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Maturity Indices of Aonla Cultivars under Rainfed Conditions of Shivalik Foothills of Himalayas

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ABSTRACT

An investigation was conducted during 2012 and 2013 to study the fruit developmental stages pertaining to quality characteristics for fixation of maturity standards in three aonla cultivars *viz*., NA-6, NA-7 and NA-10 under rainfed conditions of Jammu subtropics, India. The results of the present investigation revealed that various physical and quality parameters were very useful in fixing maturity standards in aonla. Fruits were harvested at different maturity periods at weekly intervals and were evaluated for different physicochemical characteristics. It was observed that initially fruit growth was faster and slowed down between first week of November to last week of November and increased thereafter and followed a double sigmoid growth pattern in all the three aonla cultivars. Fruit weight of aonla ranged from 0.8 to 36.5 g in NA6, 0.93 to 36.55 g in NA7 and 0.54 to 32.55 g in NA10. Specific gravity did not show any specific trend at different maturity stages in all the cultivars. TSS, sugar, and TSS/acid ratio increased as the fruits reached toward maturity. Titratable acidity and chlorophyll content showed decreasing trend. In all cultivars, ascorbic acid increased during development and remained constant till fruits attained physiological maturity. The ideal time for harvesting of aonla was found to be the last week of December and first week of January depending on cultivar.

Keywords: Biochemical parameters, Harvesting time, Physical parameters, TSS/acid ratio.

INTRODUCTION

Aonla (*Emblica officinalis* Gaertn.) is one of the most important traditional and underutilized fruits of Indian origin, having immense potential for cultivation on marginal or wastelands. It belongs to family Euphorbiaceae and indigenous to tropical Asia. Among all the fruit crops, aonla is the richest source of ascorbic acid, except Barbados cherry. It is grown all over Asia for its nutritional, medicinal and commercial value. Wild aonla trees are also found in China, Sri Lanka, Pakistan, USA (Hawaii and Florida) and Puerto Rico. In recent years, the processing and value addition of aonla has increased many folds due to increase in its area and production. Aonla has acquired wide popularity all over the world for its medicinal properties. Its fruits are used in traditional Indian system of medicines, like ayurvedic, due to its therapeutic values (Agarwal and Chopra, 2004). The growing popularity for alternate medicines, health foods, and herbal products are enhancing the demand for aonla fruit.

Its fruits are rich in vitamin C, protein, fat, crude fibre, starch, sugars, minerals and tannins. Because of its highly acidic and astringent nature, the consumers do not relish this fruit in fresh form (Goyal *et al*., 2008). Aonla fruits are processed into a

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number of products like preserve, candy, pickle, juice, shreds, Ready-To-Serve (RTS) beverages, dried powder, etc. (Tandon *et al*., 2003). The increase in yield and fruit quality is directly related to its time of maturation. Being an underutilized fruit crop, little attention has been given to establishing reliable maturity indices of aonla. Parameters like days from flowering to maturity, heat units, color of fruit surface and TSS: acid ratio can be used for determining the maturity index of aonla cultivar in a particular region (Singh and Kumar, 1997: Singh *et al*., 2004). Slow increment in fruit, stone and pulp weight, pulp: stone ratio, total soluble solids and ascorbic acid with the advancement of maturity in aonla has been reported by Gupta *et al*. (2003). Therefore, to find out the optimum time of harvest in aonla under rainfed conditions of Jammu subtropics, this study was conducted on three aonla cultivars; as so far, no such work has been done on aonla in this region. Therefore, the detailed knowledge gained regarding change in different parameters during growth and developments of aonla will be useful to determine the appropriate harvest stages and optimize its production.

MATERIALS AND METHODS

A field experiment was carried out in the Rainfed Research Sub-station for Subtropical F ruits (RRSS), Raya of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J) during 2011-13. The aonla cultivars selected for the study were NA-6, NA-7, and NA-10. Trees selected were uniform in size and vigour and had received uniform cultural practices as per the package of practices of SKUAST-J for fruit crops. Four branches were selected randomly from each side of the trees and were tagged before swelling of fruits in August. Sampling was done based on calendar dates. Recording data of various physicochemical parameters of fruits was started 134 days after fruit set. First sampling was taken on 11th October in both 2012 and 2013 in all the cultivars. Further samples were taken at seven days interval during different stages of fruit growth and development. Total number of samples collected was 14 and for each sample contained twenty fruits harvested from all branches marked earlier on each tree, mixed well and subjected to the following observations, while physical parameters were measured by following standard procedures.

