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# Foliar application of plant growth regulators to improve fruit retention, yield and quality of aonla cv. NA-7

**Goutam Jangid, Goutam Mandal, Kamal Kumar Mandal and Rocky Thokchom**

**Abstract**
To assess the influence of $GA_3$ and NAA on fruit retention, yield and quality of aonla cv. NA-7, the present investigation was carried on 8 years old aonla trees during 2016-17. Foliar application of $GA_3$ (20 and 40 ppm), NAA (20 and 40 ppm) and their factorial combination were sprayed during the flowering and pea size stage of the fruits. Various quantitative and qualitative physicochemical parameters analyses revealed that maximum fruit retention (17.66 %) and yield (18.70 kg tree$^{-1}$) was recorded in treatment of $GA_3$ @ 20 ppm + NAA @ 40 ppm. Whereas maximum fruit size (length 34.73 mm and fruit breadth 35.73 mm), fruit weight (30.79 g), fruit volume (28.99 cm$^3$), pulp weight (29.60 g), stone weight (1.19 g) and pulp/stone ratio (24.87) was recorded in treatment of $GA_3$ @ 40 ppm + NAA @ 20 ppm. Quality traits like TSS (11.43 $^o$Brix), ascorbic acid (486.22 mg 100g$^{-1}$) and sugars content was recorded significantly highest in treatment of $GA_3$ @ 40 ppm + NAA @ 40 ppm. The maximum acidity (2.03 %) was recorded in control treatment of water.

**Keywords:** aonla, $GA_3$, NAA, retention, yield, physicochemical quality

## Introduction
Aonla (*Emblica officinalis* Gaertn.) is a small size, and minor subtropical fruit belongs to the family Euphorbiaceae with the chromosome number 2n = 28, is native to tropical south-east Asia (Pathak, 2003) [15]. It has been cultivated in India since time immemorial for it's widely used in the Indian system of medicine (Agarwal and Chopra 2004; Kumar *et al.*, 2012) [1, 13] and has the medicinal cures for many diseases (Goyal *et al.*, 2008) [10]. It is highly nutritious and has a rich source of vitamin C next to the Barbados cherry (*Malpighia glabra* L.) (Chadha, 2002; Singh *et al.*, 2006) [5, 23]. It thrives well throughout tropical and subtropical India and is widely cultivated in the region extending from the base of Himalaya to Ceylon and Malaysia to south China. During 2015-16, India ranks first in production of aonla occupying an area of 0.08 mha with an annual production of 0.97 mt (Anonymous, 2017) [2]. In India its commercial production is confined in marginal areas of Uttar Pradesh, Haryana, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu states (Pathak 2003) [15]. In West Bengal, aonla cultivation is confined in Purulia, Bankura, Birbhum and West Midnapore districts (Singh, 2012) [20] as a minor fruit crop. Value added products can be prepared from aonla fruit by converting it into various processed products by employing different methods of preservation (Kadam, 2001) [11]. In West Bengal, the demand for aonla fruits has been progressively increased due to its popularity in the constituent in *Ayurvedic* medicines and value added product (preserve, candy, pickle, dried salted segments known as '*Supari'*, spice salted powder known as *'Aonla Churan'* etc.). Since aonla is suitable for semi-arid and arid regions and can withstands well in salinity and drought conditions its cultivation has been gradually expanded in the red lateritic zone of Eastern India. The major constraint of aonla cultivation in this zone is the occurrence of heavy fruit drop. A hormonal imbalance is one of the major causes accounting fruit drops (Singh *et al.*, 2008) [22]. Although fruit drop in aonla is a common phenomenon (Patil *et al.*, 2012) [16], the fruit drop in red lateritic soil is severed and it continued till harvest resulting low yield of mature fruits. Earlier investigations of Ghosh *et al.* (2009) [8]; Chandra *et al.* (2015) [6]; Patel *et al.* (2017) [14] reported that application of $GA_3$ and NAA improve fruit retention, yield and fruit quality of aonla. In spite, of many studies on the evaluation of the potential of plant growth regulators (PGR's.) in overcoming the fruit drop in different aonla cultivars, yet no systematic efforts have been made to test the efficacy of PGR's to provide viable solution to heavy fruit drop which often takes a heavy toll in commercial aonla orchards.

