

Physical and biochemical changes in guava (*Psidium Guajava* L.) during various stages of fruit growth and development

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ABSTRACT

Physiological and biochemical changes during fruit growth, development and maturity of eleven genotypes of guava fruit were studied at 30, 60, 90, 105, 120 and 127 days after fruit set (DAFS). Fruit weight, length and diameter of guava fruit increased continuously from the initial stage of fruit development till maturity and ripening in all the genotypes. The increases in fruit weight and diameter were comparatively more between 30 to 60 DAFS and 90 to 127 DAFS than 60 to 90 DAFS where the increase in fruit weight and diameter was slow in most of the genotypes. However, RCG-1, RCG-2 and RCG-3 showed the continued rapid increase in fruit weight upto 120 days and thereafter the rate of increase was quite slow. A gradual increase in total soluble solids (TSS) was observed in all the genotypes throughout development and ripening stage of the fruits. However, the amount of total titratable acidity increased steadily in the beginning upto 105 days after fruit set in most of the genotypes except RCG-1, RCG-2 and RCG-3 which showed upto 90 days only and afterwards there was a continuous reduction till ripening. The fruits showed continuous and progressive increase in TSS: acid ratio from 30 DAFS till maturity and ripening in all the genotypes except RCG-11, RCGH-1 and RCGH-7 that showed from 60 DAFS. Based on the present findings, days taken from flowering to harvest maturity (>105 days), TSS (>9.50%) and TSS: acid ratio (>15.00) were some of the parameters for judging the maturity indices of genotypes like RCG-1, RCG-2 and RCG-3. Similarly, days taken from flowering to harvest maturity (>110 days), TSS (>10.50%), TSS: acid ratio (>21.00) and fruit skin colour (whitish green) for RCGH-1 were some of the parameters for judging the maturity indices. Whereas, other genotypes were also exhibited the variation for days taken from flowering to harvest maturity (>120 days), skin colours, TSS (9.20-11.00%) and TSS: acid ratio (13.50-23.50).

Highlights

- Physiological and biochemical changes during fruit growth, development and maturity of eleven genotypes of guava fruit were studied at 30, 60, 90, 105, 120 and 127 days after fruit set (DAFS).
- The increases in fruit weight and diameter were comparatively more between 30 to 60 DAFS and 90 to 127 DAFS than 60 to 90 DAFS.
- A gradual increase in total soluble solids (TSS) was observed in all the genotypes throughout development and ripening stage of the fruits. However, the amount of total titratable acidity increased steadily in the beginning upto 105 days after fruit set in most of the genotypes except RCG-1, RCG-2 and RCG-3, which showed upto 90 days only, and afterwards there was a continuous reduction till ripening.

Keywords: Guava, physical and biochemical changes, fruit development, maturity.

Guava (*Psidium guajava* L.) is one of the most well known edible tree fruits grown widely in more than sixty countries throughout the tropical and subtropical regions of the world. The fruits are delicious, rich in vitamin 'C', pectin and minerals like calcium, phosphorus and iron. Guava fruits are used as fresh as well as for making jam, jelly, nectar, paste etc. (Patra *et al.* 2004). Furthermore, high concentrations of pectin in guava fruit may play a significant role in the reduction of cholesterol and thereby decrease the risk of cardiovascular disease. Considered as "poor man's apple", the guava truly happens to be the fruit for masses in terms of its availability in the market and accessibility to the poor (Jayachandran *et al.* 2005). Since, guava plants bears flowering and fruiting once in a year during April-May and October-November respectively in this region as compared to twice or thrice crops per year in other parts of the India. Standardization of the external features, physical characters and chemical composition of commercially important guava cultivar is therefore needed. It is known that the quality and storage life of fruits depend on various physiological and biological changes, which occur during fruit growth, development and maturity (Harding and Hatoon 1967). Harvesting at correct stage of maturity has great bearing on the quality of fruits. The information pertaining to the physical and biochemical changes in guava at different stages of fruit growth and maturity is very scanty under mid hills of northeastern region of India. Such information are required because physico-chemical changes during maturity can be used as important criteria for determining the optimum stage of fruit harvesting for better quality and extended shelf life. Therefore, keeping these facts in view a comprehensive study was carried out on various physical and biochemical changes at different stages of fruit maturity to determine the appropriate maturity standards so as to harvest the fruits in appropriate time for better quality and desirable shelf life.