TSS was determined using a hand refractometer with a range of 0 to 32%, and the value was expressed as per cent TSS of the juice. Titratable acidity and total sugars of the fruits were determined by AOAC suggested method (1995). TSS: acid ratio was calculated by dividing the value of Total Soluble Solids (TSS) by per cent titratable acidity. Ascorbic acid content was determined (Sadasivam and Manicham, 1996) using 2, 6-dichlorophenol indophenols dye procedure, total chlorophyll content in leaves was estimated by spectrophotometric method suggested by Thimmaiah (1999) and expressed as mg g^{-1} of leaf tissue. All the data were subjected to a one-way Analysis Of Variance (ANOVA) using OPSTAT. The level of significance tested for each variables was at 5%.

RESULTS AND DISCUSSION

Physical Parameters

Fruit weight, length, breadth, and volume increased at a fast rate from early stage of fruit development to middle growth period i.e. from 11th October to 15th November. This might be due to the increase in auxin, gibberellins and cytokinnis increased during the rapid growth period of aonla fruit (Ram and Rao, 1981). After that, the development process slowed down and almost 70% of growth was completed during this period, however, growth increased thereafter, following double sigmoid growth pattern in all the cultivars. The double sigmoid growth

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pattern is very well demonstrated in Figure 1. Data shown in tables cannot be very well focused/interpreted by observing the date.

Growth of fruits in term of weight, length, and breadth increased from first sampling date till maturity in January (Figures 1, 2, and 3). The maximum fruit weight was recorded in NA-7 (40.51 g) followed by NA-6 (37.61 g) on December and NA-10 (32.80 g) on January. Physicochemical changes in fruits of aonla cultivars Chakaiya and Desi were studied by Gupta *et al*. (2003)

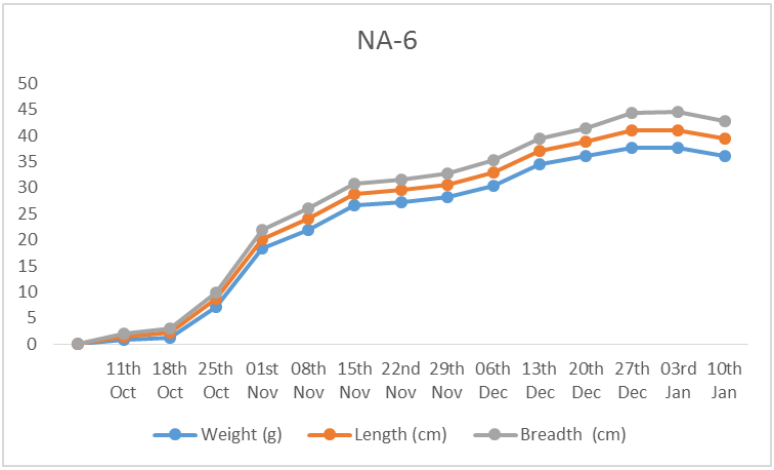

Figure 1. Periodic changes in fruit weight, length, and breadth in aonla *cv*. NA-6.

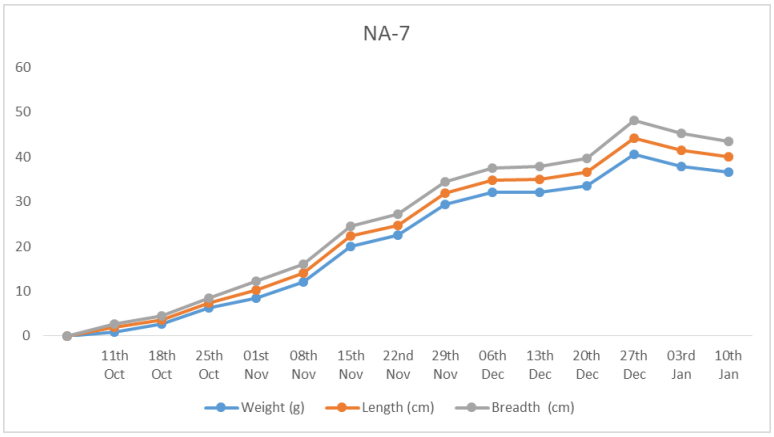

Figure 2. Periodic changes in fruit weight, length, and breadth in aonla *cv*. NA-7.