Therefore, the present investigation was carried out to assess the efficacy of $GA_3$, NAA and their factorial combination to improve fruit retention, yield and physicochemical quality of aonla cv. NA-7.

## Materials and Methods

### Site of study

The present research was carried out during 2016 to 2017, in association of 'Department of Horticulture and Postharvest Technology, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India' and 'Regional Fruit Research Sub-station, Bidhan Chandra Krishi Vishwavidyalaya, Sekhampur, Birbhum, West Bengal, India.' For the study, eight years old, 27 uniform healthy trees of aonla cultivar 'NA-7' were selected in experimental orchard of aonla at 'Regional Fruit Research Sub-station, Bidhan Chandra Krishi Viswavidyalaya, Sekhampur, Birbhum, West Bengal.' The experimental orchard is located at an elevation of 40 m above mean sea level at 23º 42' N latitude and 87$^0$ 47'30" E longitudes, representing humid sub-tropical region under the 'Red lateritic zone' of eastern India. The experiment was laid out in a randomized block design comprising of nine treatments, which were replicated thrice. Details of the treatments are as follows.

### Different treatment combination and application

$T_1$ = ($GA_3$ @ 20 ppm),
$T_2$ = ($GA_3$ @ 40 ppm),
$T_3$ = (NAA @ 20 ppm),
$T_4$ = (NAA @ 40 ppm),
$T_5$ = ($GA_3$ @ 20 ppm + NAA @ 20 ppm),
$T_6$ = ($GA_3$ @ 20 ppm + NAA @ 40 ppm),
$T_7$ = ($GA_3$ @ 40 ppm + NAA @ 20 ppm),
$T_8$ = ($GA_3$ @ 40 ppm + NAA @ 40 ppm) and
$T_9$ = (Control spray of water).

The treatments were imposed two times, first at flowering stage and second at pea size stage of fruits during July, 2016 around the tree canopy and water was sprayed in control trees.

### Fruit retention and yield

Fruit drop and fruit retention were recorded in the orchard, five branches on different aspects of the tree were tagged for counting flowers and fruit retention per cent. Fruit retention per cent was recorded three weeks after petal fall and was calculated by using the formula given by Westwood (1978) [26].

For physicochemical analysis of fruits, freshly harvested fruits of uniform size, shape, colour, free from disease and bruises were harvested at the physiological mature stage during the morning hours and brought to the laboratory of 'Department of Horticulture and Postharvest Technology, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India.'

### Size, weight and volume

Size of the fruits was measured by vernier calliper. Fruit weight was measured by selecting ten fruits randomly and was weighed on electric top pan balance and express in g fruit$^{-1}$. Fruit volume was measured by water displacement method and expressed in cm$^3$ fruit$^{-1}$.

### Total soluble solids (TSS) and sugar content

The total soluble solids (TSS) level of the fruits was determined using a digital refractometer (AR-2008, Kruss, Germany) according to the method of Daramola and Asunni, (2007) [7]. The measured value was expressed as °Brix. A substantial amount of extracted juice was dropped onto the refractometer. The reading shown was the reading of the total soluble solids for the juice. Sugar's content was determined according to AOAC (2000) [3].

### Titratable acidity and ascorbic acid

Titratable acidity was determined from juices extract and expressed as lactic acid (%) according to the standard methods in AOAC (2000) [3] and the ascorbic acid content was also estimated by the method described in AOAC (2000) [3].

### Statistical analysis

The experiment was carried out in randomized block design and each treatment was replicated thrice. Data were subjected to one way analysis of variance (ANOVA) as suggested by (Gomez and Gomez, 1984) [9]; and to mean separation with the Fisher's Least Significant Differences (LSD) test with $P \leq 0.05$, using the statistical analysis program (SPSS).

