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Morpho-biochemical characterization of pomelo (*Citrus grandis* L.) accessions and assessment of bioactive compounds under western part of West Bengal

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ABSTRACT

Rich genetic base of Pomelo (Citrus grandis L.*) in India as a whole and Eastern India in particular, made wide variation in their fruit morphology, quality and presence of bioactive compounds. Thus the present study has been undertaken to characterize twelve pomelo accessions selected from different locations of Birbhum distrct which comes under western dry tract of West Bengal during the year 2023 at Department of Horticulture & Postharvest Technology, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal (India). Wide fruit morphological variation with respect to fruit length (14.2 to 25.0cm), fruit diameter (14.1 to 23.5) and rind thickness (1.15 to 2.36cm) were observed within the studied pomelo accessions. Considerable wider ranges of fruit weight (478.7 to 1323.6g), pulp weight (326.2 to 1051.5g), number of segments (13.6 to 18.0) have also been noted. Mean value of number of seeds and 10 seed weight was 46.18/fruit and 3.17g respectively which exhibited the range of 27.5 to 61.7/fruit and 2.22 to 4.79g respectively. Juice content varied from 48.7 to 65.1 ml/100g fruit pulp with 58.23 ml/100g as mean value. Moderate to high TSS (7.5 to 12.4^{o}Brix), good range of total sugar (5.2 to 7.7%) and reducing sugar (3.0 to 4.6%) have been noted from different pomelo accessions. Mean value of acidity was 0.87% and TSS-acidity ratio was ranged from 8.06 to 16.37. Richness of the fruit in ascorbic acid content was noted (31.9 to 49.9 mg/100g pulp) along with high to moderate antioxidation capacity (30.8 to 65.4 DPPH IC_{50}). Pomelo fruits were rich in flavonoid content (3.2 to 7.2 mgRE/g) with high total phenolics (272.9 to 412.0 µgGAE/g) and diverse anthocyanin content (5.3 to 48.5 mg/100g).*

***Keywords*:** Bioactive compounds, diversity, fruit morphology, pomelo accessions, quality parameters

INTRODUCTION

Citrus grandis L. (syn. *Citrus maxima* L.) is commonly known as pomelo, is a citrus fruit native to Southeast Asia. This popular fruitbelongs to the order Sapindales under the family Rutaceae and genus *Citrus* (Rouseff *et al*., 2009; Hung *et al*., 2020; Zhao *et al*., 2019) and very closer but different from grapefruit (Ahmed *et al*., 2018; Gupta *et al*., 2021). It is a large, evergreen tree with a rounded canopy. Its glossy, dark green leaves are ovate to elliptical, with winged petioles (Jayaprakash *et al*., 2017). The tree bears large, pear-shaped fruits with thick, yellow to pale green rind, often with a slightly rough texture. The flesh ranges from pale yellow to pink or red, depending on the variety, and is segmented like other citrus fruits.Fruits consist of a thick, spongy rind with a dimpled texture, protecting the juicy segments inside (Roy and Saraf, 2006). The segments are surrounded by a membranous layer called the albedo, which separates them from the bitter, white pith.Seeds are typically large, round, or deltoid and white to creamy white in colour. They are found within the juicy segments of the fruit, embedded in the flesh and monoembryonic in nature (Glabasnia *et al*., 2018).Pomelo is rich in essential nutrients and offers several health benefits. It is low in calories (100g serving of pomelo only provides about 38 calories) and contains no cholesterol or saturated fats. It is an excellent source of vitamin C and contain significant amounts of potassium, vitamin A, dietary fiber, and antioxidants such as flavonoids and limonoids (Huang *et al*., 2021; Nadi *et al*., 2019; Wang *et al*., 2017). It supports immune function, aid digestion, promote skin health, and help reduce the risk of chronic ailments like cardiovascular diseases (CVD) and cancer of different types (Fan *et al.*, 2019; Arora *et al.*, 2018; Gualdani *et al*., 2016).

In Southeast Asian countries like Thailand, Vietnam, and Malaysia, pomelo displays notable diversity in its varieties, farming methods, and cultural significance. Thailand, renowned for its "Siamese Ruby" pomelo, boasts a wide array of pomelo cultivars, each distinguished by unique traits such as size, color, taste, and scent (Tian *et al*., 2007). This fruit holds cultural importance in Vietnam, often featuring in traditional celebrations and rituals. Vietnamese varieties like "PhucTrach" and "Da Xanh" are valued for their sweet taste and fragrant aroma. Malaysia, with its varied climates, supports various pomelo cultivars like "Buntong" and "Jelai," adapted to different ecological conditions (Montoya *et al*., 2019). Farming techniques for pomelo vary across these countries, ranging from small-scale family orchards to large commercial plantations, reflecting local agricultural customs and preferences. The diversity of pomelo in Southeast Asia not only enhances the region's culinary diversity but also contributes significantly to its agricultural sector and biodiversity conservation endeavors (Mohammad *et al*., 2021; Kore and Chakraborty, 2015; Corazza-Nunes *et al*., 2002). Ongoing efforts in research and conservation aim to preserve and utilize this diversity for sustainable pomelo cultivation and genetic enhancement, ensuring the fruit's continued prominence in the region.

