Ripening associated physico-chemical changes in star gooseberry [*Phyllanthus acidus* (L.) Skeels], an underutilized fruit of North-East Himalayan region.

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ABSTRACT

Star gooseberry [Phyllanthus acidus (L.) Skeels] is a small berry type fruit, found to grow in North-east Himalayan states of India; yellow in colour, having ethnomedicinal uses by the ethnic tribes living here and used for preparation of syrup, juice, jelly, pickle etc. The physico-biochemical changes of the fruit, from their set to harvest is hitherto unknown, which should be considered as prime factor for considering the stage of harvest for its targeted utilization. Therefore, a research attempt was made to evaluate the ripening associated physico-bichemical changes of star gooseberry fruits, grown at Mizoram. Results of the physical parameters revealed that at 2 days after fruit set (DAFS) fruit length (4.40±0.55 mm), diameter (4.60±0.89 mm), weight (0.09±0.01 g); seed length (0.80±0.45 mm) and seed weight (0.01±0.00g) was low; which got increased and recorded maximum at 24 DAFS [fruit length (15.20±0.84 mm), diameter (20.80±1.30 mm), weight (4.64±0.22 g); seed length (5.20±0.84 mm) and seed weight (0.37±0.07 g)]. However, data of the mentioned parameters clearly indicated an initial period incremental growth, followed by a slow growth as lag phase and subsequently a rapid growth phase, signified double sigmoid growth in star gooseberry fruits. While biochemical parameters like total soluble solids (TSS), TSS:acid ratio, sugars and ascorbic acid content had marked increment and scored highest, whereas titratable acidity and total phenol content was minimum at 24 DAFS. Based on physico-biochemical parameters, it can be concluded that star gooseberry fruits are of optimum maturity for harvesting after 22-24 days from fruit set for further utilization.

***Keywords*:** Ascorbic acid, double sigmoid, firmness, peel colour, pulp recovery, total phenol

INTRODUCTION

Star gooseberry [*Phyllanthus acidus* (L.) Skeels] is a sour yellowish berry fruit of Phyllanthaceae family which is thought to be originated from tropical Madagascar. Within India, apart from southern part; in north-east Himalayan region, which falls under Indo-Myanmar hotspot; this fruit tree is commonly found in states like Mizoram, Manipur, Tripura, Nagaland and Arunachal Pradesh, where it is either found in home stead gardens or in forest land. Fruits are generally sold in weekly market and consumed raw or with adding salt. Ethnic tribes inhabited here use the unripe and ripe fruit for their health wellness and different ethno-medicinal preparations. The tree bears fruits in cluster during October-November and ripe fruits are available in November-December, during winter months. Ripe fruits are preserved into

sugar syrup and consumed later by the local people. Fruits can be utilized for making syrup, juice, jelly, chutney, sweet preserve, pickle, vinegar etc. (Mazumdar, 2004). Apart from leaves which is commonly reported to have immense medicinal uses like anti-diabetic, hepatoprotective, antimicrobial, analgesic, laxative, antibilious, anti-diarrhoea and diaphoretic properties; fruits also have medicinal uses as liver tonic, stomachic, blood purifier, purgative and as digestive stimulant (Lemmens *et al.*, 1999; Banik *et al.*, 2010).

The fruit is reported to have multiple health benefits and potential post-harvest uses. However, only a negligible quantity is utilized compared to other commercial fruits, perhaps due to its lack of systematic orcharding, leaving it under-utilized. Though the fruits are with immense potentiality of processing and value addition apart from its medicinal uses, still is commercially underutilized in this region. Moreover, there is no scientific report on its ripening behaviour and associated physico-chemical changes, which is quite important for commercial and therapeutic utilization of the fruit. Stages of ripening with its maximum pulp recovery, TSS: acid ratio, ascorbic acid and phenolic content may help to decide the stage of maturity and subsequent use for processing or ayurvedic formulations. So, research attempt was made to evaluate the physico-chemical changes in star gooseberry fruits at different stages after fruit set.