## Result and Discussion

### Fruit retention and yield

All the PGR's treatments significantly improved fruit retention as compared to control and resulted in corresponding increase in yield (Fig 1.) of aonla fruits. The maximum fruit retention (17.66 %) and yield (18.70 kg/tree) were recorded under the $T_6$ treatment spray of $GA_3$ (20 ppm) + NAA (40 ppm) whereas the minimum fruit retention (13.92 %) and yield (14.09 kg/tree) were recorded in control. Beneficial effect of NAA application over $GA_3$ application in improving fruit retention was observed during the experiment. Beneficial effect of NAA application in reducing fruit drop and correspondingly increasing fruit retention and yield may be explained from the fact that auxin maintains the on-going physiological and biochemical process of inhibition of abscission (Taylor and Whitelaw, 2001; Aziz, 2003) [25, 4]. While, the role of gibberellins in controlling fruit drop appears to be indirect. Gibberellins are also known to promote auxin biosynthesis (Krishnamoorthy, 1993) [12]. Yadav *et al.* (2010) [27], Ghosh *et al.* (2009) [8] and Singh *et al.* (2007) [21] observed NAA application to improve fruit retention and resulted in maximum yield of aonla fruits. Combined beneficial effect of $GA_3$ and NAA treatment over control treatment in fruit yield of aonla has been earlier reported by Chandra *et al.* (2015) [6] and Prakash *et al.* (2017) [17].

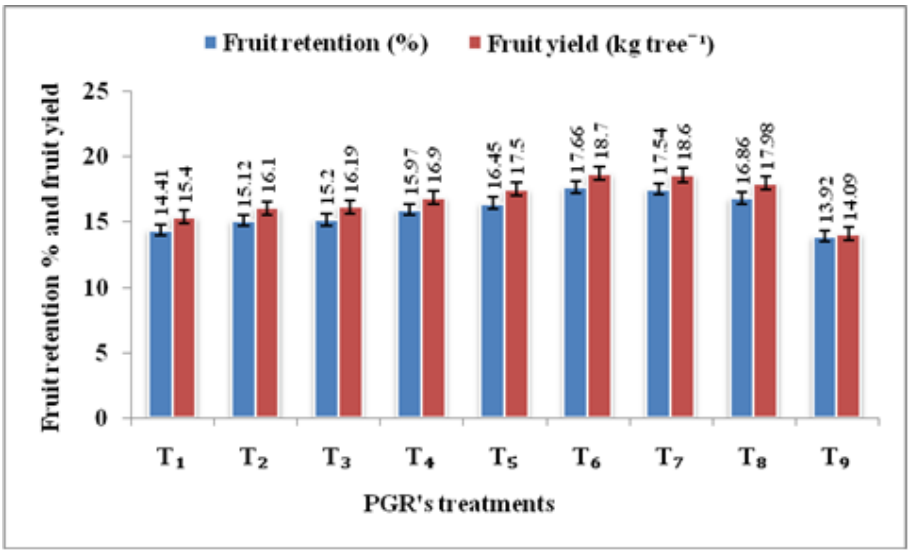


**Fig 1:** Effect of PGR's on fruit retention and yield of aonla cv. NA-7

**Fruit size, weight and volume**

Fruit size, weight and volume were significantly affected by all the growth regulators over control (Table 1). The maximum fruit size (34.73 mm length and 35.73 mm diameter) was recorded under the $T_7$ treatment spray of $GA_3$ (40 ppm) + NAA (20 ppm) compare to control treatment. This finding are in accordance with the findings of Singh and Singh (2015) [19]; Yadav *et al.* (2010) [27] and Pakash *et al.* (2017) [17] which shows evidences of exogenously application of $GA_3$ and NAA significantly increase fruit size in different aonla cultivars.

As perusal of data's in Table 1, maximum fruit weight (30.79 g) and fruit volume (28.99 $cm^3$) were recorded in the treatment $T_7$ ($GA_3$ 40 ppm + NAA 20 ppm) correspondingly where maximum fruit size was recorded. The increase in fruit weight and volume in NAA and $GA_3$ treated trees may be due to their role in cell enlargement and division, increase in intercellular spaces in the mesocarpic cells and higher translocation of photosynthates and mineral nutrients from vegetative parts towards the developing fruits that are extremely active metabolic sink (Krishnamoorthy, 1993) [12]. Further, Yadav *et al.* (2010) [27] exhibited significant improvement in fruit weight and volume of aonla in treatment application of NAA, whereas Shukla *et al.* (2011) [18]; Chandra *et al.* (2015) [6] exhibited in treatment application of $GA_3$.

