RESEARCH ARTICLE

Fruit Quality of Aonla (*Emblica officinalis* Gaertn.) Cultivars and New Accessions

Devendra Pandey, Sanjay Kumar Singh*, Shardulya Shukla and Shiv Poojan

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Abstract

Fruits of seven cultivars of aonla *viz*. *NA-6*, *NA-7*, *NA-10*, *Laxmi –52*, *Krishna*, *Kanchan* and *Chakaiya* were evaluated for changes in physico-chemical attributes at different stages of fruit growth and maturation. The observations were recorded at 30-day intervals starting from 120 days after fruit set (DAFS) and up to 255 DAFS.

Results of different parameters revealed that fruit size in terms of width, weight and TSS showed exponentially upward growth trends from the initial stages of maturity up to the final stage of harvest, i.e., October to February months. *NA-6* Aonla had shown the highest gain (128.46%) in fruit weight amongst the tested cultivars; however, overall, the maximum fruit weight was recorded in *Laxmi-52* (52.15 g). '*Krishna*' Aonla had the lowest fruit weight. Baring Aonla cv. Kanchan, other varieties showed an increasing trend of fruit Total Suspended Solids ranges from 6.52 to 12.54 ^{0}B during the maturity period. During the last month of maturity, the '*Krishna*' Aonla had the highest TSS (12.54 ^{0}B) and acidity (2.12%) while the lowest was recorded in *Kanchan* (8.62 ^{0}B). February month could be best for harvesting aonla's cv. *Krishna*. The growth of fruits of Aonla cv. *Kanchan* and *NA-7* ceased after January months, and TSS also got reduced, therefore these varieties should be harvested by the end of January month. Ascorbic acid was highest in *NA-6* across the maturity period but for a harvesting point of view, the *NA-10*, *Laxmi -52,* and Krishna should not be harvested beyond December month. Conclusively, it is inferred from the results that *NA-10*, *Laxmi -52* and *Krishna* matures early, i.e., during December month, *Kanchan* and *NA-7* during January month and *NA-6* during February month. CISH-A-1 and CISH-A-2 could be found to be better than other cultivars in terms of ascorbic acid and polyphenols.

Highlights

- Aonla cv. *NA-10*, *Laxmi -52* and *Krishna* should be harvested in December month, *Kanchan* and *NA-7* during January month and *NA-6* during February month.
- CISH-A-1 and CISH-A-2 could be better than other cultivars in terms of ascorbic acid and polyphenol content.

Keywords: Accession, Aonla, Ascorbic acid, Cultivars, Maturity indices, Polyphenols,

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Introduction

Aonla or *Indian gooseberry* (*Embilica officinalis* Gaertn.) is known for its medicinal and therapeutic properties from ancient times in India and is considered a wonder fruit for health-conscious people grown all over Asia for its nutritional, medicinal and commercial value. Although indigenous to the Indian subcontinent, the fruit is the richest source of vitamin 'C' (500 to 1500 mg per 100 g pulp) among fruits except Barbados cherry (Asengo, 1953). Owing to its significant medicinal and nutritive value, it finds a prominent place in ancient Indian mythological literature and is considered as *amrit phal* (life-giving fruit).

In recent years, the processing and value addition of Aonla has increased many folds due to an increase in area and production. The fruit is rich in quercetin, phyllamblic compound, gallic acid, tannins, flavonoids, pectin and vitamin C and also contains a wide range of phytochemicals compounds including terpenoids, alkaloids, flavonoids and tannins it possesses as useful biological. Aonla is a therapeutically important underutilized fruit due to the presence of high amounts of two well-known antioxidants, ascorbic acid and polyphenols (Bhattacherjee *et al.,* 2020). A single Aonla fruit contains almost 20 times more ascorbic acid than two oranges (Yadav *et al.,* 2011). Due to the presence of high amounts of phenolic compounds, fruits are astringent in taste and difficult to consume fresh, resulting in their main use in processing and ayurvedic medicine. The value-added products prepared from Aonla are juice, preserve (murabba), candy, pickles, segments-in-syrup, powder, laddoo, etc. (Rakesh *et al*., 2001).

