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Flowering, Fruiting Behavior and Nutritional Quality of Selected Guava Genotypes

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Abstract
Guava is one of the most important commercial fruit crop in Bangladesh due to its high nutrient value, good taste and high health benefits. This study was conducted to investigate the flowering, fruiting behavior and nutritional quality of guava genotype suitable for coastal region of Bangladesh. Fifteen genotypes (PG 01 to PG 15) having satisfactory growth were selected for this study. One branch was randomly selected in each direction (North, South, East and West) to collect field data from each plant. Among the genotypes, the highest percentage (87.62%) of fruit setting and the maximum time (115.8 days) required for fruit maturation were recorded from PG 13 and PG 14, respectively. The PG 12 had the highest fruit weight (312.6 g) and the longest fruit (9.34 cm), whereas the highest diameter (26.28 cm) of fruit was recorded in PG 06. The maximum numbers of seeds (411.20) were counted from PG 10 whereas no seed was obtained in the PG 01 and PG 02. Maximum anthocyanin (0.17 mg/100 g FW), lowest pH (3.31), maximum vitamin C content (91.25 mg/ 100g FW), total sugar (6.56 %) and TSS (5.19 ^{o}Brix) were also recorded in the seedless genotype (PG 01). Moreover, the quality characteristics, pulp percentage of seedless genotype (PG 01 and PG 02) was comparatively higher than the other genotypes. The genotypes PG 01 and PG 02 have shown important pomological traits for further study, variety improvement and selection as new variety.

Keywords: Genetic variation, Nutritional quality, Pomological trait.

Introduction

Guava (*Psidium guajava* L.) belonging to the family Myrtaceae, is believed to be the most important commercial fruit crop in Bangladesh. It is originated from American tropics (Mexico to Peru) but at present the major guava producing countries are the USA, Cuba, Taiwan, Mexico, Peru, China, Malaysia, India, Pakistan, Thailand and Bangladesh. It is one of the most popular fruit due to its comparative low price, high nutrient value, good taste and high health benefit than some other fruits (Beenu Tanwar et al., 2014). Sometimes guava is called "the apple of the tropics". Regarding the issue of area and production, guava considered to be the most substantial fruit after mango, banana, jackfruit, pineapple and melon in Bangladesh (BBS, 2016). It grows everywhere in Bangladesh in the homestead gardens even without or little care but commercially cultivated in Barisal, Gazipur, Pirojpur, Swarupkathi, Jessore, Rajshahi and Chittagong (Mondal, 2000). Guava has the potential to make a useful contribution to commercial horticulture in Bangladesh. Bangladesh produced nearly 214308 M. tons of guava

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fruits in the year 2015-2016 (BBS, 2016). It is rich source of vitamins of the B group and vitamins C, A and E. It is an excellent source of dietary fibers and minerals such as potassium, manganese, magnesium and phosphorus. It is also containing large amount of pectin, which has industrial use for the production of jam, jelly and juice (Bose and Mitra, 1990). Guava is often marked as "super fruit" because it contains 4 times higher vitamin C than sweet orange, 3 times higher proteins and 4 times more fiber than pineapple, 2 times higher lycopene than tomato and slightly higher potassium than banana (Reddy 2017). The consumption trend of fresh tropical fruits and their products is increasing steadily due to consumer's demand (FAO, 2017).

Guava plant is very hardy, profuse bearer and highly profitable even without or little care (Bose and Mitra, 1990). It has been reported that the flowering time of guava does vary from region to other region. In Bangladesh, generally guava varieties are flowering twice in a year, once in March to April and another in October to November. Temperature has great influence on flowering and high temperatures enhance shedding of flowers and fruits. Proper growth of guava plant occurs under mild sunlight or partial shade but at the time of flowering, dry weather is desirable. Guava plant produces more flowers in summer than the autumn season but during January-March, flowers may also come under irrigated conditions. It was observed that fruit yield is higher during the rainy season but the quality characteristics of fruits are better during winter compared to the rainy season (Aulakh, 2004). The economic and nutritional importance of this fruit can be further increased through systematic hybridization for which precise knowledge of time and duration of flowering, anthesis, flower bud development, floral morphology, fruit set and fruit drop, fruit development are essential prerequisites. This will help the orchardists to select suitable cultivars in relation to flowering (Fig. 1) and fruiting with good fruit set, less fruit drop and to adjust cultural practices according to environmental situation.

Due to changing consumer attitudes and market demands, it has become imperative for breeders to develop new variety, which has higher nutritional quality as well as more health benefits. Guava possesses magnificent digestive and nutritive value with high palatability and available at comparatively low price. Guava fruits also used as additive with other fruit juices which have good potential for internal as well as external trade markets (Leite et al., 2006).

Most of the commercial cultivars contain large numbers of hard seeds which seems to be the major factors responsible for restricting its consumers demand. Globally, consumers demand for high nutritional quality fruits with less or no seeds. Regarding this issue, finding seedless genotypes with high nutritional quality is of growing interest for selection as a variety. For continuous improvement of guava through selection breeding to overcome threats from disease, insect-pests and abiotic stresses or for consumer preference, study of floral biology and fruiting behavior are crucial.

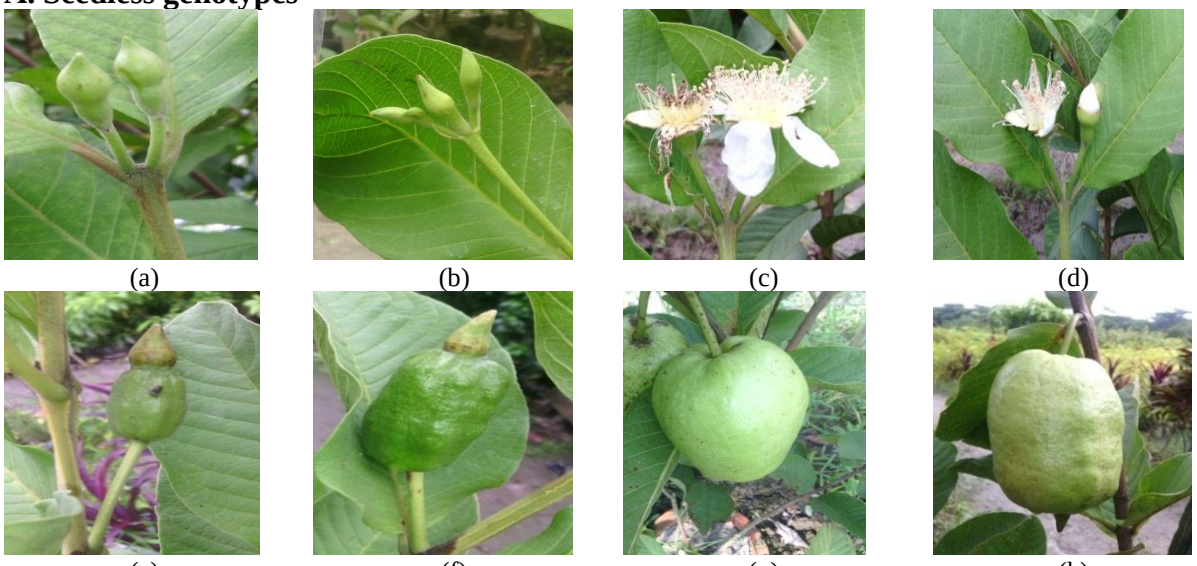
Fruits that are produced in different or even in the same areas may have different types of variations. Some of the variations are due to genetic and some of them are imposed by the environment. Environmental variation could be manipulated but genetic variations are persistent (Ahmed et al., 2011). Wide genetic variations of guava genotypes were observed in the Pirojpur coastal region of Bangladesh. Therefore, this study was conducted to investigate flowering behavior, fruit setting, fruit maturation, nutritional quality of fruits and to find out the promising genotype suitable for Pirojpur as well as coastal regions of Bangladesh.

