Variation in fruit morpho-biochemical characters and bioactive compounds of bilimbi (*Averrhoa bilimbi* L.) genotypes under semi-arid lateritic belt of West Bengal

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ABSTRACT

Bilimbi is one of the underutilized fruits and abundantly found under semi-arid lateritic belt of West Bengal. As there is no such report of scientific study on this fruit from this region, the study has been conductedduring the year 2022 and 2023 for morpho-biochemical characterization, determination of bioactive compounds and genetic diversity analysis of different bilimbi genotypes selected from natural vegetation. A wide array of distinctness with respect to fruit length (3.56 to 5.78 cm), fruit diameter (1.51 to 2.43 cm), fruit weight (9.52 to 14.11g), number of seeds (6.55 to 17.23), TSS (3.5 to 4.6ºBrix), acidity (1.26 to 1.41%) and ascorbic acid content (33.5 to 57.2 mg/100g) has been found. Additionally, the fruits are found to be rich in antioxidants (70.5 to 87.0% of DPPH inhibition), total phenols (38.4 to 30.2µgGAE/g) and flavonoids (29.7 to 41.2mgQE/g). Statistical analysis of observations gave out significantly positive correlation between number of seeds, fruit length, fruit diameter, ascorbic acid, antioxidant activity. Ascorbic acid content of bilimbi fruits has exhibited very high positive correlation with antioxidant activity, fruit weight, fruit length, fruit diameter, and total sugar. Noteworthy negative correlation was also noted between TSS and number of fruits per cluster, acidity in addition tobetween fruit diameter and number of fruits per clusterand acidity. The population of bilimbi genotypes fall under three clusters comprising 5, 7 and 4 different genotypes while five different parameter clusters have been noted to create variation among the bilimbi genotypes. With respect to fruit size and quality parameters bilimbi genotype BG-16 and BG-10 was found best under the present study.

Key words: Bilimbi, bioactive compounds, fruit morphology, genetic diversity, quality parameters,

INTRODUCTION

The bilimbi (*Averrhoa bilimbi* L.) is also commonly known as *Chemmeenpuli* in Malayalam, *Irumbanpuli* in Tamil and *Bilimbi Tenga* in Assamese (Billah *et al*., 2015). Bilimbi is also commonly referred as cucumber tree. It is hardy, long-lived tropical plant closely related to *Averrhoa carambola* (commonly known as carambola or starfruit). Bilimbi belongs to a category of minor fruits, a diverse group of plants often found growing naturally in unmanaged locations like roadsides, homesteads, and wastelands while their cultivation is generally limited. It has originated in the Southeast Asia and is claimed as a native of the West Malaysia and the Indonesian Moluccas (Veldkamp, 2004), mostly found in tropics and subtropics. Bilimbi is a nutrient-dense, medicinally valuable fruit. In addition to carambola, bilimbi is another woody plant comes under the family Oxalidaceae and only fruit-

bearing species valued for their edible fruit rich in oxalic acid (Hazmi *et al*., 2024).

Bilimbi fruits are eaten raw, as well used for preparation of pickle, vinegar, wine and as a substitute for tamarind in dishes and flavouring agent (Dewi and Juwithninglyas, 2024). Mature and ripened fruits are commonly used for preservation in sugar or are cut, sun dried and preserved for future use (Ho *et al*., 2020). Fruit juice is very sour and is utilized in beverages preparation (Nilugin and Mahendran, 2016).The fruit is high in Vitamin C, and it also contains fibers, protein, anthocyanin, tannins, and minerals (Jayawardane *et al*., 2022; Dangat *et al*., 2024). Fruits are reported to be used to cure fever, rectum inflammation, diabetes, rheumatism, whooping cough, stomach ache, ulcer, and other conditions (Iwansyah *et al*., 2021; Aparna *et al*., 2022). Different plant parts of bilimbi like leaves, seeds, bark, fruits, flowers and roots as well as the entire plant as a whole are reported touse for the treatment of many diseases, mainly utilized as antidiabetic agents (Kumar *et al*., 2013).