In any fruit sp. the increase in yield and fruit quality is directly related to the time of fruit maturity. Harvesting of fruits at the proper stage of maturity is desirable for maintaining quality and consumer acceptability (Singh *et al.,* 2006). Delay in harvesting after attaining maturity results in fruit dropping/ poor phenotypic appearances, particularly in *Banarasi* and *Francis* cultivars. It also affects adversely the following year's bearing (Pathak, 2003). Being a less utilized fruit crop, little attention has been given to establishing reliable maturity indices with a nutritional point of view in Aonla; hence, it is necessary to find out the optimum time of harvest to harness the maximum nutraceutical potential under subtropical conditions. In general,

Division of Crop Improvement and Biotechnology, ICAR-Central Institute for Subtropical Horticulture, Lucknow - 226101, India.

***Corresponding author:** Sanjay Kumar Singh, Division of Crop Improvement and Biotechnology, ICAR-Central Institute for Subtropical Horticulture, Lucknow - 226101, India., Email: sanjay.singh3@icar.gov.in

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the ideal time for harvesting aonla was found to be the last week of December and the first week of January depending on the cultivar (Bakshi *et al.,* 2018).

Earlier workers like Singh *et al*., (2016) classified aonla cultivars into different maturity groups, i.e., Balwant is an early season cultivar that matures in mid-November, *Krishna* and *Neelum* as mid-season cultivars matures during the end of November; *Kanchan* and *Chakaiya* as late season cultivars matures during mid-December under Punjab conditions.

The current study was conducted on seven Aonla cultivars, as no such work has been done on aonla in this region. However Bajpai and Shukla (1990) reported that the best time for harvesting fruits of aonla is February when fruit has maximum vitamin C content. However, no trustworthy information is available on the harvest time of aonla fruits in the subtropical region based on a nutraceutical point of view. Hence, the work was initiated to know the proper maturity stage for harvesting aonla fruits of different commercial cultivars. Therefore, the detailed knowledge obtained regarding changes in different parameters during different stages of maturity and ripening will be useful to ascertain the appropriate harvest stage and optimize its production with nutraceutical values.

Material and Methods

A field experiment was carried out at R. B. Road Campus of ICAR-CISH, Lucknow during the year 2020-21. The study was conducted with seven commercially important Aonla cultivars, viz. *NA-6, NA-7, NA-10, Krishna, Kanchan, Chakaiya and Lakshmi-52* with a layout of randomized block design, wherein one tree of each of the seven cultivars forms one replication and there were three replications per cultivar. The trees (20-25 years old) selected were uniform in size and vigor and had received uniform culture practices. Four branches were selected randomly from each side of the tree and were tagged before swelling of fruit buds during the month of August of each year of study. Fruit sampling was done based on calendar dates. Data recording for various physicochemical parameters of fruits was done at monthly intervals from October to February for the study.

The fruit samples were collected during the second week of each month of observation. The total number of samples collected was 10 and from each sample, 20 fruits were harvested from all branches marked earlier on each tree, mixed well, and were subject to recording of observations to determine optimum maturity indices during fruit growth stages. The fruits were assessed for various physio-biochemical attributes like fruit width, fruit weight, TSS, titratable acidity, reducing sugar, non-reducing sugar, ascorbic acid, and total phenol to ascertain the proper stage of harvest maturity. The physical parameters like the weight and width of the fruits were taken with the help of digital electric balance and vernier caliper, respectively. The chemical parameters *viz*. TSS was determined using a hand refractometer (0–32° B) and was expressed in the degree brix of the fruit juice. The acidity of the Aonla fruits was determined by the procedure given by Ranganna (2007). Total acid content was estimated by titrating the sample against 0.1 N NaOH using phenolphthalein as an indicator.

The ascorbic acid content was determined by titration of a known weight of sample with 2, 6-dichlorophenol indophenol dye using oxalic acid (AOAC, 2000). The 2, 6-dichlorophenol dye which is blue in alkaline solution and red in acid solution reduces ascorbic acid to a colorless form. Ascorbic acid was expressed as mg/100g pulp using the formula, i.e., Dye Factor = 0.5/ Titre.

$$\text{Ascorbic acid}\,(\text{mg}/100\ \text{g}) = \frac{\text{titre x dye factor} \times \text{volume made up} \times 100}{\text{Aliquat of extract taken} \times \text{weight or volume of the sample}}$$

Estimation of total sugars was earned by taking 50 mL clear filtrate in a 100 mL beaker. To this 5 ml of concentrated HCl was added and kept in a hot water bath for half an hour for hydrolysis. After hydrolysis, excess HCl was neutralized with sodium carbonate. The mixture was transferred to a 250 mL volumetric flask and the volume was made up to the mark. It was then titrated with 5 mL each of Fehling A and Fehling B using methylene blue as an indicator and the total sugar percentage was calculated (AOAC, 2000).