Materials and Methods

Field study was conducted at Baisakhi nursery, Swarupkathi, Pirojpur, Bangladesh under the geographic location of

22º44′50″N 90º06′13″E. Chemical analysis was done at the Plant Biotechnology Lab, Department of Horticulture, Patuakhali Science and Technology University (PSTU). Two-three years old 15 genotypes (PG 01 to PG 02= Seedless guava, PG 03 to PG 08= Swarupkathi guava, PG 09 to PG 15= Thailand guava) at planting distance 2 × 5 m (P-P × R-R), having satisfactory growth were selected for this study (Fig. 2). The field experiment was conducted in Randomized Complete Block Design (RCBD) with four replications and the chemical analysis was done in Completely Randomized Design (CRD). Randomly one branch was selected in each direction (North, South, East and West) to collect field data from each plant. The observations regarding flowering and fruiting behavior and fruit quality parameters were recorded.

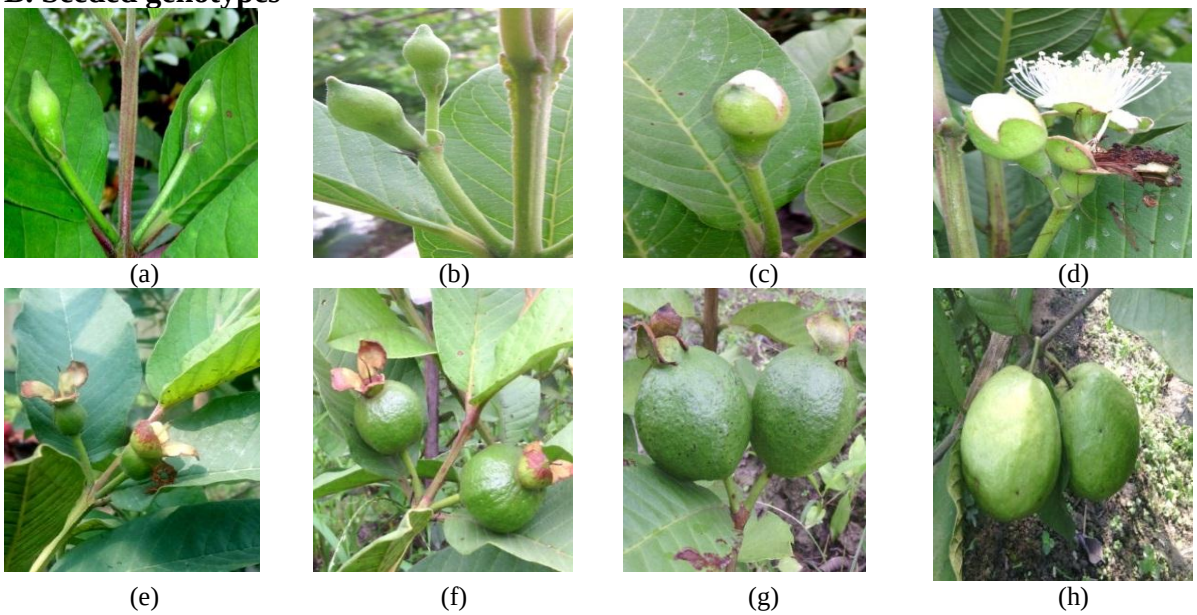
A. Seedless genotypes



(a) (b) (c) (d)

(e) (f) (g) (h)

B. Seeded genotypes



(a) (b) (c) (d)

(e) (f) (g) (h)

Fig. 1. Flowering and fruiting behavior of seedless (A) and seeded (B) guava genotypes.

(a) Five days aged bud, (b) Ten days aged bud, (c) Starting to bud blooming, (d) Calyx and ovary, (e) Immature fruits, (f) Green fruits Old bloom bud, (g) Fully mature fruits

Flowering behavior

- ***Flower bud development***

Days required for flower bud development was observed with randomly selected 60 buds (1 bud × 4 branches × 15 plants). The selected buds were tagged immediately after emergence and their development was regularly observed from the initiation of flowering shoot up to the opening of flower.

- ***Duration of flowering season, length of flower bud, length and width of petal***

The duration of flowering season of guava was considered to be the time from first flowering to last flowering by regular visiting the selected plants. Length of flower bud was measured just before flower opening. Length and width of petals were measured by using slide calipers when the flowers were completely open. Randomly selected 60 (1 × 4 × 15) completely opened flowers were used to determine the length and width of petals and expressed as cm.

Fruiting behavior

- ***Fruit set percentage***

Data on fruit set were counted after full blooming and the percentage of fruit set was recorded on the basis of number of flowers and number of fruits that had set. The percentage of fruit set was calculated according to the following formula described by Roy (1997):

$$\text{Fruit set}(\%) = \frac{\text{Total number of fruit set}}{\text{Total number of flower}} \times 100$$

Percentage of fruit drop

Data on fruit drop was calculated by deducting the number of fruit remained in the branch during harvesting from the total number of fruit was set in the branch. Then the percentage of fruit drop was calculated according to the formula described by Sharma (2004):

$$\text{Fruit drop}(\%) = \frac{\text{Total number of fruit drop}}{\text{Total number of fruit set}} \times 100$$

Time required for fruit maturation (Days)

The time required for maturation of fruit was considered as the time between the withering of the entire stigma on the female spike up to the harvest of the fruit. Withering of stigma was observed by a magnifying glass. For this purpose, randomly 60 (1 × 4 × 15) fruits are selected from withering of stigma to fully matured time.

Weight of fruit

Fully matured 60 (1 × 4 × 15) fruits were gradually collected to find out the mean weight and other traits of fruits. The weight was taken in gram with the help of a (DJ-220 A, Japan) balance sensitive to ten (10) grams.

Length of fruit

Length of the fruits was measured from basal to polar by using slide calipers and a total of 60 (1 fruits × 4 branches × 15 plants) fully matured fruits were used to determine the length of fruits in centimeter.

Diameter of fruit

Diameter of the fruits was measured by using slide calipers and a total of 60 (1 × 4 × 15) fully matured fruits were used to estimate the width of fruits in centimeters.

Number of seeds per fruit

Number of seeds per fruit was manually counted after fruit maturation. Total numbers of 60 (1 × 4 × 15) fully ripe and soft fruits were used to calculate the number of seeds per fruit.