**Pulp weight, stone weight and pulp: stone ratio**

Significant effect of plant growth regulators in pulp weight, stone weight and pulp: stone ratio was observed (Fig 2.). The maximum pulp weight (29.60 g), minimum stone weight (1.19 g) and maximum pulp: stone ratio (24.87) was recorded with the $T_7$ treatment spray of $GA_3$ 40 ppm + NAA 20 ppm. Zhang *et al.* (2007) [28] expressed that increased sink demand by induced application of GA is closely related to the activation of invertase cell wall-bound in the core and invertase neutral and NAD-dependent sorbitol dehydrogenase in the pulp during rapid fruit growth in fruit. Further Chandra *et al.* (2015) [6] and Prakash *et al.* (2017) [17] reported foliar application of GA and NAA to improved pulp: stone ratio in different cultivars of aonla.

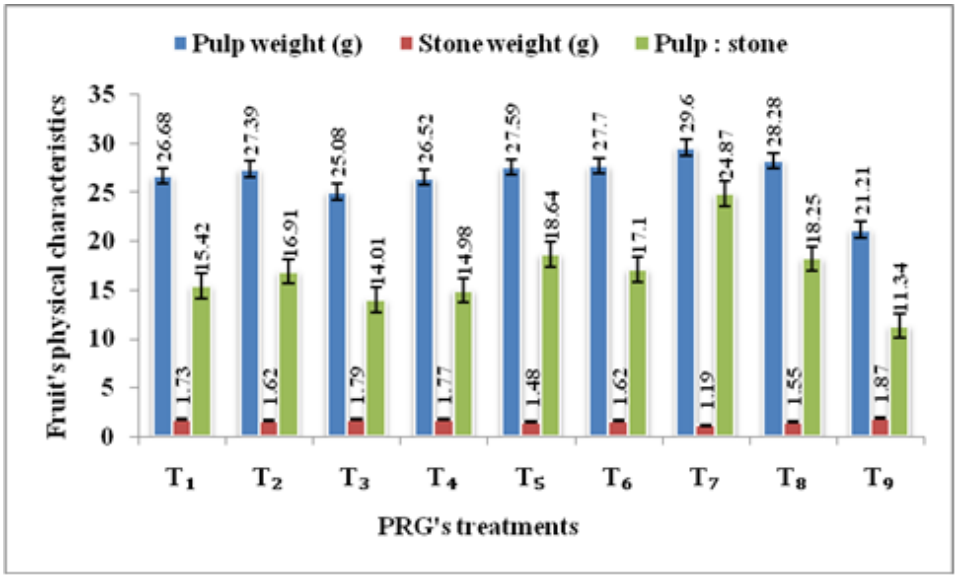


**Fig 2:** Effect of PGR's on pulp weight, stone weight and their ratio on fruits of aonla cv. NA-7.

**Table 1:** Effect of PGR's on physical characteristics of aonla cv. NA-7.

| Treatment | Fruit size | | Fruit weight (g) | Fruit volume ($cm^3$) |
|---|---|---|---|---|
| | Length (mm) | Diameter (mm) | | |
| $T_1$ | 32.62 | 34.29 | 28.41 | 26.03 |
| $T_2$ | 32.64 | 34.50 | 29.01 | 26.35 |
| $T_3$ | 29.42 | 31.99 | 26.87 | 24.75 |
| $T_4$ | 33.12 | 32.81 | 28.29 | 26.43 |
| $T_5$ | 33.53 | 34.64 | 29.07 | 27.45 |
| $T_6$ | 33.87 | 34.68 | 29.32 | 27.01 |
| $T_7$ | 34.73 | 35.73 | 30.79 | 28.99 |
| $T_8$ | 34.05 | 35.10 | 29.83 | 28.1 |
| $T_9$ | 27.90 | 28.13 | 23.08 | 20.8 |
| SEm ± | 0.62 | 0.58 | 1.09 | 1.10 |
| CD (*P*=0.05) | 1.79 | 1.68 | 3.16 | 3.19 |