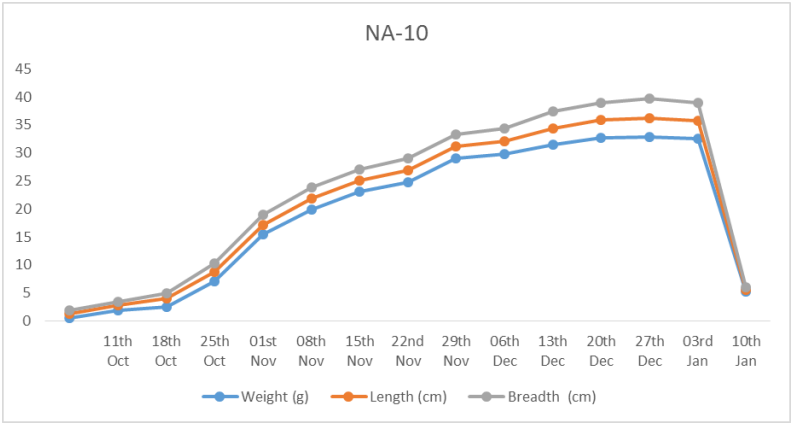

Figure 3. Periodic changes in fruit weight, length, and breadth in aonla *cv*. NA-10.

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to determine the most appropriate harvesting date for this crop. Fruit samples were collected from 5th September 2000 to 20th January 2001, at fortnight intervals. The average fruit weight, stone weight, pulp weight, pulp to stone ratio, TSS content and ascorbic acid content increased up to 5th January, and decreased thereafter. However, the increases in these parameters were more pronounced up to 5th November. The titratable acidity increased gradually up to 5th November, and decreased thereafter. These results suggested that aonla fruits attained maturity in the first fortnight of January, which may be the optimum harvesting date for this crop under Haryana conditions. On cultivars Agra Bold, Banarasi, Francis, Anand 1 and Anand 2, it is reported that specific gravity remained almost constant up to 185 days after fruit set, thereafter it increased in all the cultivars (Singh *et al*., 2006). However, no peculiar trend was observed in specific gravity during growth and development of all the three aonla cultivars (Tables 1, 2 and 3). It was close to one in all sampling dates.

NA-6 cultivar showed constant development of stone and pulp weight from early stage of fruit development i.e. from 11th October, to 20th December, after that the development process slowed down. However, in NA-7, stone and pulp weight increased up to 29th November, thereafter no more development was observed, while in NA -10, both stone and pulp weight increased up to 20th December. Pulp: stone ratio increased at early growth stages i.e. from 11th October to 15th November in NA-6, whereas in NA-7 this ratio increased significantly and the highest ratio was recorded on 27th December, probably due to increase in stone weight (Table 2). NA-10 cultivar showed an increase in pulp: stone ratio up to 6th December; after that, the development process slowed down. Hence, it can be concluded that pulp: stone ratio shows increase in the early developmental stages in all the cultivars.

Chemical Parameters

All the three aonla cultivars showed an increase in almost all the chemical parameters, except acidity, with the progress in growth and development period. The TSS, TSS/acid ratio and sugars increased at a faster rate from early stage of fruit development till physiological maturity. TSS increase during growth and development might be due to rapid conversion of various polysaccharides into soluble sugars during later stages of fruit growth. Further, Chander *et al*. (2004) reported that increased level of TSS during development was a result of translocation of photosynthates from leaves to fruits, whereas TSS/acid ratio increase was due to increase in TSS content and decrease in acidity. TSS/acid ratio is one of the important parameter that can be used for assessing maturity because, during study, it was found that TSS/acid ratio increased in later stages of developments in all the cultivars. Balasubramanyan and Bangarusamy (1998) reported that TSS steadily increased up to 120 days after fruit set, at which time there was an increase in reducing sugar content. An increase in sugar content in all the three aonla cultivars throughout the growth and development might be due to accumulated translocation of photosynthates from leaves to fruits as carbohydrates are manufactured in these leaves.