Pulp weight

Total numbers of 60 (1 × 4 × 15) fully ripe fruits were used to calculate the pulp weight. With the help of a sharp knife the pulp was separated from the fruits and weight was taken in gram with the help of a balance (DJ-220 A, Japan) sensitive to ten (10) grams.

Seed weight

Fully ripe and soft fruit was used to collect

the seeds. Seeds were separated from pulp and washed thoroughly with distilled water. Then the adjacent water was removed with the help of paper. After that the weight of seeds was taken in gram with the help of a balance sensitive to ten (10) g.

Determination of Nutritional quality of fruit

- ***Determination of titratable acidity (TA)***

Titratable acidity (TA) was calculated according to the method described by Ranganna (1977) with slight modification. Briefly, ten grams of pulp tissues were homogenized with 40 ml of distilled water using a kitchen blender for two minutes and filtered through a Whatman filter paper No.2. Five mL of the filtrate was transferred into a 100 ml conical flask and two drops of 1% phenolphthalein solution as an indicator were added. The sample was tritrated with 0.1 M sodium hydroxide (NaOH) solution until the color changed to pink and persistent for at least 15 seconds. The titer volume was recorded and the result was expressed as percentage citric acid, which was calculated using the following formula:

$$\text{Titratable acidity}(\%) = \frac{\text{Titre}(\text{ml}) \times \text{NaOH}(0.1\ \text{N}) \times \text{Vol. made up} \times \text{Vol. made up} \times \text{Citric acid eq.wt.}(64\text{g})}{\text{Volume of sample for titrate}(5\ \text{ml}) \times \text{Weight of sample taken}(10\text{g}) \times 1000} \times 100$$

TSS Content

The TSS of guava pulp was determined by using a digital refractometer (BOECO, Germany). The remaining of the filtrated juice from TA determination was used to measure the TSS of the fruit pulp. Before measurement, the refractrometer was calibrated with distilled water to give a 0% reading. Approximately 1-2 drops of the filtrate were placed on the prism glass of the refractrometer to obtain the TSS reading.

Vitamin C content

Vitamin C was calculated according to the dye method as described by Ranganna (1977) with minor modification. Shortly, ten gram of pulp tissue was homogenized with 40 mL of 3% cold met phosphoric acid (HPO_3) using a blender for two minutes and filtered through the Whatman filter paper no. 2. Five mL of aliquot was titrated with 2, 6-dichlorophenol-indophenol dye until the solution used was recorded and ascorbic acid content was calculated using the following formula:

$$\text{Vitamin C}(\text{mg}/100\text{g}) = \frac{\text{Titre}(\text{ml}) \times \text{dye factor} \times \text{vol.made up}(\text{ml}) \times 100}{\text{Aliquot used for estimation}(\text{ml}) \times \text{sample weight}(\text{g})}$$

Determination of pH

The remainder of the filtrated juice from TA determination was used to measure the pH of the fruit pulp. The pH was determined by using a glass electrode pH meter (GLP 21, Crison, Barcelona, EEC). The pH meter was calibrated with buffers at pH 4.0 followed by pH 7.0. After that, the glass electrode was placed into the filtrate to measure the pH and stabilized reading was recorded. For accuracy of the reading, the glass electrode was washed after each reading with distilled water and wiped to dry with soft tissue paper.

Estimation of total anthocyanin content

Total anthocyanin content of peel was estimated by the method described by Sims and Gamon (2002) with slight modification. For chlorophyll measurement, 5 g tissue samples were properly homogenized with 10 mL (1:2) 80% cold acetone (pH = 7.8) and centrifuged for 4 min at 800 rpm at 4 ^{0}c. The clear supernatant diluted to a final volume of 5 mL with additional acetone and was used for the estimation of total anthocyanin content and evaluated for antioxidant activity. The absorbance of the extract solutions at 665 nm, 649 nm, 646 nm, 663 nm, 470 nm, 529 nm and 650 nm wavelengths was measured with a double beam spectrophotometer (Dynamical HALO-DB-20S UV-VIS Double Beam Spectrophotometer). Chlorophyll-a, chlorophyll-b and anthocyanin Contents

were calculated by using the following formula:

Chlorophyll-a (µg/ml) = 12.21 A_{665} – 6.88 A_{649}
Chlorophyll-b (µg/ml) = 20.13 A_{646} – 5.03 A_{663}
Anthocyanin (µmol/ml) = A_{529} – 0.288 A_{650}
Anthocyanin (µmol/g × 207.247 = µg/g) = A_{529} – 0.288 A_{650}

Estimation of total sugar content

The amount of total sugars (TS) of guava fruit was determined by modified anthrone-sulfuric acid colorimetric method as described by Jayaraman (1981). The percentage of total sugar was calculated by using the following formula:

$$\text{Total sugar (mg/100 g FW)} = \frac{\text{Amount of sugar obtained}}{\text{Weight of samples}} \times 100$$

Statistical analyses

The collected data on various parameters under this study were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of SPSS 22.0 (IBM, New York, USA) software. The mean differences among the treatments were calculated with the help of Duncan's Multiple Range Test (DMRT) at 1% and 5% levels of probability (Gomez and Gomez, 1984).

