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Genotype × Environment Interaction of Brinjal (*Solanum melongena* L.) Genotypes for Phytochemical and Agronomic Traits

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Authors' contributions

This work was carried out in collaboration among all authors. Author Rashmi Kumari recorded the data, performed the statistical analysis and wrote the first draft of the manuscript. This study is the part of author Rashmi Kumari's PhD thesis. Author SA co-guide and author Randhir Kumar major advisor designed the study and managed the analyses of the study. Author RBV co-guide edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Twenty-one brinjal hybrids along with their seven parents and one hybrid check were evaluated in three seasons, *viz*., autumn-winter, rainy and summer for the study of genotype x environment interaction for different traits and identification of the stable genotypes. Stability analysis revealed that the variance due to genotypes was highly significant for all the characters studied when tested against pooled deviations except days to 50% flowering and days to 1st harvest. Likewise, variance due to E + (G × E) was highly significant for all characters but significant for days to 1st harvest. The genotypes × environments (linear) component for days to 50% flowering and days to 1st harvest were non-significant when tested against pooled deviation which suggested the preponderance of non-linear component as compared to linear component for both these characters. Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x BRBL-01, Rajendra Baigan-2 x BRBL-04, Muktakeshi x BRBL-01, Muktakeshi x BRBL-04, BRBL-02 x BRBL-04, Swarna Mani x BRBL-01, BRBR-01 x BRBL-01 and BRBR-01 x BRBL-04 were identified as stable hybrids and BRBL-01 and BRBL-04

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were stable parents in terms of yield/ plant. BRBL-02 x BRBL-04 was stable in terms of total sugar content, total anthocyanin content and total phenolics content. These genotypes may be utilized for planting throughout the year with good performance and utilized in breeding programmes for developing stable genotypes.

Keywords: Eggplant; hybrid; genotype × environment interaction; yield; quality.

1. INTRODUCTION

Environment plays an important role in the last phenotypic expression of a trait. A genotype is recognized to show change phenotypic responses in development when presented in different environments. The genotype × environment (G × E) interaction is predominantly significant in the appearance of quantitative characters, which are controlled by polygenic systems and are critically modified by environmental influences [1].

In India, brinjal is grown under diverse agro-climatic conditions, which results in fluctuation in its production. Brinjal has a long bearing period under mild climate but its bearing is shortened under hot summer and extreme cool winters. High temperature and high humidity during morning hours hasten the opening of flowers and dehiscence of anthers. Genetic variation exists regarding fruit setting ability under high-temperature conditions [2]. India is the 2nd largest brinjal producing country having area, production and productivity of 0.66 million ha, 12.51 million tonnes and 18.54 MT, respectively [3]. One of the constraints in increasing production is due to the lack of stability of high yielding and widely adapted varieties/hybrids. With the sound biometrical techniques available for estimating stability parameters, it would be easier to assess the genotypic response over a range of environments. Varietal adaptation to environmental fluctuations is important for stabilization of brinjal production. A stable variety/hybrid is obligatory for gaining undeviating crop yield over a wide range of environmental circumstances. Stability in productivity, therefore, is a major and important consideration to identify brinjal genotypes capable of performing well across the environments. Many promising varieties and hybrids have been released in the country and it is essential to know their stability in different environments. Eggplant hybrids with high fruit dry matter and total soluble sugars in addition to low seed weight and total phenols are greatly looked-for by the consumer and get premium price in the marketplace [4]. However, Eggplant fruit holds ascorbic acid and phenolics, both of which are dominant antioxidants [5]. Antioxidants in food have received considerable attention in recent years for their role in human health [6,7]. Anthocyanin present in eggplant fruits peel helps to provide natural protection against the harmful effect of UV irradiation, as well as providing anti-viral and anti-microbial activities [8]. The cultivation environment has a major role in determining the composition and quality of eggplant fruits. Environmental and genotypic differences can be exploited to obtain high-quality eggplant fruits. There is hardly any information available on the stability of brinjal genotypes for yield and quality parameters for different agro-climatic environments of Bihar. Since most of the economic characters in brinjal, such as number of fruits per plant and average fruit weight, are quantitative and are influenced by environmental instabilities, therefore it becomes important to estimate the stability of desired genotypes capable of giving higher yields as well as having better quality under a wide range of environment.

In the present investigation, an attempt has been made to study genotype × environment interaction for fruit yield and its contributing components as well as quality traits of 21 F_1s along with their 7 parents and one hybrid check, Pusa Hybrid-6 in three consecutive seasons/ environments i.e. autumn-winter, rainy and summer seasons and identify the stable genotypes.

2. MATERIALS AND METHODS

Seven diverse inbred lines of brinjal, Rajendra Baigan-2 (P_1), Muktakeshi (P_2), BRBL-02 (P_3), Swarna Mani (P_4), BRBR-01 (P_5), BRBL-01 (P_6) and BRBL-04 (P_7) (details about parents and their salient features in Table 1) derived from indigenous collections and maintained at Vegetable farm section of Bihar Agricultural University, Sabour, Bhagalpur. It lies on the latitude of 25° 15' 40" North and longitude of 80° 2' 42" east with an altitude of 46 meter

Table 1. Details about parents and their salient features

Sl. no.	Genotype	Source	Characteristics
1	Rajendra Baigan-2	BAU, Sabour	Plant medium stature, Fruits are soft, long greenish and medium seeded,
2	Muktakeshi	BAU, Sabour	Plant type is of spread type, fruits are soft, oblong purple with very few seeds.
3	BRBL-02	Selection from local genotype, collected from Odisha, maintained at BAU, Sabour	Fruits are glossy, purple long bearing in cluster
4	Swarna Mani	HARP, Plandu, Ranch, maintained at BAU, Sabour	Fruits are round, dark purple
5	BRBR-01	Selection from local genotype collected from Odisha, maintained at BAU, Sabour	Fruits are purple with few green stripes, round to oval
6	BRBL-01	Selection from local genotype, collected from Odisha, maintained at BAU, Sabour	Fruits are greenish oblong with white stripes
7	BRBL-04	Selection from local genotype, collected from Odisha, maintained at BAU, Sabour	Fruits are oblong, green with white stripes
8	Pusa Hybrid-6	IARI New Delhi, maintained at BAU, Sabour	Purple, round

Table 2. Meteorological data during cropping period

Month	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
Aug-2016	32.44	25.81	87.00	75.52	70.40
Sep-2016	31.16	24.61	89.77	80.13	320.90
Oct-2016	31.52	21.70	89.00	68.32	31.20
Nov-2016	28.91	14.09	90.20	55.90	0.00
Dec-2016	22.61	9.63	95.97	70.00	0.00
Jan-2016	22.60	7.75	94.90	60.71	12.40
Feb-2016	26.26	9.74	88.71	48.46	0.00
Mar-2016	29.88	15.10	87.23	55.06	9.70
Jun-2017	34.42	25.84	84.90	65.37	43.50
Jul-2017	31.57	25.68	91.68	78.13	328.20
Aug-2017	32.84	26.05	91.48	74.32	283.20
Sep-2017	33.14	25.91	90.03	76.07	147.30
Oct-2017	32.02	22.60	92.29	73.71	237.00
Nov-2017	28.86	14.37	85.87	53.30	0.00
Dec-2017	25.00	10.04	91.61	59.97	0.00
Jan-2018	18.56	6.37	96.32	73.65	0.00
Feb-2018	26.23	11.50	84.75	52.14	0.00
Mar-2018	32.53	16.03	87.16	44.19	24.20
Apr-2018	33.74	20.56	79.23	53.20	65.00
May-2018	34.44	22.81	83.94	58.03	61.00
Jun-2018	35.26	25.27	85.07	60.63	118.00
Jul-2018	33.26	24.81	90.03	75.13	254.90
Aug-2018	32.95	25.32	88.74	75.48	234.20
Sep-2018	33.18	24.82	85.93	74.70	66.30

above mean sea level in the heart of vast Indo-Gangetic plains of north India (Meteorological data during cropping period in Table 2). The pH of soil under study was 7.2. Twenty-one F_1 hybrids were developed in half diallel mating scheme excluding reciprocals in the autumn-winter season of 2015-16 and 2016-17. These 21 F_1 hybrids along with the seven parental lines and check Pusa Hybrid-6 were evaluated in randomised block design with three replications in the autumn-winter season of 2016-17 with August 2016 transplanting, rainy season of 2017 with June 2017 transplanting time and summer 2018 with February, 2018 transplanting time at the vegetable research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India. Farm yard manure was thoroughly mixed in the soil at the time of field preparation. The fertilizer dose NPK is applied in the field in the ratio 100:80:60 Kg/ha. The complete dose of phosphatic and potassic fertilizers and one third dose of nitrogenous fertilizers were given at last ploughing. The remaining dose of nitrogenous fertilizer was applied in two split doses as top dressing at one and two months after transplanting. Five random plants (leaving plants at border) per replication out of twelve were selected to record observation on each genotype for 7 different morphological characters (days to 50% flowering, days to 1^{st} harvest, fruit length, fruit girth, average fruit weight, number of fruits/plant and yield/plant) and 5 biochemical characters (total sugar, ascorbic acid, anthocyanin content, total phenolic content and total antioxidant capacity) of fresh fruits of horticultural maturity estimated from composite fruit samples taken from each selected plant of the replication.

The analysis of phenotypic stability parameters for different characters under study was carried out as per procedure outlined by Eberhart and Russell [9]. In this model three parameters were suggested to describe the stability of genotype. These three parameters are as follows:

Mean, $\bar{X} = \sum Y_{ij}/n$, Where, $\bar{X}$ = Mean of the genotype and n = Number of environments

Regression coefficient (b_i) = $b_i = \frac{\sum Y_{ij} I_j}{\sum I_j^2}$

Where, $I_j = \frac{\sum Y_{ij}}{g} - \frac{\sum\sum Y_{ij}}{ge}$

Mean square deviation (S^2d) from linear regression $s_d^2 = \frac{\sum \delta_{ij}^2}{e-2} - \frac{s_e^2}{r}$

Where, $\sum \delta_{ij}^2 = \left[\sum Y_{ij}^2 - \frac{Y_{i.}^2}{g}\right] - \frac{\left(\sum Y_{ij} I_i\right)^2}{\sum I_j^2}$

3. RESULTS AND DISCUSSION

The analysis of variance for genotypes × environments interaction is presented in Tables 3 and 4 for all the 15 characters. The variance due to genotypes was highly significant for all the characters studied when tested against pooled deviations except days to 50% flowering and days to 1^{st} harvest. Similarly, the differences due to environments and environments (linear) were also found to be highly significant for all the characters. The genotypes x environments interactions were also highly significant for all traits excluding days to 50% flowering and days to 1^{st} harvest when tested against pooled deviation. Similarly, variance due to E + (G × E) was significant for all characters. The lack of significant G × E interaction for days to 50% flowering and days to 1^{st} harvest indicated that genotypes responded consistently over the environments for these characters. The results of these characters are not, therefore, included in further study. This also indicated that environments created by sowing over seasons was justified and had linear effects. These results are in agreement with the earlier findings of Srivastva et al. [10], Mohanty and Prusti [11], Rai et al. [12] and Krishna Prasad et al. [13].