MATERIALS AND METHODS

The experiment was carried out during November-December, 2022 at the Research Laboratory, Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences and Natural Resources Management, Mizoram University situated at Tanhril, Aizawl, Mizoram, India. Fruits, which were used as samples were collected from Chawnpui, Aizawl, India. Initially in all directions of trees *viz*., north, south, east and west, two branches were tagged with ribbons during commencement of flowering. Date of fruit set was calculated based on the 50% fruit set on the tagged branch. Subsequently, fruit samples were taken from tagged branches after every 2-day interval from fruit set *i.e.*, pin-head stage of the fruit till it reaches maturity and used for fruit physical and biochemical analysis at laboratory condition.

Various physical characteristics of the fruit were recorded which includes parameters such as fruit length, diameter and weight; seed length and weight; pulp recovery and pulp: seed ratio, fruit firmness and colour. Physical parameters of 5 fruits randomly selected from the harvested lot of each stage of maturity (at 2 days interval) was measured. Fruit length, diameter and seed length was measured using digital vernier caliper (Starrett, USA) and expressed in mm. Fruit weight and seed weight was measured using digital weighing balance (Sartorius AG) and expressed in g. Pulp recovery was calculated by using the below mentioned formula at each stage:

Pulp recovery (%)

$$= \frac{(Fruit\ weight - Seed\ weight)}{Fruit\ Weight} \times 100$$

Pulp: seed ratio was calculated by dividing the fruit weight (g) with seed weight (g) from each sample and done in five samples for each stage and expressed as number. Fruit firmness was measured using digital fruit penetrometer (PCE Instruments, UK) and expressed as Ncm^{-2}. Fruit peel colour was determined at different stage of maturity using portable colorimeter (Konica Minolta, Singapore) and expressed in L,a,b. Colour chart was developed with corresponding L,a,b value using NIX Color Sensor software.

Fruits were prepared for analysis by cutting and macerating the pulp with mortar and pestle and strained with clean muslin cloth. Analysis was carried out for the following constituents in triplicate. Digital

handheld refractometer (Mettler Toledo, USA) was used for determination of TSS. Total and reducing sugars were estimated with standard procedure (AOAC, 1990) using Fehling's A and Fehling's B reagents and methylene blue as an indicator. Titratable acidity was determined by titrating the extracted juice against N/10 NaOH using phenolphthalein as an indicator (AOAC, 1990). TSS: acid ratio was calculated by dividing the TSS content value with acidity content and expressed in number. Ascorbic acid content was determined using 2,6 Dichlorophenol indophenol dye titration method (Rangana, 1986) and expressed in $mg100g^{-1}$ fruit weight. Total phenol content was estimated using folin-ciocalteu reagent and catechol as standard and expressed as mg phenols g^{-1} of fruit (Sadasivam and Manickam, 2005).

Data were analyzed for statistical inference following the statistical method for One-Way Analysis of Variance (ANOVA) described by Sahu (2017). Data were presented as mean ± standard deviation (SD) of determinations made. Further, Duncan's multiple range test ($P < 0.05$) was done to compare the means.

RESULTS AND DISCUSSION

Temporal changes in fruit dimensions

Results showed that the length and diameter of the star gooseberry fruit consistently increased from 2 days after fruit set (DAFS) to 24 DAFS. Fruit length at 2 DAFS was 4.40±0.55 mm and that increased to maximum (15.20±0.84 mm) at 24 DAFS (Table 1, Fig. 1). Whereas, the minimum diameter (4.60±0.89 mm) was recorded at 2 DAFS, which reached the maximum (20.80 ±1.30 mm) at 24 DAFS. The continuous development in terms of length and diameter in developing fruit marked the growth of the fruit from fruit set to maturity. Interestingly, a lag phase with minimal changes in both fruit length and diameter was observed from 8 to 12 DAFS. A similar increase in length and diameter was observed in *Phyllanthus emblica* fruits (Devi *et al.* 2020). However, during development of fruit, Indian gooseberry had initial period of lag phase with slow growth followed by rapid growth (Kishore, 2017).