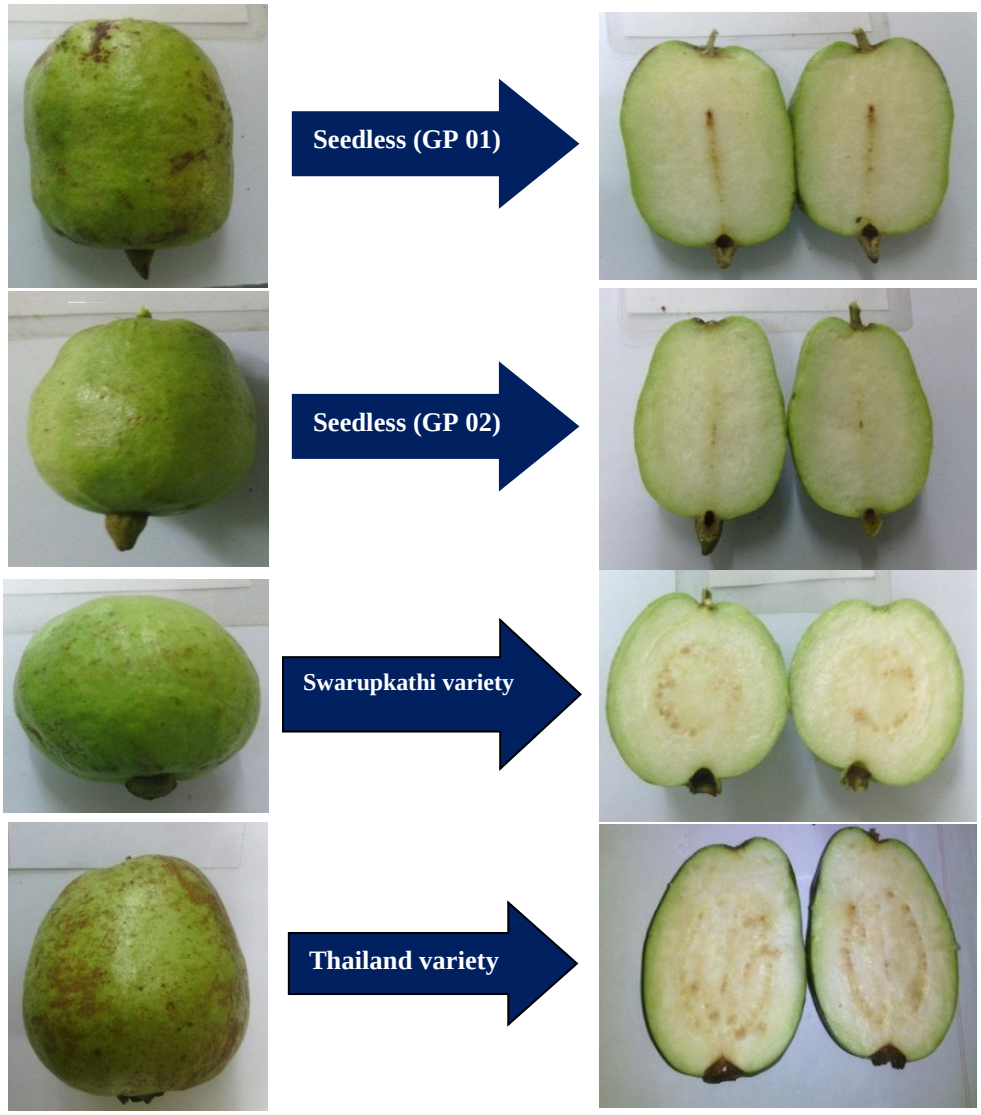


Fig. 2. The outside view and transverse section view of seedless, Swarupkathi and Thialand guava genotypes.

Results

The results regarding flowering behavior and fruit characteristics were studied during the study but nutritional quality of fruits was tested in respect of best genotypes such as Seedless, Swarupkathi and Thailand guava.

Flower characteristics

- ***Days required to flower bud development***

A significant ($P<0.01$) variation was observed in case of days required to flower bud development (Table 1). Genotype PG 01 required significantly longer time (23.20 days) to develop flower bud, which was statistically similar to PG 02 (22.20 days) whereas PG 05 took the shortest time (17.60 days) to develop floral bud which was close to the genotype PG 07 (18.20 days) and PG 13 (18.20 days). Other genotype showed intermediate results and did not differ significantly from each other.

- ***Duration of flowering time***

Significant variation ($P<0.01$) was observed among the studied genotypes in respect of duration of flowering time (Table 1). Duration of flowering time may be depending on the genetic or environmental variations. The highest duration of flowering time was recorded in genotype PG 01 (14.20 days) followed by PG 06 (12.60 days), which was statistically similar to the genotype PG 11 (12.60 days), PG 02 (12.40 days), PG 05 (12.20 days) and PG 14 (12.20 days). Whereas the lowest duration of flowering time was recorded in genotype PG 10 (10.40 days), which was statistically similar to genotype PG 03 and PG 07.

Table 1. Days required for floral bud development, of flowering, length of flower bud, length of petal and width of petal in fifteen duration guava genotypes

Genotypes No.	Days required to flower bud development	Duration of flowering (Days)	Length of flower bud (cm)	Length of petal (cm)	Width of petal (cm)
PG 01	23.20^{a}	14.20^{a}	2.12^{abcd}	1.92	1.38^{a}
PG 02	22.20^{ab}	12.40^{b}	2.40^{a}	2.06	1.20^{abc}
PG 03	20.20^{cde}	10.40^{c}	1.94^{bcd}	2.14	1.38^{a}
PG 04	20.40^{bcd}	11.20^{bc}	2.28^{abc}	1.84	1.26^{ab}
PG 05	17.60^{f}	12.20^{b}	1.92^{cd}	1.94	1.08^{bcd}
PG 06	19.20^{cdef}	12.60^{b}	2.30^{ab}	2.10	1.04^{bcd}
PG 07	18.20^{ef}	10.40^{c}	2.20^{abc}	2.16	1.00^{bcd}
PG 08	20.20^{cde}	11.80^{bc}	1.96^{bcd}	2.04	1.22^{ab}
PG 09	21.20^{bc}	11.20^{bc}	2.14^{abcd}	1.70	0.92^{cd}
PG 10	19.80^{cde}	10.40^{c}	2.08^{abcd}	1.84	1.14^{abcd}
PG 11	18.60^{def}	12.60^{b}	2.16^{abcd}	1.84	1.22^{ab}
PG12	18.40^{def}	11.60^{bc}	2.26^{abc}	1.92	1.16^{abcd}
PG 13	18.20^{ef}	11.40^{bc}	2.02^{bcd}	2.06	0.90^{d}
PG 14	19.40^{cdef}	12.20^{b}	1.96^{bcd}	1.92	1.16^{abcd}
PG 15	18.80^{def}	11.20^{bc}	1.82^{d}	1.74	1.08^{bcd}
Level of significance	**	**	*	NS	**
CV (%)	7.02	9.14	11.64	11.62	7.08

Means in a column followed by the same letter (s) do not differ significantly based on DMRT analysis.
** Significant at the 1% level of probability
* Significant at the 5% level of probability
[PG 01 to PG 02= Seedless guava, PG 03 to PG 08= Swarupkathi guava, PG 09 to PG 15= Thailand guava]

Length of flower bud

Significant difference (P<0.05) was observed among the studied genotypes in respect of length of flower bud (Table 1). Length of flower bud may predict the superiority or inferiority of a genotype. The longest flower bud was produced by PG 02 (2.4 cm), which was statistically identical to all other genotypes except for PG 03 (1.94 cm), PG 05 (1.92 cm), PG 08 (1.96 cm), PG 13 (2.02 cm), PG 14 (1.96 cm) and PG 15 (1.82 cm).

Length of petal

No significant variation was observed among the selected genotypes in respect of length of the petals (Table 1). The highest length of petal was exhibited in PG 07 (2.160 cm) and the lowest petal length was recorded in the genotype PG 09 (1.70 cm).

Width of petal

Significant variation (P<0.01) was exhibited among the selected genotypes in respect of width of the petals (Table 1). The highest width of the petal was found in PG 01 (1.38 cm), which was statistically identical to all genotypes except for PG 05 (1.08cm), PG 06 (1.04 cm), PG 07(1.00 cm), PG 09 (0.92 cm), PG 13 (0.901 cm) and PG 15 (1.08 cm) and the lowest width of petal observed from PG 13 (0.90 cm).

Fruit characteristics

- ***Percentage of fruit set***

The percentage of fruit set under natural pollination showed a wide range of significant variations (P<0.01) (Table 2). The highest percentage of fruit set was found in genotype PG 013 (87.62 %) followed by PG 08 (87.12 %), while the lowest percentage of fruit set was recorded in genotype PG 02 (60.02 %). percentage of fruit set may be depending on the genetic or environmental factors such as availability of water and light.