The genotypes x environments (linear) component for days to 50% flowering and days to 1^{st} harvest were non-significant when tested against pooled deviation which suggested the preponderance of non-linear component as compared to linear component for both these characters. The non-linear component (pooled deviation) was also found highly significant for days to 50% flowering, days to 1^{st} harvest, yield per plant, total ascorbic acid content, total sugar content, total phenolics content and total antioxidant capacity while rest of characters were non-significant for pooled deviation indicating to predict the performance of genotypes across the environments for rest of the characters. These results are following those of Chowdhury and Talukdar [14], Bhushan and Samnotra [15] and Singh and Chaudhary [16].

According to the model of Eberhart and Russell [9], a variety may be said to be stable over different environments, if it shows unit regression coefficient (b_i = 1.0) with the lowest deviation (non-significant) from the linear regression (S^2d_i

= 0). With these conditions, high and desirable *per se* performance of variety over environments is also a positive point to rate the variety/hybrid as a better and stable genotype.

3.1 Stability for Morphological Traits

As evident from Table 5 and Fig. 1, among all the genotypes, ten genotypes, Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x Swarna Mani, Rajendra Baigan-2 x BRBR-01, Rajendra Baigan-2 x BRBL-01, BRBL-02 x BRBL-01 and Swarna Mani deviated non-significantly from regression line with the average response for days to 50% flowering, recorded lower mean values than the average mean. Hence, they were considered stable because a lower mean value is desirable in the case of days to 50% flowering.

For days to the first harvest, based on the three stability parameters, among all genotypes, only two genotypes *viz*., Rajendra Baigan-2 x Swarna Mani and Muktakeshi x Swarna Mani recorded lower mean values than the population mean were found to be stable with regression coefficient close to unity with non-significant deviation from the regression line. Genotypes took less number of days to 1st harvest was considered desirable.

The examination of stability parameters revealed that 10 genotypes *viz*., Rajendra Baigan-2 x Muktakeshi, Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x BRBR-01, Rajendra Baigan-2 x BRBL-01, Rajendra Baigan-2 x BRBL-04, Muktakeshi x BRBL-02, Muktakeshi x BRBR-01, Muktakeshi, BRBL-02 and BRBL-04 were stable for fruit length (Table 6). BRBL-02 x BRBL-04 and BRBL-04 were highly responsive but only BRBL-02 x BRBL-04 had higher mean for fruit length and non-significant deviation from regression line recommended for favourable conditions. Muktakeshi x Swarna Mani, BRBR-01 x BRBL-01, Swarna Mani and Pusa Hybrid-6 were low responsive but none of these recorded higher mean values.

Out of 29 genotypes for fruit girth (Table 6 & Fig. 1), Muktakeshi x Swarna Mani, Muktakeshi x BRBR-01, Muktakeshi x BRBL-04, Swarna Mani x BRBR-01, Swarna Mani x BRBL-04 and BRBR-01 x BRBL-04, Muktakeshi, Swarna Mani, BRBL-01 and Pusa Hybrid-6 had higher mean values with regression coefficient near to one with non-significant deviation from the regression line were considered average responsive and stable. Swarna Mani x BRBL-01, BRBR-01 and BRBL-04 were highly responsive recorded higher mean values considered suitable for favourable environments.

For average fruit (Table 6) weight 11 genotypes namely Rajendra Baigan-2 x Swarna Mani, Muktakeshi x BRBL-02, Muktakeshi x BRBR-01, Muktakeshi x BRBL-04, Swarna Mani x BRBR-01, Swarna Mani x BRBL-01, Swarna Mani x BRBL-04 and BRBR-01 x BRBL-01, Muktakeshi, Swarna Mani, BRBR-01 and Pusa Hybrid-6 were considered stable having higher mean values with regression coefficient near to one and non-significant deviation from the regression line. Rajendra Baigan-2 x Muktakeshi, Muktakeshi x Swarna Mani and Muktakeshi x BRBL-01 were highly responsive with higher mean and non-significant deviation from the regression line recommended for favourable conditions.

Estimation of stability parameters for the number of fruits per plant indicated that genotypes *viz*., Rajendra Baigan-2 x Muktakeshi, Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x BRBR-01, Rajendra Baigan-2 x BRBL-01, Rajendra Baigan-2 x BRBL-04, Muktakeshi x BRBL-01, BRBL-02 x Swarna Mani, BRBL-02 x BRBR-01, BRBL-02 x BRBL-01, BRBL-02 x BRBL-04, BRBR-01 x BRBL-04, BRBR-01 x BRBL-04, BRBL-01 x BRBL-4, BRBL-02, BRBL-01 and BRBL-04 were found to be stable because of higher mean for number of the fruits per plant (Table 7) as compared to average mean and regression coefficient close to one with non-significant deviation from regression line.

For yield per plant (Table 7), stability parameters indicated that genotypes Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x BRBL-01, Rajendra Baigan-2 x BRBL-04, Muktakeshi x BRBL-01, Muktakeshi x BRBL-04, BRBL-02 x BRBL-04, BRBR-01 x BRBL-04, BRBR-01 x BRBL-04, BRBL-01 and BRBL-04 with higher yield per plant as compared to the average mean, regression coefficient close to one with non-significant deviation from the regression line was found to be stable. These could be utilized further for yield improvement in brinjal. Similar findings were given by Suneetha et al. [17], Vaddoria et al. [18] Bhusan and Samnotra [15] and Kachouli et al. [19].

Table 3. Analysis of variance for phenotypic stability pertaining to various morphological traits

Sources	DF	D50F	DFH	FrL	FrG	FrW	FrP	YP
Genotypes (G)	28	37.41	75.56	13.56 **	18.62 **	1116.37 **	100.68 **	0.17 **
E + (G x E)	58	211 **	228.21 *	10.77 **	11.95 **	542.47 **	14 **	0.23 **
Environments (E)	2	4362.48 **	4140.71 **	284.42 **	335.71 **	14225.15 **	356.19 **	5.66 **
G x E	56	67.85	93.3	1.34 **	0.78 **	70.65 **	2.2 **	0.05 **
Environments (linear)	1	8724.97 **	8281.42 **	568.84 **	671.43 **	28450.3 **	712.39 **	11.32 **
G x E (linear)	28	48.42	73.14	2.26 **	1.36 **	134.87 **	3.45 **	0.07 **
Pooled Deviation	29	84.37 **	109.68 **	0.4	0.2	6.22	0.91	0.02 **
Pooled Error	168	1.99	4.17	0.5	0.54	27.61	2.07	0.01

**, ** Significant at 5 % and at 1 % level of significance, respectively, DF (degree of freedom), Characters: Days to 50% flowering (D50F), Days to first harvest (DFH), Fruit length (FrL), Fruit girth (FrG), Average fruit weight (FrW), Number of fruit/plant (FrP) and Yield/plant (YP)*

Table 4. Analysis of variance for phenotypic stability pertaining to various biochemical traits

Sources	DF	AsA	TS	TAnth	TPC	AoxC
Genotypes (G)	28	0.9 **	0.38 **	117.11 **	20.03 **	2.33 **
E + (G x E)	58	1.73 **	0.62 **	4.79 **	38.29 **	4.2 **
Environments (E)	2	43.78 **	14.87 **	107.38 **	964.61 **	98.6 **
G x E	56	0.29 **	0.12 **	1.25 **	6.35 **	0.95 **
Environments (linear	1	87.55 **	29.74 **	214.76 **	1929.22 **	197.2 **
G x E (linear)	28	0.47 **	0.21 **	2.29 **	10.52 **	1.57 **
Pooled Deviation	29	0.1 **	0.04 **	0.2	2.1 **	0.31 **
Pooled Error	168	0	0.01	0.14	0.26	0.01

**, ** Significant at 5 % and at 1 % level of significance, respectively Characters: Ascorbic acid content (AsA), Total sugar content (TS), Total anthocyanin content (TAnth), Total phenol content (TPC) and Total antioxidant capacity (AoxC)*