In India, pomelo showcases significant diversity in its varieties and cultivation regions. Various cultivars such as Chakkorta, Bathike and Mysore Bitter are cultivated across the country, each offering unique flavors, sizes, and qualities (Sharma *et al*., 2015). Pomelo cultivation is prominent in states like Maharashtra, Karnataka, Tamil Nadu, Kerala, Bihar, West Bengal, Assam, Odisha etc. where diverse agro-climatic conditions support its growth. Additionally, local farming practices and preferences contribute to the richness of pomelo diversity in India along with the other minor or underutilized fruits (Mukherjee *et al*., 2023; Nandi *et al*., 2019). This diversity not only enriches the country's citrus industry but also provides opportunities for culinary innovation and sustainable agricultural practices (Maya *et al*., 2012).

Western dry tract of West Bengal within the lateritic belt of Chhotonagpur plateau region of Eastern India particularly the Birbhum district has wide range of diversity of pomelo with respect to their shape, size, surface characteristics, quality parameters and bioactive compounds. However, a very few of the pomelo genotypes have been studied and reported so far as scientific documents. Thus the present research has been carried out to characterize the available local pomelo accessions with respect to fruit morphological, biochemical and bioactive compound diversity under western dry tract of West Bengal.

MATERIALS AND METHODS

The present study was conducted during August 2023 to December 2023 selecting twelve different pomelo plants located different villages like Surul (23°39′N; 87°39′E),Supur (23°37′; 87°41′), Ruppur (23°39′; 87°27′), Raipur (23°37; 87°36′), Ballavpur (23°41′; 87°38′), Moldanga (23°40′; 87°39′), Bahadurpur (23°39′; 87°37′), Mahidapur (23°39′; 87°38′), Binuria (23°38′; 87°40′), Saldanga (23°39′; 87°25′), Kartikdanga (23°37′; 87°38′) and Deuli (23°36′; 87°38′) of Bolpur Sriniketan Block, Birbhum, West Bengal. Pomelo plants selected under the present study have aged between 10 to 20 years and were in full bearing stage under mostly at household gardens. The passport data of the plants were also collected. This area undergoes an extended period of arid winter, stretching from the second week of December to the second week of February, followed by a gentle spring lasting until March. The dry and hot summer season begins in the first week of April, featuring extremely high temperatures reaching up to 45°C, and persists until mid-June. Summers are marked by heatwaves and intense sunlight. The soil in this region is typified by red and lateritic sandy loam, with a pH range of 5.5 to 6.5, abundant in iron and aluminum, and with low organic matter content. The five mature ripe fruits of different selected pomelo plants have been collected and brought to the laboratory of the Department of Horticulture & Postharvest Technology for recording observations with respect to fruit morphological, biochemical as well as quantification of bioactive compounds. The following procedure was adopted for recording the observations:

Fruit morphological parameters:

Fruit length and diameter: Fruit length and diameter of five pomelo fruits was recorded by placing the fruits in a plain surface and having vertical and horizontal arrangement of a measuring scale respectively and measurement was taken in centimeter up to the top level of the fruits.**Rind thickness:** As the fruit is hesperidium, the thickness of outer flavedo and albedo was measured as rind thickness by digital verneer caliper and expressed in centimeter. **Fruit weight and pulp weight:** Fruit weight and pulp weight of pomelo fruits were measuredwith digital balance and expressed in gram by measuring the whole fruit and only the pulp respectively. **Number of segments:** Total number of the segments in pomelo fruits has been counted by making horizontal section of each fruit. **Number of seeds per fruit**: Seeds of pomelo fruits counted separately for each fruit and the average was calculated for each accession. **Juice content**: Volume of juice was measured from hundred gram of pulp from every pomelo fruits and expressed in milliliter.

Fruit biochemical parameters

Total soluble solids (TSS in ^{o}Brix): Total soluble solids of pomelo fruits were measured by digital TSS meter (Model: ATAGO PAL-1, 3810, Japan) taking few drops of juice in the glass plate of TSS meter at ambient temperature. TSS was expressed in degree brix.

Total sugar and reducing sugar: The total sugar content of the fruit juice was measured by titrating it after hydrolysis with HCl against Fehling 'A' and Fehling 'B' solutions, with methylene blue serving as an indicator. The results were expressed as a percentage (A.O.A.C., 2018). Similarly, the reducing sugar content was determined by titrating the diluted juice against Fehling 'A' and Fehling 'B' solutions, also using methylene blue as an indicator, and reported as a percentage (A.O.A.C., 2018).

Acidity: The total acidity of the diluted fruit juice was assessed by titrating it against a 0.1 N NaOH solution, employing phenolphthalein as an indicator. The findings were presented as a percentage of the fruit's fresh weight (Ranganna, 1986). **TSS-Acidity ratio**: Ratio of total soluble solids and acidity of pomelo fruits juices were determined by simply dividing the total soluble solids content by acidity of the respective fruit juices. **Ascorbic acid content**: The ascorbic acid content of the fruit was assessed using the 2,6-dichlorophenol indophenol dye titration method recommended by Ranganna (1986), with the findings presented as mg per 100 g of fruit.

