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Study on physico-chemical properties of aonla (*Emblica officinalis* Gaertn.) cultivars during fruit growth and development

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Abstract

To evaluate the aonla cultivars in Chhattisgarh the physico-chemical characters of eight aonla cultivars viz. Banarasi, Chakaiya, Francis, Kanchan, Krishna, NA-6, NA-7 and NA-10 were studied. Significant variation in average weight, volume, length, diameter and stone weight of different cultivars were found coupled with a similar variation in their contents of TSS, acidity, ascorbic acid and total sugars. Among the physical characters at maturity the maximum dimensions of fruit weight, fruit volume, fruit diameter, fruit length and stone weight respectively were possessed by the cvs. Banarasi (57.74 g), Krishna (57.97 ml), NA-7 (4.38 cm), Banarasi (4.76 cm) and Krishna (5.03 g). Similarly, among the chemical characters at maturity the maximum chemical content of TSS, acidity, ascorbic acid and total sugars respectively were possessed by the cvs. Banarasi (15.71%), Banarasi (2.32%), Banarasi (882.11 mg/100g of pulp) and Krishna (8.23%). Thus, from the overall physical characteristics point of view the cv. Banarasi may be declared to be of best fruit size (fruit weight = 57.74 g, fruit volume = 56.68 ml, fruit diameter = 4.10 cm, fruit length = 4.76 cm) followed by Krishna, Kanchan, Chakaiya and Francis, with the fruit of most inferior size to be the cv. NA-6. Similarly, from the chemical characteristics point of view, the best chemical composition at maturity may be attributed to Banarasi (TSS = 15.71%, acidity = 2.32%, total sugars = 8.09%, ascorbic acid = 882.11 mg/100g of pulp) followed by the cvs. Chakaiya and Francis. However, no single cultivar stands out to be of most inferior chemical quality.

Key words: *Aonla, growth and development and physico-chemical characteristic.*

Introduction

Aonla (*Emblica officinalis* Gaertn.) is an important fruit crop of India, which belongs to the family *Euphorbiaceae*, sub-family *Phyllanthoideae*. Next to Barbados cherry (*Malpighia glabra*) aonla is the richest and cheapest source of Vitamin 'C' among fruits (Asenjo, 1953), and a fair source of minerals, carbohydrates, carotene, thiamin and riboflavin (Pillay and Mahadeva, 1958). Looking to better prospects created by some medicinal corporates in recent years, which are encouraging the local farmers for cultivation of aonla in their wastelands, the scope of cultivation of this crop is increasing day by day in wasteland situations. Further, considering the high productivity per unit area, hardy nature of the plant, high medicinal and nutritional value of aonla, there is a high possibility that it will be one of the most important fruit of the future. Its cultivation has increased in wasteland situations during recent years because it can be successfully gown in variable agro-climatic areas and variable soil conditions like that of Chhattigarh as its plant is resistant to hardy and opposite actions of nature. It is the native of tropical south eastern Asia, particularly central or south India (Firminger, 1947; Mortan, 1960). It is being cultivated since ancient times of India. Seedling trees in large numbers are common in Vindhyan hills (M.P. and U.P.) and Himalayan hills up to an elevation of 1350 M (Anon., 1960; Ram, 1974). Its cultivation is more common in central Uttar Pradesh apart from some western and eastern segments (Bajpai, 1965; Ram, 1971). It is also cultivated in Gujarat, Maharashtra, Haryana and Rajasthan. Chhattisgarh is situated between 17°14'N-24°45'N latitude and 79°30'E-84°15'E longitude. Raipur falls between 26°16'N latitude and 80°36' longitude at an altitude of 289.6 meters above the mean sea level. Aonla cultivation suits very well to all the soil conditions of Chhattisgarh, namely, Bhatta (morrum soil), Matasi, sandy loam and clayey soils. It has great tolerance to salinity and sodicity and can be successfully cultivated in pH range of 6.0 to

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8.0. It can be grown in irrigated as well as un-irrigated rain fed area, because the plant of aonla is resistant to hardy and opposite actions of nature. Since its roots penetrate into deep soil and absorb the moisture, it can also be grown easily in unfavorable conditions. The leaves of aonla are narrow in size so the evaporation of water is less. The bark of aonla is thick and semi-dry, which makes it resistant to water evaporation. These traits of aonla make it suitable for dry land areas.