Table 5. Stability parameters for reproductive traits

Character	Days to 50% flowering			Days to 1st harvest		
Genotypes	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**
Rajendra Baigan-2 X Muktakeshi	65.22	0.58	13.87 **	74.67	0.68	0.92
Rajendra Baigan-2 X BRBL-02	60.67	0.73	-0.69	64.56	0.95	94.68 **
Rajendra Baigan-2 X Swarna Mani	58.00	0.86	-0.99	73.11	0.48	-3.02
Rajendra Baigan-2 X BRBR-01	57.33	0.15	1.9	69.67	-0.17	-1.59
Rajendra Baigan-2 X BRBL-01	62.00	0.67	0.18	75.22	0.66	4.06
Rajendra Baigan-2 X BRBL-04	64.67	0.22	0.95	74.67	0.48	88.14 **
Muktakeshi X BRBL-02	65.22	1.36	197.6 **	75.78	1.9	29.5 **
Muktakeshi X Swarna Mani	62.00	1.72	159.17 **	68.45	1.12	4.69
Muktakeshi X BRBR-01	59.78	1.05	48.27 **	75.67	1.94	217.2 **
Muktakeshi X BRBL-01	62.78	1.14	-1.88	68.45	1.34	96.73 **
Muktakeshi X BRBL-04	60.00	0.46	365.98 **	64.67	0.14	40.18 **
BRBL-02 X Swarna Mani	62.11	0.72	6.24 *	80.11	1.7	279.51 **
BRBL-02 X BRBR-01	57.11	0.91	72.39 **	70.33	0.95	43.48 **
BRBL-02 X BRBL-01	59.33	0.93	1.94	67.78	0.65	11.95 *
BRBL-02 X BRBL-04	68.89	1.12	0.01	81.11	1.17	-3.88
Swarna Mani X BRBR-01	66.67	1.17	65.36 **	74.78	1.05	-4.04
Swarna Mani X BRBL-01	61.44	1.16	43.14 **	73.56	1.12	195.96 **
Swarna Mani X BRBL-04	61.00	1.11	-0.16	72.33	1.18**	-4.11
BRBR-01 X BRBL-01	65.89	1.89	39.28 **	69.67	1.24	55.77 **
BRBR-01 X BRBL-04	68.00	1.06	91.79 **	71.78	0.93	26.82 **
BRBL-01 X BRBL-04	63.89	1.30	28.2 **	74.56	1.26	57.25 **
Rajendra Baigan-2	65.56	1.44	270.02 **	68.45	1.28	119.86 **
Muktakeshi	64.00	1.68	335.34 **	83.33	2.02	135.24 **
BRBL-02	59.33	0.47	16.41 **	69.33	0.79*	-4.1
Swarna Mani	58.56	0.78	3.47	81.89	0.34	218.91 **
BRBR-01	63.67	0.82	12.46 **	78.04	1.24	297.35 **
BRBL-01	64.44	1.08	111.49 **	71.78	1.35	81.21 **
BRBL-04	68.89	1.14	188.39 **	78.11	1.09	306.78 **
Pusa Hybrid-6	59.67	1.00	203.75 **	70.04	0.54	278.26 **
Population Mean	**62.62**	**-**	-	**73.17**	**-**	-

Table 6. Stability parameters for fruit morphological traits

Character	Fruit Length (cm)			Fruit Girth (cm)			Average fruit weight (g)		
Genotypes	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**
Rajendra Baigan-2 X Muktakeshi	13.68	1.11	1.01	9.78	0.83	-0.02	84.62	1.33*	-27.83
Rajendra Baigan-2 X BRBL-02	12.41	1.14	-0.46	8.53	0.77	-0.36	60.60	0.77*	-27.96
Rajendra Baigan-2 X Swarna Mani	10.81	1.07	-0.19	10.76	0.84	-0.27	87.23	1.36	-25.79
Rajendra Baigan-2 X BRBR-01	12.01	1.29	-0.25	10.21	0.81	-0.46	75.14	0.98	-28.08
Rajendra Baigan-2 X BRBL-01	12.71	1.11	0.08	8.90	0.77*	-0.53	74.54	0.82	-25.23
Rajendra Baigan-2 X BRBL-04	11.82	0.83	-0.09	8.27	0.74	0.10	61.99	0.56	-10.56
Muktakeshi X BRBL-02	12.45	1.16	-0.47	10.71	0.9	-0.08	82.04	1.08	-27.76
Muktakeshi X Swarna Mani	9.29	0.57*	-0.48	11.75	1.13	-0.14	110.12	1.62*	-27.34
Muktakeshi X BRBR-01	11.45	0.87	-0.46	12.67	0.99	-0.46	100.09	1.48	-22.83
Muktakeshi X BRBL-01	11.14	0.64	-0.46	11.43	0.94	-0.17	92.37	1.47*	-28.15
Muktakeshi X BRBL-04	11.06	0.84	-0.35	11.92	0.95	-0.35	89.81	1.35	19.32
BRBL-02 X Swarna Mani	9.35	0.84	0.11	11.14	0.92	-0.42	65.32	0.87	-21.98
BRBL-02 X BRBR-01	9.93	0.76	0.57	9.66	0.87*	-0.52	58.50	0.73	-27.30
BRBL-02 X BRBL-01	10.95	0.78	-0.36	9.21	0.88	-0.38	51.53	0.52	-16.28
BRBL-02 X BRBL-04	12.47	1.08**	-0.49	8.87	0.84	-0.42	52.71	0.47**	-28.27
Swarna Mani X BRBR-01	9.91	0.87	-0.42	15.95	1.44	-0.14	107.33	1.54	-19.94
Swarna Mani X BRBL-01	9.01	0.9	-0.46	14.56	1.19*	-0.53	90.34	1.34	-1.69
Swarna Mani X BRBL-04	10.47	0.76	-0.45	13.91	1.17	-0.34	79.19	1.17	-25.51
BRBR-01 X BRBL-01	9.82	0.56*	-0.47	10.78	0.81*	-0.52	78.88	1.07	-16.81
BRBR-01 X BRBL-04	9.05	0.82	-0.45	11.61	0.74	-0.28	66.25	0.71	-21.63
BRBL-01 X BRBL-04	8.76	0.95	-0.47	9.74	0.82	-0.38	61.08	0.55*	-28.15
Rajendra Baigan-2	17.89	2.28	3.89 **	10.01	1	-0.41	69.56	1.05	-23.75
Muktakeshi	12.94	1.13	-0.2	13.74	1.34	-0.46	117.45	1.48	-17.72
BRBL-02	13.71	1.21	0.52	8.67	0.94	-0.21	54.61	0.56	-25.49
Swarna Mani	8.29	0.74*	-0.49	16.28	1.47	-0.06	95.33	1.3	-23.13
BRBR-01	10.47	0.94	-0.48	14.58	1.41*	-0.52	82.26	1.03	-28.14
BRBL-01	12.24	1.14	-0.39	13.54	1.35	-0.07	69.42	0.75	-26.98
BRBL-04	11.02	1.24*	-0.49	11.79	1.06**	-0.53	57.33	0.57*	-27.83
Pusa Hybrid-6	9.21	0.66**	-0.49	14.89	1.48	-0.48	96.80	1.2	-26.94
Population Mean	**11.18**	**-**	-	**11.51**	**-**	-	**78.36**	**-**	-

Table 7. Stability parameters for number of yield and attributing traits

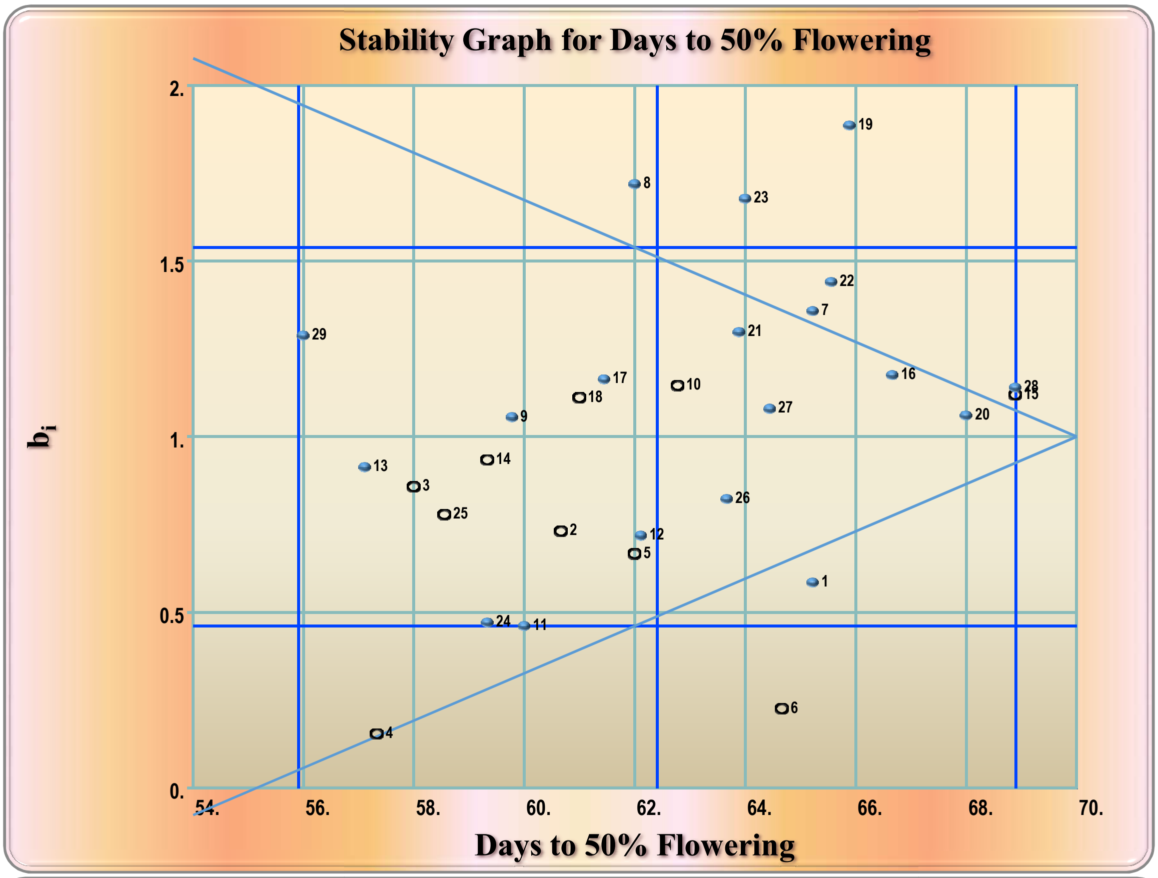
Character	Number of fruits/plant			Yield/plant (kg)		
Genotypes	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**
Rajendra Baigan-2 X Muktakeshi	19.72	1.57	-1.60	1.47	2.17	0.11 **
Rajendra Baigan-2 X BRBL-02	22.77	1.1	-1.81	1.33	1.19	-0.01
Rajendra Baigan-2 X Swarna Mani	17.13	1.12	-0.43	1.30	1.69	0.03 *
Rajendra Baigan-2 X BRBR-01	18.05	1.62	2.46	1.15	1.65	0.08 **
Rajendra Baigan-2 X BRBL-01	23.39	1.22	0.46	1.70	1.38	0.01
Rajendra Baigan-2 X BRBL-04	22.52	1.49	0.14	1.38	1.15	-0.01
Muktakeshi X BRBL-02	12.42	0.56	-1.53	1.09	0.39*	-0.01
Muktakeshi X Swarna Mani	10.87	0.51	-1.92	1.11	0.9	0
Muktakeshi X BRBR-01	12.59	0.38*	-2.02	1.16	0.96	0
Muktakeshi X BRBL-01	17.93	0.8	-2.01	1.69	1.17	0
Muktakeshi X BRBL-04	14.35	0.56	-1.79	1.36	0.58	0
BRBL-02 X Swarna Mani	18.37	0.88	-2.02	1.24	0.94	0
BRBL-02 X BRBR-01	20.55	1.01	-2.03	1.14	1.12	0
BRBL-02 X BRBL-01	21.09	0.97	-1.51	1.38	-0.01	0.02 *
BRBL-02 X BRBL-04	28.14	1.88	4.59	1.47	1.12	0
Swarna Mani X BRBR-01	11.29	0.74	-1.85	1.13	1.18	0
Swarna Mani X BRBL-01	16.26	0.6	-1.58	1.46	1.09	0
Swarna Mani X BRBL-04	16.01	1	-2.04	1.47	0.95	0.09 **
BRBR-01 X BRBL-01	12.86	0.8*	-2.04	1.37	0.14	0
BRBR-01 X BRBL-04	21.05	1.28	-2.01	1.39	1.23	-0.01
BRBL-01 X BRBL-04	23.17	1.12	-1.77	1.51	0.91	0.1 **
Rajendra Baigan-2	16.19	1.01	-0.94	1.03	1.26	0.01
Muktakeshi	7.97	0.69**	-2.04	0.88	0.7	-0.01
BRBL-02	19.67	0.74	-0.79	1.01	0.8	-0.01
Swarna Mani	8.92	0.69	-1.53	0.86	0.68	-0.01
BRBR-01	9.29	0.89	-1.86	0.66	0.53*	-0.01
BRBL-01	21.67	1.01	-1.06	1.48	1.16	0
BRBL-04	25.76	1.3	-0.21	1.45	1.15	0
Pusa Hybrid-6	12.16	0.72	-1.93	1.15	0.79	0
Population Mean	**17.32**	**-**	-	**1.27**	**-**	-

