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STUDIES ON CHANGES DURING GROWTH AND DEVELOPMENT OF AONLA *(EMBLICA OFFICINALIS* GAERTN.) FRUITS cv. NA-7

SHIKHA PANDEY[1], BHAGWAN DEEN[2]

1. Research scholar, Department of Fruit Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj Ayodhya -224229 (U.P.) India

2. Professor Department of Horticulture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya -224229 (U.P.) India

Corresponding address- shikshapandey11072002@gmail.com

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ABSTRACT

The present investigation was carried out during 2023-2024 at the Main Experiment Station, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) in Randomized Block Design (RBD) with four replications. The study aimed to assess the physical and chemical changes that occur during fruit development and to determine maturity indices for optimal harvest. Observations began on August 6, when fruits became visible, and continued at 15-day intervals until maturity. Fruit parameters such as length (4.72-40.16 mm), width (4.92-40.21 mm), weight (0.88-40.32 g), volume (0.29-39.61 cc), pulp content (80.28%-94.28%), fibre (0%-1.60%), and pulp and seed ratio (8.56-21.75) increased steadily. Chemical traits, including TSS (0.5%-9.5%), vitamin C (14.67-603.22 mg/100g), moisture (74.15%-87.68%), TSS/acid ratio (0.45–9.45), reducing sugars (0.53%-4.69%), non-reducing sugars (0.43%-4.29%), and total sugars (0.96%-8.93%), also rose. Conversely, seed content (10.13%-3.34%), specific gravity (1.89-1.20), acidity (2.30%-1.19%), chlorophyll (16.18-3.28 mg/100g), and total phenols (446.63-192.67 mg/100g) declined over the 165 days ending on January 18.

INTRODUCTION

Aonla (*Emblica officinalis* Gaertn.) commonly known as Indian gooseberry, belongs to the family Euphorbiaceae and is native to Tropical South-East Asia, particularly Central and Southern India (Morton, 1960). Botanically, Aonla is a small to medium-sized deciduous tree characterized by a unique phyllanthoid branching pattern. It bears two types of shoots: determinate shoots (branchlets), which carry the flowers and fruits and are shed post-fruiting, and indeterminate shoots, which develop into permanent branches (Pathak, 2003). According to data from the Ministry of Agriculture and Farmers Welfare (MoA& FW, 2023-24), aonla is cultivated on approximately 107,000 hectares, with a production volume of around 1.378 million metric tons in India. Aonla is considered one of the most nutritious indigenous fruits, particularly due to its very high vitamin C content (about 500 mg per 100g of pulp), ranking second only to the Barbados cherry. It is also a good source of minerals such as iron, phosphorus, calcium, magnesium, and also rich in pectin, sugars, and organic acids. The fruit contains gallic acid and leuco-anthocyanins, which have strong antioxidant properties.). Although it is seldom consumed fresh due to its sour and astringent taste, aonla is extensively used in the processing industry to produce preserves, candies, pickles, juices, shreds, ready-to-serve (RTS) beverages, and dried powder (Tandon *et al.*, 2003). Medicinally, aonla fruit is a key ingredient in traditional formulations like Chyawanprash and Triphala powder. The ideal harvest period in the Northern Plains is between November and December, although in some cultivars, fruits may stay on the tree until February without a significant drop. However, aonla fruits have a short post-harvest shelf life of only 5-6 days under ambient conditions (Pathak *et al.*, 2009), making storage and transportation a challenge. The growth and development of fruit influences the harvest index and fruit use as fresh, processed product, transportation, and stability. This study was undertaken to identify that understanding physical and chemical changes during fruit development is vital for determining optimal harvest maturity, affecting quality, shelf life, and market value. Limited studies exist in Eastern U.P.; hence, monitoring may reveal reliable maturity indices.