Materials and Methods

An experiment was conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya,

India. Five years old bearing plant of eleven genotypes of guava viz., RCG-1, RCG-2, RCG-3, RCG-11, RCGH-1, RCGH-4, RCGH-7, Allahabad Safeda, Lucknow-49, Lalit and Sangam were selected for this study. The experiment was laid out in randomized block design with three replications and three plants per replication. One hundred fruits just after fruit set were tagged on each of the three selected plant in each replication of all the genotypes. Ten randomly selected fruit amongst tagged fruits from all directions of each plant and genotype at 30, 60, 90, 105, 120 and 127 days after fruit set (DAFS) were harvested for study the fruit size, weight and biochemical parameters.

Physical changes

Fruit length and diameter were measured from randomly selected fruit during study. The length from base of fruit to the base of the calyx and diameter at the maximum bulge of fruit from both side were measured with help of 'digital vernier caliper' and mean values of length and diameter were presented in cm. The weight of the fruits was calculated on the basis of 10 representative fruits and the mean was expressed in gram.

Biochemical changes

Biochemical parameters i.e., total soluble solids (TSS), acidity and TSS: acid ratio of guava fruits were estimated at 30, 60, 90, 105, 120 and 127 days after fruit set (DAFS) for all genotypes. The pulp was extracted from fruits by crushing and squeezing through muslin cloth. The total soluble solids (TSS) of the pulp were determined by placing the small quantity of pulp on the prism of digital refractometer. Total titratable acidity was determined by dissolving a known weight of pulp in a known volume of distilled water. The aliquot was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was recorded in terms of percent citric acid on fresh weight basis (AOAC 2000). The TSS: acidity ratio was calculated by dividing the value of TSS by that of titratable acidity.



Results and Discussion

Fruit weight

A significant variation in fruit weight of guava was observed among the genotypes at various stages of fruit development. The data presented in Figure 1 showed an increasing trend in fruit weight from initial stage of fruit growth till maturity and ripening (127 days) in all the genotypes. The increases in fruit weight was rapid between 30 to 60 DAFS and 90 to 127 DAFS whereas, the rate increase in weight was little bit slow between 60 to 90 DAFS in most of the genotypes. However, RCG-1, RCG-2 and RCG-3 showed the continued rapid increase in fruit weight

upto 120 days and thereafter the rate of increase was quite slow (Figure 1). Similar finding was also reported by Dhillon et al. (1987) they found that fruit weight in Allahabad Safeda and Sardar increased upto 130 and 120 days, respectively, in the rainy season and upto 140 and 130 days, respectively in the winter season. The slow growth during 60 to 90 DAFS might be due to rapid development of seed resulting in slow growth of the pulp. The increase in fruit weight could be attributed to an increase in the size of the cells and accumulation of food substances in the intercellular spaces in fruit (Bollard, 1970). The findings is analogous to this observation were also reported by Dhillon et al. (1987), Mercado-Silva et al. (1998) and Singh and Jain (2007).