- ***Percentage of fruit drop***

A wide range of significant variations (P<0.01) was observed among the selected genotypes in respect of the percentage fruit drop (Table 2). The highest fruit drop percentage was exhibited in genotype PG 02 (39.98 %) followed by PG 01 (34.83 %) and the lowest percentage of fruit drop was recorded in PG 13 (12.39 %), which was statistically similar to PG 08 (12.90 %) and other genotypes [PG 07 (17.62 %), PG 08 (12.90 %), PG 09 (14.40 %), PG 11 (17.32%), PG 12 (14.41 %) and PG 15 (16.17 %)] showed intermediate results.

Table 2. Percentage of fruit set, fruit drop percentage, time required for fruit maturation and weight of fruit in fifteen guava genotypes

Genotypes No.	Fruit set (%)	Fruit drop (%)	Time required for fruit maturation (Days)	Weight of fruit (G)
PG 01	65.18^{f}	34.83^{b}	104.40^{bcd}	140.80^{f}
PG 02	60.02^{g}	39.98^{a}	100.60^{cde}	92.26^{g}
PG 03	75.14^{de}	24.88^{cd}	106.20^{abcd}	161.40^{def}
PG 04	80.48^{bc}	19.52^{ef}	85.80^{g}	228.60^{b}
PG 05	71.14^{e}	28.88^{c}	87.80^{fg}	171.60^{de}
PG 06	84.94^{ab}	15.07^{fg}	108.40^{abc}	214.20^{b}
PG 07	82.40^{ab}	17.62^{fg}	98.40^{cdef}	220.00^{b}
PG 08	87.12^{a}	12.90^{g}	112.20^{ab}	203.00^{bc}
PG 09	85.60^{ab}	14.40^{fg}	97.80^{cdef}	170.40^{de}
PG 10	77.00^{cd}	23.02^{de}	96.40^{defg}	204.60^{b}
PG 11	82.68^{ab}	17.32^{fg}	98.60^{cdef}	145.40^{ef}
PG12	85.60^{ab}	14.41^{fg}	97.60^{cdef}	312.60^{a}
PG 13	87.62^{a}	12.39^{g}	89.20^{efg}	158.20^{def}
PG 14	76.54^{cd}	23.46^{de}	115.80^{a}	178.60^{cd}
PG 15	83.84^{ab}	16.17^{fg}	96.54^{defg}	92.80^{g}
Level of significance	**	**	**	**
CV (%)	4.91	10.4	7.8	10.74

Means in a column followed by the same letter (s) do not differ significantly based on DMRT analysis ** Significant at 1% level of probability, [PG 01 to PG 02= Seedless guava, PG 03 to PG 08= Swarupkathi guava, PG 09 to PG 15= Thailand guava]

Time required for fruit maturation

Time required for fruit maturation is the most important trait of a fruit crop. A wide range of significant variations (P<0.01) was observed among the selected genotypes in respect of days required for fruit maturation (Table 3). Days required for fruit maturation may be depending on the genetic characteristics of plant or availability of water and essential nutrients. The genotype PG 14 took the highest number of days (115.8), which ranked equal to the PG 08 (112.2 days), PG 06 (108.4 days), PG 03 (106.2 days) and PG 01 (104.4 days). In contrast, the genotype PG 04 took the lowest number of days (85.8) for fruit maturation, which was similar to PG 05, PG 10, PG 13 and PG 15.

Table 3. Length of fruit, diameter of fruit, number of seeds/fruit, pulp weight and seed weight of fifteen guava genotypes

Genotypes No.	Length of fruit (cm)	Diameter of fruit (cm)	No. of seeds/fruit	Pulp weight (g)	Seed weight (g)
PG 01	8.26^{b}	17.60^{d}	0.00^{l}	140.80^{de}	0.00^{c}
PG 02	6.40^{e}	16.30^{d}	0.00^{l}	92.28^{f}	0.00^{c}
PG 03	6.66^{de}	23.26^{ab}	182.0^{g}	142.20^{de}	19.22^{abc}
PG 04	7.80^{bc}	24.84^{ab}	131.00^{i}	210.80^{b}	17.78^{abc}
PG 05	7.82^{bc}	22.50^{bc}	385.80^{b}	155.60^{d}	16.04^{abc}
PG 06	7.62^{bcd}	26.28^{a}	152.20^{h}	199.10^{bc}	15.14^{abc}
PG 07	7.84^{bc}	22.26^{bc}	289.60^{d}	205.50^{b}	14.52^{abc}
PG 08	7.74^{bcd}	24.88^{ab}	109.40^{j}	181.40^{c}	21.60^{abc}
PG 09	7.50^{bcd}	22.92^{abc}	73.98^{k}	159.40^{d}	10.98^{bc}
PG 10	8.24^{b}	22.80^{abc}	411.20^{a}	186.20^{c}	18.36^{abc}
PG 11	6.16^{e}	21.98^{bc}	216.40^{e}	134.70^{e}	10.74^{bc}
PG12	9.3^{a}	25.36^{ab}	119.30^{ij}	292.90^{a}	19.70^{abc}
PG 13	6.98^{cde}	23.56^{ab}	318.40^{c}	133.40^{e}	24.76^{ab}
PG 14	7.62^{bcd}	22.42^{bc}	312.20^{c}	143.70^{de}	34.92^{a}
PG 15	6.76^{cde}	19.44^{cd}	202.20^{f}	80.30^{f}	12.50^{abc}
Level of significance	**	**	**	**	**
CV (%)	10.19	10.70	5.09	8.46	9.47

Means in a column followed by the same letter (s) do not differ significantly based on DMRT analysis.

** Significant at 1% level of probability, [PG 01 to PG 02= Seedless guava, PG 03 to PG 08= Swarupkathi guava, PG 09 to PG 15= Thailand guava]

Fruit weight

Significant difference (P<0.01) was observed in respect of fruits weight among the fifteen guava genotypes (Table 2). The highest fruit weight was recorded in genotype PG 12 (312.6 g) followed by PG 04 (228.6 g), which was statistically identical to the genotypes PG 06 (220.0 g), PG 06 (214.2 g), PG 10 (204.6 g) and PG 08 (203.0 g), whereas the lowest fruit weight was recorded from the genotype PG 02 (92.26 g) which was statistically similar to PG 15 (92.80 g).

Fruit length

Significant variation (P<0.01) was observed among the selected genotypes in respect of fruit length (Table 3). The longest fruit was obtained from genotype PG 12 (9.34 cm) followed by PG 01 (8.26 cm), whereas the shortest fruit was recorded in PG 11 (6.16 cm) followed by PG 02 (6.40 cm).

Fruit diameter

Statistically significant variation (P<0.01) was observed among the selected genotypes in respect of fruit diameter (Table 3). The highest fruit diameter was recorded in genotype PG 06 (26.28 cm), which was statistically similar to the genotypes PG 03 (23.26 cm), PG 04 (24.84 cm), PG 08 (24.88 cm), PG 09 (22.92 cm), PG 10 (22.80 cm), PG 12 (25.36 cm), and PG 13 (23.56 cm), whereas the lowest

diameter of fruit (16.30 cm) was recorded in PG 02, which was also statistically identical to PG 01 (17.60) and PG 15 (19.44).