Development in fruit weight

Fruit weight of star gooseberry had increased throughout the period of growth from fruit set to maturity. At 2 DAFS, weight was the minimum (0.09±0.01g), which increased and recorded the maximum value (4.64±0.22 g) at 24 DAFS (Table 1). Fruit weight gain was relatively fast at initial period (2-6 DAFS) followed by a period with comparatively slow (8-16 DAFS) and further subsequent acceleration till maturity (18-24 DAFS). Indian gooseberry fruits were reported to have an initial rapid increment in fruit weight followed by a relatively slow growth and a comparatively rapid phase of fruit weight increment at last stage, signified a double sigmoid growth pattern (Singh *et al.*, 2006). Increment in hormonal activity of auxin, gibberellins and cytokinin was though to be the reason for rapid growth increment (Mariotti *et al.*, 2011; Sosnowski *et al.*, 2023).

Progressive changes in seed length and weight

Length of the seed was found very short (0.80±0.45 mm) at 2 DAFS, and it remained reasonably low till 12 DAFS (< 3.60±0.55 mm). From 14 days after fruit set, seed length was increased rapidly and attained the maximum (5.20±0.84 mm) at 24 DAFS. In parity with the rate of development in seed length, seed weight also accelerated after 12 DAFS. Initially (up to 4 DAFS) seed weight was found negligible (0.01±0.00 g) whereas, at 12 DAFS it was recorded 0.14±0.01g and reached the maximum (0.37±0.07g) at 24 DAFS. Seed weight was reported to have significant increment with advancement of fruit growth in Indian gooseberry (Bakshi *et al.*, 2018) and longan (Mukherjee *et al.*, 2023). Due to promotion of growth it was noticed that seed weight increased with the

increasing fruit weight (Drvodelic *et al.*, 2018).

Temporal trends in pulp recovery percentage and pulp: seed ratio

The developing star gooseberry fruit was found quite unique in terms of pulp recovery percentage and pulp: seed ratio. It was observed that recovery percentage of fruit pulp was initially high (ranged between 93.28±1.53 to 94.74±1.11 %) at 2 to 4 DAFS, followed by a consistent dip from 6 to12 DAFS (ranged from 94.73±0.78 to 82.30±1.71 %) and subsequent increment (ranged between 83.08±1.35 to 92.07±1.48 %) from 14 DAFS to 24 DAFS. Having a close similarity with it, pulp: seed ratio too recorded initially high (ranged between 92.07±1.48 to 18.00±5.23) at 2 to 4 DAFS, followed by significant reduction (from 17.96±2.48 to 4.65±0.56) at 6 to12 DAFS and further increment (from 4.91±0.43 to 11.61±2.98) at 14 to 24 DAFS. Initially pulp recovery and pulp: seed ratio was high as the seed weight was very low compared to fruit weight; which was followed by reasonable gain in seed weight that may have reduced the pulp recovery and pulp: seed ration, however, as there were significant gains in fruit weight at later stages which significantly impacted higher pulp recovery and pulp: seed ration in star gooseberry. Small seed size has resulted higher flesh recovery in developing litchi fruit (Wang *et al.*, 2017). Pulp recovery which was recorded low, had drastic increment at final stage of fruit growth in developing red fleshed dragon fruit (Lalduhsangi and Mandal, 2023).

Dynamic changes in Fruit firmness

Developing star gooseberry fruits had consistent increment in fruit firmness from 2 DAFS (11.98±1.26 N cm^{-2}) to 12 DAFS (27.78±0.68 N cm^{-2}). However, from 14 DAFS (24.96±3.37 N cm^{-2}) to 24 DAFS (19.67±2.70 N cm^{-2}) fruit firmness had reasonably reduced with advent of maturity of the fruit. Fruit maturity and ripening had decreased fruit firmness (Bron and Jacomino, 2006). Ripening of fruit increased the ethylene production, which impacted the activities of pectic enzyme and caused the loss of firmness (Jeong *et al.*, 2002).