Determination of bioactive compounds

Antioxidant (DPPH IC_{50}) : Antioxidant activity was measured using 2,2- Diphenyl Picrylhydrazyl (DPPH) free radical inhibition assay (Jumina *et al*., 2019; Alanon *et al*., 2011; Dewanto *et al*., 2002). The fruit juice (0,5,10,25 and 50 µl/ml) was mixed with DMSO solution and ethanol for shaking and after that absorbance was taken at 517 nm in UV visible spectrophotometer (LABMAN, Model LMS PUV 1200). Linear plot of percent inhibition concentration of analyzed Jews has been prepared to find out the IC_{50} of each juice sample collected from the pomalo fruits.

Flavonoid (mgRE/g): For determination of the flavon compounds the juice were placed in beaker with 100 ml ethanol and covered with aluminum foil and placed in water bath at 80^{o}C for three hours after that the whole solution was filtered and allowed to evaporate into dryness at 60^{o}Cto get the solids. 0.05 gram of solids wire mixed with 5% sodium nitrite 10% aluminum nitrate and sodium hydroxide solution for final aliquot to be taken for absorbance at 500 nm while other component mixtures except sample are taken as blank. Flavonoid content was expressed in milligram of rutin equivalent per gram of sample (He *et al.*, 2008).

Total phenolics (µgGAE/g): Total phenolic content was estimated by Folin Ciocalteu's method. 1 ml of aliquots and standard gallic acid (10, 20, 40, 60, 80, 100 µg/ml) was positioned into the test tubes and 5 ml of distilled water and 0.5 ml of Folin Ciocalteu's reagent was mixed and shaken. 1.5 ml of 20 % sodium carbonate was added and allowed to incubate for 2 hours at room temperature. Absorbance was measured at 750 nm using UV visible spectrophotometer (LABMAN, Model LMS PUV 1200) after appearance of intense blue color considering gallic acid as standard (Dewanto *et al.*, 2002). The phenolic contents were expressed as mg of gallic acid equivalent weight (GAE)/100 g).

Anthocyanin content (mg/100g): For determination of anthocyanin content pomelo juice was mixed with acidic ethanol and stirred for one hour in magnetic stirrer.Dilution of the mixture was done in volumetric flask by using buffers. The absorbance of the ethanolic extract was measured (LABMAN, Model LMS PUV 1200) at 520 nm as well as 700 nm using distilled water as blank (Nile *et al.*, 2015).Anthocyanin pigment concentration was calculated and expressed as equivalent of cyanidine 3 glucoside at mg/100g.

Statistical analysis: Statistical analysis of the collected data with respect to different parameters of morphological, biochemicalparameters along with bioactive compounds have been subjected tomean variance analysis considering the each plant as sources of variation and five fruits from each plant as a single sample (Gomez and Gomez, 1984; Frans *et al.*, 2021). The analysis of variance (ANOVA) is prepared for each parameter and cited in the tables. The Box-Whisker plot (Tukeys Honestly Significant Different Test or Tukeys HSD test) for all the parameters were prepared to compare the degree of diversity of characters within the pomelo accessions (PA) under the present study (Nanda *et al.*, 2021).

RESULT AND DISCUSSION

Fruit morphological parameters

The mean variance analysis of different fruit morphological parameters is presented in Table 1 and the distribution pattern of the parameter quartiles is also presented by Box-Whicker plots (Figure 1, 2 and 3).

Fruit length of twelve different pomelo accessions (PA) has been ranged from 14.2 to 25.0 cm with a mean fruit length of 19.15cm. Pomelo accession PA 12 has shown lowest fruit length while PA 5 exhibited highest fruit length. **Fruit diameter** of different pomelo accessions was measured from 14.1 to 23.5 cm in PA1 and PA 5 respectively with a mean diameter of 17.68 cm. The **rind thickness** of pomelo accessions was varied from 1.15 to 2.36 cm with a mean value of 1.94 cm. PA 1 has exhibited exceptionally thin rind and on the other hand PA 11 has shown thickest rind. Pomelo accessions like PA 11, PA 4, PA 10 have recorded good fruit size in the present study (23.9cm x 21.8cm, 23.6cm x 19.3cm, 22.0cm x 19.5cm in length and diameter). Lower rind thickness was also noted in PA 12, PA 2 and PA 6 (1.81cm, 1.84cm and 1.86cm).

Significantly highest **fruit weight** (1323.6g) was noted in PA 5 and very low fruit weight (478.7g) was observed in PA 12, although the mean fruit weight was moderate (876.34g). Higher fruit weight has also been recorded in PA 4, PA11 and PA 10 (1158.4g, 1132.5g and 1094.8g). **Pulp weight** of different pomelo accessions was varied significantly and the range of pulp weight was measured from 326.2 to 1051.5g. Maximum fruit pulp content was noted in PA5 and minimum in PA 12. Pomelo accessionsPA 11, PA 4 and PA 10 has also possessed higher pulp weight (889.4g, 845.8g and 825.6g).