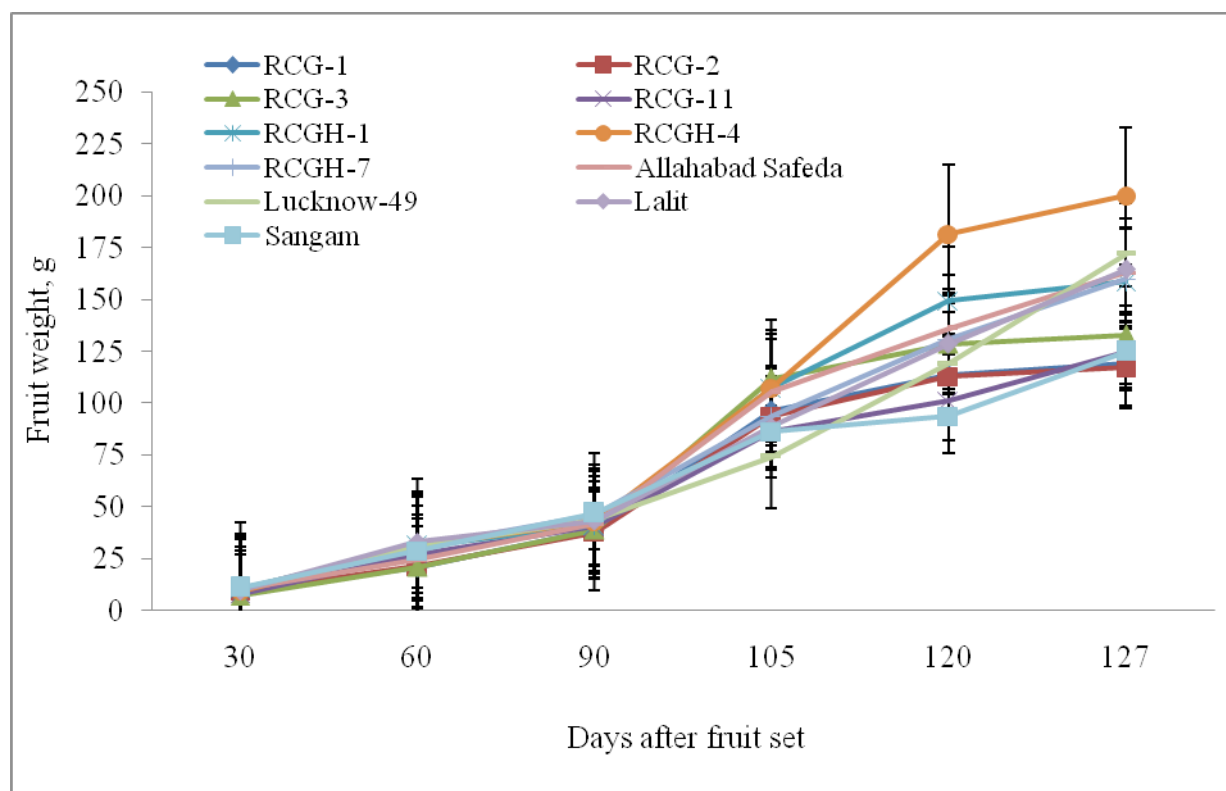


Figure 1 Fruit growth pattern (weight) of guava genotypes

Variation for fruit weight among genotypes was significant and it was ranged from 93.64 to 181.67 g and 117.12 to 200.07 g at 120 and 127 days after fruit set, respectively. The highest fruit weight was observed in RCGH-4 (181.67 g) followed by RCGH-1 (149.50 g) and Allahabad Safeda (136.13 g) while, lowest weight was observed in Sangam (93.64 g) at 120 DAFS. The highest fruit weight at 127 DAFS was recorded in RCGH-4 (200.07 g), which was significantly higher than other genotypes. Lucknow-49 (172.02 g), Lalit (164.42 g) and Allahabad Safeda (163.07 g) exhibited at par values within themselves. The lowest fruit weight was recorded in RCG-2 (117.12 g) closely followed by RCG-1 (118.95 g). The variation in fruit weight was because of genetic behavior of different cultivars or genotypes with bigger or smaller sizes varying with weight (Man Bihari and Suryanarayan 2011).

Fruit growth

Fruit length

The fruit length varied significantly among genotypes during study. The length of developing fruits was found to increase with the advancement in

age (Table 1). Highest length of fruits was possessed in RCG-2 (6.61 cm) followed by RCG-1 (6.50 cm) and lowest length of fruit was observed in Sangam (5.26 cm) on 120 DAFS. However at 127 DAFS, the highest fruit length was obtained in Lucknow-49 (6.81 cm) and RCG-2 (6.71 cm) and lowest length of fruit was exhibited in RCG-11 (5.89 cm) and Sangam (5.93 cm). Man Bihari and Suryanarayan (2011) also observed the variation among fourteen genotypes studied in respect to fruit weight, fruit length and fruit diameter.