The semi-arid lateritic belt of West Bengal comprises the districts Birbhum, Bankura, West Burdwan and parts of Purulia. The scorching heat with heat wave during summer followed by high humid rainy season and cold winter are the climatic features of this region. Most of the soils are red-lateritic in nature and resulted from incomplete weathering of rocks. Soils are deficient in carbon and other major nutrients. Natural vegetation and discrete forest area are also the reservoir of flora diversity including a considerable number of underutilized fruits. Distribution of bilimbi plants in natural greeneries, backyard gardens and household vegetations are common in the districts of Birbhum, West Burdwan and Bankura district but no scientific reports are there with respect to the genetic diversity of the fruit. Despite the lack of scientific research findings with respect to morpho-bichemical diversity, bilimbi is popular among local peoples for its unique sweet and sour flavour, rich nutritional profile and medicinal properties like as other minor fruits (Pradhan *et al*., 2015). Therefore, the present study has been aimed to determine the diversity analysis of available bilimbi genotypes under semi-arid lateritic belt of West Bengal with respect to morpho-biochemical characters and bioactive compounds.

MATERIALS AND METHODS

Present investigation has been performed selecting sixteen different bilimbi genotypes, all aged between 15 to 20 years, from various locations of Birbhum, West Burdwan and Bankura Districts of West Bengal which come under semi-arid lateritic zone, during the year 2022 and 2023. The GPS coordinates of each bilimbi plant were recorded using a handheld Garmin GPS 12H device (Table 1). The fully mature and ripe bunch of bilimbi was brought to Department of Horticulture and Post-harvest Technology, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India. Physical parameters of the fruit were recorded on-site, and samples of both the bunch and fruit were collected for further physical and biochemical analysis.The specifics of the experiment, including the materials used and the techniques employed, are detailed as follows.

Fruit physical characters: The fruit morphological characteristics of selected bilimbi plants were recordedas per the need of the study. Measurements included fruit length, diameter, weight, seed count, number fruits in a single bunch etc. Fruit length and diameterwere measured using a vernier caliper. Fruit weight, seed weights weremeasured using a digital balance. **Fruit biochemical Characters:** Total Soluble Solids (TSS) content was measured by digital refractometer (0-65°B, Konika Minolta, Japan) and expressed in °Brix. Acidity of bilimbi fruit juice was measured by titration method (Rangana, 1986). Total sugarwas measured following the method as described by AOAC (1990).Ascorbic acid was quantified using the indophenol dye

method (Rangana, 1986). Antioxidant activity has been determinedusing the DPPH assay (Brand-Williams *et al*., 1995) with the help of a double beam UV-Visible spectrophotometer (LABMAN, LUV2000T, India). Total phenolic content was measured by Folin Ciocalteu's method (Dewanto *et al*., 2002) using UV visible spectrophotometer (LABMAN, Model LMS PUV 1200)and expressed as mg of quercetin equivalent weight (mgQE/100 g).

Statistical analysis of data: The data on the observations were subjected to descriptive statistics and analysis of variance, following the method proposed by Ronald A. Fisher (Gomez and Gomez, 1984).The fruit morphological and biochemical data were investigatedwith thestatistical softwareSPSS (Statistical Package for Social Sciences, IBM SPSS Version 27)for correlation and cluster analysis.

RESULTS AND DISCUSSION

The present study focused on diversity of morphological, biochemical parameters of sixteen different bilimbi genotypes and their bioactive compounds. The mean variance analysis of morphological characters, biochemical characters and bioactive compounds of sixteen bilimbi (*Averrhoa bilimbi* L.) genotypes are discussed below:

Morphological characters: All the statistically analyzed observations on fruit morphological characters are cited in Table 2. **The number of fruits per cluster** of different bilimbi genotypes under the present study has been ranged from 4.21 to 8.71. The bilimbi genotype BG-3(8.71) produced the maximum average number of fruits per cluster, followed by BG-5 (8.44), BG-7 (7.17) and BG-11 (6.81) and it was lowest in BG-16 (4.21) and preceded by BG-13 (4.67), BG-14 (4.99). The meanvalue of number of fruits per cluster of bilibmi genotypes was 6.15. **The length of fruits** across sixteen bilimbi genotypes varied between 3.56 cm to 5.78 cm. The highest fruit length was observed in BG-16 (5.78 cm) followed by BG-10 (5.65 cm), BG-14 (5.37 cm) and BG-6 (5.22 cm). The lowest reading was noted in BG-5 with a fruit length of 3.56 cm preceded by BG-3 (3.99 cm) and BG-1 (4.06 cm).**The diameter of bilimbi fruits** in the present study ranged from 1.51 to 2.43 cm. The lowest fruit diameter was observed in BG-3 (1.51 cm) preceded by BG-9 (1.62 cm), BG-2 (1.63 cm) and BG-5 (1.63 cm). The maximum fruit diameter was found in the genotype BG-16 (2.43 cm) followed by BG - 6 (2.20 cm).**The fruit weight** of different bilimbi genotypes varied between 14.11 g in BG-16 to 9.52 g in BG-5. Higher fruit weight was also recorded in BG-10 (13.25 g), BG-14 (12.83 g) and BG-13 (12.57 g). Lowest fruit weight was also recorded in BG-3 (10.06 g) followed by BG-7 (10.53 g) and BG-1 (10.85 g).**The number of seeds per fruit** of bilimbi genotypes under the study ranged from6.55 to 17.23. The lowest number of seeds was observed in BG-3 (6.55) and followed by BG-1 and BG-5 (7.78 and 8.56 respectively). The highest number of seeds per fruit was noted from BG- 10, BG-16 and BG-14 (17.23 16.63, 15.56).**The 10 seed weight** of the bilimbi genotypes varied between 1.52 to 1.91 g under the present study. The highest reading was observed in BG-1 (1.91 g) followed by BG-12 (1.90 g), BG-3 (1.88 g) and BG-5 (1.85 g). The lowest reading was observed in BG-10 (1.52 g), BG-13 (1.57 g) and BG-14 (1.61 g).

The result of the current investigation with respect to fruit length, fruit diameter and fruit weight has the similarity with the findings of Dangat *et al*. (2014). The average numbers of seeds of bilimbi fruits in the present study are in line with the findings of Bhaskar and Shantaram (2013). The difference in the findings are might be due to the genotypic variation of bilimbi plants.

Biochemical characters: All the statistically analyzed observations on fruit biochemical characters are furnished in Table 3. **The total soluble solids** content of bilimbi fruits significantly varied from 5.5º to 6.6º Brix, with 5.8º Brix in general (Table 2). In which

maximum TSS of bilimbi fruits was noted in genotype BG-16 and lowest in genotype BG-3 and BG-5. Elevated TSS was also found in BG-14 and BG-6 (6.5and 6.4º Brix respectively). The percentage of **total acidity** in bilimbi genotypes have been ranged from 1.26% to 1.41%. BG-14, BG-16, and BG-13 were categorized under the low-acid group, with acidity levels of 1.26%, 1.28%, and 1.29%, respectively. Conversely, BG-2, BG-4, and BG-1 were classified under the high-acid group, with acidity levels of 1.41%, 1.40%, and 1.39%, respectively.The percentage of **total sugar** also revealed considerable variation from 4.02 to 5.80 % with an average of 4.60 %.The total sugar percentage was extremely low in BG-1(4.02%) preceded by BG-8 (4.09%) and BG-2 (4.17%). On contrary BG-16 (highest), BG-14, BG-10 and BG-6 were scored higher total sugar content. The Bilimbi genotypes in the present experiment exhibited an extensive array of **ascorbic acid content** (33.5 to 57.2 mg/100g). The truncated ascorbic acid content was observed in BG-9 (33.5mg/100g),gone advanced by BG-5 (33.8 mg/100g). The maximum ascorbic acid content was noted in accession BG-14 (57.2mg/100gm), closely followed by BG-10 (55.2mg/100gm).