Significant variation in the **number of segments** of pomelo fruits was noted in the present study and a range of 13.6 to 18.0 numbers of segments was counted for twelve different accessions. Maximum segment was noted in PA 3 and minimum in PA 12 with a mean of 15.70 segments. PA 9 and PA 2 has shown lower number of segments (13.7 and 14.1). **Number of seeds** of different pomelo accessions in the present study has been ranged from 27.5 to 6 1.7. The smallest fruit of PA 12 has exhibited lowest number of seeds while PA10 possessed highest number of seeds, although the average number of seeds of twelve different pomelo accessions was 46.18. Size of the seeds of pomelo accessions varied significantly in the present study and **10 seed weight** was ranged from 2.22 to 4.79 g with a mean value of 3.17 g.lower seed weight was also counted in PA 10 and PA 9 (2.24g and 2.41g/10 seeds). **Juice content** of pomelo fruits was extracted from 100 gof pulp and the volume of the juice has been varied widely from 48.7 ml in PA 9 to 65.1 ml in PA 6.PA 12 and PA 4 has observed as higher juice yielder (61.8ml and 63.8ml/100g pulp).

The comparative length of Box-Whisker plot diagram (Figure 1) clearly denotes the wider variation of fruit length moderate variation of fruit diameter and very low variation in rind thickness of twelve pomelo accessions. On the other side the

Table 1:Fruit morphological characters of pomelo accessions under western dry tract of West Bengal

Pomelo accessions	Fruit length (cm)	Fruit diameter (cm)	Rind thickness (cm)	Fruit weight (g)	Pulp weight (g)	No of segments	No of seeds/fruit	10 seed weight (g)	Juice content (ml/100g pulp)
PA 1	16.5	14.1	1.15	814.3	684.0	15.2	29.6	3.56	51.4
PA 2	15.7	16.4	1.84	704.5	534.1	14.1	31.2	3.23	56.0
PA 3	21.3	18.3	2.02	936.4	714.6	18.0	48.8	2.75	57.9
PA 4	23.6	19.3	2.21	1158.4	845.8	16.3	56.7	2.22	63.8
PA 5	25.0	23.5	1.99	1323.6	1051.5	17.8	59.5	2.53	61.5
PA 6	17.6	16.4	1.86	759.9	637.2	14.9	42.3	4.48	65.1
PA 7	15.5	15.0	2.11	596.2	418.6	15.7	49.1	3.78	57.0
PA 8	19.1	17.6	1.89	875.1	678.7	14.8	41.3	3.46	53.8
PA 9	15.4	14.7	1.87	641.7	499.5	13.7	48.0	2.41	48.7
PA 10	22.0	19.5	2.17	1094.8	825.6	16.5	61.7	2.24	62.5
PA 11	23.9	21.8	2.36	1132.5	889.4	17.8	58.4	2.63	59.2
PA 12	14.2	15.6	1.81	478.7	326.2	13.6	27.5	4.79	61.8
Mean	**19.15**	**17.68**	**1.94**	**876.34**	**675.43**	**15.70**	**46.18**	**3.17**	**58.23**
SD	**3.84**	**2.92**	**0.30**	**258.52**	**209.05**	**1.59**	**12.00**	**0.86**	**5.09**
CV	**20.07**	**16.50**	**15.58**	**29.50**	**30.95**	**10.12**	**25.99**	**27.17**	**8.73**
Range	**14.2 - 25.0**	**14.1 - 23.5**	**1.15 - 2.36**	**478.7 - 1323.6**	**326.2 - 1051.5**	**13.6 – 18.0**	**27.5 - 61.7**	**2.22 - 4.79**	**48.7 - 65.1**

Table 2: Fruit biochemical parameters and bioactive compounds of pomelo accessions under western dry tract of West Bengal

Pomelo	Biochemical parameters						Bioactive compounds			
accessions	TSS (ºB)	Total sugar (%)	Reducing sugar (%)	Acidity (%)	TSS-Acidity ratio	Ascorbic acid (mg/100g)	Antioxidant (DPPH IC_{50})	Flavonoid (mgRE/g)	Total phenolics (µgGAE/g)	Anthocyanin content (mg/100g)
PA 1	8.5	5.4	3.5	0.95	8.94	34.7	56.7	3.8	384.5	22.6 (P)
PA 2	7.5	5.2	3.4	0.93	8.06	32.5	60.2	3.2	376.8	35.2 (P)
PA 3	11.7	7.0	4.6	0.89	13.14	46.2	37.5	5.7	321.5	41.1 (P)
PA 4	12.4	7.5	4.4	0.85	14.58	31.9	48.9	4.6	362.2	11.7 (W)
PA 5	11.1	7.7	4.5	0.78	14.23	42.6	32.7	6.9	272.9	48.5 (P)
PA 6	8.3	6.0	3.7	0.86	9.65	38.3	59.8	4.2	298.7	39.6 (P)
PA 7	8.9	6.4	3.2	0.98	9.08	35.9	65.4	3.8	401.5	6.8 (W)
PA 8	9.2	6.7	3.6	0.87	10.57	40.7	41.5	4.9	356.7	38.5 (P)
PA 9	9.1	6.0	3.5	0.94	9.68	36.1	45.6	3.7	324.2	41.3 (P)
PA 10	11.3	7.2	4.3	0.69	16.37	41.5	35.4	7.2	294.6	32.6 (P)
PA 11	9.5	6.9	4.0	0.75	12.66	49.9	30.8	5.6	345.1	5.3 (W)
PA 12	8.7	6.3	3.0	0.91	9.56	31.8	51.6	3.7	412.0	45.2 (P)
Mean	**9.68**	**6.53**	**3.81**	**0.87**	**11.38**	**38.51**	**47.18**	**4.78**	**345.89**	**30.70**
SD	**1.55**	**0.79**	**0.54**	**0.09**	**2.70**	**5.81**	**11.75**	**1.31**	**44.25**	**15.24**
CV	**15.98**	**12.07**	**14.09**	**10.10**	**23.72**	**15.09**	**24.91**	**27.53**	**12.79**	**49.64**
Range	**7.5 - 12.4**	**5.2-7.7**	**3.0-4.6**	**0.69-0.98**	**8.06 – 16.37**	**31.9 -49.9**	**30.8 - 65.4**	**3.2-7.2**	**272.9-412.0**	**5.3-48.5**