MATERIALS AND METHODS:

An experiment was conducted for NA-7 aonla cultivar at the Main Experiment Station, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya during 2023-24. After fruit set, the branches with uniform fruit set were tagged on all four directions of the selected tree. sample were collected at a fornight interval form August 2023 to January 2024. About 10 to 15 fruits on each sampling date were harvested randomly from all directions of the trees and analyzed for different quality parameters. The length and width of the fruit was measured with Vernier calipers. Fruit weight was estimated by weighing ten fruits by using an electronic balance and the values were expressed in grams and fruit volume (cc), specific gravity, pulp (%), seed (%), fibre (%), pulp and seed ratio were also recorded.TSS was determined by using an Erma hand refractometer and the values were expressed as a percentage. Titratable acidity and moisture percent were estimated by standard procedures described by Ranganna (2010). Reducing sugars, non-reducing sugar, total sugars of the fruits were determined suggested method of (Lane and Eynon,1923), The TSS: acid ratio was calculated by dividing the value of Total Soluble Solids (TSS) by per cent titratable acidity. Ascorbic acid content was determined using 2, 6-dichlorophenol indophenols dye procedure, total chlorophyll content in fruit was estimated by the spectrophotometric method as suggested by Arnon (1949). and expressed as mg/100g. and total

phenol content were estimated by the described method of (Singleton *et al.*, 1999). The experiment was laid out asa randomized block design (RBD) with three replications. The data were analyzed using the appropriate method as outlined by Panse and Sukhatme (1978).

RESULTS

Physical Parameters

The analysis of physical parameters under study is presented in table1. All charecters like that Fruit length, Fruit width, Fruit weight, fruit volume, Specific gravity, Fibre, Pulp, seed, Pulp and Seed ratio Fruit length increased progressively from 4.72 mm to 40.16 mm over 165 days, with rapid growth observed until the 105-day interval. However, differences between successive stages were statistically non-significant (Devi *et al.,* 2020). Fruit width grew consistently from 4.92 mm to 40.21 mm, with a noticeable rise until the 135-day interval, showing a clear upward developmental trend consistent with previous research on Aonla fruits. Fruit weight rose steadily from 0.88g to 40.32g, showing the most rapid gain between the 0- and 135-day intervals. Initial increases were driven by cell division, while later gains were due to carbohydrate accumulation.Volume increased significantly from 0.29 cc to 39.61 cc by 165 days, reflecting a continuous expansion in fruit size throughout development, in line with earlier observations in cultivar NA-7.Specific gravity declined gradually from 1.89 to 1.20 during the growth period, indicating decreased density as fruit size and volume increased, with findings aligning with prior studies on Aonla.

Fibre content showed a continuous rise throughout the developmental stages, reaching a maximum of 1.60% by 165 days, suggesting structural maturation of the fruit during its growth period (Parveen and Khatkar 2015).Pulp percentage increased steadily from 80.28% to 94.28%, with significant differences becoming apparent at later stages, indicating progressive soft tissue development in the maturing fruit (Bakshi *et al.,* 2018).Seed percentage decreased from 10.13% to 3.34%, showing a declining trend in proportion to overall fruit mass, as pulp content became more dominant during fruit development.The pulp-to-seed ratio rose consistently from 8.56 to 21.75 over time, reflecting a higher relative increase in pulp compared to seed, highlighting fruit quality improvement during maturation.