Evolution of fruit colour

Perusal of the data presented in Table 4 and Fig. 2 corresponding colour, it was found that external colour of the fruit peel changed from bright green (L:45.44, a:-19.87, b: 42.60; at 2DAFS) to light green (L:58.02, a:-11.19, b: 55.55; at 18DAFS), to greenish yellow (L:54.24, a:0.65, b: 47.62; at 20DAFS) and finally to yellowish (L:70.69, a:0.57, b: 52.27;at 24 DAFS) at maturity. During fruit maturity, peel colour of carambola also found to change from green to yellow (Martins *et al.*, 2006). Change in fruit colour during ripening is reported to be controlled by growth hormone, gene, transcription factors, enzymes related to biosynthetic pathway of pigments and environmental factors (Wang *et al.*, 2020; Kapoor *et al.*, 2022).

TSS, titratable acidity and TSS: acid ratio

Star gooseberry fruits gained significantly in total soluble solids (TSS) content during its period of fruit growth and development. TSS content which was recorded minimum (2.13±0.12 ^{0}Brix) at 2 DAFS increased consistently and become maximum (8.20±0.40 ^{0}Brix) at 24 DAFS. However, fruit acidity lowered with advent to ripening. Titratable acidity of the star gooseberry fruit was found highest (3.42±0.15 %) at 2 DAFS and subsequently it reduced throughout the developmental period and scored lowest (2.75±0.24 %) at 24 DAFS. TSS: acid ratio got significant change through the period of fruit growth. It was minimum at 2 DAFS (0.62±0.06) and considerably increased in parity with advancement of fruit growth and development and scored maximum (2.98±0.37) at 24 DAFS. Increment in TSS content while decreasing acidity is the most common biochemical changes reported in both climacteric fruits like tomato, mango and non-climacteric fruits like passion fruit, Kinnow mandarin *etc*. during ripening, which resulted in higher TSS: acid ratio (Moneruzzaman *et al.*, 2008; Goldenberg *et*

al., 2012; Nordey *et al.*, 2016; Nawaz *et al.*, 2020). Sugar content and metabolism of organic acid in ripening fruits are dependent on climacteric and factors responsible for senescence (Obando-Ulloa *et al.*, 2009). Accumulation of sugar in the later stages of fruit development has caused higher TSS and with dropping acidity resulted in high TSS: acid ratio (Ladaniya and Mahalle, 2011). Enzymatic hydrolysis of starch to sugar is responsible for increment in sugar and TSS content in ripened fruit (Bashir *et al.*, 2003) while malic and citric acid, the major players in fruit acidity use to decrease at ripening as malate used as respiratory substrate and citric acid due to catabolism of citrate (Batista-Silva *et al.*, 2018).

Changes in total sugars and reducing sugars contents

Both total sugars and reducing sugars content of the fruit had significant increment during the period of growth. It was observed that total sugar content was lowest (1.62±0.02%) at 2 DAFS and it consistently increased and attained highest (5.94±0.70%) at 24 DAFS. Fully matured aonla fruits was reported to have 5-6 % total sugar content (Datta *et al.*, 2024). Likewise, reducing sugar content of the developing fruit was recorded minimum (1.05±0.05%) at 2 DAFS contrasting with the value at 24 DAFS (4.73±0.55%), where it was found maximum. With maturation of fruit and advent of ripening sugar generally use to accumulate which was observed in ripening of apples (Li *et al.*, 2012), loquat (Cai *et al.*, 2019), tomato (Moneruzzaman *et al.*, 2008), banana (Li *et al.*, 2011), mango (Nordey *et al.*, 2016), litchi (Fan *et al.*, 2021), grapes (Castellarin *et al.*, 2011) etc. both in climacteric and non-climacteric fruit.

Accumulation of sugar in ripening fruit is related to breakdown of the starch, import of sugar form other plant part, fruit metabolic changes, sugar signaling and hormonal influence (Duran-Soria *et al.*, 2020). Unlike endogenous ethylene, which is prevalent in fruit ripening and sugar increment in developing climacteric fruit, ABA plays the crucial role and found to have positively correlated with sugar accumulation in maturation of non-climacteric fruit by suppressing the activity of GA and IAA (Alferez *et al.*, 2021).