The reducing sugar in the sample was estimated by the volumetric method of Lane and Eynon reported by AOAC (2000). Freshly prepared 25 g of sample was taken in 250 mL volumetric flask. To it, 10 mL of lead acetate (2%) was added for clarification. The excess of lead acetate was precipitated with potassium oxalate solution and the volume was made to 250 mL with distilled water. The mixture was stirred well and allowed to stand for some time and then filtered. The clear filtrate was titrated with 5 mL each of Fehling A and Fehling B solutions to brick red precipitation using methylene blue as an indicator and the sugars calculated were presented on a percent basis. The amount of non-reducing sugar in the product was obtained by subtracting reduced sugar from total sugars and multiplying the same with the factor of 0.95.

The total phenols were estimated by the Folin-Ciocalteu procedure given by AOAC (2000) and expressed as mg/100 g of sample. The data were subjected to statistical analysis as per the method of Gomez and Gomez (1984).

Results and Discussion

Physical characteristics

Among the cultivars, Aonla cv. *Laxmi-52* (44.62 cm), *NA-6* (43.55 cm) and *Chakaiya* (43.18 cm) had maximum fruit width than the other cultivars. The fruit width was improved from October to March month and after January, the fruit size increased (in terms of fruit width) by 7 to 10% in Aonla cv. *Chakaiya* and *NA-6*. The maximum fruit width was recorded during February month in *Laxmi-52*, followed by *NA-6* and the least was recorded in *Kanchan*. The growth of the fruit almost ceased in Aonla cv. *NA-7* and *Kanchan* after January month. In February, the fruit width was least in Aonla cv. *Kanchan* and *NA-7* while in October, it was *Krishna* and *Chakaiya* had the least fruit width. The highest gain in fruit width was recorded with Aonla cv. *Chakaiya* followed *Krishna* and *Laxmi-52*. The last change in fruit width was recorded with *NA-7* Aonla. Singh *et al*. (2006), observed that the fruit growth in Aonla was faster initially and slowed down between the last week of September to the first week of October and increased slightly thereafter and followed a double sigmoid growth pattern in almost all the cultivars. (Table 1).

While assessing the fruit weight of Aonla cultivars (Table 2) it was found that *Laxmi-52* had the highest average fruit weight

Table 1: Variation in fruit width of aonla cultivars across the maturity period

Cultivars	*Fruit width (cm)*					*% increase**
	October	*November*	*December*	*January*	*February*	
NA-6	31.66	37.33	38.38	40.27	43.55	37.55
NA-7	32.83	34.22	37.72	40.14	40.96	24.76
NA-10	31.33	35.11	38.46	40.17	41.55	32.62
Laxmi-52	32.38	36.06	40.06	41.39	44.62	37.80
Krishna	29.77	37.99	39.27	40.87	41.69	40.04
Kanchan	30.53	33.65	36.24	38.96	40.34	32.13
Chakaiya	29.97	33.11	37.67	39.47	43.18	44.07
$CD_{0.05}$	0.623	0.598	1.364	0.461	1.00	-

**Over October month*

Table 2: Improvement in fruit weight of aonla cultivars across the maturity period

Cultivars	*Average fruit weight (g)*					*% increase**
	October	*November*	*December*	*January*	*February*	
NA-6	20.97	42.55	38.36	43.72	47.91	128.46
NA-7	22.40	39.96	35.70	41.13	42.74	90.80
NA-10	22.31	32.62	36.90	38.60	40.57	81.84
Laxmi-52	29.25	43.62	43.08	48.14	52.15	78.29
Krishna	24.83	40.69	36.59	37.51	38.72	55.94
Kanchan	22.93	39.34	33.80	35.20	38.47	67.77
Chakaiya	22.31	42.18	35.87	39.52	42.44	90.22
$CD_{0.05}$	2.028	0.912	4.33	0.85	1.12	-