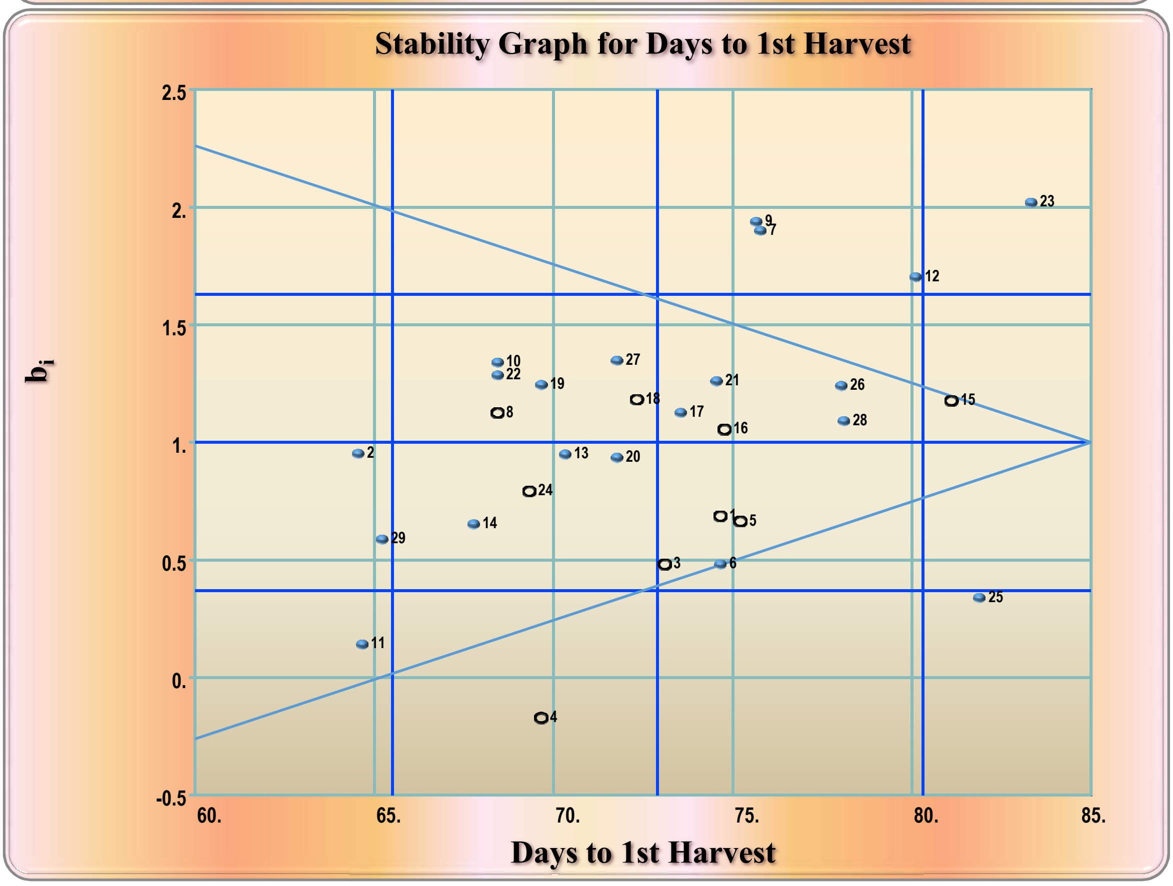
Table 8. Stability parameters for quality traits

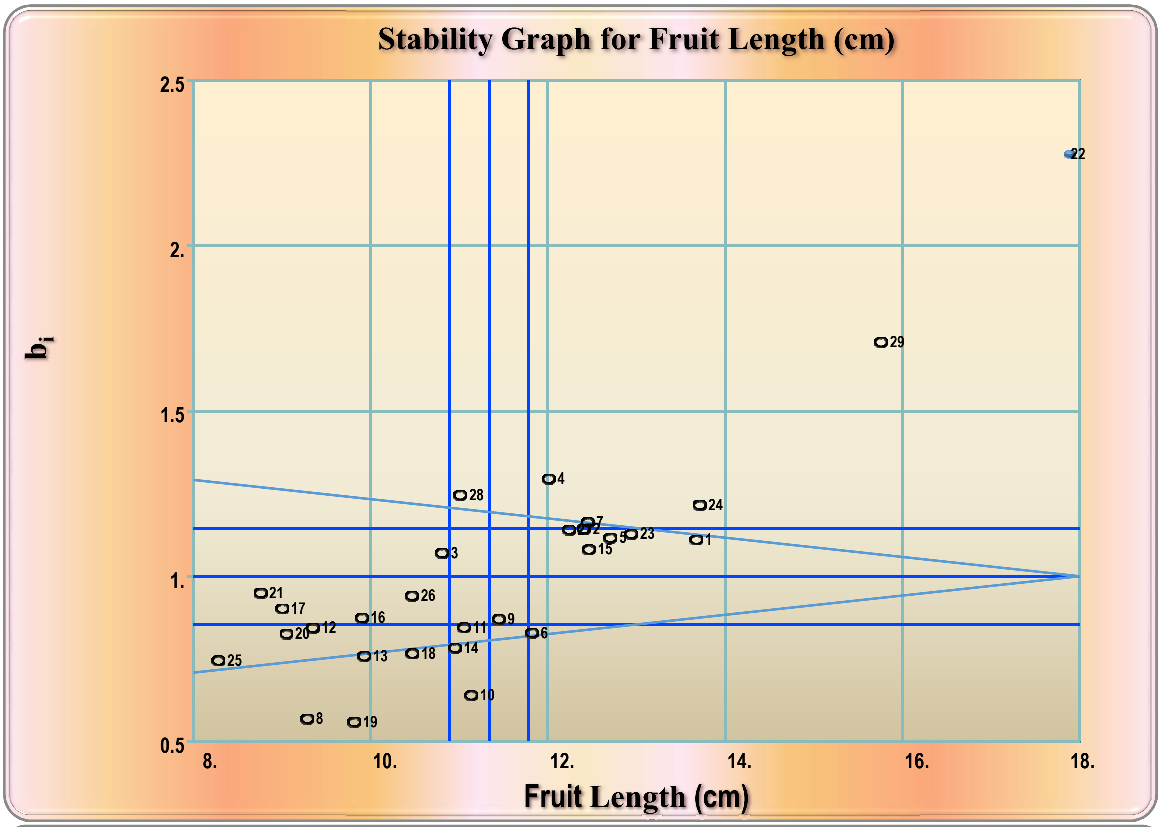
Character	Ascorbic acid content(mg/100 g)			Total sugar content (%)			Total anthocyanin content (mg/100 g)		
Genotypes	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**
Rajendra Baigan-2 X Muktakeshi	2.83	0.72	0.34 **	2.64	0.4*	-0.01	14.32	1.77	-0.08
Rajendra Baigan-2 X BRBL-02	2.53	1.09	0.06 **	2.94	0.83	-0.01	13.55	0.8	-0.05
Rajendra Baigan-2 X Swarna Mani	4.33	1.58*	0	2.96	0.7	0	12.00	1.47*	-0.14
Rajendra Baigan-2 X BRBR-01	2.43	0.99	0	3.00	0.85	0	11.37	1.01	-0.07
Rajendra Baigan-2 X BRBL-01	3.62	1.09	0.01 **	2.68	0.5*	-0.01	1.80	0.22*	-0.12
Rajendra Baigan-2 X BRBL-04	3.10	1.53	0	3.32	0.87	0.02 *	1.55	0.29*	-0.13
Muktakeshi X BRBL-02	2.24	0.75	0.08 **	2.86	1.08	-0.01	18.88	1.06	0.44 *
Muktakeshi X Swarna Mani	4.46	2.19	1.13 **	3.20	0.93	-0.01	16.98	1.2	0.18
Muktakeshi X BRBR-01	2.64	1.73	0.05 **	3.09	0.97	0.04 **	16.37	0.87	-0.13
Muktakeshi X BRBL-01	2.74	1.22	0.12 **	3.14	1.03	-0.01	15.23	1.75	0.08
Muktakeshi X BRBL-04	2.54	0.59*	0	3.22	1.51	0.04 *	13.54	1.02	0.04
BRBL-02 X Swarna Mani	2.96	0.58*	0	3.74	1.92	0.13 **	17.73	0.49	-0.11
BRBL-02 X BRBR-01	2.75	0.99	0	2.92	0.68	-0.01	16.77	1.75	0.38
BRBL-02 X BRBL-01	2.46	0.86	0.08 **	3.07	0.66	0.01	13.26	1.77	0.89 **
BRBL-02 X BRBL-04	2.86	1.25	0.18 **	3.34	1.28	0	12.22	1.11	-0.11
Swarna Mani X BRBR-01	3.32	0.66**	0	2.65	0.37**	-0.01	17.11	1.01	0.07
Swarna Mani X BRBL-01	2.51	0.97	0.05 **	2.94	1.44	0	14.85	1.68	0.5 *
Swarna Mani X BRBL-04	2.58	0.65	0.01 *	3.54	2.41	0.6 **	13.12	0.91	-0.1
BRBR-01 X BRBL-01	3.13	0.54	0.04 **	3.41	1.09	0.1 **	6.08	0.85	-0.13
BRBR-01 X BRBL-04	2.83	0.88	0.01 *	3.07	1.01	0	7.29	0.73	-0.03
BRBL-01 X BRBL-04	2.63	0.63	0.01 *	2.99	1.29	0.03 *	1.47	0.13*	-0.14
Rajendra Baigan-2	2.46	0.74	0.02 **	2.17	0.61	0	1.45	0.15**	-0.14
Muktakeshi	2.52	1.21	0.16 **	2.42	0.91	0.04 **	17.46	1.52	0
BRBL-02	2.52	0.68*	0	2.60	0.68*	-0.01	14.30	1.24	-0.04
Swarna Mani	2.22	0.96	0.1 **	3.16	1.43	0	17.39	1.24	-0.13
BRBR-01	3.35	0.88	0	2.63	0.92	0	17.10	1.34	0.02
BRBL-01	3.46	0.7	0.08 **	2.30	1.23	0.05 **	2.04	0.19*	-0.14
BRBL-04	2.85	0.69	0.01 *	2.69	0.43	0	1.56	0.27	-0.1
Pusa Hybrid-6	3.26	1.66	0.33 **	2.90	0.58	0	17.22	1.96	1.33 **
Population Mean	**2.90**			**2.95**			**11.86**		

