902	2.7671
G_8	1.3755	1.3094	1.1675	1.9028	2.0795
G_9	1.1177	1.0857	0.8879	1.7347	1.284
G_{10}	1.0145	1.0237	1.0792	1.6445	1.0642
G_{11}	1.3768	1.4274	1.1515	1.6509	1.2577
G_{12}	1.034	1.8844	1.3128	1.5282	1.0361
G_{13}	1.2787	1.5068	0.8018	1.8908	1.8517
G_{14}	1.2889	1.0889	1.2025	1.2044	1.1455
G_{15}	0.8815	0.9325	1.071	1.8672	1.8614
G_{16}	1.0858	1.3717	1.2223	1.8043	1.2333
G_{17}	1.0482	1.3512	1.2078	1.8217	0.9496
G_{18}	1.0946	0.9892	1.0964	2.0123	1.9058
G_{19}	1.0249	1.1735	1.1907	1.0615	1.3101
G_{20}	1.0685	1.1503	1.0617	1.1318	1.5409
G_{21}	1.1434	1.0918	1.063	1.4114	1.133
G_{22}	1.0164	1.405	1.2182	1.0016	1.3295
G23	0.6309	0.8954	1.3076	1.1696	1.08
G24	1.2096	1.8979	1.3032	1.95	1.9706
G25	1.0542	1.2823	1.1575	2.2819	1.4016
G26	0.9019	1.7531	0.9021	2.5963	1.0684
G27	1.0712	1.2601	1.1965	0.951	1.123
G28	0.9978	1.1646	1.1737	1.1628	1.7285
G29	0.7473	0.9814	1.097	1.0397	1.0126
G30	1.4663	0.7409	1.1372	1.3149	1.7791
G31	1.8851	1.6854	1.2473	1.1888	0.8527
G32	1.5103	1.0876	0.9634	0.8865	1.1029
G33	1.0595	1.6857	1.2376	1.1423	1.6609
G34	0.889	0.9075	1.0131	1.127	0.9789
G35	0.8635	1.2476	0.8564	0.9431	1.0358
G36	1.1829	0.7645	1.1023	1.2254	1.5649

CONCLUSION

The genotype G_2 (ICO-354749) and G_4 (ICO-361838) recorded high *per se* fruit yield per plant in all the three locations and the genotype G_2 (ICO-354749) performed well with other yield contributing characters such as fruit length and average fruit weight. Analysis of variance for stability also indicated that both predictable (linear) and non-predictable (non-linear) components contributed towards significant differences in stability among the genotypes for all the characters. The Genotype × Environment analysis indicated that the genotypes G_9(ICO-427008), G_{19} (ICO-334660) and G_{36} (CO_2) to be comparatively stable for fruit yield per plant with better yield. Hence, these genotypes can be used as parent (donor) in breeding programmes and also for general cultivation after testing over a wide range of environments.

FUTURE SCOPE

In future, further stability studies must be conducted over more environments and seasons. Apart from the Eberhart and Russell model, researchers should explore other stability models like Finlay and Wilkinson model and AMMI model. Such a comparative analysis will give a more reliable interpretation while selecting a stable genotype or hybrid.

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Conflict of Interest. None.

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