**Over October month*

Table 3: Improvement in fruit TSS of aonla cultivars across the maturity period

Cultivars	*TSS (^{0}B)*					*%increase/decrease**
	October	*November*	*December*	*January*	*February*	
NA-6	7.65	8.48	9.45	10.62	10.91	42.61
NA-7	7.29	8.82	9.23	9.71	10.15	39.23
NA-10	7.97	8.54	9.41	10.64	11.20	40.52
Laxmi-52	8.32	8.80	9.21	10.41	11.32	36.05
Krishna	8.60	9.02	9.81	10.92	12.54	45.81
Kanchan	6.52	7.52	8.51	9.44	8.62	32.20
Chakaiya	7.40	8.55	8.64	9.27	10.22	38.10
$CD_{0.05}$	0.473	0.363	0.368	0.212	0.573	-

**Over October month*

(52.15 g) during February month. However, the increase in the rate of growth of fruit in terms of fruit weight was recorded with *NA-6* (128.46%) followed by *NA-7* and *Chakaiya* Aonla (from October–February). The lowest gain in fruit weight was recorded with *Krishna* (55.94%) Aonla. After *Laxmi-52* (52.15 g) Aonla, the maximum fruit weight was in *NA- 6* and *NA-7* (47.91, 42.74 g, respectively) amongst the cultivars. However, the highest fruit size was obtained in *NA-7* and the lowest in *Hathijhool* cultivars of Aonla by Tewari *et al.* (2019).

In this investigation, the fruit weight improved from December onwards also, while Bakshi *et al*. (2018) observed that initially fruit growth in Aonla is faster and slowed down between the first week to the last week of November and increased thereafter and followed by a double sigmoid growth pattern in Aonla cvs. NA-6, NA-7 and NA-10 in the Jammu region of India.

Fruit quality attributes

Based on the data presented in Table 3, the highest TSS was recorded with Aonla cv. *Krishna* (12.54 ^{0}B) followed by *Laxmi-52* (11.32 ^{0}B) during the October months. However, in Aonla cv. *Kanchan*, the TSS was highest (9.44 ^{0}B) during January months, which may be the best month for harvesting this variety.

Table: 4: Improvement in fruit's acidity of aonla cultivars across the maturity period

Cultivars	*Titratable acidity (%)*					*%increase/decrease*[*]
	October	*November*	*December*	*January*	*February*	
NA-6	2.25	2.34	2.44	2.31	1.52	-32.44
NA-7	2.59	2.75	2.83	2.56	1.59	-38.61
NA-10	2.49	2.60	2.49	2.36	1.66	-33.33
Laxmi-52	1.78	1.75	1.89	2.31	1.90	6.74
Krishna	2.64	2.58	2.54	2.37	2.12	-19.69
Kanchan	2.58	2.49	2.60	2.38	1.71	-33.72
Chakaiya	2.15	1.79	1.94	1.88	1.46	-32.09
$CD_{0.05}$	0.28	0.4	0.17	0.29	0.34	-

**Over October month*

Table 5: Improvement in fruit's total sugars of Aonla cultivars across the maturity period

Cultivars	*Total sugar (%)*					*%increment*[*]
	October	*November*	*December*	*January*	*February*	
NA-6	3.76	3.53	3.71	3.68	3.85	2.39
NA-7	3.48	3.48	3.32	3.37	3.33	- 4.31
NA-10	4.63	3.99	4.59	4.61	4.40	- 5.22
Laxmi-52	4.50	4.12	4.21	4.55	4.21	- 6.44
Krishna	4.49	4.42	4.38	4.37	4.33	-3.56
Kanchan	4.59	4.51	4.58	4.35	4.44	- 3.26
Chakaiya	4.23	4.45	4.59	4.49	4.58	8.27
$CD_{0.05}$	0.393	0.443	0.398	0.465	0.534	-