Raipur is classified under dry and sub-humid agro-climatic region. The annual rainfall of this region ranges between 1200-1400mm, of which about 85% is received from third week of June to mid September and very little during October to February. May is the hottest month and December is the coolest. The maximum temperature of this region may reach as high as 46°C during summer and minimum may fall to as low as 6°C during winter. The atmospheric humidity is higher from June to October. The available cultivars in Chhattisgarh so far are not ideal for commercial cultivation because they do not fulfill domestic or export requirements. Therefore, it has been felt necessary to evaluate aonla cultivars in Chhattisgarh. The knowledge about the physico-chemical changes in the fruit at various stages (say, Initial, Middle and Maturity) of its growth and development may be helpful in evaluating the cultivars. The available cultivars so far are not ideal for commercial cultivation because they do not fulfill domestic or export requirements. Sufficient information on physico-chemical changes during growth and development of aonla cultivars, especially in Chhattisgarh, is not available. Hence the present study has been conducted at Raipur, Chhattisgarh.

Materials and methods

The investigations were carried out in the Horticulture Department, Indira Gandhi Agricultural University, Raipur, Chhattisgarh. The experiment was conducted on the layout of Randomized Block Design, wherein 2 trees of each of above eight cultivars have been randomly grown within each replication. Some of the observations were recorded in percent, like in case of total soluble solids (%), titrable acidity (%) and sugars (%). Such percent variables do not follow normal distribution; therefore, a direct analysis of variance for these variables will be invalid. Thus, to maintain the validity of the analysis, arcsine-transformation of the above per cent characteristics were done and then subsequent analyses of variance were carried out for the transformed variables, following Snedecor and Cochran (1967). But for the ease of interpretation, means of these transformed values are presented along with their inverse transformed means in original units.

The observations were recorded at three stages, one at 10 days from the initiation of fruit growth (i.e. initial stage), second at 85 days during fruit development (i.e. middle stage) and third at 145 days (i.e. maturity stage or harvesting stage of fruit). Ten fruits of uniform physiological age from each plant were randomly selected on the date of observation from three side branches of the tree. These fruits were used for recording the physiological characters and then subsequently utilized for chemical analysis. The fruits were thoroughly washed and their weights were measured with the help of electronic balance. Similarly, the fruit volume was ascertained through water displacement method. The length and diameter of each fruit was measured with the help of Vernier Callipers. The pulp of fruit was separated and relative weight of seed was determined with the help of electronic balance. Total soluble solids content was determined by hand refractometer (0-32° Brix). Acidity was determined by alkali titration method and expressed in terms of percent citric acid. Vitamin 'C' was estimated in accordance with A.O.A.C. (1980) method using 2, 6 dichlorophenol indophenol dye and expressed as mg/100g of pulp. Total sugars were determined by the method of Lane and Eynon (1960).

Results and discussion

The observations on various characters, which have been recorded during the course of the experiment, are presented in Table 1 and 2. While, discussing the results of the experiment it may already be borne in mind that although most of the cultivars started their fruiting normally, the cultivars Chakaiya and Francis started their fruiting very late compared to other cultivars, so late that their 10-days-after-fruit-growth-initiation coincided with 55-days-after-fruit-growth-initiation of other cultivars.

Physical characteristics of aonla at different growth stages:

The perusal of data on average fruit weight in Table 1 indicates that Banarasi cultivar maintained uniformly highest average fruit weight at the middle (47.19 g) and maturity (57.74 g) stages of fruit except that it was second to NA-7 in the initial stage. It also significantly differed at 5% level of significance from all the cultivars at all the three stages. The findings of Pathak (1965), which states that fruit weight of aonla increases continuously from early stage to maturity stage, supports the present finding. Table 1. indicates that the average pattern of growth of fruit volume was similar to the growth of average fruit weight as also obtained earlier by Udai Raj (1994). Both the fruit weight as well as fruit volume increased significantly from one stage to the other stage of growth. Comparing fruit diameter of all the cultivars based on Table 1, it was found that the average fruit diameter of aonla cv. NA-7 was uniformly maximum at all the stages of growth (i.e., initial stage, 2.09 cm; middle stage, 3.79 cm and maturity stage 4.38 cm) and was significantly more than those of other cultivars. As for the minimum fruit diameter is