Accumulation of ascorbic acid and total phenol content over time

The ascorbic acid content of star gooseberry fruit increased during its growth and development. From 2 to 6 days after fruit set (DAFS), the ascorbic acid content was relatively low, ranging from 13.33±2.89 to 18.33±2.89 mg 100 g^{-1}. This was followed by a steady increase from 8 to 14 DAFS (22.42±3.44 to 32.78±2.68 mg 100 g^{-1}) and a rapid rise from 16 to 24 DAFS (36.67±1.67 to 48.75±2.17 mg 100 g^{-1}), reaching a maximum increase of approximately 12 mg 100 g^{-1} over this period. Similar increases in ascorbic acid content during ripening have been observed in other fruits, such as tomatoes (Yahia *et al.*, 2001), strawberries (Cruz-Rus *et al.*, 2011), and grapes (Cruz-Rus *et al.*, 2010). Biosynthetic enzymes, including D-galacturonate reductase, monodehydroascorbate reductase, and myo-inositol oxygenase, have been positively correlated with ascorbic acid accumulation during fruit ripening (Cruz-Rus *et al.*, 2011), suggesting similar mechanisms may contribute to the observed trends in star gooseberry.

Star gooseberry fruits are rich in total phenolic constituents at immature stage. Besides, the total phenol content of the fruits significantly decreased with the advancement of growth. It was found that the total phenol content of the fruit was the maximum (120.31±2.34 mg CE g^{-1}) at 2 DAFS, which got decreased and become minimum (66.56±1.12 mg CE g^{-1}) at 24 DAFS. Total phenol content of fruit like aonla (Devi *et al.* 2020), guava (Bashir *et al.*, 2003), peach (Li *et al.*, 2023) etc. reduced drastically with fruit maturation and ripening. Changes in total phenol content have relationship with

the fruit enzymatic activities. It was reported that increased activity of polyphenol oxidase with decreased activity of phenylalanine ammonia lyase, superoxide dismutase, guaiacol peroxidase and catalase are responsible for decrease in total phenol content with fruit maturity and ripening (Zainudin *et al.*, 2014).

CONCLUSION

This study revealed that during the growth and development of star gooseberry fruit, physical parameters, including fruit length, diameter, weight, seed length, and seed weight, increased and reached their maximum at 24 days after fruit set (DAFS; Table 1). These parameters exhibited a double sigmoid growth pattern, characterized by initial rapid growth (2–6 DAFS), a lag phase with slow growth (8–12 DAFS), and final rapid growth (13–24 DAFS). In contrast, pulp recovery and pulp: seed ratio were high from 2 to 10 DAFS, decreased from 12 to 16 DAFS, and increased again from 18 to 24 DAFS. Fruit firmness was low at 2–4 DAFS, peaked from 6 to 14 DAFS, and then consistently declined until 24 DAFS. The fruit skin color, initially green, transitioned to yellow at full maturity (22–24 DAFS). Biochemical parameters, including total soluble solids (TSS), TSS: acid ratio, total and reducing sugars, and ascorbic acid content, increased throughout development, while titratable acidity consistently decreased. Total phenol contents decreased during development but remained relatively high in fully ripened fruit. Therefore, star gooseberry fruits are suitable for harvest at 22–24 DAFS, when they are fully mature and ripened, exhibiting optimal physical and biochemical qualities for utilization.

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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Fig. 1. Star gooseberry fruits at different stages of development

Table 1: Changes in fruit length, diameter and weight of star gooseberry during fruit growth and development

Stage of Fruit Growth (DAFS)	Fruit Length (mm)	Fruit Diameter (mm)	Fruit Weight (g)
2 DAFS	4.40±0.55 a	4.60±0.89 a	0.09±0.01 a
4 DAFS	5.50±0.79 ab	5.20±0.45 ab	0.19±0.01 ab
6 DAFS	6.40±0.55 b	6.20±0.84 b	0.30±0.01 b
8 DAFS	7.70±0.67 c	9.20±1.10 c	0.48±0.01 c
10 DAFS	7.80±0.84 cd	9.24±0.43 c	0.61±0.03 c
12 DAFS	8.80±0.84 cde	10.40±0.89 cd	0.79±0.02 d
14 DAFS	9.00±0.71 de	11.60±1.14 de	1.01±0.03 e
16 DAFS	9.80±0.45 e	12.60±0.55 ef	1.26±0.04 f
18 DAFS	11.40±0.55 f	13.60±0.55 f	1.85±0.04 g
20 DAFS	12.20±0.84 f	15.20±0.45 g	2.49±0.16 h
22 DAFS	14.60±0.55 g	17.40±0.55 h	3.76±0.13 i
24DAFS	15.20±0.84 g	20.80±1.30 i	4.64±0.22 j

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).