**Over October month*

Based on TSS values, Aonla cv. *Krishna* can be harvested during February month and *Kanchan* during January month. Overall, amongst the varieties, the *Kanchan* (6.52–9.44 ^{0}B) has the lowest TSS and *Krishna* (8.60–12.54 ^{0}B) has the highest TSS across the maturity period. In contrast, Prasad and Banker (1993) recorded TSS content of *Kanchan* fruits was more than *Krishna* Aonla in arid zone of Rajasthan. The highest increase in TSS over October month was recorded in cv. *Krishna* (45.81%) followed by Aonla cv. NA-6 (42.61%). Devi *et al*. (2020) also found exponentially upward growth trends in fruit size, weight and stone weight from the initial stages of maturity up to the final harvest. According to Prasad and Banker (1993), the TSS increased up to December month in aonla (*Emblica officinalis* Gaertn.) cvs. *Krishna* and *Kanchan* may occur because of the conversion of starch to sugar as maturity advances. In aonla (Singh *et al.,* 2006), total soluble solids, and total and reducing sugar contents increased as the fruits reached maturity in a semi-arid region.

From a perusal of data presented in Table 4, except in Aonla cv. *Laxmi-52*, all other cultivars of aonla showed a reducing trend of titratable acidity after December month. In *Laxmi-52*, after January only the acidity decreases. During February month, the highest titratable acidity was recorded with Aonla cv. *Krishna* (2.12%) followed by *Laxmi-52* (1.90%). During December month, the *NA-7* and *Kanchan* aonla had the highest acidity (2.83, 2.60%, respectively). Aonla cv. *Laxmi-52* is the only variety that has improved acidity percentage (6.74%) from October to February, while a maximum reduction in acidity was recorded with *NA-7* (-38.61%) and *Kanchan* (-33.72%). Singh *et al*. (2006) also found an increment in titratable acidity during the initial period of fruit development then declined in Aonla under Gujarat conditions.

The total sugar (TS) from October to February month was also measured and it was observed (Table 5) that most of the cultivars (except *NA-7* and *NA-10*) had reduced TS from December to January but improved up to some extent in February (in cvs. *NA-6*, *Kanchan* and *Chakaiya*). The highest TS was recorded in *NA-10* (4.63 g) during October month which declined till February month. In Aonla cv. *Chakaiya* the TS was improved from October to February (8.27%) while it got reduced in almost all cultivars (2–6% decline). It was also found that the TS content was least in Aonla cv. NA-7 across the maturity period. The Aonla cv. Krishna had almost stable TS content from December to February, rather the variety had a meager declining trend of TSS from October to February months. Based on data presented in Table 5, the *Laxmi-52* and *NA-10* Aonla should be harvested in January month as it contained a higher TS (4.55, 4.61) than the other cultivars. Likewise, Aonla cv. *Chakaiya,* the *Kanchan* can be harvested during February month as it has higher TS (4.58, and 4.44%, respectively) than the other cultivars. There was incremental growth in fruit's TS in Aonla cv. *Chakaiya* by 8.27% from October to February and 2.39% in *NA-6*. Rest cultivars showed negative growth of TS during the complete maturity period i.e. October to January/February months.