Ferreira *et al*. (2022) and Arroxelas *et al*. (2001) have found the TSS range of 3.2 to 4.3º Brix which has the consonance with the findings of present experiment. More or less closer result with respect to acidity of bilimbi fruits has been reported by Nilugin and Mahendran (2016) and Ferreira *et al*. (2022). Nilugin and Mahendran (2016) has found average 4.2% total sugar in bilimbi fruits. The range of ascorbic acid content in bilimbi has been reported as 26.5 to 51.2 mg/100g in the studies by other scientists like Ho *et al*. (2020), Nilugin and Mahendran (2016), Dewi and Juwithninglyas (2024) and Arroxelas *et al*. (2001) which support the similarity of the result of present experiment.

Bioactive compounds: All the statistically analyzed observations on fruit bioactive compounds are presented in Table 3. **Antioxidant activity (DPPH radical scavenging activity %)**of sixteen different bilimbi accessions has been ranged from 70.5 to 87.0%. The maximum total antioxidants percentage was expressed by the germplasm BG-14 (87%)on the other hand BG-1(70.5%) possessed lowest content of antioxidant, preceded by BG-9 (71.3%) and BG-5 (72.7%). Some other potential bilimbi accessions with respect to higher antioxidant content are BG-13 (83.2%) and BG-16 (82.1%).**Total Phenolic compound:** Total phenolics are also considered as important bioactive compound. The bilimbi fruits of sixteen different genotype possessed considerable high range of total phenolics (30.2 to 38.4 µgGAE/g) in the bilimbi fruit (BG-7 and BG-5) followed by higher phenolics content recorded under genotype BG-4 (37.9µgGAE/g) and BG-6 (35.3µgGAE/g). **Flavonoid content (mgQE/g):**The different genotypes of bilimbi fruits have exhibited a greater variation in flavonoid content. Highest flavonoid content (41.2 mgQE/g) was recorded in BG-6 and lowest in BG-16 (29.7 mgQE/g). The bilimbi accessions namely BG-5 and BG-3 also possessed higher flavonoid content of 39.0 and 38.4 mgQE/g.

Very high antioxidant activity of bilimbi fruit juice and the pulp have been noted by Asna and Noriham (2014), Iwansyah *et al*. (2021) and Sreedharan *et al*. (2020) and they have found the range of DPPH inhibition range of 69.2 to 87.4% which is closely supports the result of the current study. Iwansyah *et al*. (2021) and Abraham (2016) found considerable phenol content in bilimbi fruits which have ranged from 28.6 to 38.7mgQE/g. Thus the phenol content of bilimbi genotypes under present study has the consonance with the report of Iwansyah *et al*. (2021) and Abraham (2016). Supporting to the result of flavonoid content of bilimbi fruits of present study, Iwansyah *et al*. (2021), Ferreira *et al*. (2022), Abraham (2016) and Asna and Noriham (2014) have reported similar result. All the variations of results on bioactive compounds of bilimbi

fruits conceivably be due to genetic makeup and environmental variation of growing conditions.