Number of seeds per fruit

Number of seeds per fruits among the selected genotypes was found to be statistically significant (P<0.01) (Table 3). No seed was observed in the genotype PG 01 and PG 02 (seedless).

Pulp weight

Significant variation (P<0.01) was observed among the selected genotypes in respect of pulp weight (Table 3). The highest pulp weight was exhibited in PG 12 (292.9 g), whereas the lowest Pulp weight was recorded in genotype PG 15 (80.30 g).

Seed weight

Among the fifteen genotypes significant difference (P<0.01) was observed in respect of seed weight (Table 3). The highest seed weight was recorded in genotype PG 14 (34.92 g), whereas no seed weight was recorded in genotype PG 01 and PG 02 (0.00 g) due to their seedlessness trait.

Nutritional properties of different guava varieties

- ***Total anthocyanin contents***

Anthocyanins are a group of phenolic compounds in the plant kingdom and they exhibit good antioxidant properties. The data showed that the different guava genotypes had significant variation (P<0.01) in respect of anthocynine content (Fig. 3 A). It was found that, the anthocyanin content was higher in seedless guava (0.1760) followed by Thailand guava (0.082) variety and the lowest anthocyanin content was detected in the Swarupkathi guava (0.0460).

- ***Titratable acidity content***

No significant different (P<0.01) was observed among the guava varieties in respect of titratable acidity content (Fig. 3 B). The maximum (0.47%) titratable acidity present in Seedless guava genotypes followed by Swarupkathi (0.43%), whereas the lowest (0.36%) titratable acidity was present in the Thialand guava variety.

- ***Vitamin C content***

The data showed that the different varieties of guava had significant variation (P<0.01) in respect of vitamin C content (Fig. 3 C). It was found that, the vitamin C content was higher in seedless guava (91.25 mg/100 g FW) followed by Swarupkathi guava (76.98 mg/100 g FW) variety and the lowest vitamin C was present in the Thailand guava (71.56 mg/100 g FW) variety.

- ***Total soluble solids (TSS)***

The highest TSS% indicates superiority of a guava fruit. TSS showed significant variation (P<0.01) among different guava genotypes. The highest percentage of TSS was detected in seedless guava variety (5.19%), while the lowest percentage was found in Thailand variety (2.57%) (Fig. 3 D).

- ***Fruit juice pH content***

Significant variation (P<0.01) was observed in case of pH among the guava varieties (Fig. 3 E). It was found that, the fruit juice pH was higher in Swarupkathi variety (5.25) followed by Thailand variety (4.48), whereas the lowest pH content was recorded in seedless guava (3.31) variety.

- ***Total sugar content***

Significant variation (P<0.01) was observed in case of reducing sugar content among the guava varieties (Fig. 3 F). It was found that, the total sugar content was higher in seedless guava variety (6.56%) followed by Swarupkathi variety (5.89%), whereas the lowest total sugar content was counted in Thailand guava (4.39%) variety.

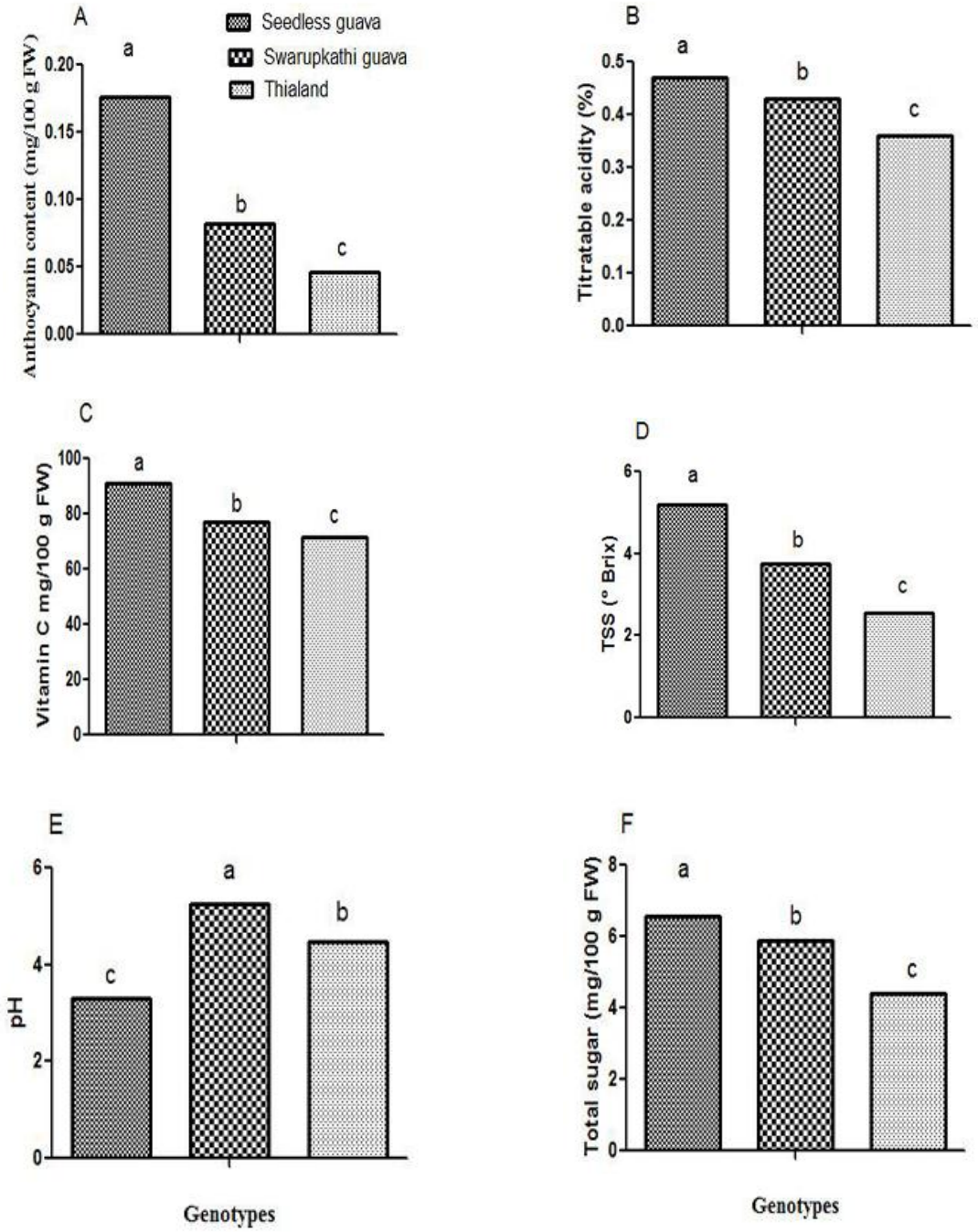


Fig. 3. Nutritional quality of three guava genotypes. (A) Anthocyanin content, (B) Titratable acidity, (C) Vitamin C content, (D) Total soluble solid (TSS), (E) pH and (F) Total sugar content.

Discussion

Flowering behavior

The knowledge of flowering and fruiting behavior of fruit trees is indispensable for a fruit grower and breeder. The duration of flower bud development varied from one genotype to another genotype. Genotype PG 01 was required significantly higher time to develop flower bud, which was statistically similar to PG 02, whereas PG 05 took the shortest time to develop floral bud. This result was in line with the findings of Singh and Sehgal (1968) who reported that guava requires 30 days from flower bud differentiation to complete the development of calyx cracking stage.