Chemical parameters

The analysis of Chemical parameters under study is presented in table 2. Traits like Total soluble solids (TSS) in Aonla fruits increased consistently from 0.5% to 9.5% between 6 August and 18 January, with a rapid rise until 135 days, aligning with previous maturation studies (Singh *et al.,* 2021). Acidity peaked at 2.43% on day 45, then declined to 1.20% by 165 days. This trend reflects an initial acid build-up followed by reduction during fruit maturation, consistent with earlier findings. Vitamin C content rose from 14.67 mg/100g to 603.22 mg/100g by 165 days, indicating substantial accumulation as fruits matured. These levels align well with earlier research on Aonla cultivars. Moisture content increased from 74.15% to 87.68% over the growth period, showing a steady upward trend, reflecting enhanced water accumulation as the fruit developed toward maturity. TSS to acid ratio increased significantly from 0.45 to 9.65 between 6 August and 18 January, demonstrating improved sweetness and maturity, corroborating previous findings in Aonla fruit development. Chlorophyll content declined sharply to 3.28 mg/100g by day 165, indicating pigment degradation and fruit ripening. The loss in chlorophyll is linked to synthesis of other ripening-associated pigments (Sharma *et al.*, 2008). Reducing sugars rose from 0.53% to 4.69% over the development period, with a statistically significant increase, showing enhanced sugar accumulation during fruit maturation, similar to earlier reports. non-reducing sugars increased significantly from 0.43% to 4.29% by 165 days, reflecting advancing fruit maturity and starch-to-sugar conversion, in agreement with prior Aonla studies. Total sugar content climbed steadily from 0.96% to 8.93% between 0 and 165 days, showing significant increase and confirming continuous sugar synthesis during fruit development stages (Bakshi *et al.*, 2015). Total phenol content was highest (446.63 mg/100g) at the early marble stage, then declined with maturity, indicating phenolic degradation over time, as reported in related Aonla research (Kumar *et al.*, 2016).

Changes in fruit attributes to determine during harvesting index for fruit harvesting

The analysis of Changes in fruit attributes to determine during harvesting index for fruit harvesting under study is presented in table 3. Analysed traits like Fruit weight increased steadily from 0.88 g to 40.32 g in cultivar NA-7, with rapid growth up to 135 days and maximum weight at 165 days. Early gains were due to cell division, while later increases resulted from carbohydrate accumulation and cell enlargement, consistent with findings in Aonla and dragon fruits. Fruit volume expanded significantly from 0.29 cc to 39.61 cc over the growth period, reflecting a continuous and statistically significant rise until maturity, aligning with previous research on Aonla NA-7 cultivar development. Total soluble solids (TSS) reached 9.5% at 165 days, indicating optimum fruit maturity for harvest. TSS showed a steady increase with development, consistent with established maturity indicators in Aonla.

Acidity was 1.19% at the 165-day interval, decreasing after an initial rise in early growth stages. This decline toward maturity signals optimal harvest timing, corroborated by past studies in Aonla fruits. Vitamin C content peaked at 603.22 mg/100g at 165 days, increasing throughout development and stabilizing at maturity, marking this stage as ideal for harvesting based on nutritional quality. Specific gravity declined to 1.20 by the 165th day, signifying reduced density as fruit matured. This final stage aligns with optimal harvest standards reported in similar Aonla cultivar studies. T.S.S. to acid ratio reached 9.65 at day 165, rising steadily through fruit development. This ratio confirms full ripeness and supports mid-December to mid-January as the best harvesting period.

Table1: Changes in physical attributes during growth and development of Aonla fruits cv. NA-7

Interval (Days)	Fruit length (mm)	Fruit width(mm)	Fruit weight(g)	Fruit volume(cc)	Specific gravity	Fibre (%)	Pulp (%)	Seed (%)	Pulp and seed ratio
0	4.72	4.92	0.88	0.29	1.89	Not detectable	80.28	10.13	8.56
15	9.45	9.48	1.58	1.15	1.73	Not detectable	83.71	8.81	11.96
30	18.17	18.27	3.84	3.75	1.71	Not detectable	88.87	8.75	13.26
45	26.45	26.19	10.82	10.41	1.70	Not detectable	89.68	6.60	15.07
60	30.51	30.79	17.02	19.29	1.66	0.22	89.73	5.63	17.53
75	33.40	34.29	22.30	23.48	1.63	0.43	90.20	5.42	18.48
90	35.31	36.38	26.28	24.88	1.50	0.56	91.80	5.26	19.35
105	37.48	38.78	34.35	33.25	1.43	1.13	92.05	4.46	20.42
120	38.53	39.33	36.35	35.20	1.37	1.15	93.16	4.21	20.70
135	39.90	39.88	38.36	36.65	1.38	1.48	93.75	3.55	21.58
150	40.14	40.16	39.77	39.58	1.23	1.53	94.26	3.37	21.73
165	40.16	40.21	40.32	39.61	1.20	1.60	94.28	3.34	21.75
S.Em±	**0.16**	**0.21**	**0.33**	**0.48**	**0.12**	**0.04**	**1.41**	**0.21**	**0.43**
CD at 5%	**0.45**	**0.60**	**0.96**	**1.39**	**0.36**	**0.11**	**4.07**	**0.61**	**1.24**