(P: Pink fleshed and W: white fleshed pulp, noted on parentheses of anthocyanin content of fruits).

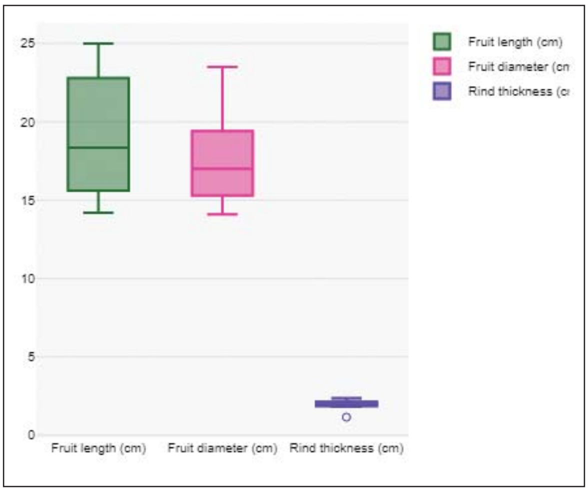

Fig. 1: **Box-Whisker plot of fruit length (cm), fruit diameter (cm) and rind thickness (cm) of different pomelo accessions.**

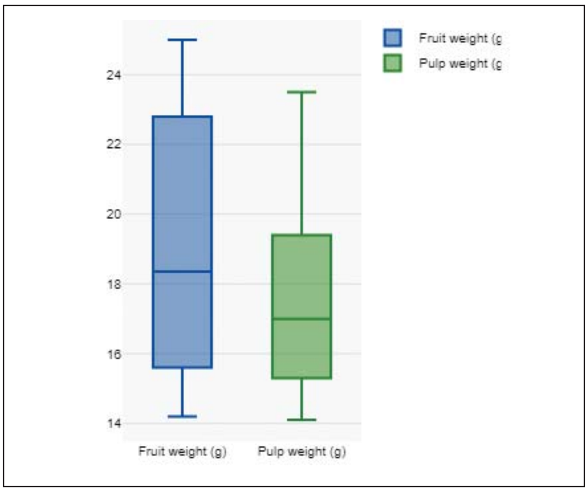

Fig. 2: **Box-Whisker plot of fruit weight (g) and pulp weight (g) of different pomelo accessions.**

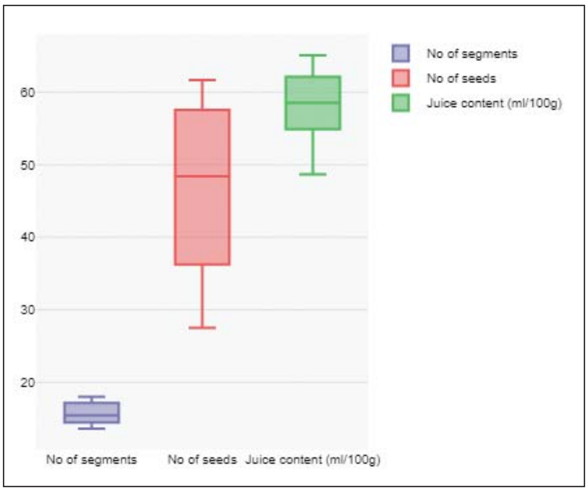

Fig. 3: **Box-Whisker plot of number of segments, number of seeds and juice (ml/100g) of different pomelo accessions.**

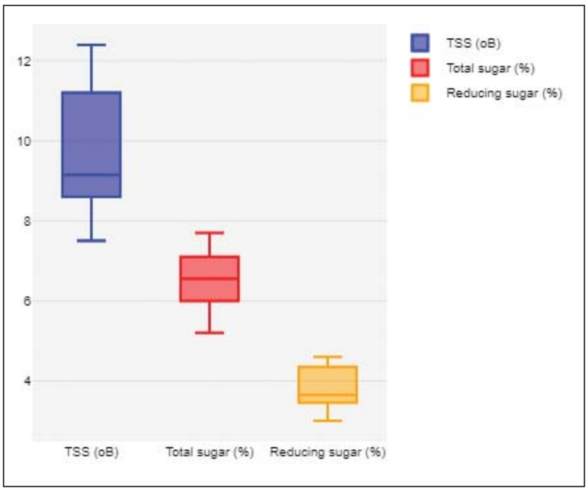

Fig. 4: **Box-Whisker plot of number of TSS (oBrix), total sugar (%) and reducing sugar (%) of different pomelo accessions.**