Significant decrease was observed in acidity from early stage of fruit development till physiological maturity in NA-6 and NA-10, but, in NA-7 acidity increased up to 25th October, after that decrease in acid was observed. This decrease in acidity might be due to rapid utilization of organic acids and conversion of organic acids into their salts and sugars either by enzymes invertase during the period of ripening or by the reaction involving the reversal of glycolytic pathway (Ruffner *et al*., 1975). Similarly, Singh *et al*. (2008) reported that titratable acidity of fruits increased up to 155 days after fruit set, thereafter it declined in all the

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Table 1. Periodic changes in physicochemical parameters of NA-6 (pooled data of 2 years).

Sampling dates	Volume (mL)	Specific gravity	Stone weight (g)	Pulp weight (g)	Pulp/ Stone ratio	TSS (ºB)	Acid (%)	TSS/ Acid ratio	Sugar (%)	Ascorbic acid (mg 100 g^{-1})	Chlorophyll content (mg 100 g^{-1})
11th Oct	0.78	1.03	0.38	0.41	3.97	1.40	3.04	0.45	1.02	38.00	17.50
18th Oct	1.24	1.03	0.53	0.74	3.60	1.52	3.07	0.49	1.56	69.68	15.57
25th Oct	16.66	1.02	1.19	15.84	13.31	1.75	3.03	0.57	1.65	110.35	15.33
01st Nov	17.75	1.03	1.62	16.62	10.40	2.30	2.99	0.76	2.30	194.35	13.77
08th Nov	21.73	1.01	1.92	20.01	10.46	3.45	2.87	1.20	2.70	195.68	13.50
15th Nov	26.50	1.00	2.31	24.38	10.71	3.52	2.66	1.32	3.20	219.26	12.49
22nd Nov	26.55	1.01	2.43	24.49	9.03	4.30	2.58	1.66	3.75	289.36	11.57
29th Nov	28.79	1.01	3.02	25.12	8.32	4.60	2.48	1.84	4.48	288.48	9.87
06th Dec	32.08	1.05	3.30	27.11	8.28	6.80	2.12	3.22	5.28	299.08	8.90
13th Dec	34.01	1.02	3.60	30.81	8.64	7.52	1.98	3.81	5.52	355.08	6.50
20th Dec	36.93	1.00	3.93	33.20	8.43	9.55	1.65	5.95	6.05	401.16	4.10
27th Dec	37.01	1.00	4.01	33.62	8.38	10.51	1.53	6.96	7.24	473.75	2.49
03rd Jan	37.10	1.00	4.05	33.53	8.26	11.80	1.29	9.15	9.43	514.98	1.89
10th Jan	35.83	1.00	4.00	32.02	8.00	11.48	1.27	9.03	8.30	501.25	1.48
CD (P= 0.05)	4.01	NS	0.41	2.79	3.46	0.02	0.35	1.11	0.54	2.33	0.77

Table 2. Periodic changes in physicochemical parameters of NA-7 (pooled data of 2 years).