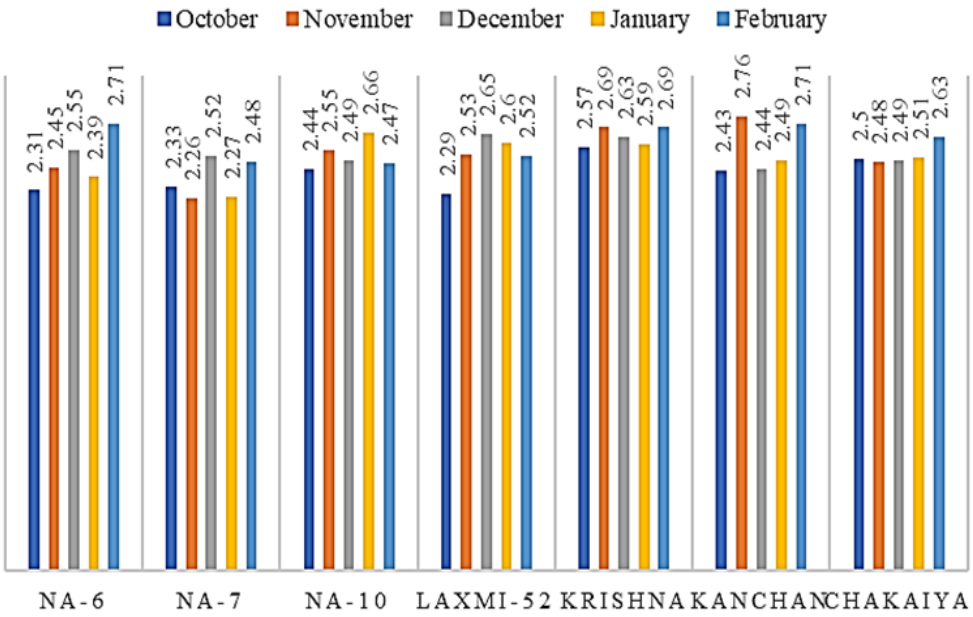

Fig 1: Improvement in fruit's reducing sugars of aonla cultivars across the maturity period

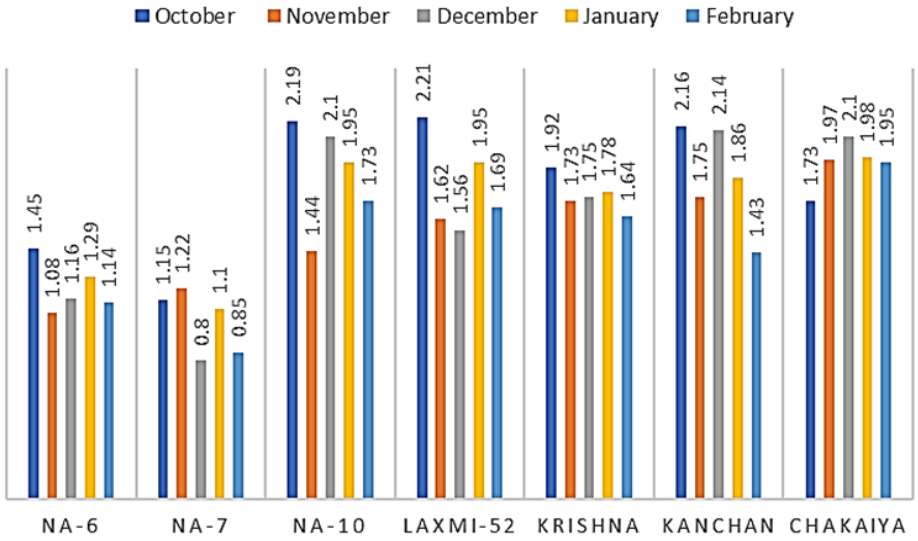

Fig. 2: Improvement in fruit's non-reducing sugars of Aonla (*E. officinalis*) cultivars across the maturity period.

The perusal of data in Fig. 1 showed that the reducing sugars (RS) content of Aonla fruits was highest in *Krishna* (2.57%) followed by *Chakaiya* (2.50%) during October month. During February month, the highest RS was recorded in aonla cv. *NA-6* and *Kanchan* (2.71%) while the least RS in *NA-10*/*NA-7* (2.47, 2.48%, respectively). The *Chakaiya* and *Krishna* Aonla had shown an increasing trend of RS from December onward while most of the cultivars (barring *NA-10* and *Laxmi-52*) showed improvement in RS from January to February months.

The perusal of data in Fig. 2 showed that most of the aonla cultivars showed a continuous reduction in NRS after December month. The non-reducing sugars (NRS) content of aonla fruits was highest in *Laxmi-52* (2.21%) followed by *NA-10* (2.19%) during October month. During February month, the highest NRS was recorded in aonla cv. *Chakaiya* (1.95%) while least NRS in *NA-7* (0.85%). Rather, Aonla cv. *NA-7* had the lowest NRS across the maturity period. *Laxmi-52* has shown a declining trend of NRS across the whole fruit's maturity period. The aonla cultivars *Chakaiya*, *Kanchan* and *NA-10* recorded a reducing trend of NRS content after December month, while *Laxmi-52* had the highest NRS during January months and NA-10 had the maximum during December. In February month, Aonla cv. *Chakaiya* had maximum NRS. Devi *et al.* (2020) observed reducing sugar and total sugars in Aonla increased with the advancement of maturity.