tall Box-Whisker plot diagram (Figure 2) express very high variation of fruit weight and pulp weight of different pomelo accessions where the pomelo accessions under lowest quartiles of both the parameters has closer value and most wide variation of fruit weight of pomelo accessions in 2nd upper quartile but first upper quartile in pulp weight. Number of segments in the pomelo fruits under present experiment has exhibited narrow variability while the number of seeds has shown very high variability and juice content of the fruits recorded moderate variability (Figure 3). The pomelo accessions fall under lower two quartile of Box-Whisker plot of both the number of seeds and juice content has significant variation. Angami *et al*. (2022) has found variability in pomelo genotypes in fruit morphological characters like fruit weight (567.52 – 1581.48 g), number of segments per fruit (13.00 - 114.33), peel thickness (1.22 - 3.26 cm), juice percent (14.40 - 20.54) etc.and these finding has conformity with the present findings.Pan *et al*. (2021) studied the fruit morphological variation of pomelo genotypes under northern China condition and found great variation in fruit length (14.05 to 20.7 cm), fruit width (13.12 to 19.56cm), fruit weight (264.63 to 1730.98g) and

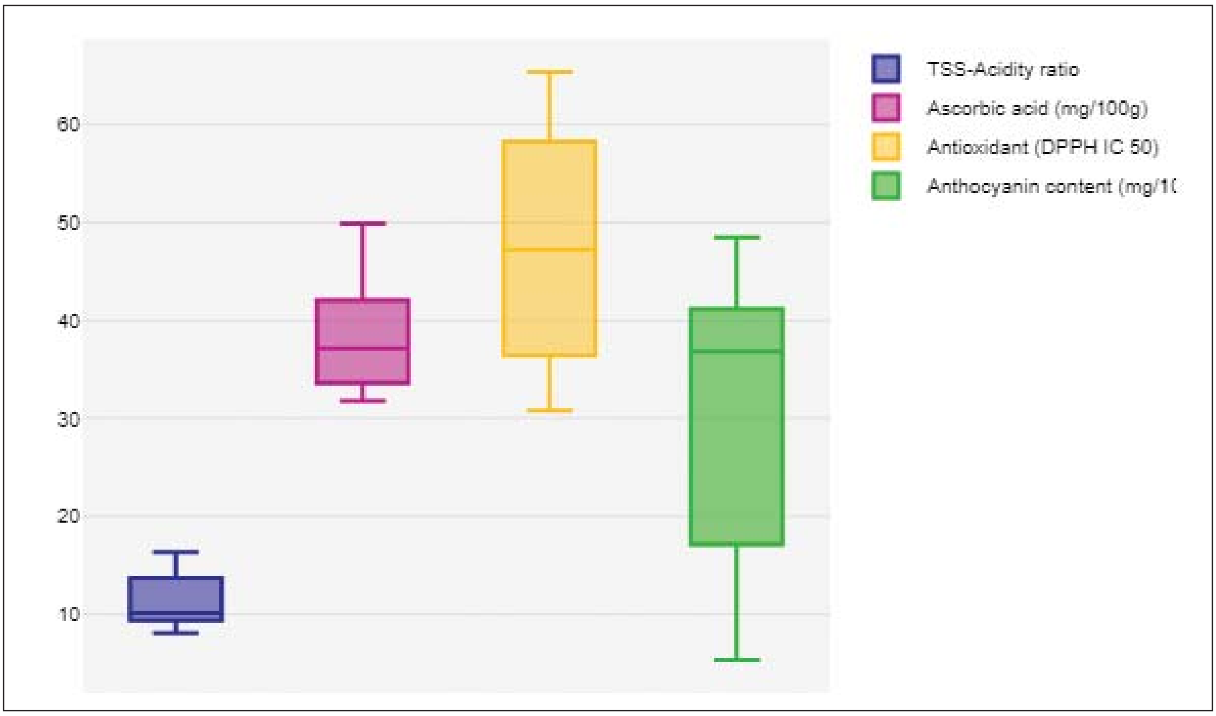

Fig. 5: **Box-Whisker plot of number of TSS-acidity ratio, ascorbic content (mg/100g), antioxidant capacity (DPPH IC50) and anthocyanin content (mg/100g) of different pomelo accessions.**

pulp weight (210.25 to 1257.27g), peel thickness (0.46 to 2.43cm)which has also in line with the results of the present experiment. More or less similar report have been referred by Bankar *et al*. (2021) who has found significant variation in fruit morphology with respect to fruit length (12.55 to 20.76cm), fruit weight (492.2 to 1036.4g), pulp weight (164.29 to 620.89g) and number of seeds 40.67 to 840. Hossain *et al*. (2018) has found the heaviest and lightest fruits in genotype Hybrid (1283.33 g) and Accession-52 (300 g), while the maximum weight of non-edible portion (463.33 g), pulp to peel ratio (3.97), thickness of pulp (11.50 cm), amount of juice (366.67 ml), number of seeds (114) and weight of seeds (58 g) in genotype Hybrid. Above scientific reports on the variability of morphological parameters of pomelo genotypes has the conformity with the findings of the present experiment and the variation is mainly due to the genetic variation and differences in growing condition.