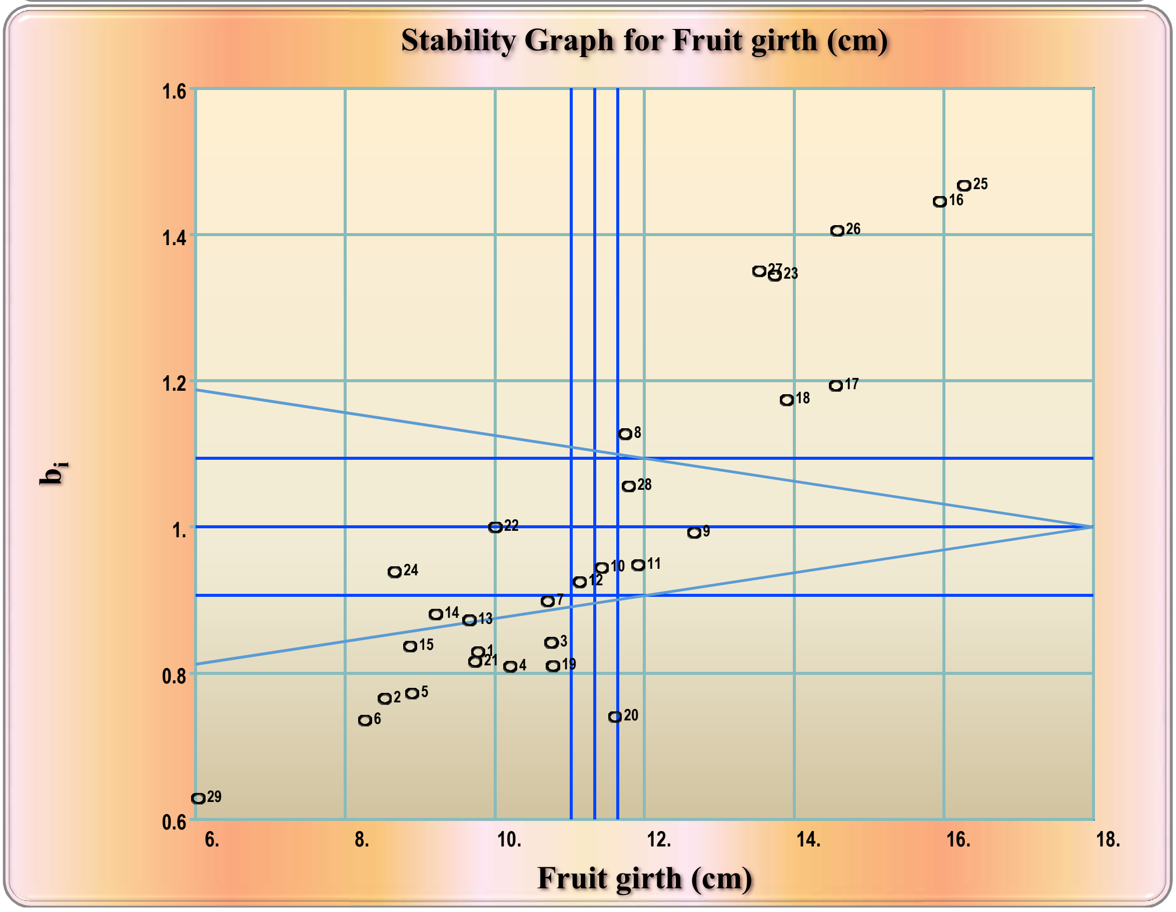
Table 9. Stability parameters for bioactive compounds

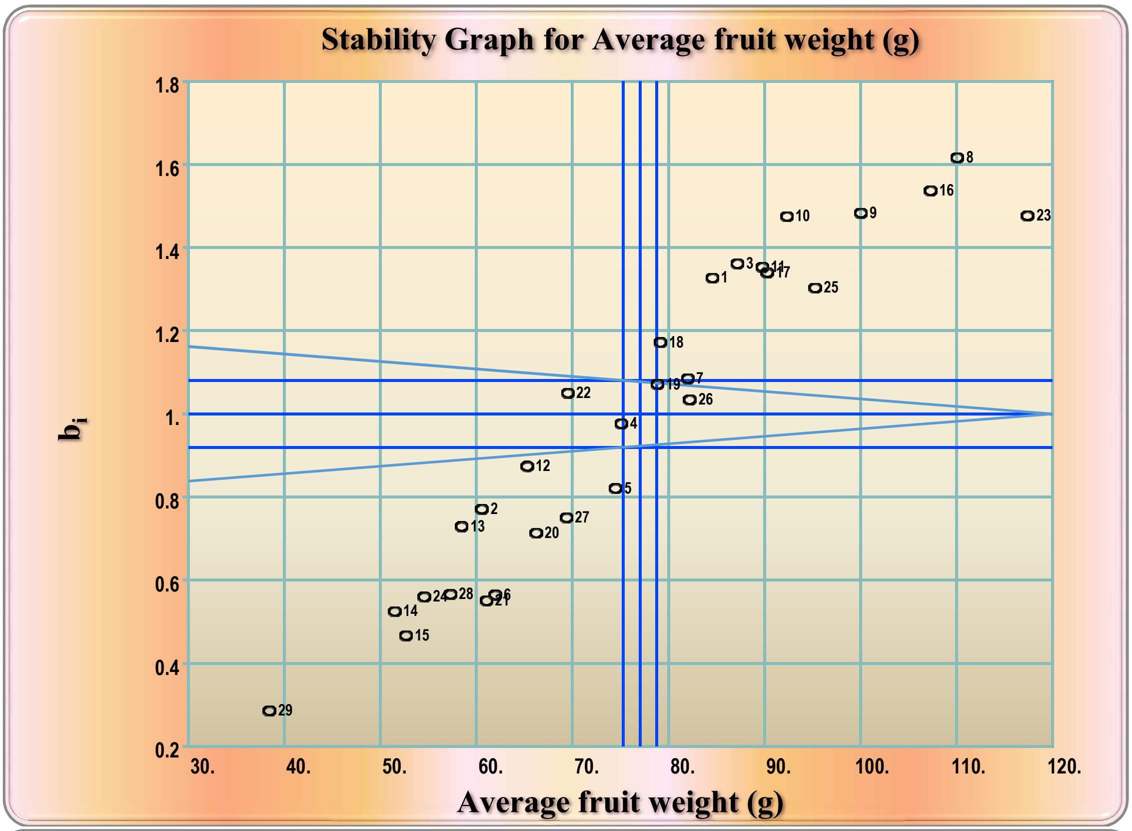
Character	Total phenolics content (mg/100 g)			Total antioxidant capacity (μ mol Trolox equivalent/g)		
Genotypes	**μ**	**b_i**	**S^2d_i**	**μ**	**b_i**	**S^2d_i**
Rajendra Baigan-2 X Muktakeshi	17.15	0.52**	-0.25	2.18	0.65	0.04
Rajendra Baigan-2 X BRBL-02	19.37	0.87	7.09 **	3.00	0.57	0.08 *
Rajendra Baigan-2 X Swarna Mani	19.04	1.34*	-0.24	3.58	1.94	2.37 **
Rajendra Baigan-2 X BRBR-01	17.79	1.07	2.62 **	2.20	0.85	0
Rajendra Baigan-2 X BRBL-01	18.95	0.63	-0.16	3.15	1.08	0.05 *
Rajendra Baigan-2 X BRBL-04	15.25	0.63	0.82 *	2.40	0.61	0.24 **
Muktakeshi X BRBL-02	19.55	1.25	3.81 **	2.83	0.77	0.08 **
Muktakeshi X Swarna Mani	20.13	1.76	1.8 **	4.54	2.01	0.48 **
Muktakeshi X BRBR-01	23.29	1.05	3.77 **	3.85	1.24	0.07 *
Muktakeshi X BRBL-01	17.30	0.86	1.18 *	3.29	0.84	0.02
Muktakeshi X BRBL-04	16.22	0.78	-0.14	2.68	0.72	0.03
BRBL-02 X Swarna Mani	19.95	1	0.88 *	3.59	1.65	1.75 ***
BRBL-02 X BRBR-01	24.46	0.89	5.58 **	3.10	0.61	0.02
BRBL-02 X BRBL-01	17.53	0.7	0.25	2.74	0.62	0.11 **
BRBL-02 X BRBL-04	22.39	1.22	-0.19	4.10	0.72	0.63 **
Swarna Mani X BRBR-01	25.23	2.31	17.47 **	5.41	1.68	0.82 **
Swarna Mani X BRBL-01	22.14	1.62	8.22 **	5.23	2.37*	0.02
Swarna Mani X BRBL-04	17.63	0.69	-0.21	2.97	1.03	0.34 **
BRBR-01 X BRBL-01	16.93	1.19	0	2.90	1.35	0.73 **
BRBR-01 X BRBL-04	23.50	1.2	0.83 *	2.95	0.82	0.01
BRBL-01 X BRBL-04	16.22	0.58	0.99 *	2.90	1.02	0.08 **
Rajendra Baigan-2	18.66	0.93	0.68	2.12	0.73	0.07 *
Muktakeshi	19.03	0.97	-0.08	3.17	0.99	0.02
BRBL-02	19.55	0.68	-0.14	2.33	0.51	0.23 **
Swarna Mani	18.76	0.81*	-0.24	3.28	1.08	0.1 **
BRBR-01	15.87	0.54	-0.02	2.28	0.62	0.03
BRBL-01	17.91	1.12	-0.18	2.12	0.6	0.14 **
BRBL-04	16.91	0.64	1.02 *	2.51	0.54	0.01
Pusa Hybrid-6	17.79	1.46*	-0.2	1.62	0.6*	-0.01
Population Mean	**19.19**	**-**	-	**3.10**	**-**	-