Sampling dates	Volume (mL)	Specific gravity	Stone weight (g)	Pulp weight (g)	Pulp/ Stone ratio	TSS (ºB)	Acid (%)	TSS/ Acid ratio	Sugar (%)	Ascorbic acid (mg 100 g^{-1})	Chlorophyll content (mg 100 g^{-1})
11th Oct	0.92	0.98	0.79	0.14	0.17	0.76	4.82	0.16	0.60	45.06	11.00
18th Oct	2.59	1.02	0.99	1.67	1.69	1.07	4.72	0.22	0.94	115.02	9.66
25th Oct	5.94	1.03	1.45	4.76	3.28	1.53	4.86	0.31	1.14	127.61	8.50
01st Nov	3.52	1.02	1.93	6.47	3.35	2.43	4.72	0.50	1.41	166.12	7.10
08th Nov	11.99	1.00	2.05	10.00	4.88	3.19	4.19	0.76	1.70	194.01	7.00
15th Nov	19.67	1.01	2.28	17.77	7.80	3.57	4.03	0.88	2.55	205.71	6.75
22nd Nov	22.35	1.00	2.40	20.05	8.36	3.90	3.96	0.98	2.95	287.06	6.30
29th Nov	29.19	1.01	2.85	26.77	9.39	5.13	3.46	1.47	3.88	363.50	5.15
06th Dec	32.02	1.00	3.04	29.22	9.60	6.73	3.25	2.09	5.62	407.11	5.03
13th Dec	32.03	1.00	3.10	29.05	9.39	8.05	2.81	2.86	5.96	447.16	3.32
20th Dec	32.98	1.01	3.19	30.38	9.51	9.07	2.72	3.33	6.87	487.56	2.12
27th Dec	40.10	1.01	3.35	37.37	11.09	10.85	1.97	5.51	7.50	507.31	1.12
03rd Jan	37.93	1.01	3.35	34.81	10.33	10.79	1.70	6.47	8.47	518.81	1.36
10th Jan	35.74	1.02	3.35	33.41	9.92	10.74	1.61	6.92	8.12	599.02	1.22
CD (P= 0.05)	7.39	N S	0.18	7.02	1.63	0.99	0.77	1.21	1.39	27.37	0.56

Table 3. Periodic changes in physicochemical parameters of NA-10 (pooled data of 2 years).

Sampling dates	Volume (mL)	Specific gravity	Stone weight (g)	Pulp weight (g)	Pulp/ Stone ratio	TSS (°B)	Acid (%)	TSS/ Acid ratio	Sugar (%)	Ascorbic acid (mg 100 g^{-1})	Chlorophyll content (mg 100 g^{-1})
11th Oct	0.53	1.01	0.06	0.48	8.35	1.71	4.54	0.38	1.15	45.35	14.50
18th Oct	1.84	1.01	0.13	1.75	13.10	2.22	4.26	0.54	1.45	105.32	10.50
25th Oct	2.44	1.01	0.17	2.32	12.60	2.86	4.15	0.71	1.99	114.75	8.90
01st Nov	6.84	1.02	0.32	6.78	21.90	3.38	3.74	0.92	2.21	170.70	8.75
08th Nov	14.82	1.03	0.45	14.97	34.40	4.12	3.45	1.25	2.93	217.35	7.65
15th Nov	19.36	1.02	0.50	19.38	38.10	5.30	3.15	1.71	3.78	245.81	6.80
22nd Nov	22.43	1.02	0.61	22.42	36.60	6.32	2.72	2.34	4.15	291.70	6.55
29th Nov	24.39	1.01	0.64	24.15	37.20	7.58	2.54	3.02	5.06	306.92	4.70
06th Dec	28.29	1.01	0.68	28.29	41.35	7.79	2.45	3.27	6.85	343.00	3.70
13th Dec	29.39	1.02	0.74	29.16	39.30	8.17	2.39	3.45	8.09	409.20	2.80
20th Dec	30.46	1.02	0.80	30.95	38.30	8.63	2.25	3.90	9.27	462.20	2.20
27th Dec	31.50	1.03	0.83	31.82	38.40	9.18	1.95	4.70	8.67	493.92	1.75
03rd Jan	31.80	1.02	0.83	31.97	38.60	9.30	1.95	4.77	8.46	496.01	1.65
10th Jan	31.77	1.01	0.83	31.72	38.30	8.17	1.86	4.67	8.22	493.55	1.55
CD (P= 0.05)	5.03	N S	0.22	5.09	8.14	1.98	0.55	0.94	11.62	34.14	0.63