Table 2: Changes in chemical attributes during growth and development of Aonla fruits cv. NA-7

Interval (Days)	TSS (%)	Acidity (%)	Vitamin C(mg/100g)	Moisture (%)	TSS to acid ratio	Chlorophyll content (mg/100g)	Reducing sugars (%)	Non reducing sugar (%)	Total sugars (%)	Total Phenol (mg/100g)
0	0.5	0.96	14.67	74.15	0.45	16.18	0.53	0.43	0.96	446.63
15	1.2	1.18	29.33	76.55	1.66	14.06	1.47	1.19	2.64	425.58
30	3.2	2.30	31.67	78.57	2.35	12.63	1.84	1.51	3.36	385.79
45	5.3	2.43	37.22	79.44	2.59	11.30	2.47	2.47	4.82	372.42
60	5.7	2.23	163.72	80.74	2.75	10.68	2.93	2.77	5.81	333.13
75	6.1	2.22	229.72	81.53	2.90	8.67	3.53	3.01	6.66	327.13
90	6.6	2.05	274.18	83.17	3.04	8.62	3.58	3.25	6.86	321.08
105	7.0	1.87	359.20	83.51	6.59	7.52	3.66	3.52	7.57	285.71
120	7.4	1.75	436.28	85.02	7.89	5.16	4.33	3.74	8.05	236.42
135	8.9	1.67	549.82	85.28	9.48	5.11	4.57	4.21	8.65	232.96
150	9.4	1.20	597.52	87.31	9.63	3.32	4.67	4.25	8.92	209.46
165	9.5	1.19	603.22	87.68	9.65	3.28	4.69	4.29	8.93	192.67
S.Em±	**0.15**	**0.03**	**10.34**	**0.59**	**0.24**	**0.12**	**0.29**	**0.17**	**0.02**	**3.28**
CD at 5%	**0.43**	**0.07**	**29.75**	**1.70**	**0.69**	**0.35**	**0.84**	**0.48**	**0.67**	**9.45**

Table 3: Changes in fruiting attributes to determine harvesting index for fruit harvesting

Interval (Days)	Fruit weight (g)	Fruit volume (cc)	TSS (%)	Acidity (%)	Vitamin C (mg/100g)	Specific gravity	TSS to acid ratio	Pulp and seed ratio
0	4.72	0.29	0.5	0.96	14.67	1.89	0.45	8.56
15	9.45	1.15	1.2	1.18	29.33	1.73	1.66	11.96
30	18.17	3.75	3.2	2.30	31.67	1.71	2.35	13.26
45	26.45	10.41	5.3	2.43	37.22	1.70	2.59	15.07
60	30.51	19.29	5.7	2.23	163.72	1.66	2.75	17.53
75	33.40	23.48	6.1	2.22	229.72	1.63	2.90	18.48
90	35.31	24.88	6.6	2.05	274.18	1.50	3.04	19.35
105	37.48	33.25	7.0	1.87	359.20	1.43	6.59	20.42
120	38.53	35.20	7.4	1.75	436.28	1.37	7.89	20.70
135	39.90	36.65	8.9	1.67	549.82	1.38	9.48	21.58
150	40.14	39.58	9.4	1.20	597.52	1.23	9.63	21.73
165	40.16	39.61	9.5	1.19	603.22	1.20	9.65	21.75
S.Em±	**0.16**	**0.48**	**0.15**	**0.03**	**10.34**	**0.12**	**0.24**	**0.43**
CD at 5%	**0.45**	**1.39**	**0.43**	**0.07**	**29.75**	**0.36**	**0.69**	**1.24**