Ascorbic acid and polyphenols together account for the antioxidant properties of amla fruit. Ascorbic acid is the

predominant vitamin present in Aonla fruit and the main reason for its therapeutic activity. In this investigation, the '*NA-6*' Aonla contained the maximum amount of ascorbic acid across most of the maturity period and the lowest in cv. *Chakaiya* from October to December, then become stable. *NA-7* aonla had the highest vitamin C during November month. Bakshi *et al.* (2018) reported in most of the cultivars of aonla, ascorbic acid increased during development and remained constant till fruits attained physiological maturity.

As per data given in Table 6, vitamin C seemed to be highest during December month in *NA-6* (449.7 mg per 100 g), *Laxmi-52* (417 mg per 100 g), *NA-10* (386.83 mg per 100 g) and further declined. Singh *et al.* (2006) observed that vitamin C increased during development and became constant till the fruits attained physiological maturity in Aonla under a semi-arid environment. In this investigation, the Aonla cv. *Kanchan* (402 mg per 100g) and *Chakaiya* (399 mg per 100g) should be harvested during January month because these varieties contain the highest vitamin C. *NA-6* Aonla (457.57 mg per 100 g) had the highest vitamin C during February month and least in *NA-10* (363.54 mg per 100 g) Aonla. According to Tewari *et al.* (2019), the ascorbic acid content was significantly different ($p \leq 0.05$) in all cultivars which varied between 498.81 and 585.00 mg/100 g with the highest value for *Chakaiya* cultivar. The TSS and ascorbic acid content are found to be maximum at final maturity and minimum during the initial stages of fruit development. The total phenol content in Aonla decreases with the maturity of the fruits (Devi *et al.,* 2020)

Phenolic compounds are another important antioxidant present in Aonla fruits which also vary from cultivar to cultivar. Even the amount of individual phenolic compounds also varied significantly from cultivar to cultivar. As per data depicted in Table 7, the total phenol (TP) (in terms of gallic acid) was highest in *Laxmi-52, Krishna and NA-7* during December month, so it should be harvested during this month. *NA-10* had the highest TP (1.78 mg g^{-1} FW) during January month, so it should be harvested during January month. Amongst the cultivars, the Aonla cv. *Laxmi-52* showed the highest TP (2.0 mg g^{-1} FW) during

Table 6: Improvement in fruit's vitamin C of aonla cultivars across the maturity period

Cultivars	*Ascorbic acid (mg per 100 g pulp)*					*% increase**
	October	*November*	*December*	*January*	*February*	
NA-6	441.61	436.19	449.97	435.67	457.57	3.61
NA-7	407.15	422.32	399.53	401.95	394.44	3.12
NA-10	384.67	387.85	386.83	369.28	363.54	5.49
Laxmi-52	404.27	413.81	417.00	405.73	404.47	0.05
Krishna	440.77	417.53	425.87	416.55	404.91	8.13
Kanchan	382.53	375.17	393.60	402.02	378.49	- 1.05
Chakaiya	368.32	370.66	391.88	399.00	394.18	7.02
$CD_{0.05}$	23.02	21.07	15.81	10.52	27.49	-

**Over October month*

Table 7: Improvement in fruit's total phenols of aonla cultivars across the maturity period

Cultivars	*Total phenols (in terms of gallic acid) (mg g^{-1} FW)*					*% increase/decrease**
	October	*November*	*December*	*January*	*February*	
NA-6	1.24	1.28	1.60	1.76	1.78	43.54
NA-7	1.13	1.18	1.54	0.93	0.84	- 24.77
NA-10	1.05	1.43	1.63	1.78	1.77	68.57
Laxmi-52	1.16	2.27	2.20	1.60	2.00	72.41
Krishna	0.85	1.87	2.02	1.69	1.81	112.94
Kanchan	1.27	1.27	1.23	1.14	1.33	4.72
Chakaiya	1.48	1.35	1.55	1.46	1.83	23.64
$CD_{0.05}$	0.15	0.12	0.096	0.318	0.282	-

**Over October month*

Table 8: Physical and biochemical attributes of *CISH-Aonla-1*, *CISH Aonla-2* and *Kanchan*

Varieties/ Genotypes	*Average fruit weight (g)*	*Pulp (%)*	*T.S.S. (°Brix)*	*Vitamin 'C' (mg/100 g pulp)*	*Phenol (%)*	*Acidity (%)*	*Total Sugar (%)*	*TSS/Acid ratio*
CISH-Aonla-1	40.65	96.69	9.41	500.94	1.43	2.40	6.57	3.91
CISH-Aonla-2	24.42	94.94	9.14	417.44	1.72	2.11	6.34	4.33
Kanchan	32.15	96.12	7.52	376.04	1.26	2.48	4.52	3.02

February month and had a declining trend after November month in the present investigation. During February month, the TP was highest in *Chakaiya* and *Kanchan* Aonla. Only *NA-7* Aonla had a reducing trend (- 24.77%) of fruit's TP during the whole maturity period, the rest of the cultivars had improved TP content during the same period.