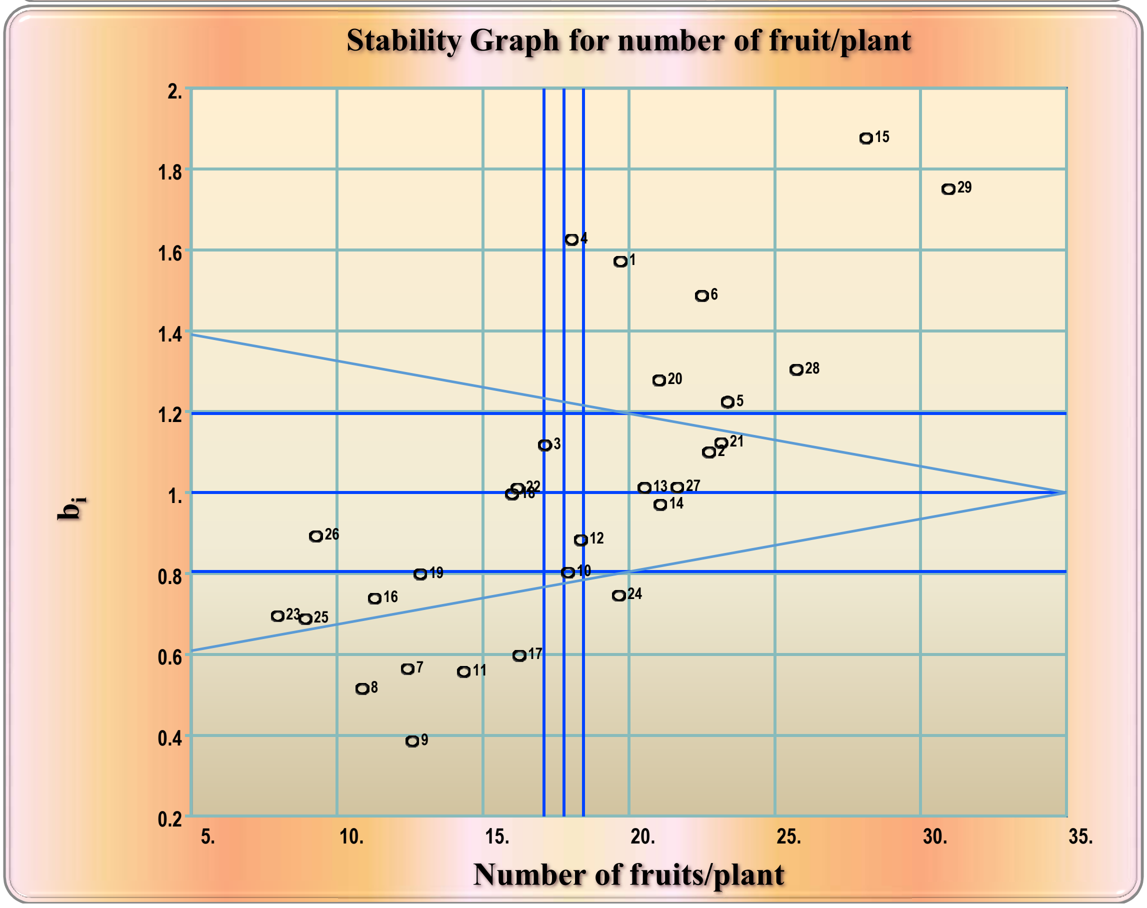

Stability Graph for Days to 50% Flowering
bi
2.
1.5
1.
0.5
0.
54.
56.
58.
60.
62.
64.
66.
68.
70.
Days to 50% Flowering

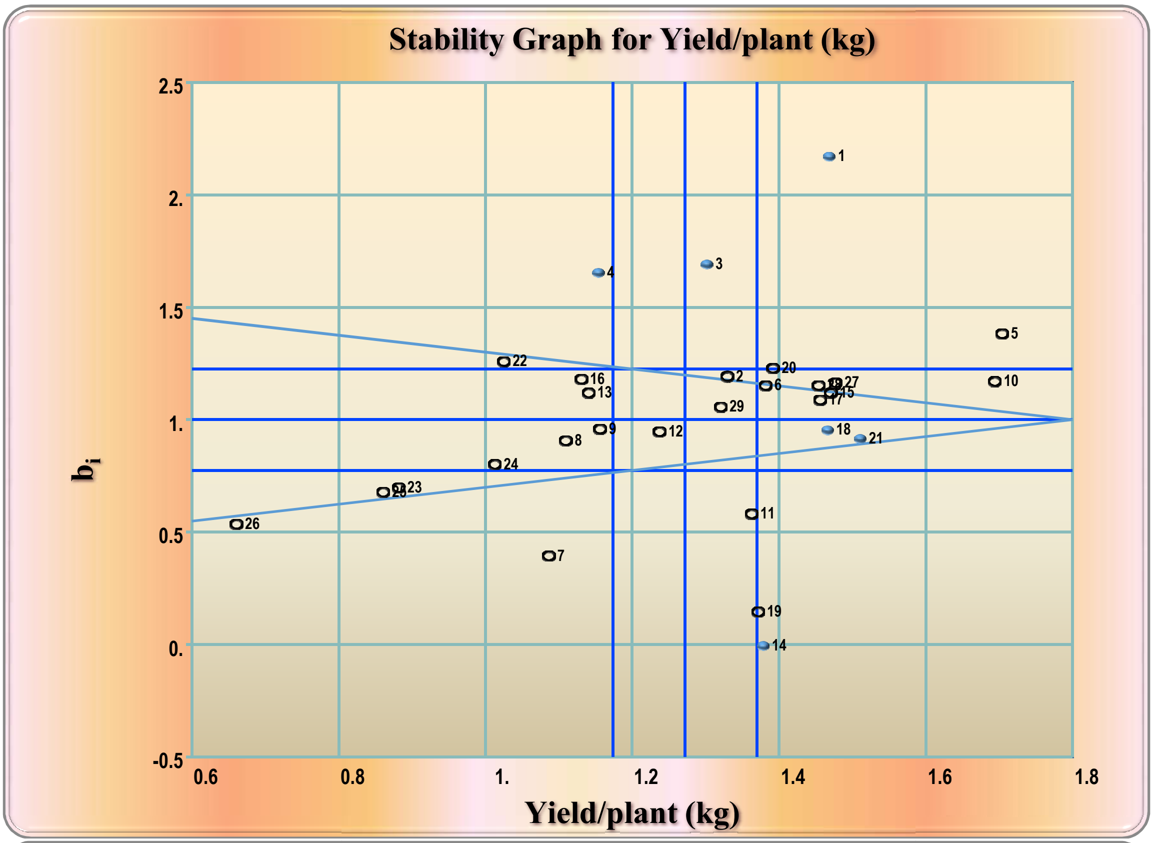

Stability Graph for Days to 1st Harvest
bi
2.5
2.
1.5
1.
0.5
0.
-0.5
60.
65.
70.
75.
80.
85.
Days to 1st Harvest