DISCUSSION

Physical Parameters

The progressive enhancement in physical parameters of Aonla fruit (cv. NA-7) reveals a well-defined growth pattern characterized by early acceleration and late stabilization. Fruit length increased from 4.72 mm to 40.16 mm, though differences between successive stages were statistically non-significant after 105 days, indicating a shift from active cell division to cell expansion. Fruit width exhibited a steady rise from 4.92 mm to 40.21 mm, suggesting uniform radial development. Fruit weight increased significantly from 0.88 g to 40.32 g, with the most rapid gain observed up to 135 days. Fruit volume expanded from 0.29 cc to 39.61 cc, reflecting consistent internal development. Specific gravity decreased from 1.89 to 1.20, implying increased internal water content and reduced density. Fiber content increased progressively, reaching 1.60% at 165 days, indicative of cell wall development. Pulp percentage rose from 80.28% to 94.28%, while seed content dropped from 10.13% to 3.34%. Consequently, the pulp-to-seed ratio improved markedly from 8.56 to 21.75, enhancing fruit quality and suitability for processing.

Chemical Parameters

Biochemical changes during the maturation of Aonla fruit (cv. NA-7) followed a consistent pattern aligned with ripening-related metabolic activity. Total soluble solids (TSS) increased markedly from 0.5% to 9.5%, especially up to 135 days, indicating active sugar synthesis and flavour enhancement. Acidity initially peaked at 2.43% on day 45, then steadily declined to 1.20% by 165 days, reflecting a shift from organic acid accumulation to its dilution or metabolism. Vitamin C content rose sharply from 14.67 mg/100g to 603.22 mg/100g, highlighting the fruit's increasing antioxidant value. Moisture content rose from 74.15% to 87.68%, correlating with fruit enlargement and internal water retention. The TSS to acid ratio increased from 0.45 to 9.65, demonstrating a substantial improvement in flavour balance. Chlorophyll content dropped to 3.28 mg/100 g, indicating pigment degradation and the onset of ripening. Reducing sugars rose from 0.53% to 4.69%, and non-reducing sugars from 0.43% to 4.29%, with total sugars increasing to 8.93%. Total phenols peaked at 446.63 mg/100g early, then declined, suggesting ripening-related phenolic degradation.

Changes in Fruit Attributes to Determine Harvesting Index

Evaluating the integration of physical and chemical parameters provides a comprehensive and practical approach to determining the harvest maturity index of Aonla fruits (cv. NA-7). By day 165, the fruit achieved its peak physiological and nutritional potential, with fruit weight reaching 40.32 g, volume expanding to 39.61 cc, and vitamin C content peaking at 603.22 mg/100g. The decline in specific gravity from 1.89 to 1.20 indicates a maturity-associated increase in internal moisture and sugar concentration relative to dry matter. Total soluble solids (TSS) rose to 9.5%, and the TSS-to-acid ratio increased to 9.65, suggesting optimal flavor development and ripeness. Pulp content also reached its maximum at 94.28%, while seed proportion decreased significantly to 3.34%, enhancing the edible portion. The pulp-to-seed ratio improved substantially from 8.56 to 21.75, increasing the fruit's processing value. Moisture content rose to 87.68%, while reducing and non-reducing sugars reached 4.69% and 4.29%, respectively. These trends support mid-December to mid-January as the ideal harvest window, with day 165 representing the optimal point for maximum yield, quality, and marketability.

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