concerned, it was found to be different at different stages, however, at maturity it was minimum in the case of cv. Chakaiya and NA-6. In terms of average length (Table 1), though, the cv. NA-7 had maximum length (2.23g /fruit), which was also significantly different from others at the initial stage, the cv. Banarasi maintained uniformly and significantly highest fruit length at the middle and maturity stages (4.39 g and 4.76 g respectively) closely followed by the cv. Krishna. These results are in conformity with the observations made by Bajpai (1963) and Pathak (1965). Taking the aggregate view of different sizes of cultivars, i.e., in terms of fruit weight, fruit volume, fruit diameter and fruit length, at the maturity stage the cv. Banarasi may be declared to be of the best fruit size followed by Krishna, Kanchan, Chakaiya and Francis, respectively and similarly the cv. NA-6 may be declared to be of most inferior fruit size. Perusal of Table 1, shows that, although, the cv. Krishana possessed the maximum stone weight at maturity stage (5.03 g), if we consider all the stages of fruit growth, we find the cv NA-7 to be possessing in general a maximum stone weight, leaving apart the cvs. Chakaiya and Francis, as they had late fruit-growth-initiation. However, the stone weight of Banarasi was at par with that of NA-7 at all the stages. Similarly, the stone weight of NA-6 was minimum at all the stages of fruit growth followed by that of NA-10.

Chemical characteristics of aonla at different growth stages:

The total soluble solids (TSS), titrable acidity and total sugars were all measured in the percent units. As the percent units do not follow normal distribution, they invalidate the F-test of the analysis of variance and the subsequent t-tests for means. Therefore, to validate these tests, arcsine transformation of all the percentage data were carried out and then subsequent analyses of variance were performed. The average arcsine values of different chemical parameters under study are given in Tables 2, along with the relevant critical differences and standard errors of difference between two cultivar's means. However, to comprehend the average arcsine values in the original percent units, the same were also presented into brackets in the tables after transforming back the average arcsine values into percent units by inverse arcsine transformation. The Table 2 gives the estimated values of TSS contents of different cultivars. More TSS in cultivars causes less moisture content leading to their enhanced disease resistance capacity and increased storage life because lack of moisture creates an anti-microbial environment within the fruits. Consequently, TSS in a sense is an indicator of storage life of the cultivars. The perusal of Table 2 clearly indicates that, even though, initially the cv. NA-7 possessed the uppermost TSS (transformed average arcsine value 18.37, i.e., 9.93% TSS), later it was taken over by the cv. Banarasi, which uniformly maintained the highest TSS contents during the middle (23.04, i.e., 15.31%) as well as maturity (23.35, i.e., 15.71%) stages. These TSS contents were also significantly different from those of other cultivars at the middle stage; however, the same were at par with those of cvs. Chakaiya, Francis, Kanchan and Krishna at the maturity stage. Analogous

Table 1. Average fruit weight, Fruit volume, Fruit diameter, fruit length and weight of stone of aonla cvs. at different growth stages.

	Fruit weight (g)			Fruit volume (ml)			Fruit diameter (cm)			fruit length (cm)			Weight of stone (g)		
Cultivars	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]
Banarasi	4.47^{c}	47.19^{e}	57.74^{c}	4.27^{e}	46.31^{f}	56.68^{d}	2.02^{e}	3.78^{f}	4.10^{c}	2.01^{d}	4.39^{f}	4.76^{f}	0.42^{c}	3.82^{e}	4.09^{d}
Chakaiya	✧	11.50^{a}	41.00^{b}	✧	10.72^{a}	38.67^{a}	✧	2.39^{a}	3.40^{a}	✧	2.78^{a}	4.20^{c}	✧	0.81^{a}	3.40^{c}
Francis	✧	14.13^{a}	45.92^{c}	✧	13.31^{b}	42.68^{b}	✧	2.66^{b}	3.73^{b}	✧	2.82^{a}	4.15^{c}	✧	1.41^{b}	3.21^{b}
Kanchan	2.88^{b}	36.37^{cd}	53.91^{d}	2.61^{b}	34.93^{d}	52.03^{c}	1.74^{c}	3.58^{e}	4.10^{c}	1.58^{b}	4.06^{e}	4.39^{d}	0.29^{b}	2.43^{c}	2.93^{a}
Krishna	2.69^{a}	38.94^{d}	56.68^{de}	2.42^{a}	37.55^{e}	57.97^{d}	1.63^{a}	3.52^{de}	3.78^{b}	1.58^{b}	4.34^{f}	4.62^{e}	0.23^{a}	3.41^{d}	5.03^{e}
NA-6	3.89^{c}	32.22^{b}	36.40^{a}	3.62^{c}	31.68^{c}	35.15^{a}	1.73^{b}	3.33^{c}	3.40^{a}	1.51^{a}	3.46^{b}	3.84^{a}	0.22^{a}	3.79^{c}	4.13^{d}
NA-7	5.83^{f}	35.74^{c}	45.95^{c}	5.67^{f}	34.11^{d}	44.19^{b}	2.09^{f}	3.79^{f}	4.38^{d}	2.23^{e}	3.77^{d}	4.30^{cd}	0.42^{c}	3.98^{e}	4.25^{d}
NA-10	4.23^{d}	33.01^{bc}	43.59^{bc}	4.01^{d}	31.39^{c}	41.14^{b}	1.83^{d}	3.45^{cd}	3.50^{a}	1.98^{c}	3.60^{c}	3.97^{b}	0.22^{a}	3.87^{c}	4.20^{d}
Sem±	0.04	0.96	0.99	0.02	0.60	1.31	0.007	0.04	0.04	0.02	0.02	0.03	0.01	0.07	0.07
CD (5%)	0.11	2.77	2.83	0.07	1.76	3.96	0.01	0.13	0.13	0.08	0.09	0.10	0.03	0.2	0.18