**TSS and sugars content**

The TSS content of fruits was found to influence by application of all the PGR's over control (Fig 3.). However, the maximum TSS (11.43º B) was observed under $T_8$ treatment spray of $GA_3$ 40 ppm + NAA 40 ppm. This might be due to activation of enzymes which affect the physiological processes, which in turn hydrolyzed the starch and helps in metabolic activity during the change in available starch into sugar and soluble solid content. NAA had shown significant increase in sugar and soluble solid content of aonla fruits and this might be due to synthesis of auxin in plant that increased the physiological activities. The results are also in accordance with the findings of Ghosh *et al.* (2009) [8], Srivastava *et al.* (2009) [24], Yadav *et al.* (2010) [27], Shukla *et al.* (2011) [18] and Patel *et al.* (2017) [14] in different aonla cultivars.

All sugars content (Table 2) in aonla fruits significantly increased in trees sprayed with $GA_3$ (40 pm) + NAA (40 ppm) i.e. $T_8$ treatment. This might be due to involvement of PGR's in the breaking down of organic acids into sugars at the time of fruit ripening. Further, plant growth regulators might assist the translocation of sugars from vegetative parts to developing fruits. Gibberellins are known to play a crucial role in the sugar metabolism of plants. Gibberellins actively participate in the hydrolysis of sucrose and starch. They promote the activity of enzyme invertase which catalyzes the hydrolysis of sucrose, thereby yielding glucose and fructose. Gibberellins also induce higher activity of α- and ß-amylases which degrade starch and represent best means for the mobilization of carbohydrate reserves in the plant. Moreover, bound gibberellins exist in pant tissues at gibberellic glycosides (i.e. conjugates with sugar), suggesting their role in sugar metabolism (Krishnamoorthy, 1993) [12]. Such result has also been reported by Singh *et al.* (2007) [21], Yadav *et al.* (2010) [27], Singh and Singh (2015) [19] and Patel *et al.* (2017) [14] by application of NAA and GA in different aonla cultivars.

**Table 2:** Effect of PGR's on chemical characteristics of aonla cv. NA-07.

| Treatment | Ascorbic acid (mg/100g) | Total Sugar (%) | Reducing Sugar (%) | Non-reducing Sugar (%) |
|---|---|---|---|---|
| $T_1$ | 372.18 | 4.39 | 2.79 | 1.60 |
| $T_2$ | 389.25 | 4.47 | 2.94 | 1.53 |
| $T_3$ | 412.97 | 4.62 | 3.00 | 1.62 |
| $T_4$ | 423.19 | 4.72 | 3.14 | 1.58 |
| $T_5$ | 436.01 | 4.78 | 3.24 | 1.54 |
| $T_6$ | 442.26 | 4.93 | 3.33 | 1.60 |
| $T_7$ | 477.24 | 4.96 | 3.35 | 1.61 |
| $T_8$ | 486.22 | 5.20 | 3.50 | 1.70 |
| $T_9$ | 360.53 | 4.29 | 2.68 | 1.61 |
| SEm ± | 1.32 | 0.15 | 0.14 | 0.15 |
| CD (*P*=0.05) | 3.83 | 0.44 | 0.42 | 0.45 |

**Titratable acidity and ascorbic acid**

Observation recorded on titratable acidity content depicted clearly indicated that titratable acidity content of fruit (Fig 3.) was markedly reduced under all the treatments as compared to control application of $T_9$ treatment (water). It could have been possible due to the transformation of organic acids into sugars at the time of ripening. This result is in accordance with the findings of Singh and Singh (2015) [19] in aonla under north India condition. As perusal of Figure 3 TSS/Acidity ratio of fruits was found to influence by application all the growth regulators over control.

The ascorbic acid of the fruits was appreciably influenced by all the growth regulators over control. However, the maximum ascorbic acid (486.22 mg 100 $g^{-1}$) was recorded under $T_8$ treatment of $GA_3$ 40 ppm + NAA 40 ppm. As ascorbic acid is synthesized from sugars, particularly L-glucose, any increase in sugar content in fruits would be conducive to the higher synthesis of ascorbic acid in fruits due to PGR's (Krishnamoorthy, 1993) [12]. Singh *et al.* (2007) [21]; Yadav *et al.* (2010) [27]; Singh and Singh (2015) [19] also observed higher ascorbic acid content in aonla fruits treated with GA and NAA in different cultivars.