Fruit diameter

Significant variations during changes in fruit diameter of guava were recorded among the genotypes. The fruit diameter of guava was recorded an increasing trend from initial stage of fruit growth till maturity and ripening (127 days) for all genotypes. The increase in fruit diameter was comparatively more between 30 to 60 DAFS and 90 to 127 DAFS than 60 to 90 DAFS where the increase in diameter was slow. Fruit growth of guava showed a double sigmoid pattern. The first and second rapid growth phases were noticed between 30 to 60 days and 90 to 127 days after fruit set depending on the genotypes

Table 1 Performance of guava genotypes for fruit length at different days after fruit set

Genotypes	Fruit length (cm)					
	Days after fruit set (DAFS)					
	30	60	90	105	120	127
RCG-1	2.90	3.65	4.46	6.03	6.50	6.57
RCG-2	3.03	3.66	4.67	6.06	6.61	6.71
RCG-3	2.95	3.81	4.63	6.05	6.33	6.47
RCG-11	2.65	3.79	4.19	5.37	5.55	5.89
RCGH-1	2.74	4.01	4.35	5.39	5.81	6.48
RCGH-4	2.80	3.87	4.38	5.45	6.24	6.66
RCGH-7	2.89	3.81	4.44	5.51	5.92	6.59
Allahabad Safeda	2.63	3.69	4.22	5.13	5.75	6.42
Lucknow-49	2.89	3.79	4.27	5.04	5.59	6.81
Lalit	2.58	3.76	4.22	4.95	5.51	6.22
Sangam	2.72	3.66	4.32	5.03	5.26	5.93
CD (P= 0.05)	0.08	0.13	0.18	0.12	0.12	0.12



(Figure 2). The major increase in fruit growth could be attributed to the increase in cell size whereas; slow growth in between 60 to 90 days after fruit set was perhaps due to faster development of seed during this period that attributed to slow growth of the pulp. Results of the present investigations are in close conformity with the findings of Dhillon et al. (1987) and Mercado-Silva et al. (1998) they reported double sigmoid growth curve in guava fruit. The analysis at 120 days revealed the significant superiority of RCGH-4 (6.38 cm) for the traits over others. The second best genotype that followed RCGH-4 in fruit diameter was RCGH-1 (6.11 cm). RCG-1 (5.15 cm) revealed the lowest fruit diameter followed by at par values of RCG-2 (5.19 cm). Analysis at 127 days also revealed the significant superiority of RCGH-4 (7.01 cm) for the traits over others. RCG-1 (5.29 cm) revealed the lowest fruit diameter followed by RCG-2 (5.34 cm) both were at par with each other.

Total Soluble Solids

A gradual increase in total soluble solids (TSS) was observed in all the genotypes throughout development and ripening stage of the fruits (Figure

3). Increase in TSS during ripening might be due to depolymerisation of polysaccharides and conversion of fruit starch to sugars. Data showed the significant variation among genotypes for total soluble solids (TSS) content. The results at 105 days of fruit set revealed that the highest TSS content was present in RCG-1 (9.83%) followed by RCG-3 (9.55%) showing at par each other while, lowest content was exhibited by RCGH-4 (8.75%). However at 120 DAFS, significantly highest TSS content was observed in RCG-11 (11.08%) and RCGH-1 (10.76%) showing at par each other and significantly superior over other genotypes followed by RCG-1 (10.29%), RCGH-7 (10.25%), Lucknow-49 (10.0%), Allahabad Safeda (9.95%) and RCGH-4 (9.92%) exhibiting at par values within themselves. Significantly lowest content was present in Sangam (9.22%) followed by Lalit (9.43%) and RCG-2 (9.62%) showing at par values. On 127 days of fruit set, RCG-11 revealed the highest TSS content (12.19%) and found significantly superior over rest of the genotypes. The next best performers were RCGH-1 (10.91%) and RCGH-7 (10.55%) exhibiting at par each other while, RCG-1 (10.34) and Lucknow-49 (10.30%) showing at par with RCGH-