However, this variation may be attributed to environmental influence to this trait and also due to genetic constitution of the variety.

Duration of flowering time is an important character in a good-quality genotype. The flowering in different cultivars commenced at different dates, which were varied with time and duration of flowering. The highest duration of flowering time was recorded in genotype PG 01 while the lowest duration of flowering time was detected in genotype PG 10. Our results are in agreement with Dubey et al. (2004) who reported that the time of and duration of flowering are varietal characters influenced by climatic conditions of a particular region. Therefore, the time and duration of flowering vary depend on the cultivars and localities. Length of flower bud may predict the superiority or inferiority of a genotype. The longest flower bud was produced by PG 02, which was statistically identical to all other genotype except for the PG 03, 05 08, and PG 15. Similar findings were also observed by Singla and Dhaliwal (2003) who reported that flower size in term of diameter, stamens and petals varied significantly, whereas the number of sepals was not varied. Therefore, the differences in flower size, numbers of petals and stamens per flower in each cultivar might be attributed to genetic variations.

Fruit characteristics

- ***Percentage of fruit set***

The percentage of fruit set under natural pollination showed a wide range of significant variation. The highest percentage of fruit set was found in genotype PG 013, while the lowest percentage of fruit set was recorded in genotype PG 02. Percentage of fruit set may be depending on the genetic or environmental factors such as availability of water and light. The most frequent reasons are pollination failure, or nonfunctional eggs or sperms. Self-incompatibility genes limit successful fertilization to cross-pollination between genetically different male and female parents. Guavas are primarily self-pollinated, although some strains seem to produce more fruits when cross-pollinated with another variety. Some degree of self- and cross-incompatibility does happen in guava. These incompatibilities are the result of excess or poor growth of pollen-tube in the style. In our study, we observed that the highest percentage of fruit set was recorded in seeded genotype (PG 13), whereas the lowest percentage of fruit set was recorded in seedless (PG 02) genotype. We speculated that self-incompatibility and variation during pollen germination of seedless guava limit its successful fertilization. Our results validated the results of Marak and Mukunda (2007), they reported that the number of fruits per plant varied from 128 (A.C. Seln.10/3) to 61 (*Allahabad Safeda*) in an evaluation study of six-year-old Apple Colour progenies, conducted under Bangalore, India conditions. The percentage of fruit set among the different cultivars were thought to be due to variation in the pollen germination was noticed by Kundu and Mitra (1994). Similar trends of results were also obtained by Chatterjee et al. (1992) who reported that the ultimate fruits were harvested 64, 62 and 60% in Allahabad Safeda, Red Fleshed and Lucknow-49, respectively. Heavy fruit drop of small immature fruits may collectively be due to, birds, climatic factors and physiological disturbances. Day required for fruit maturation is the most important character for a fruit crop. A wide range of significant variations was observed among the selected genotypes in respect of day required for fruit maturation. The genotype PG 14 took the highest number of days, while the genotype PG 04 took the lowest number of days for fruit maturation. Day required for fruit maturation may be depending on the genetic characteristics of plant or availability of water and essential

nutrients. Significant difference was observed in respect of fruits weight and fruit length among the fifteen guava genotypes. The highest fruit weight and fruit length were recorded in genotype PG 12, whereas the lowest fruit weight and fruit length were recorded in the genotype PG 02. This result agreed with results of Athani et al. (2007) who evaluated 19 guava cultivars under Arabhavi conditions and found that mean fruit weight ranged from 156.32 g in cv. Sardar to 46.84 g in GW-3 and GR-3. The increase in fruit weight might be associated with the increase in cells size and gathering of food materials in the intercellular spaces of the fruit (Bollard, 1970). These results corroborate with Man Bihari and Suryanarayan (2011), who also found the variation in respect of fruit weight, fruit length and fruit diameter among studied genotypes. In our study, we observed that fruit diameter significantly varied among the genotypes. Our findings were similar to the findings on Dharwar- 34. Prakash (1976) who compared two guava cultivars for quality characters of fruit and revealed that cv. *Sardar* has maximum fruit diameter (6.19 cm), while it has minimum (5.85 cm) in cv. *Dharwar*. Similar results were observed by Phadnis (1970), who evaluated guava selections under Pune conditions and found that fruit diameter ranged from 7.5 cm in Sel. Dholka-7 to 4.6 cm in Sel. The causes of absence of seed in PG 01 and PG 02 may be environmental such as due to natural mutation or may be genetically such as abnormal gamete formation due to polyploidy. But several numbers of seeds were recorded in other genotypes. The lowest number of seeds was found in PG 09 and the highest number of seeds in PG 10. The most frequent reasons for lack of seed development are pollination failure, or nonfunctional eggs or sperms or may be chromosomal imbalance. These results were agreed with Yonemori et al. (2000) who reported that, seedless variety may occur due to parthenocarpy. Weight of fruit pulp varied significantly and in agreement with Mitra et al. (1983), who evaluated eleven cultivars of guava and reported that weight of pulp ranged from 77.8 g in cv. *Lucknow-49* to 53.6 g in cv. *Seedless* under West Bengal conditions. Among fifteen genotypes we found two (PG 01 and PG 02) genotypes contained no seeds but other genotypes contained seeds. Prakash (1976) also reported that cv. *Sardar* had minimum weight of seeds (1.53 g).

Nutritional properties of different guava varieties

- ***Total anthocyanin contents***

In case of nutritional quality, we compared seedless genotypes with Thialand and Swarupkathi guavas. The results showed that all analyzed nutritional parameters were significantly varied with each other and nutritional quality is higher in seedless genotype compared to Thialand and Swarupkathi guavas. Among the nutritional parameters, anthocyanins are a group of phenolic compounds in the plant kingdom and they exhibit good antioxidant properties. The quality of fruits also depends on anthocyanin content and its pigmenting power makes the fruits more attractive to be used as food colorants (Ajila et al., 2007). Maftoonazad et al. (2008) reported that titratable acidity is the indicator of acidity of fleshy fruit, is directly related to the amount of organic acid present in the fruit, during maturity the devaluation of acidity may be due to the metabolic changes in fruit and use of organic acid in the respiratory process of fruit. Vitamin C is the major organic acid in guava and the level decreases slightly during ripening (Marak and Mukunda, 2007). In another study, Pandey et al. (2007) also reported that the ascorbic acid in guava fruit decreases gradually throughout the fruit development until it reaches the full ripe stage. Our results are in accordance to findings obtained by Bashir et al. (2003); Hegde and Chharia

(2004) and Singh and Jain (2007) who reported that TSS increased during ripening of guava fruits. With the advancement of fruit maturity organic acids concentration declined. The organic acids are used in the respiration process during advances of fruit from development to ripening stages and increase the sugar content of fruit resulting in higher pH (Kafkas et al., 2007). Increase in sugar content during maturity and ripening might be due to depolymarization of polysaccharides and conversion of fruit starch to sugar. These results are in accordance to findings obtained by Singh and Jain (2007). In our study, we found higher anthocyanin content, titratable acidity, vitamin C, TSS, total sugar and lower pH in seedless guava genotypes than Thialand and Swarupkathi guavas, which are indicative of higher quality of seedless guava than other genotypes.