Correlation analysis: The analysis of correlation between different parameters (level of significance =0.05) is exhibited in Table 4. Average number of seeds present in single bilimbi fruit under the present study has shown high positive Correlation with fruit length (+0.86) fruit diameter (+0.81) ascorbic acid (+0.84) antioxidant activity (+0.82)and T.S.S. (+0.78). While a great extent of negative correlation between number of seeds per fruit and number of fruits per cluster (-0.76), acidity(-0.72),10 seed weight (- 0.71) and flavonoid content (-0.67) have been noticed. Amount of ascorbic acid in bilimbi fruits has exhibited very high positive correlation with antioxidant activity (+0.91), fruit weight (+0.88), fruit length (+0.84), fruit diameter (+0.84) and total sugar (+0.82). Moderate negative correlation between amount of ascorbic acid in bilimbi fruits and number of fruit per clusters (-.76), 10 seed weight (- 0.66), flavonoid content (-0.69) and acidity (-0.64) were recorded. Positive correlation of antioxidant activity with fruit length (0.79), fruit weight (+0.78), total sugar (+0.77) and T.S.S. (+0.68) have been found. On contradictory,negative correlation have been found between antioxidant activity with acidity (-0.72), number of fruits per cluster (-0.68), flavonoid content (-0.58) and 10 seed weight (-0.58). TSS of bilimbi fruits has shown high positive correlation with fruit weight (+0.83), total sugar (+0.78), fruit length (+0.76) and fruit diameter +0.76). Notable negative correlation between T.S.S. and number of fruits per cluster (-0.79), acidity (-0.76) were also observed in the present experiment. Total sugar was greatly positively correlated with fruit weight (+0.81), fruit diameter (+0.80) and fruit length (+0.79), while resolutely negative correlation has been found with acidity (-0.75). Fruit diameter was under positive correlation with fruit length (+0.86) and fruit weight (+0.89) and notable negative correlation noticed with number of fruits per cluster (-0.75) and acidity (-0.65).Although the fruit length has shown high positive correlation with fruit weight (0.92),however it resembledraised negative correlation with number of fruits per cluster (-0.77) and flavonoid content (-0.66).Fruit weight possessed high degree of negative correlation with number of fruits per cluster (-0.87), flavonoid content (-0.74) and acidity (-0.63). Acidity of bilimbi fruits in the present research has shown moderate positive correlation with total phenolics (+0.57), flavonoid content (+0.53) have been observed in bilimbi fruits.

Till date there is no report of correlation studies of fruit morphological and biochemical characters of bilimbi fruit. However, Pawar *et al*. (2014) have reported the strong positive correlation of fruit weight with fruit length, fruit diameter, volume of fruits, and number of seeds in carambola. This report of Pawar *et al*. (2014) has similarity with the findings of present experiment. The dissimilarity of the results might be attributed to the variation in genotypes and difference of growing conditions.

Two-way hierarchical clustering: Two-way hierarchical clustering of sixteen bilimbi genotypes has shown in Figure 1 with clear picture of three clusters in the present population. Five bilimbi genotypes (BG-16, BG-10, BG-13, BG-14 and BG-6) have been placed in a far most cluster (Cluster I), the second cluster (cluster II) comprised of seven bilimbi genotypes (BG-15, BG-11, BG-2, BG-12, BG-8, BG-4 and BG-7). The smallest cluster (cluster III) was populated with four bilimbi genotypes (BG-3, BG-1,BG-5 and BG-9). Out of these three clusters, cluster I was most distant and farthest from other two clusters (cluster II and cluster III). The genotypes under third cluster where most close to each other.Clustering of parameters shows five distinct divisions out of which antioxidant activity was in the nearest distinction (parameter cluster I) followed by fruited and number of seeds per fruit (parameter cluster

II). Acidity, fruit diameter and ten seed weight has created little bit greater variation among the bilimbi genotypes under present experiment (parameter cluster III). While fruits per cluster, TSS,fruit length and total sugar has also contributed a good variation among bilimbi genotypes (parameter cluster IV). Ascorbic acid content, total phenolic and flavonoid content have created most distinct variation among the bilimbi genotypes (parameter cluster V).

Padun and Singh (2018) have found four clusters of carambola genotypes under Arunachal condition out of which three major clusters were prominent and this finding has consonance with the findings of present experiment.