Note

1. The symbol ✧ indicates that there was no fruiting upto 40 days in cvs. Chakaiya and Francis.
2. Figures in brackets [ ] indicate days after fruit growth initiation for Chakaiya and Francis cultivars.
3. The superscripts letters indicate that the treatment means with same letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level. These letters have been affixed based on CD-value comparisons of treatment means.

remarks with TSS contents of aonla cultivars were reported by Pathak (1965) and Pathak et al. (1985). The cv NA-10 performed with minimum TSS content at the initial and maturity stages. Acidity along with sugar is an indicator of good taste of the fruit. Furthermore, its presence also discourages microbial growth leading to its better keeping quality. Just as in case of TSS, both cultivars NA-7 and Banarasi maintained the same pattern in terms of highest acidity too (Table 2). However, at the maturity stage the Banarasi (8.76, i.e., 2.32% acidity) had at par acidity with those of Chakaiya, Francis, NA-7 and NA-10. In case of lowest acidity there was no such pattern. The other thing that was uniformly true for all the cultivars was that the acidity increased up to the middle stage of growth; thereafter it continuously decreased up to the maturity stage. This observation in aonla is in harmony with those of Pathak (1965), who recorded a gradual increase in citric acid content upto 28th November and thereafter, a gradual decline till the harvest at maturity stage in Banarasi and Deshi cultivars. Mukherjee (1959) also likewise reported rise in acid percentage during the early period of fruit growth followed by a continuous decline till the final harvesting of mango fruit. A similar observation is reported in the findings of Singh and Singh (1995) in case of Litchi cvs. Muzzafarpur and Calcuttia.

Ascorbic acid is genuine "Vitamin C" whose presence provides the power of resistance in fruits against the diseases like scurvy, diarrhea, dyspepsia, chronic dysentery, cough and cold etc. The perusal of Table 2 shows that the ascorbic acid content increased continuously from the initial to final maturity stage in respect of all the cultivars, however, the rates of increase differed among different cultivars. Although, in the initial (82.39 mg/100g of pulp) and middle (572.24 mg/100g) stages of development the cv. NA-7 recorded the highest ascorbic acid content, in the maturity stage it was dislodged by the cv. Banarasi (882.11mg/100g of pulp) from the first rank followed by Krishna, Chakaiya, NA-7 and others. Bajpai (1969) reported similar observation with the developing fruits of Banarasi. Aonla is a fruit well known for the richest source of Vitamin 'C' derived from its ascorbic content. At maturity, it was observed to vary from 702.48 to 882.11 mg/ 100g of pulp among different cultivars (Table 2) in different cultivars. The minimum ascorbic acid content was observed in the cv. Kanchan. At all stages of development, the ascorbic content of all cultivars were in general significantly different from each other, except that at initial stage Kanchan and NA-6 were at par, Krishna, NA-6 and NA-10 were at par; while at maturity NA-7 and NA-10 were at par in terms of ascorbic content. A wide variation in ascorbic acid content in different aonla cultivars at the time of maturity of fruits were also reported by Teaotia *et* al. (1968) and Pathak *et* al. (1985).