cultivars NA-7, Krishna, Kanchan, and Chakaiya under semi-arid conditions of Gujarat. Ascorbic acid content increased rapidly from the beginning of sampling till physiological maturity i.e. 11th October to 10th January. The increase in ascorbic acid content during growth and development of the fruit might be associated with increase in total sugars, which served as precursors for its synthesis in fruits (Mapson, 1970). The physicochemical characters of 7 aonla cultivars i.e. Banarasi, Krishna, Chakaiya, Kanchan, NA-7, NA-9, and NA-10 were studied by Godara *et al*. (2004) during 2002 and 2003, at full maturity stage (10th November) and after delayed harvesting (10th December) and they recorded significant variation in average weight, length and diameter of fruit as well as seed and pulp content. Chakaiya showed the highest amount of Vitamin-C (536 mg 100 g^{-1} pulp) on 10th December. However, a remarkable increase in total soluble solids, ascorbic acid, fruit weight and a decrease in percentage acidity were observed on 10th December in almost all cultivars. Yadav and Yadav (2010) reported that quality parameters TSS (9.44^0B), ascorbic acid (505.64 mg 100 g^{-1} pulp), and acidity (2.12%) were very useful in fixing the maturity standards in NA-7 aonla cultivar. Chlorophyll is the major pigment that dominates in unripe stages of fruits. The surface pigment changes have been recorded during ripening/senescence of fruits, but under *in vivo*, degradation of chlorophylls and its derivatives is least understood (Durand and Martin, 1974). Chlorophyll content in all three cultivars showed slow decreasing trend from the beginning till maturity i.e. 11th October to 20th December and reached the lowest on the last date of sampling i.e. 10th January.

From this investigation, it is concluded that NA-7 fruit is ready for harvesting by the last week of December, whereas fruit of NA-6 and NA-10 aonla cultivars mature during the first week of January under rainfed conditions of Jammu. Among various quality parameters, fruit weight, volume, TSS, ascorbic acid, and TSS/acid ratio were very useful in fixing the maturity standards in aonla.

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شاخص های مرحله رسیدن میوه کولتیوارهای Aonla در شرایط دیم منطقه Shivalik در دامنه های هیمالایا

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چکیده

پژوهش حاضر در سال های ۲۰۱۲ و ۲۰۱۳ برای تعیین مراحل رشد ونمو میوه در ارتباط با ویژگی های کیفی مربوط به تثبیت استاندارد های مرحله رسیدن میوه Aonla در سه کولتیوار (NA-6، NA-7، و NA-10) در شرایط دیم منطقه نیمه گرمسیری جامو درهند انجام شد. نتایج این پژوهش آشکار ساخت که چندین پارامتر فیزیکی و کیفی برای تعیین استانداردهای مرحله بلوغ و رسیدن میوه Aonla بسیار مفید بودند. میوه ها در دوره های مختلف بلوغ در فواصل یک هفته ای برداشت شد و از نظر ویژگی های مختلف فیزیکوشیمیایی ارزیابی شد. چنین مشاهده شد که رشد میوه ها در مراحل اولیه سریعتر بود و سپس بین هفته اول و هفته آخر نوامبر کند شد و بعد از آن سرعت گرفت و در هر سه کولتیوار از یک الگوی رشد دوگانه سیگموئیدی پیروی کرد. وزن میوه های Aonla در محدوده ۰/۸– ۳۶/۵ گرم در NA-6 تا ۰/۹۳– ۳۶/۵۵ گرم در NA-7 و ۰/۵۴– ۳۲/۵۵ گرم در NA-10 تغییر میکرد. جرم مخصوص میوه های هر سه کولتیوار روند خاصی را در مراحل مختلف برداشت نشان نداد. با نزدیک شده به مرحله رسیدن میوه ، TSS، قند و برخه اسیدیته/ TSSافزایش یافت. اسیدیته قابل تیتراسیون و کلروفیل روند کاهشی نشان داد. در همه کولتیوارها، اسکوربیک اسید در طی رشد ونمو تا مرحله ای که میوه ها به بلوغ فیزیولوژیکی رسید ثابت ماند. نتایج نشان داد که زمان مناسب برداشت میوه Aonla بسته به نوع کولتیوار در آخرین هفته دسامبر و اولین هفته ژانویه می باشد.

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