CONCLUSION

Present investigation revealed a wide array of variation on fruit morpho-biochemical characters and bioactive compounds of bilimbi genotypes grown under semi-arid lateritic belt of West Bengal. Determination of bioactive compounds of bilimbi genotypes also shown away the fruits to be rich in antioxidants (70.5 to 87.0% of DPPH inhibition), total phenols (38.4 to 30.2µgGAE/g) and flavonoids (29.7 to 41.2mgQE/g). Positive correlation between number of seeds, fruit length, fruit diameter, ascorbic acid, antioxidant activity and TSSwas noted. Additionally, ascorbic acid content has exhibited very high positive correlation with antioxidant activity, fruit weight, fruit length, fruit diameter, and total sugar. Noteworthy negative correlation was also noted between TSS and number of fruits per cluster, acidity in addition to between fruit diameter and number of fruits per clusterand acidity. The population of bilimbi genotypes fall under three clusters comprising 5, 7 and 4 different genotypes while five different parameter clusters have been noted to create variation among the bilimbi genotypes. With respect to fruit size and quality parameters bilimbi genotype BG-16 and BG-10 was found best under the present study.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: GPS locations of bilimbi genotypes selected under present study:

Genotypes (BG)	Address	GPS location
BG-1	Ruppur village, Bolpur, Birbhum, West Bengal	23.66ºN, 87.60ºE
BG-2	Kasthagara, Mallarpur, Birbhum, West Bengal	24.11ºN, 87.70ºE
BG-3	Gunutia, Birbhum, West Bengal	23.86ºN, 87.83ºE
BG-4	Gangarampur, Khoirashole, Birbhum, West Bengal	23.81ºN, 87.20ºE
BG-5	Goalmal, Murarai, Birbhum, West Bengal	24.40ºN, 87.90ºE
BG-6	Barshal, Rampurhat, Birbhum, West Bengal	24.15ºN, 87.78ºE
BG-7	Dhundabad, Kulti, West Burdwan, West Bengal	23.77ºN, 86.88ºE
BG-8	Nimsa, Pandabeshwar, West Burdwan, West Bengal	23.72ºN, 87.19ºE
BG-9	Shokna, Panagarh, West Burdwan, West Bengal	23.44ºN, 87.42ºE
BG-10	Bhagabanpur, Mankar, West Burdwan, West Bengal	23.40ºN, 87.57ºE
BG-11	Senara, Raghunathpur, Bankura, West Bengal	23.57ºN, 86.74ºE
BG-12	Nidhirampur, Gangajalghati, Bankura, West Bengal	23.47ºN, 87.11ºE
BG-13	Kuludihi, Chhatna, Bankura, West Bengal	23.32ºN, 86.96ºE
BG-14	Chechurya, Taldangra, Bankura, West Bengal	23.05ºN, 87.08ºE
BG-15	Rajganja, Joypur, Bankura, West Bengal	23.03ºN, 87.44ºE
BG-16	Sihas, Kotulpur, Bankura, West Bengal	23.00ºN, 87.63ºE

Table 2: Fruit morphological diversity of different bilimbi genotypes under semi-arid lateritic part of West Bengal

Bilimbi genotypes (BG)	No. of fruits/ cluster	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	No. of seeds/ fruit	10 seed weight
BG-1	6.55	4.06	1.80	10.85	7.78	1.91
BG-2	6.34	4.11	1.63	11.21	8.92	1.65
BG-3	8.71	3.99	1.51	10.06	6.55	1.88
BG-4	5.93	4.88	1.90	11.50	10.31	1.62
BG-5	8.44	3.56	1.63	9.52	8.56	1.85
BG-6	5.82	5.22	2.20	12.46	14.82	1.70
BG-7	7.17	4.72	1.71	10.53	12.40	1.66
BG-8	5.08	5.01	1.99	11.92	12.72	1.70
BG-9	6.12	4.59	1.62	11.35	10.86	1.78
BG-10	5.74	5.65	2.11	13.25	17.23	1.52
BG-11	6.81	4.73	1.91	11.84	12.35	1.81
BG-12	6.22	4.92	1.82	11.96	10.29	1.90
BG-13	4.67	5.11	1.88	12.57	15.14	1.57
BG-14	4.99	5.37	2.11	12.83	15.56	1.61
BG-15	5.72	4.14	1.77	11.44	13.25	1.69
BG-16	4.21	5.78	2.43	14.11	16.63	1.72
SD	1.18	0.61	0.23	1.14	3.13	0.11
Mean	6.15	4.74	1.87	11.71	12.08	1.72