Fruit biochemical parameters

The mean variance analysis of different fruit biochemical parameters is presented in Table 2 and the distribution pattern of parameter quartiles is also presented by Box-Whicker plots (Figure 4 and 5).

Total soluble solids content of different pomelo accessions was significantly varied from 7.5^{o} to 12.4^{o}Brix which was highest in PAS 4 and lowest in PA 2. Higher TSS was also recorded in PA 3, PA 10 and PA 5 (11.7, 11.3 and 11.1^{o}Brix respectively). Mean value of TSS was 9.68^{o}Brix. A considerable numbers of pomelo accessions have scored higher total sugar content like PA 5 (highest), PA 4, PA 10 and PA 3 (7.7,7.5,7.2 and 7.0% of total sugar) with a mean value of 6.53%. Similarly, pomelo accessions like PA 3, PA 5, PA4 and PA 10 exhibited with greater quantity of reducing sugar (4.6, 4.5, 4.4 and 4.3%) with a mean value of 3.81.

Titrable acidity of the pomelo fruits were varied widely with a range of 0.69 to 0.98% as citric acid equivalent. PA 10, PA 11 and PA 5 were under the low acid group with acidity of 0.69, 0.75 and 0.78% respectively. On contrary PA 7, PA 1, PA 2 and PA 12 were recorded under high acid group (0.98, 0.94, 0.93 and 0.91% acidity respectively).

TSS-acidity ratio of pomelo fruits under the present study was varied from 8.06 to 16.37 with a mean value of 11.38. Pomelo accession PA 10 has possessed highest TSS-acidity ratio and some other accessions like PA 4, PA 5, PA 3 and PA 11 have also recorded higher TSS-acidity ratio (14.58, 14.23, 13.14 and 12.66 respectively). On contrary, lower TSS-acidity ratio was noted in PA 2 (lowest), PA1, PA 7, PA 12, PA 6 and PA 9 with value of 8.06, 8.94, 9.06, 9.56, 9.65 and 9.68 respectively.

Pomelo accessions in the present experiment have shown a wide range of **ascorbic acid content** in their pulp (31.9 to 49.9 mg/100g). Highest ascorbic acid content was recorded in the fruits of PA 11 and lowest in PA 4 with mean value of 38.51 mg/100g. Higher ascorbic acid content in pomelo fruits under the present study was recorded in PA 3, PA 5, PA 10and PA 8 with a value of 46.2, 42.6, 41.5 and 40.7 mg/100g of pomelo pulp.

Box-Whisker plot of TSS signifies very high variability of pomelo accessions where the accessions under upper second quartile have shown wider variation and third quartile has very closer value of TSS (Figure 4). The interpretation of Box-Whisker plot with respect to the total sugar and reducing sugar signifies low-moderate variability of pomelo accessions (Figure 4). The variation of pomelo accessions in view of TSS-acidity ratio was very narrow and out of which the accessions at the lower quartile has the closer value (Figure 5). The analysis of the result with respect to the ascorbic acid content of pomelo accessions have exhibited moderate variability and out of which the upper first quartile accessions have possessed greater variability and narrow in lower quartile. Angami *et al.* (2022) have found wider variation in different fruit quality aspects of pomelo genotypes under Arunachal Pradesh condition and they found variability in TSS (7.50 - 10.75 ºB), titratable acidity (0.39 - 1.71 %), ascorbic acid (27.57 - 48.28 mg/100 ml), total sugar (5.53 - 9.85 %) and total phenols (2.01 - 3.31 mg/100 ml) and this findings are in line with the findings of the present experiment. The report of Pan *et al.* (2021) regarding the variation of pomelo genotypes under northern China condition with respect to fruit biochemical parameters like TSS (9.4 to 12.42ºBrix), ascorbic acid content (34.79 to 84.58mg/100g), total sugar (6.13 to 9.47 g/100g) etc. has similarity with the result of present research. Similarly the wider variability in fruit biochemical parameters were reported by Bankar *et al.* (2021) in TSS (8.56 to 12.51ºBrix), total sugar (2.46 to 3.88%), reducing sugar (1.71 to 2.13%), acidity (0.43 to 1.02%) and ascorbic acid content (48.39 to 58.46 mg/100g). A greater variability in fruit quality of pomelo genotypes has also been reported by Hossain *et al.* (2018) under Bangladesh condition and Li *et al.* (2019) in China condition. Thus the findings of these fruit quality aspects of pomelo genotypes support the findings of the present experiment. In all these reports as well as in the findings of the present experiment, the variation of fruit quality parameters is due to the wider genetic makeup as well as the differences in growing conditions of pomelo genotypes.

Bioactive compounds

The mean variance analysis of different fruit biochemical parameters is presented in Table 2 and the distribution pattern of parameter quartiles is also presented by Box-Whicker plots (Figure 5).