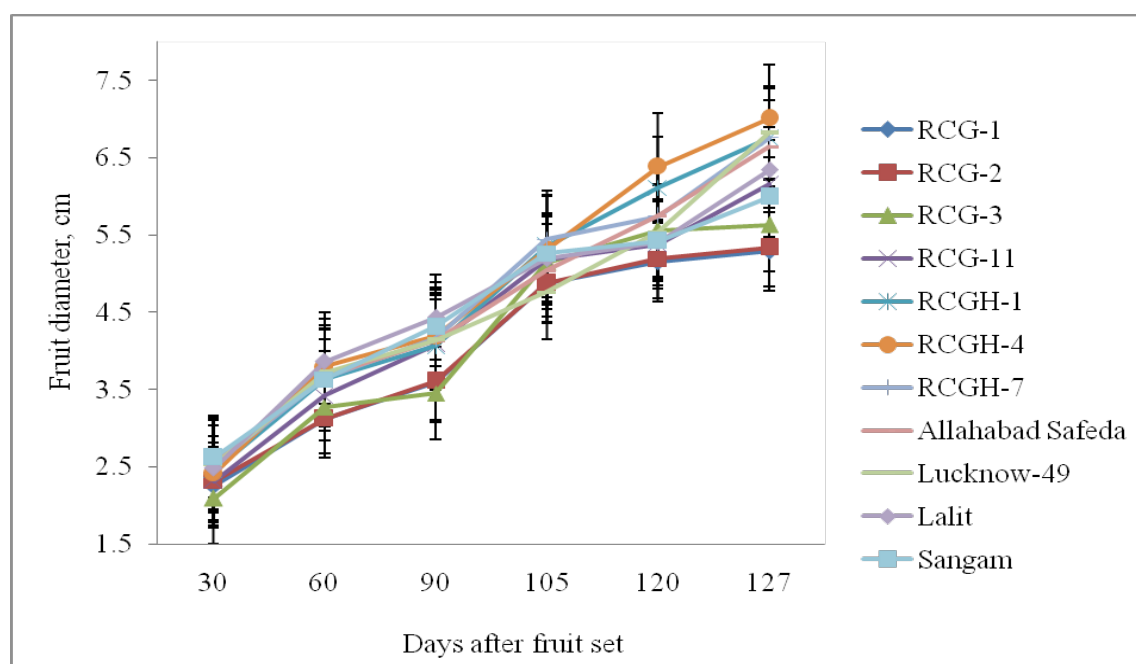


Figure 2. Fruit growth pattern (diameter) of guava genotypes

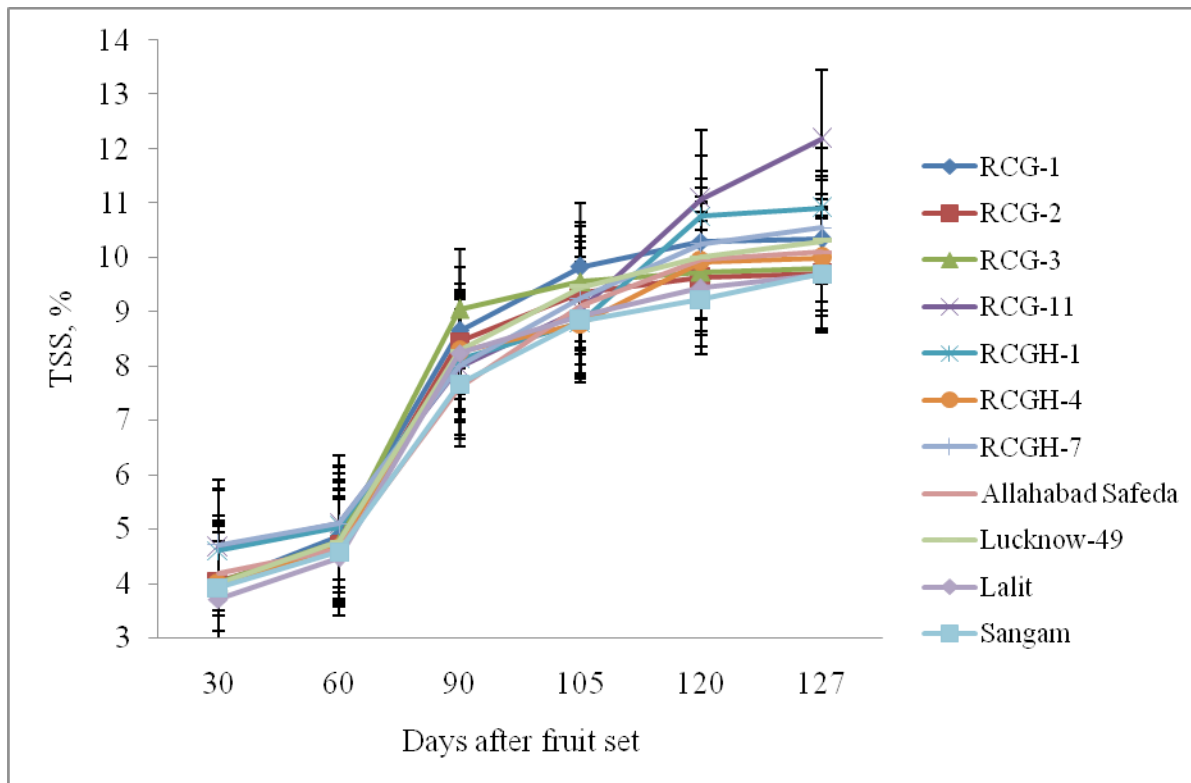


Figure 3. Changes in TSS content of guava genotypes

7. Significantly, lowest TSS content was recorded in Lalit (9.68%), which was closely followed by RCG-2 (9.69%), Sangam (9.70%) and RCG-3 (9.79%) showing at par values. The highest value of TSS on 105 DAFS in RCG-1 and RCG-3 might be due to genetic characteristics of these genotypes to mature early after fruit set. Results are in accordance to findings obtained by Dhillon *et al.* (1987); Bashir *et al.* (2003); Hegde and Chharia (2004) and Singh and Jain (2007).

Titrateable acidity

The amount of total titrateable acidity increased steadily in the beginning upto 105 days after fruit set in most of the genotypes except RCG-1, RCG-2 and RCG-3 which showed upto 90 days only and afterwards there was a continuous reduction till ripening (Fig. 4). The increase in acidity might be attributed to increased bio-synthesis of organic acids during initial period of fruit growth (Naik 1985).

The decrease in titrateable acidity at the later stages of fruit maturity and ripening was considered to be due to conversion of organic acids into sugars. Similar result was also observed by Mercado-Silva *et al.* (1998), Hegde and Chharia (2004) in guava, Deka *et al.* (2006) in Khasi mandarin and Dhillon *et al.* (2007) in pear.

Data presented in Figure 4 revealed significant variations among genotypes for acidity content. The highest acidity was present in Sangam (1.71%), which was closely followed by RCGH-7 (1.59%) and both were at par each other while, lowest content was registered in RCG-2 (0.61%) followed by RCG-1 (0.62%) and RCG-3 (0.66%) showing at par values on 105 DAFS. Significantly highest acidity on 120 days of fruit set was noticed in Sangam (0.69%) followed by Lalit (0.66%) and Allahabad Safeda (0.63%) which were at par themselves while, lowest acidity was recorded in RCG-1 & RCG-11 (0.48%)