Sugar along with acidity is an indicator of sweetness with a typical blend of sourness leading to a good flavoured taste. A perusal of Table 2 indicates that the total sugars content gradually increased from the initial stage to maturity stage in respect of all cultivars under study. More than 70 per cent of the total sugars approximately were gathered up to the middle stage of fruit growth, the remaining being gathered till the maturity stage. Further, while the cv. Krishna possessed minimum sugar at the initial stage, it topped in the total sugars at the middle (14.33, i.e., 6.12% total sugars) and maturity (16.67, i.e., 8.23%) stages, which was also significantly different from those of all other cultivars. This was followed closely by the cv. Banarasi both in the middle (14.03, i.e., 5.87%) as well in the maturity (16.53, i.e., 8.09%) stages. Banarasi was followed by Kanchan (15.51, i.e., 7.15%), Francis (15.47, i.e., 7.11%) and Chakaiya (15.02, i.e., 6.72%), respectively at the maturity stage. Pathak (1965) also observed gradual augment, up to maturity stage, in the amount of reducing, non-reducing as well as in total sugars content in Banarasi and Deshi cultivars of aonla. Singh and Singh (1995) also observed a similar pattern of total sugars in Litchi cvs. Muzzafarpur and Calcuttia. Udai Raj (1994) observed the same thing in aonla cv. NA-7.

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Table 2. Arcsine transformed values of average TSS, Acidity, Ascorbic acid and total sugar of aonla cvs. at different growth stages.

Cultivars	TSS (%)			Acidity (%)			Ascorbic acid (mg/100 ml)			Total sugar (%)		
	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]	10 days	85 [40]	145 [100]
Banarasi	*16.66^{d} (8.22)	23.04^{d} (15.31)	23.35^{b} (15.71)	*5.28^{b} (0.85)	9.86^{g} (2.93)	8.76^{b} (2.32)	32.59^{c}	454.93^{g}	882.11^{g}	*8.40^{ab} (2.13)	14.03^{e} (5.87)	16.53^{d} (8.09)
Chakaiya	✧ ✧	17.58^{a} (9.12)	22.04^{b} (14.08)	✧ ✧	8.29^{b} (2.08)	8.62^{b} (2.25)	✧	176.49^{b}	783.43^{e}	✧	8.57^{a} (2.22)	15.02^{b} (6.72)
Francis	✧ ✧	19.24^{b} (10.86)	22.19^{b} (14.26)	✧ ✧	7.58^{a} (1.74)	8.14^{a} (2.01)	✧	164.17^{a}	720.93^{b}	✧	9.73^{b} (2.86)	15.47^{c} (7.11)
Kanchan	15.91^{c} (7.52)	21.55^{c} (13.50)	22.84^{b} (15.07)	4.66^{a} (0.66)	9.25^{d} (2.59)	8.16^{a} (2.01)	24.09^{a}	365.70^{d}	702.48^{a}	7.30^{a} (1.62)	12.62^{d} (4.78)	15.51^{c} (7.15)
Krishna	15.61^{b} (7.24)	20.89^{c} (12.72)	23.07^{b} (15.36)	5.28^{b} (0.85)	9.67^{e} (2.82)	8.43^{a} (2.15)	29.77^{b}	440.22^{f}	844.85^{f}	7.05^{a} (1.51)	14.33^{f} (6.12)	16.67^{e} (8.23)
NA-6	14.47^{a} (6.24)	17.96^{a} (9.51)	19.89^{a} (11.57)	5.37^{b} (0.88)	8.76^{c} (2.32)	8.33^{a} (2.10)	26.25^{ab}	285.83^{c}	750.31^{c}	7.94^{a} (1.91)	11.33^{c} (3.86)	12.03^{a} (4.34)
NA-7	18.37^{c} (9.93)	19.26^{b} (10.88)	20.89^{a} (12.72)	8.20^{c} (2.03)	8.95^{cd} (2.42)	8.54^{b} (2.21)	82.39^{d}	572.24^{h}	770.42^{d}	10.52^{b} (3.34)	11.85^{c} (4.22)	12.30^{a} (4.54)
NA-10	14.40^{a} (6.18)	19.04^{b} (10.65)	19.77^{a} (11.44)	5.36^{b} (0.87)	8.81^{c} (2.35)	8.43^{ab} (2.15)	27.88^{b}	395.96^{e}	765.76^{d}	7.94^{a} (1.91)	11.40^{c} (3.91)	12.09^{a} (4.39)
Sem±	0.05	0.28	0.41	0.12	0.13	0.12	0.96	1.97	2.94	0.75	0.06	0.15
CD(5%)	0.15	0.86	1.23	0.38	0.39	0.35	2.78	5.67	8.48	2.36	0.18	0.44

Note:

1. Note the symbol ✧ indicates that there was no fruiting upto 40 days in cvs. Chakaiya and Francis.
2. The symbol * indicates the mean arcsine transformed value.
3. Figures in brackets [ ] indicate days after fruit growth initiation for Chakaiya and Francis cultivars.
4. The superscripts letters indicate that the treatment means with same letters are at par at 5% level of significance, while the means with different letters are significantly different at 5% level. These letters have been affixed based on CD-value comparisons of treatment

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