Antioxidant activity of twelve different pomelo accessions in terms of DPPH IC_{50} value has been ranged from 30.8 to 65.4. Lower the IC_{50} value navigates higher antioxidant content of the fruit pulp. Thus PA 11 has been observed as potential pomelo accession for highest antioxidant activity with lowest IC_{50} value and on the other hand PA 7 possessed lowest content of antioxidant due to the highest IC_{50} value of DPPH. Some other potential pomelo accessions with respect to higher antioxidant content are PA 5, PA 10 and PA 3 with DPPH IC_{50} value of 32.7, 35.4 and 37.5 respectively.

Flavonoid is one of the most important bioactive compounds present in pomelo and in the present experiment it has been observed that the accessions of pomelo fruits have exhibited a significant variation in flavonoid content. Highest flavonoid content (7.2 mgRE/g) was recorded in PA 10 and lowest in PA 2 (3.2 mgRE/g). The pomelo accessions namely PA 5 and PA 11 also possessed higher flavonoid content of 6.9 and 5.6 mgRE/g.

Phenolic compounds are also considered as important bioactive compound which has antioxidation capacity as well many other positive cellular functions. The pomelo fruits of twelve different accessions possessed significant variation and a range of 272.9 to 412.0 µgGAE/g total phenolics in the fruit pulp (of pomelo accessions PA 5 and PA 12) with a mean value of 345.89 µgGAE/g. On the other hand very high phenolics also responsible for development of oxidized polyphenols resulting into brownish or bluish black colour development of the cut fruit pieces.

Difference in fruit pulp colour of different pomelo accessions in the present study has resulted wide variation in **anthocyanin content** of pulp (Table 2). White fleshed accessions (W) expressed very low anthocyanin content like PA 11, PA 7 and PA 4 (5.3, 6.8 and 11.7 mg/100g). On the other hand, higher pulp anthocyanin content have been observed frompink fleshed pomelo accessions (P) like PA 5, PA 9 and PA 3 (48.5, 41.3 and 41.1 mg/ 100g). The mean anthocyanin content of pomelo accessions were 30.70 mg/100g.

The analysis of variability of pomelo accessions in the present study in respect of antioxidant activity has a clear long range and most of all the accessions are distributed equally within the range (Figure 5). Yin *et al*. (2023) has reported the amounts of the total phenols ranged from 5.428 - 11.97 mg/ 100 g EP and the amounts of the total flavonoid ranged from 47.12 - 135.9 mg/100 g EP in pomelo genotypes. Additionally they reported that the DPPH IC_{50} antioxidant activity of water extracts of pomelo was ranged from 13.8 to 77.6 mg/ml. Anagami *et al*. (2022) has found the range of phenolic compounds in pomelo genotypes as 2.01 - 3.31 mg/100 ml). This report has similarity with the findings of present experiment. Deng *et al*. (2022) has evaluated the flavonoid profiles of different pomelo genotypes and found wider variations from 13.4 to 193.3 mg CE/100 g FW. They have also reported the phenolics content of pomelo genotypes 91.8 to 170.9 mg GAE/100g FW and Anh *et al.* (2021) have found total phenolic and total flavonoid contents of the pomelo extracts under optimal condition as 16.79 mg GAE/g and 10.69 mg RE/g, respectively. Thus these findings have the conformity with the findings of present research. Nishad *et al*. (2018) reported antioxidant activity of pomelo accessions as 2.16–4.04 ìmol TE/ml, total phenol from 22.18 to 48.0 mg GAE / 100ml. Bioactive Flavonoids, Antioxidant Behaviour and cytoprotective effects of dried Grapefruit have been studied by JiajiaYina *et al*. (2023), Yin *et al*. (2023), Vazquez *et al*. (2016), and they have reported that pomelo has considerable potential as a source of natural bioactive flavonoids with outstanding antioxidant activity which can be used as agents in several therapeutic strategies. The findings of such all the scientist are in line with the results of the present study. The variation in the quantification of bioactive compounds is mainly due to the genetic differences of pomelo genotypes.

CONCLUSION

Wide fruit morphological variation with respect to fruit length (14.2 to 25.0cm), fruit diameter (14.1 to 23.5) and rind thickness (1.15 to 2.36cm) were observed within the studied pomelo accessions. Considerable wider ranges of fruit weight (478.7 to 1323.6g), pulp weight (326.2 to 1051.5g), number of segments (13.6 to 18.0) have also been noted. Juice content varied from 48.7 to 65.1 ml/ 100g fruit pulp with 58.23 ml/100g as mean value. Moderate to high TSS (7.5 to 12.4^{o}Brix), good range of total sugar (5.2 to 7.7%) and reducing sugar (3.0 to 4.6%) have been noted from different pomelo accessions. Mean value of acidity was 0.87% and TSS-acidity ratio was ranged from 8.06 to 16.37. Richness of the fruit in ascorbic acid content was noted (31.9 to 49.9 mg/100g pulp) along with high to moderate antioxidant content (30.8 to 65.4 DPPH IC_{50}) and rich in flavonoid content (3.2 to 7.2 mgRE/g). High total phenolics (272.9 to 412.0 µgGAE/g) and diverse anthocyanin content (5.3 to 48.5 mg/100g) has also been noted in pomelo fruits. In conclusion, among the pink fleshed pomelo accessions PA 5 has possessed higher fruit size better fruit quality and rich in bioactive compounds. On contrary PA 11 was found best within white fleshed pomelo.

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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