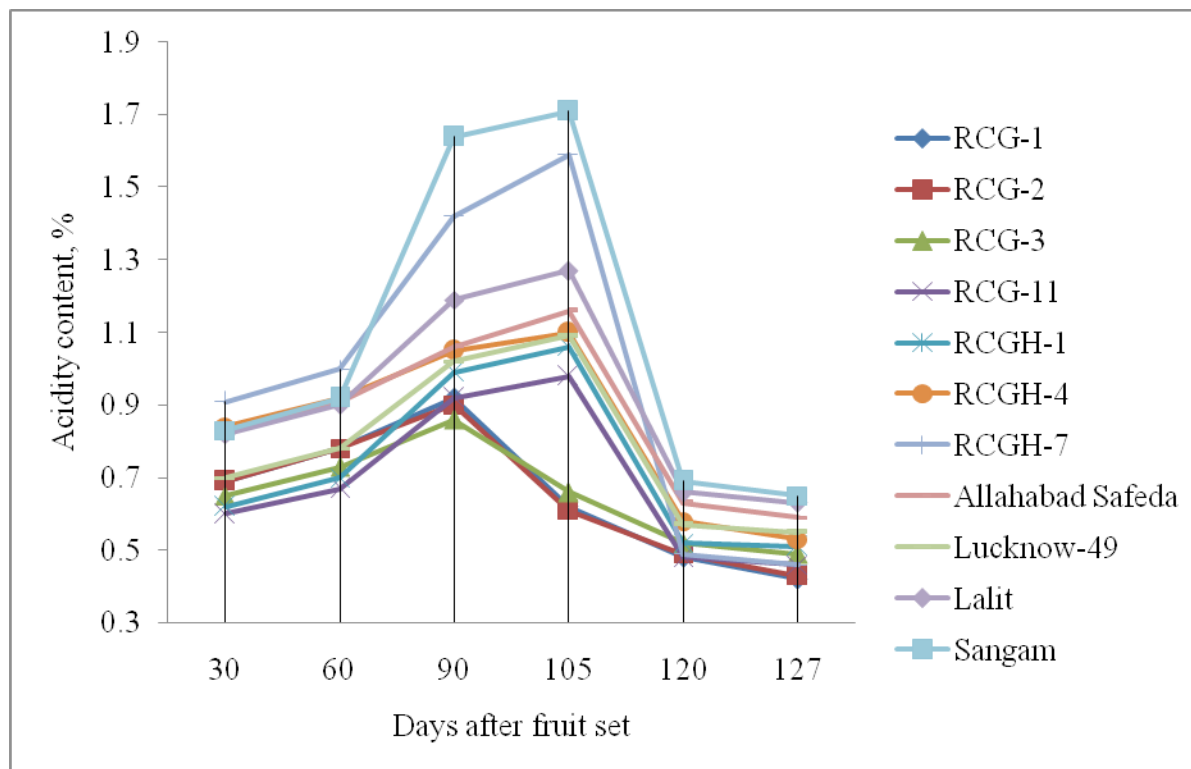


Figure 4. Changes in acidity content of guava genotypes

each) followed by at par values in RCG-2 & RCGH-7 (0.49% each), RCG-3 & RCGH-1 (0.52% each) and Lucknow-49 (0.57%). On 127 days of fruit set also, Sangam revealed the highest acidity (0.65%) which was at par with Lalit (0.63%) and Allahabad Safeda (0.59%) whereas, significantly lowest acidity content was present in RCG-1 (0.42%) followed by RCG-2 (0.43%), RCG-11 & RCGH-7 (0.46% each) and RCG-3 (0.49%) showing at par values.

TSS: acid ratio

The fruits showed continuous and progressive increase in TSS: acid ratio from 30 DAFS till maturity and ripening in all the genotypes except RCG-11, RCGH-1 and RCGH-7 that showed from 60 DAFS. The highest TSS: acid ratio was observed in RCG-1 (16.25) followed by RCG-2 (15.68) and RCG-3 (14.65) while, lowest ratio was noticed in Sangam (5.15) on 105 DAFS. The highest TSS: acid ratio was recorded in RCG-11 (23.53 and 27.12) followed by RCG-1

(22.11 and 25.20) and lowest in Sangam (13.53 and 14.92) followed by Lalit (14.54 and 15.64) at 120 and 127 DAFS, respectively (Table 2). Increase in TSS: acid ratio till maturity and ripening might be due to increasing in TSS and decreasing in acidity. The TSS: acid ratio was increased markedly towards the last growth stage of guava as reported by Kundu et al. (1998).

Table 2 Performance of guava genotypes for TSS: acid ratio at different days after fruit set

Geno-types	TSS: acid ratio					
	Days after fruit set (DAFS)					
	30	60	90	105	120	127
RCG-1	5.83	6.47	9.48	16.25	22.11	25.20
RCG-2	5.98	6.11	9.50	15.68	19.93	22.90
RCG-3	6.37	6.84	10.50	14.65	19.40	20.11
RCG-11	7.88	7.86	8.76	9.33	23.53	27.12
RCGH-1	7.65	7.46	8.29	8.39	21.01	21.77