Table 2: Changes in seed length and seed weight of star gooseberry during fruit growth and development

Stage of Fruit Growth (DAFS)	Seed Length (mm)	Seed Weight (g)
2 DAFS	0.80±0.45 a	0.01±0.00 a
4 DAFS	1.80±0.45 b	0.01±0.00 a
6 DAFS	2.40±0.55 bc	0.02±0.00 a
8 DAFS	3.20±0.45 cd	0.03±0.01 a
10 DAFS	3.40±0.55 cde	0.05±0.01 a
12 DAFS	3.60±0.55 def	0.14±0.01 b
14 DAFS	4.20±0.45 defg	0.17±0.01 bc
16 DAFS	4.40±0.55 efg	0.18±0.01 bc
18 DAFS	4.60±0.55 fg	0.21±0.04 c
20 DAFS	4.80±0.84 g	0.22±0.04 c
22 DAFS	5.00±0.71 g	0.31±0.02 d
24DAFS	5.20±0.84 g	0.37±0.07 e

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).

Table 3: Changes in pulp recovery percentage, pulp: seed ratio and fruit firmness of star gooseberry during fruit growth and development

Stage of Fruit Growth (DAFS)	Pulp recovery (%)	Pulp: seed ratio	Fruit firmness (N cm^{-2})
2 DAFS	93.28±1.53 de	13.89±2.69 cd	11.98±1.26 a
4 DAFS	94.74±1.11 e	18.00±5.23 d	17.55±1.65 b
6 DAFS	94.73±0.78 e	17.96±2.48 d	26.13±1.93 bc
8 DAFS	92.80±1.97 de	12.88±3.25 c	26.79±2.92 cd
10 DAFS	91.43±1.95 d	10.67±2.17 bc	27.03±2.63 de
12 DAFS	82.30±1.71 a	4.65±0.56 a	27.78±0.68 de
14 DAFS	83.08±1.35 a	4.91±0.43 a	24.96±3.37 de
16 DAFS	85.82±0.81 b	6.05±0.43 a	24.67±2.84 de
18 DAFS	88.60±1.84 c	7.77±1.26 ab	24.49±1.25 de
20 DAFS	91.24±1.07 d	10.42±1.25 bc	23.82±0.46 e
22 DAFS	91.75±0.74 d	11.12±1.17 bc	22.45±1.10 e
24DAFS	92.07±1.48 de	11.61±2.98 bc	19.67±2.70 e

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).

Table 4: Changes in external colour of star gooseberry fruit during fruit growth and development

Stage of Fruit Growth (DAFS)	L	A	b
2 DAFS	45.44	-19.87	42.6
4 DAFS	44.65	-14.99	36.07
6 DAFS	49.87	-12.78	43.32
8 DAFS	49.41	-10.96	39.83
10 DAFS	41.58	-9.87	41.12
12 DAFS	50.12	-13.48	41.41
14 DAFS	41.54	-12.11	35.51
16 DAFS	51.84	-6.93	49.16
18 DAFS	58.02	-11.19	55.55
20 DAFS	54.24	0.65	47.62
22 DAFS	63.28	3.11	43.59
24DAFS	70.69	0.57	52.27