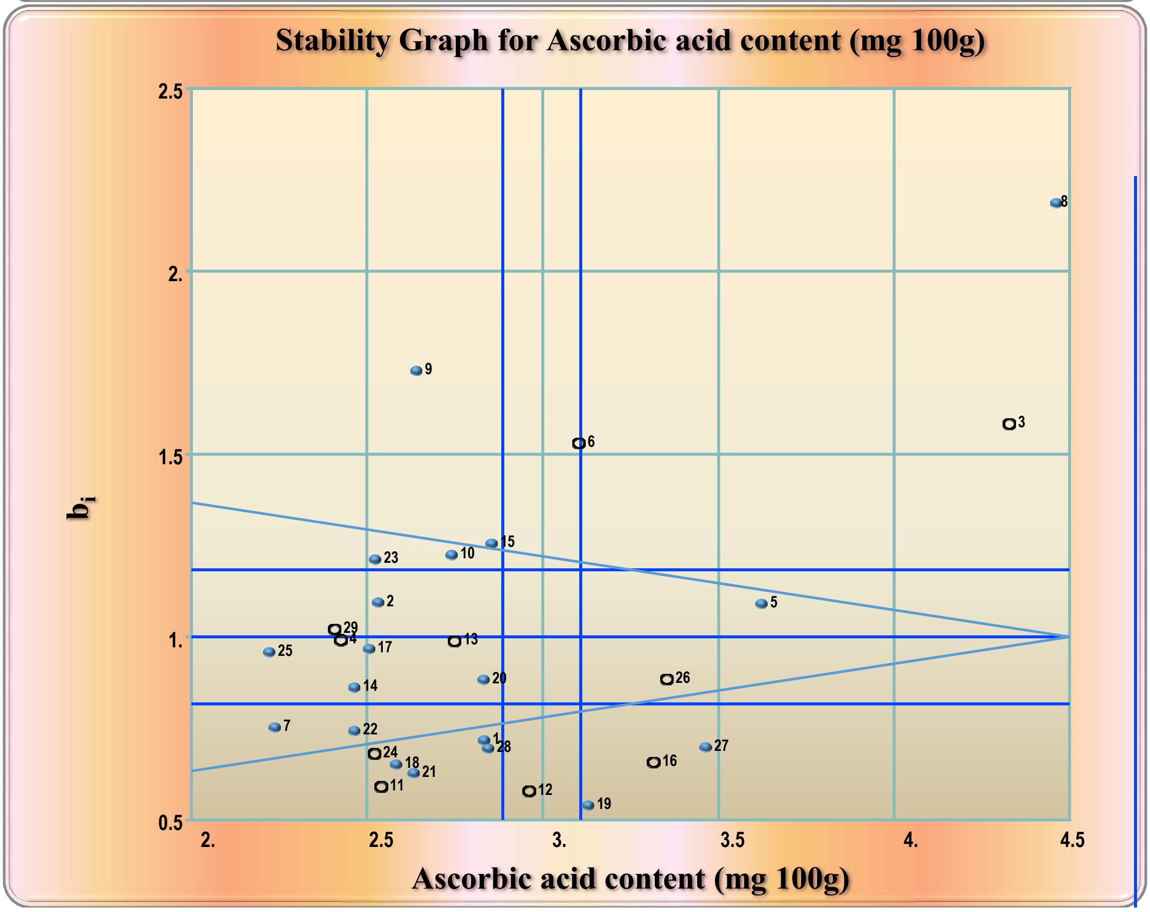

Stability Graph for Fruit Length (cm)
b_i
Fruit Length (cm)

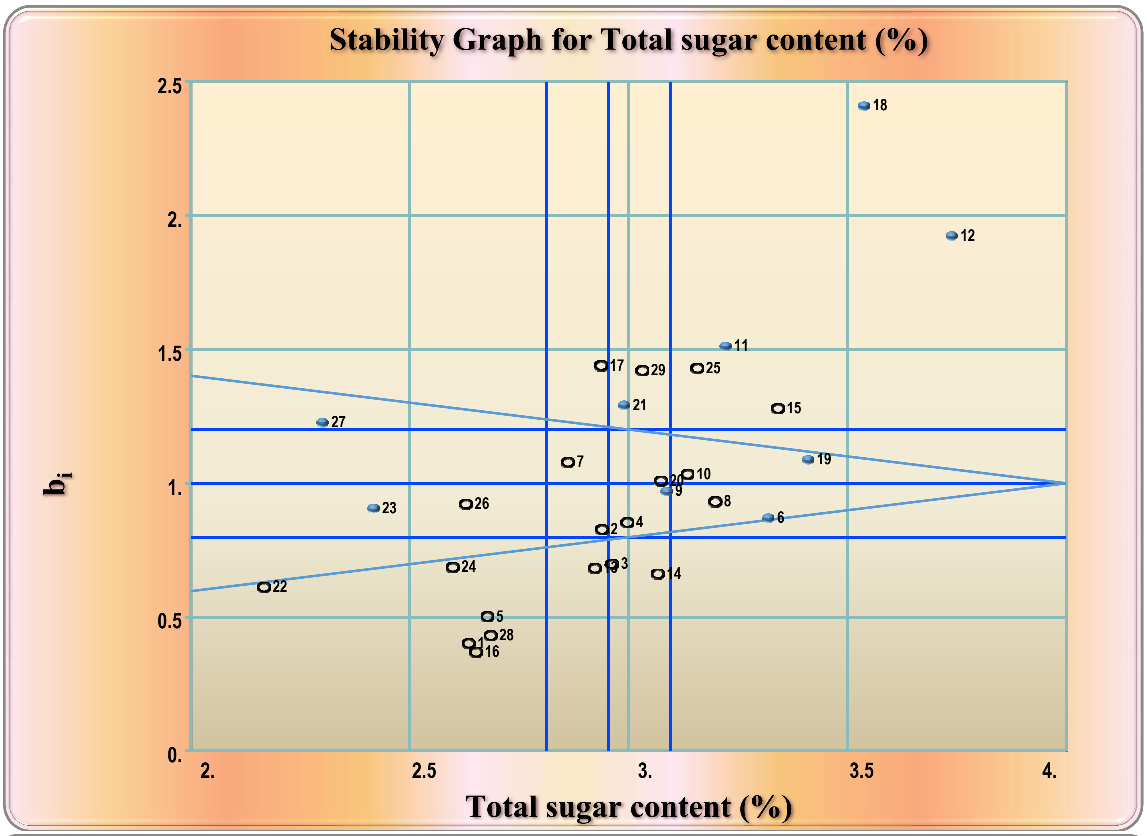

Stability Graph for Fruit girth (cm)
b_i
Fruit girth (cm)

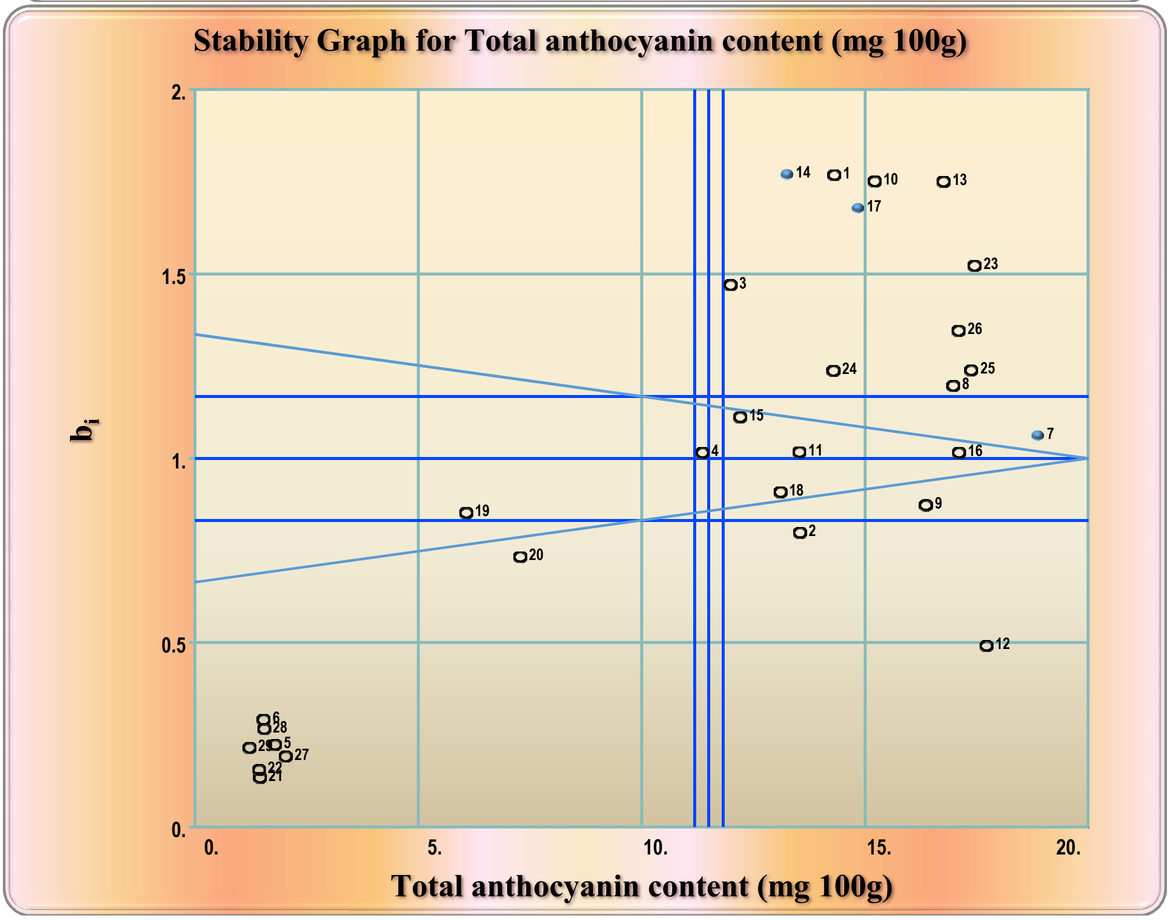

Stability Graph for Average fruit weight (g)
b_i
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
30.
40.
50.
60.
70.
80.
90.
100.
110.
120.
Average fruit weight (g)
8
16
10
9
23
3
11
1
17
25
18
19
7
22
26
4
12
5
2
13
27
20
24
28
6
21
14
15
29