Table 3: Biochemical characters and bioactive compound diversity of different bilimbi genotypes under semi-arid lateritic part of West Bengal

Bilimbi genotypes (BG)	TSS (ºBrix)	Acidity (%)	Total sugar (%)	Ascorbic acid (%)	Antioxidant activity (DPPH % inhibition)	Total phenolics (mg GAE/g)	Flavonoid content (mgQE/g)
BG-1	5.8	1.39	4.02	38.3	70.5	33.7	37.1
BG-2	5.8	1.41	4.17	40.6	75.2	32.8	36.8
BG-3	5.5	1.37	4.30	37.1	73.6	32.5	38.4
BG-4	5.7	1.40	4.56	44.2	74.3	37.9	36.6
BG-5	5.5	1.32	4.35	33.8	72.7	30.2	39.0
BG-6	6.4	1.30	5.11	49.5	81.8	35.3	41.2
BG-7	5.7	1.40	4.20	38.0	76.0	38.4	37.3
BG-8	6.0	1.31	4.09	45.6	79.9	33.7	33.8
BG-9	6.3	1.33	4.38	33.5	71.3	33.2	35.9
BG-10	6.1	1.30	5.25	55.2	80.7	31.6	30.4
BG-11	5.9	1.34	4.28	41.3	76.4	32.9	36.0
BG-12	5.7	1.38	4.44	43.8	78.6	33.5	35.9
BG-13	6.2	1.29	5.03	50.8	83.2	31.4	32.3
BG-14	6.5	1.26	5.39	57.2	87.0	31.3	31.5
BG-15	5.8	1.37	4.24	43.7	75.8	33.4	35.2
BG-16	6.6	1.28	5.80	52.9	82.1	32.0	29.7
SD	0.33	0.04	0.52	7.10	4.52	2.15	3.07
Mean	5.96	1.34	4.60	44.09	77.44	33.36	35.44

Table 4: Correlation analysis of different morphological, biochemical parameters and bioactive compounds of sixteen bilimbi genotypes under semi-arid lateritic belt of West Bengal

	No. of seeds/ fruit	Ascorbic acid	Antioxidant activity	TSS	Total sugar	Fruit diameter	Fruit length	Fruit weight	Acidity	Total phenolics	Fruit length	No. of fruits/ cluster	Flavonoid content
No. of seeds/ fruit	1												
Ascorbic acid	+0.84	1											
Antioxidant activity	+0.82	+0.91	1										
TSS	+0.78	+0.68	+0.68	1									
Total sugar	+0.78	+0.82	+0.77	+0.78	1								
Fruit diameter	+0.81	+0.84	+0.74	+0.76	+0.80	1							
Fruit length	+0.86	+0.84	+0.79	+0.76	+0.79	+0.86	1						
Fruit weight	+0.86	+0.88	+0.78	+0.83	+0.81	+0.89	+0.92	1					
Acidity	-0.72	-0.64	-0.72	-0.76	-0.75	-0.65	-0.60	-0.63	1				
Total phenolics	-0.12	-0.20	-0.23	-0.22	-0.30	-0.06	0.05	-0.18	+0.57	1			
10 seed weight	-0.71	-0.66	-0.58	-0.43	-0.49	-0.41	-0.57	-0.53	+0.33	-0.1	1		
No. of fruits/ cluster	-0.76	-0.76	-0.68	-0.79	-0.60	-0.75	-0.77	-0.87	+0.50	+0.05	+0.58	1	
Flavonoid content	-0.67	-0.69	-0.58	-0.55	-0.60	-0.55	-0.66	-0.74	+0.53	+0.40	+0.51	+0.70	1

(Level of significance P=0.05)

Figure 1: Two-way hierarchical clustering of sixteen bilimbi genotypes grown under semi-arid lateritic belt of West Bengal