RCGH-4	4.78	5.13	7.89	8.00	17.45	19.45
RCGH-7	5.18	5.12	5.64	5.86	21.27	23.50
Allahabad Safeda	5.09	5.14	7.20	7.90	16.05	17.03
Lucknow-49	6.16	6.19	8.20	8.70	17.92	18.91
Lalit	4.55	4.98	6.94	7.03	14.54	15.64
Sangam	4.79	5.04	4.66	5.15	13.53	14.92
CD (P=0.05)	0.75	1.23	0.78	1.60	3.11	2.94

Conclusion

Physiological and biochemical changes during fruit growth, development and maturity of eleven genotypes of guava fruit were studied at 30, 60, 90, 105, 120 and 127 days after fruit set (DAFS) revealed that the fruit weight, length and diameter of guava fruit increased continuously from the initial stage of fruit development till maturity and ripening. A gradual increase in total soluble solids (TSS) was observed in all the genotypes throughout development and ripening stage of the fruits. However, the amount of total titratable acidity increased steadily in the beginning upto 105 days after fruit set in most of the genotypes except RCG-1, RCG-2 and RCG-3, which showed upto 90 days only, and afterwards there was a continuous reduction till ripening. The fruits showed continuous and progressive increase in TSS: acid ratio from 30 DAFS till maturity and ripening in all the genotypes except RCG-11, RCGH-1 and RCGH-7 that showed from 60 DAFS.

References

- AOAC (2000). Official methods of analysis. 17th edn, Association of Official Analytical Chemist, Washington DC.
- Bashir Hind A, Abu-Goukh, Abu-Bakr, A (2003). Compositional changes during guava fruit ripening. *Food Chem* **80**: 557-563.
- Bollard EG (1970). The physiology and nutrition of developing fruits. In: A.C. Hulme (Ed.) "The biochemistry of fruits and their products". I, Academic Press, London, pp. 387-425.
- Deka BC, Sharma S, Borah SC (2006). Post harvest management practices of mandarin. *Indian J of Hort* **63**: 251-255.
- Dhillon BS, Singh SN, Kundal GS, Minhas PPS (1987). Studies on the developmental physiology of guava fruit (*Psidium guajava* L.) II. Biochemical characters. *Punjab Hort J* **27**: 212-221.
- Dhillon WS, Singh A, Singh R (2007). Biochemical changes in developing semi soft pear fruits. *Indian J of Hort* **64**: 81-83.
- Harding PL, Hatton TT (1967). Mangoes at their best. Proceeding of International Symposium on Subtropical and Tropical Horticulture, Horticultural Society of India, Bangalore: 137-145.
- Hegde MV, Chharia AS (2004). Developmental and ripening physiology of guava (*Psidium guajava* L.) fruit I. Biochemical changes. *Haryana J of Hort Sci* **33**: 62-64.
- Jayachandran KS, Srihari D, Narayanreddy Y (2005). Pre-harvest sprays of different sources of calcium to improve shelf life of guava. *Indian J of Hort* **62**: 68-70.
- Kundu S, Mitra S, Mitra SK (1998). Fruit growth and maturity of five guava cultivars. *The Hort J* **11**: 91-96.
- Man Bihari and Suryanarayan, 2011. Genetic diversity, heritability, genetic advance and correlation coefficient in guava (*Psidium guajava*). *Indian Journal of Agricultural Sciences* **81**: 107-110.
- Mercado-Silva, Benito Bautista EP M de los A, Garcia Velasco (1998). Fruit development, harvest index and ripening changes of guavas produced in central Mexico. *Postharvest Bio and Tech* **13**: 143-150.
- Naik SK (1985). Studies of physico-chemical changes in Alphonso and Ratna mango (*Mangifera indica* L.) fruits during growth, development and storage. A M.Sc. (Ag) Thesis submitted to Konkan Krishi Vidyapeeth, Dapoli.
- Patra RK, Debnath S, Das B C, Hasan MA (2004). Effect of mulching on growth and fruit yield of guava cv. Sardar. *Orissa J Hort* **32**: 38-42.
- Singh P, Jain V (2007). Fruit growth attributes of guava (*Psidium guajava* L.) cv. Allahabad Safeda under agro-climatic conditions of Chhattisgarh. In: Singh et al. (ed) Proceedings of the first International guava Symposium Acta Hort 735: 335-338.