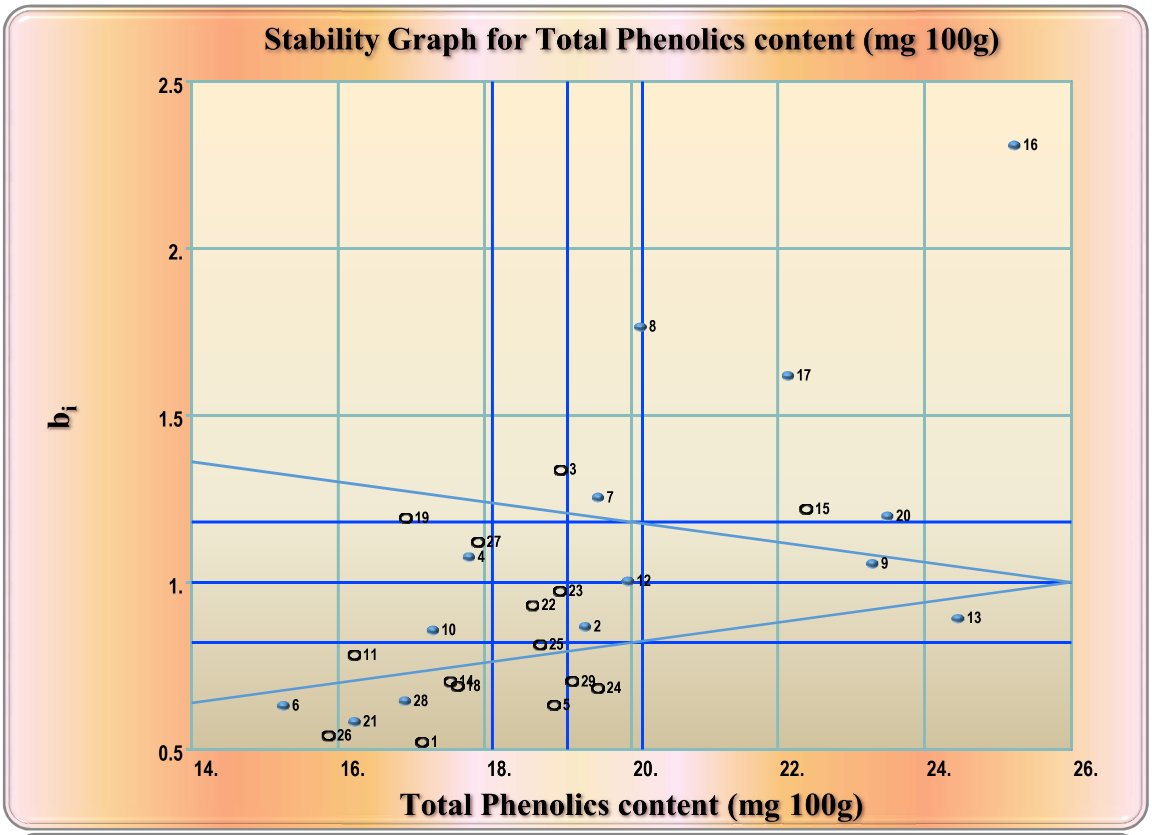

Stability Graph for number of fruit/plant
b_i
2.
1.8
1.6
1.4
1.2
1.
0.8
0.6
0.4
0.2
5.
10.
15.
20.
25.
30.
35.
Number of fruits/plant
15
29
4
1
6
20
28
5
21
2
3
22
18
13
27
14
26
12
19
10
16
24
23
25
17
7
11
8
9


Stability Graph for Yield/plant (kg)
2.5
2.
1.5
1.
0.5
0.
-0.5
b_i
0.6
0.8
1.
1.2
1.4
1.6
1.8
Yield/plant (kg)


Stability Graph for Ascorbic acid content (mg 100g)
2.5
2.
1.5
1.
0.5
b_i
2.
2.5
3.
3.5
4.
4.5
Ascorbic acid content (mg 100g)


Stability Graph for Total sugar content (%)
bi
Total sugar content (%)


Stability Graph for Total anthocyanin content (mg 100g)
bi
Total anthocyanin content (mg 100g)



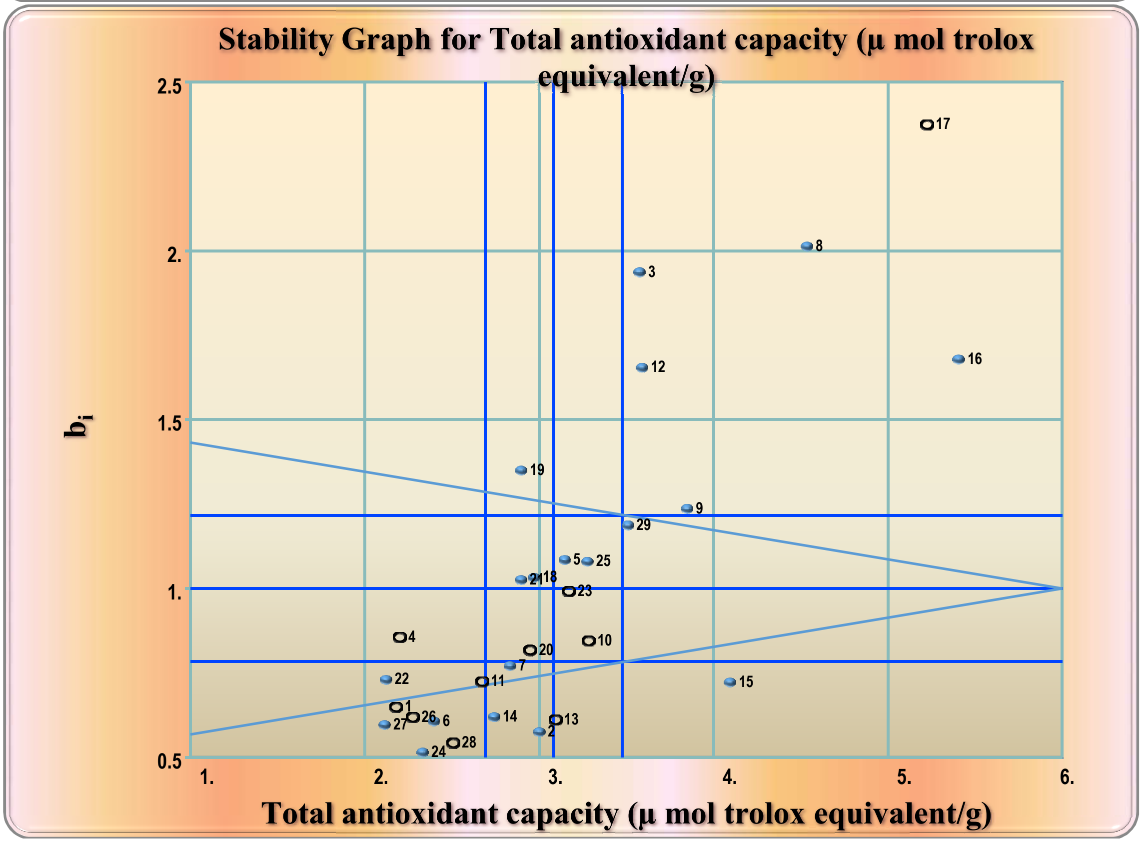


Fig. 1. Scatter graph of mean values versus regression coefficient for 12 morpho-biochemical characters

3.2 Stability of Biochemical Traits

Brinjal, grown all over the year, is a communal and popular vegetable crop in the India, therefore, can play an important role in reaching the nutritional security [20]. Being a main source of plant-derived nutrients, choice of brinjal genotypes with higher nutrients and better consumer preference could be useful for people, predominantly for deprived consumers. Eggplant has a high antioxidant capacity [21], and this is credited to its high content in phenolic complex. The numerous health aids of brinjal, which consist of anti-oxidant, anti-diabetic, hypotensive, cardioprotective and hepatoprotective effects [22,23], are largely credited to its phenolic content, in particular to chlorogenic acid. Studies have shown that eggplant extracts suppress the development of blood vessels required for tumor growth and metastasis [24] and inhibit inflammation that can lead to atherosclerosis [25]. Due to its low calorific value (24 kcal 100 g-1) and high potassium content (200 mg 100 g-1), it is suitable for diabetes, hypertensive and obese patients [26].

For ascorbic acid content (Table 8 and Fig. 1) only Rajendra Baigan-2 x BRBL-04 and BRBR-01 had higher mean values than the average mean with regression coefficient close to one and deviating non-significantly from zero were suitable to all environments. Similarly, Bhusan and Samnotra [15] observed that for ascorbic acid content, only two genotypes viz., Sandhya and Chhaya were stable.

Rajendra Baigan-2 x Swarna Mani, Rajendra Baigan-2 x BRBR-01, Muktakeshi x Swarna Mani, Muktakeshi x BRBL-01, BRBL-02 x BRBL-01, BRBL-02 x BRBL-04, BRBR-01 x BRBL-04 and Swarna Mani had higher mean values than the average mean for total sugar content (Table 8) with regression coefficient close to unity and non-significant deviation from regression lines were stable in all seasons. Kachouli et al. [19] also worked to know genotype × environment interaction for ascorbic acid and total sugar content.

For total anthocyanin content (Table 8) among seven parents, four purple coloured genotypes Muktakeshi, Swarna Mani, BRBL-02 and BRBR-01 were average responsive and stable in all seasons because of higher mean values than the average mean and non-significant deviation from the regression line. Among 21 hybrids, Rajendra Baigan-2 x Muktakeshi, Rajendra Baigan2 x BRBL-02, Muktakeshi x Swarna Mani, Muktakeshi x BRBR-01, Muktakeshi x BRBL-01, Muktakeshi x BRBL-04, BRBL-02 x Swarna Mani, BRBL-02 x BRBR-01, BRBL-02 x BRBL-04, Swarna Mani x BRBR-01 and Swarna Mani x BRBL-04 had higher mean with regression coefficient close to one and non-significant deviation from the regression line were considered stable.

Only BRBL-02 x BRBL-04 and BRBL-02 recorded higher mean values than the average mean with regression coefficient close to one and deviated non-significantly from zero, could be recommended for all seasons for total phenolics content (Table 9). Suneetha et al. [18] also observed two brinjal hybrids *viz*., Morvi 4-2 x JBPR-1 and AB 98-10 x Morvi 4-2 to be stable under Anand, Gujarat conditions. Bhusan and Samnotra [15] reported that one genotype PPL-74 was average responsive and thus adapted to all types of environments for total phenol content.

For total antioxidant capacity (Table 9), out of 29 genotypes, only Muktakeshi x BRBL-01, BRBL-02 x BRBR-01 and Muktakeshi had higher mean values than the population mean for total antioxidant capacity with regression coefficient not significantly deviating from one and non-significant deviation from regression line were average responsive and suitable for all environments.

In the present investigation, hybrids showed better performance than the corresponding parents. The probable reason is that hybrids have broader genetic base as compared to parents which increase the adaptability of hybrids [27,28,29,30].

4. CONCLUSION

Rajendra Baigan-2 x BRBL-02, Rajendra Baigan-2 x BRBL-01, Rajendra Baigan-2 x BRBL-04, Muktakeshi x BRBL-01, Muktakeshi x BRBL-04, BRBL-02 x BRBL-04, Swarna Mani x BRBL-01, BRBR-01 x BRBL-01 and BRBR-01 x BRBL-04 could be indentified stable hybrids and BRBL-01 and BRBL-04 as stable parents in terms of yield/plant. BRBL-02 x BRBL-04 was stable in terms of total sugar content, total anthocyanin content and total phenolics content. Parent BRBL-01 was stable for fruit length, fruit girth, number of fruits/plant and yield/plant. Hybrids Rajendra Baigan-2 x BRBL-

02, Rajendra Baigan-2 x BRBL-01 and Rajendra Baigan-2 x BRBL-04 were stable for fruit length, number of fruits/plant and yield/plant. These genotypes were identified as the stable genotypes for fruit yield and its component traits and hence, can be employed in breeding programme for incorporation of stability in present condition.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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