Tiwari *et al.* (2019) also found varied polyphenol contents of the different fruit cultivars as 24.61 to 31.12%. He observed *Chakaiya* cultivar had the highest polyphenols content which was significantly ($p \leq 0.05$) different from other aonla cultivars. The varietal difference in total phenol content could be attributed to the harvest of fruits at different stages, genetic inheritance characteristics and agronomic conditions (Wang and Zheng, 2001).

Evaluation of new accessions of Aonla with a check variety (i.e. Kanchan)

We also evaluated the recently identified accessions of Aonla i.e. *CISH-A-1* and *CISH-A-2* and made a comparison with other cultivars (e.g. *Kanchan*) and found that both the accession is much superior to the existing cultivars (Table 8). The content of ascorbic acid varied from 363 to 457 mg 100 g^{-1} in tested cultivars irrespective of the cultivars themselves, whereas vitamin C of other accessions ranged between 417.44 mg 100 g^{-1} (*CISH A-2*) and 500.94 mg 100 g^{-1} (*CISH A-1*) among the identified accessions at ICAR-CISH, Lucknow. Among the cultivars/accessions studied, Aonla possessed a range of total polyphenols (0.84–2.27%) while our accessions like CISH A-2 (1.72%) and CISH-A-1 (1.43%) had high polyphenols. Bhattacherjee *et al.* (2020) also reported that aonla cultivars like '*NA-6*', '*Krishna*' and '*Laxmi*-52' are also rich in both nutraceuticals (phenolic compounds and ascorbic acid) properties. These cultivars and accessions are not only beneficial for human health but can also be used in the processing and phytopharmaceutical industries.

Earlier workers like Killadi *et al.* (2015) inferred that NA-10 and Krishna being early, attained optimum maturity after 95 days, while NA-7 and Chakaiya attains maturity after 105 days of initial fruit growth, based on weight, yellowness index, glossy appearance, translucent skin with distinct stripes and maximum vitamin C content. Prasad and Banker (1993) reported optimum time for harvesting Aonla, fruits (*Krishna* and *Kanchan*) is the last week of December onwards. In this investigation also, we found that Aonla cvs. *NA-7*, *Laxmi-52* and *Krishna* should be harvested in December month (as it had the highest total polyphenols). Based on TSS, *Kanchan* may be harvested in January and *Krishna* in February month. For recovery of high total sugars in the fruits, *Laxmi-52* and *NA-10* should be harvested in January (*NA-10* had the highest total phenols during this month) as February month is better month for harvesting of *Chakaiya* and *Kanchan* Aonla. For high vitamin C and total phenols, the *Kanchan* and *Chakaiya* should be harvested in January and *NA-6* in February month. Newer accession (*CISH A-1* and *CISH A-2*) had the highest amount of vitamin C and total phenols during January month, so this month is best for harvesting these potential varieties.

Conclusion

In this investigation, the Total Suspended Solids and ascorbic acid content were found maximum at final maturity and minimum during the initial stages of fruit development. Total phenol content showed a decreasing trend with the maturity of the fruits. Reducing sugar and total sugars was increased with the advancement of maturity. Among different cultivars, fruit size, weight, stone weight, and TSS attributes were higher in *Laxmi-52* and minimum in *Kanchan*. The vitamin C content and total phenol content in fruits were highest in NA-6 and lowest in NA-10. The total and reducing sugars were significantly highest in *Laxmi-52*, *NA-10* and *Krishna* Aonla cultivars. The varieties were characterized as early, mid, and late season based on physico-chemical parameters.

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Author Contributions

DP: Collection of samples monitored and guided for the experiment; SP and SS: Recorded observation SKS: Written manuscript, monitored and guided for the experiment.

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Availability of Data and Materials

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