Conclusion

The result of the present study may provide useful information regarding flowering, fruiting behavior and nutritional quality of guava. The quality characteristics, pulp percentage of seedless genotypes (PG 01 to PG 02) is comparatively better than other genotypes. Besides the nutritional qualities, these two genotypes contained no seeds which could be the great advantages for consumers. Therefore, these two genotypes (PG 01 and PG 02) may be selected as seedless varieties with superior nutritional quality.

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References

1. Ahmed K.S, Mukund C. 2011. Tropical and subtropical fruits. AVI Publ. Co., Westport, CT, 121-156.
2. Ajila A.D, Bhat G.H. 2007. Characteristics of color development and relationship between anthocyanin synthesis and phenylalanine ammonia-lyase activity in 'Starking Delicious', 'Fuji' and 'Mutsu' apple fruits. Journal of the Japanese Society for Horticultural Science 54, 424-430.
3. Athani, S.I, Prabhuraj H.S, Ustad A.I, Swamy G.S.K, Patil P.B, Kotikal Y.K. 2007. Effect of organic and inorganic fertilizers on growth, leaf, major nutrient and chlorophyll content and yield of guava cv. Sardar. Acta Horticulture 735, 351-356.
4. Aulakh P.S, Dhaliwal G.S, Jawanda J.S. 1980. Studies on flower bud development, flower anthesis and flowering density in Pear. The Punjab Horticulture Journal 21, 175-181.
5. Bashir Hind A, Abu-Goukh, Abu-Bakr A. 2003. Compositional changes during guava fruit ripening. Food Chemistry 80, 557-563.
6. BBS. 2016. Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of People's Republic of Bangladesh.28th series. 216.
7. Bollard E.G. 1970. The physiology and nutrition of developing fruits. In: A.C. Hulme (Ed.) "The biochemistry of fruits and their products". I, Academic Press, London. 387-425.
8. Bose T.K, Mitra S.K. 1990. Guava Fruits Tropical and Subtropical. Ed. T.K. Bose, Nayaprakash, India. 280-303.
9. Chattarjee D, Singh, Umesh P, Thakur S, Kumar, R. 1992. A note on bearing habit of guava (*Psidium guajava* L.). Haryana Journal of Horticultural Science 21, 69-71.
10. Dubey P.S, Hoda M.N, Singh J, Singh S.K. 2004. Flowering and fruiting characters of guava varieties during rainy season fruiting. The Orissa Journal of Horticulture 32, 23-25.
11. FAO. 2017. The future of food and agriculture –trends and challenges. Rome, Italy.
12. Gomez K.A, Gomez A.A. 1984. Statistical Procedure for Agricultural Research. 2nd ed. John Willey and Sons. New York 64.
13. Hegde M.V, Chharia A.S. 2004. Developmental and ripening physiology of guava (*Psidium guajava* L.) fruit I. Biochemical changes. Haryana Journal of Horticultural Science 33, 62-64.

14. Jayaraman J. 1981. Laboratory Manual in Biochemistry. Wiley Eastern Ltd. New Delhi, India.

15. Kafkas E, Kosar M, Paydas S, Kafkas S, Baser K.H.C. 2007. Quality characteristics of strawberry genotypes at different maturation stages. Food Chemistry 100, 1229-1236.

16. Kundu S, Mitra S.K. 1994. Studies on flowering and fruiting of guava cultivars in the laterite tract of West Bengal. Haryana Journal of Horticultural Science 23, 213-218.

17. Leite K.M, Tadiotti A.C, Baldochi D, Oliveira O.M. 2006. Partial purification, heat stability and kinetic characterization of the pectin methyl esterase from Brazilian guava, Plauma cultivars. Food Chemistry 94, 565-72.

18. Maftoonazad N, Ramaswamy H.S, Marcotte M. 2008. Shelf life extension of peaches through sodium alginate and methyl cellulose edible coatings. International Journal of Food Science and Technology 43, 951-957.

19. Man B. 2011. Genetic diversity, heritability, genetic advance and correlation coefficient in guava (*Psidium guajava*). Indian Journal of Agricultural Sciences 81, 107-110.

20. Marak K, Mukunda S.C. 2007. Effect of growth, flowering and fruiting of some apple cultivars. M.Sc. Thesis, Fac. Agriculture Cairo University.

21. Mendez M, Jones D.G, Manetas Y. 1999. Enhanced UV-B radiation under field conditions increases anthocyanin and reduces the risk of photo inhibition but does not affect growth in the carnivorous plant *Pinguicula vulgaris*. New Phytologist 144, 275-282.

22. Mitra N.A. 1983. A note on seasonal variations in the physico-chemical composition of Guava **(***Psidium guajava* L.) cultivar Sardar andApple under Terai condition of UP. Haryana Journal of Horticultural Science 16, 90-91.

23. Mondal M.F. 2000. Production and Storage of Fruits 160 (in Bangla)

24. Pandey N.A. 2007. Origin of Cultivated Guava Plants. Vegal Paul Trench and Company, London 1-67.

25. Phadnis N.A. 1970. Physico-chemical composition of guava fruits. Indian Journal of Horticulture 27, 417-433.

26. Prakash N.A. 1976. Studies on growth and fruiting in Sardar guava (*Psidium guajava* L.). M. Sc. (Ag.) Thesis, University. of Agriculture Sciences, Dharwad.

27. Ranganna S. 1977. Manual of analysis of fruit and vegetable products. New Delhi: Mc Graw-hill.

28. Reddy O.S.K. 2017. Nutrition facts & health benefits of guava fruit. Green Universe Environmental Services Society.

29. Roy A.K. 1997. Studies on growth habit, flowering and fruiting behaviour of jackfruit. An MS Thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh 32.

30. Sharma D. 2004. Characterization of jackfruit of Brahmaputra char areas of Mymensingh. MS. thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh 43.

31. Singh P, Jain V. 2007. Fruit growth attributes of guava (*Psidium guajava* L.) cv. Allahabad Safeda under agroclimatic conditions of Chhattisgarh. Proceedings of the first International Guava Symposium. Acta Horticulture 735, 335-338.

32. Singla R, Dhaliwal G.S. 2003. Floral morphology and flowering behavior of different genotypes of guava. Journal of Research 40, 371-374.

33. Tanwar B, Andallu B, Chandel S. 2014. Influence of Processing on Physicochemical and Nutritional Composition of *Psidium Guajava* L. (Guava) Products. International Journal of Agriculture and Food Science Technology 5(2), 47-54.

34. Upadhyay N.P, Tripathi B.M. 1985. Postharvest changes during storage and ripening of mango (*Mangifera indica* L.) fruit. Propagation of Horticultural Crops 171, 25-27.

35. Yonemori K, Sugiura A, Yamada M. 2000. Persimmon genetics and breeding. Plant breeding Reviews 19, 191-225.