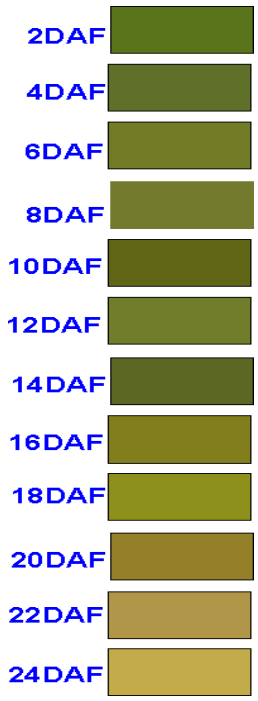

Fig. 2. Peel colour of star gooseberry at fruit developmental stages

Table 5: Changes in total soluble solids (TSS), titratable acidity and TSS: acid ratio of star gooseberry during fruit growth and development

Stage of Fruit Growth (DAFS)	TSS (^{0}Brix)	Titratable Acidity (%)	TSS: acid ratio
2 DAFS	2.13±0.12 a	3.42±0.15 d	0.62±0.06 a
4 DAFS	2.73±0.31 ab	3.37±0.20 cd	0.81±0.14 ab
6 DAFS	3.13±0.50 bc	3.22±0.35 bcd	0.97±0.28 abc
8 DAFS	3.80±0.40 cd	3.12±0.31 abcd	1.22±0.30 bcd
10 DAFS	3.93±0.42 cde	3.10±0.15 abcd	1.27±0.12 cd
12 DAFS	4.40±0.53 de	3.05±0.20 abcd	1.44±0.30 d
14 DAFS	4.67±0.42 e	2.95±0.26 abc	1.58±0.17 d
16 DAFS	4.73±0.50 e	2.88±0.18 ab	1.64±0.27 d
18 DAFS	6.53±0.70 f	2.86±0.30 ab	2.28±0.27 e
20 DAFS	7.27±0.31 fg	2.82±0.17 ab	2.58±0.38 ef
22 DAFS	7.87±0.70 gh	2.78±0.25 ab	2.83±0.15 f
24DAFS	8.20±0.40 h	2.75±0.24 a	2.98±0.37 f

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).

Table 6: Changes in total sugar and reducing sugar content of star gooseberry during fruit growth and development

Stage of fruit growth (DAFS)	Total sugar (%)	Reducing sugar (%)
2 DAFS	1.62±0.02 a	1.05±0.05 a
4 DAFS	2.17±0.07 ab	1.23±0.07 a
6 DAFS	3.08±0.43 bc	1.78±0.38 ab
8 DAFS	3.65±0.43 cd	2.36±0.25 bc
10 DAFS	3.75±0.80 cde	2.65±0.26 cd
12 DAFS	3.81±0.66 cde	2.89±0.17 cde
14 DAFS	3.96±0.23 cdef	3.16±0.69 def
16 DAFS	4.23±0.44 cdef	3.28±0.57 def
18 DAFS	4.55±0.71 def	3.42±0.23 def
20 DAFS	4.87±1.02 efg	3.68±0.59 ef
22 DAFS	5.06±0.86 fg	3.84±0.61 f
24DAFS	5.94±0.70 g	4.73±0.55 g

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).

Table 7: Changes in ascorbic acid and total phenol content of star gooseberry during fruit growth and development

Stage of Fruit Growth (DAFS)	Ascorbic Acid (mg $100g^{-1}$)	Total Phenol (CE mg g^{-1})
2 DAFS	13.33±2.89 a	120.31±2.34 j
4 DAFS	15.56±2.55 ab	118.72±2.44 i
6 DAFS	18.33±2.89 bc	107.48±2.49 h
8 DAFS	22.42±3.44 cd	97.92±2.14 g
10 DAFS	24.24±2.78 de	95.92±2.25 fg
12 DAFS	28.33±2.52 e	93.28±1.28 f
14 DAFS	32.78±2.68 f	89.62±1.73 e
16 DAFS	36.67±1.67 fg	83.95±1.49 d
18 DAFS	39.72±2.10 gh	79.84±2.87 c
20 DAFS	42.22±1.73 hi	74.63±1.55 b
22 DAFS	45.42±1.91 ij	69.74±1.32 a
24DAFS	48.75±2.17 j	66.56±1.12 a

*DAFS=Days after fruit set. The values are mean ± SD of determinations made in five times. Mean values followed by different letters within same column differ significantly ($p < 0.05$).