Base on the investigation, application of factorial combination of $GA_3$ @ 20 ppm and NAA @ 40 ppm can check fruit drop in aonla cv. NA-7 up to some extend and has a direct beneficial impact on fruit retention per cent and yield. Whereas physical and chemical characteristics of fruits can be maintained and improved by foliar application of $GA_3$ @ 40 ppm + NAA @ 20 ppm and $GA_3$ @ 40 ppm + NAA @ 40 ppm respectively. The results obtained from the investigation will be a valuable in the guidelines of fruit drop controlling and retention of physicochemical characteristics of aonla cv. NA-7 in the red lateritic zone of eastern India and would be a valuable source and guideline for future investigations.

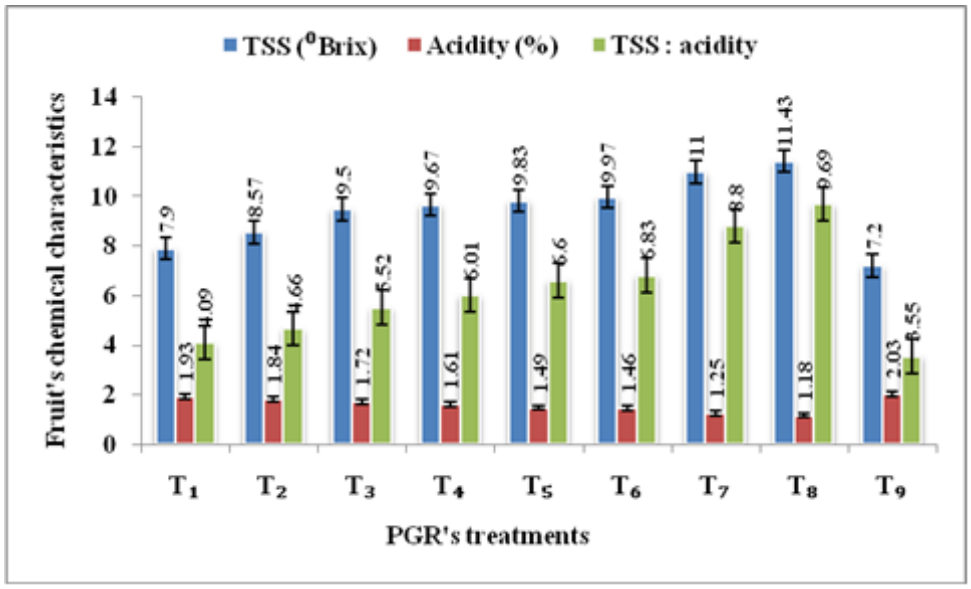


**Fig 3:** Effect of PGR's on TSS, acidity and their ratio on fruits of aonla cv. NA-7.

## References


1. Agarwal S, Chopra CS. Studies on changes in ascorbic acid and total phenols in making aonla products. Beverage and Food World. 2004; 31:32-4.
2. Anonymous. Horticultural Statistics at a Glance. Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2017. Retrieved from: www.agricoop.nic.in
3. AOAC. Official Methods of Analysis, 17th edition. Association of Official Analytical Chemists, Washington DC, USA, 2000.
4. Aziz A. Spermidine and related-metabolic inhibitors modulate sugar and amino acid levels in *Vitis vinifera* L.: possible relationships with initial fruit let abscission. Journal of Experimental Botany. 2003; 54(381):355-363.
5. Chadha KL. Hand book of horticulture. Publisher, Indian Council of Agricultural Research, New Delhi, India, 2002.
6. Chandra R, Singh KK. Foliar application of zinc sulphate, magnesium sulphate and copper sulphate on the yield and quality of aonla (*Emblica officinallis* Gaerth L.) cv. "NA-7" under Garhwal Himalaya. Journal of Medicinal Plants Studies. 2015; 3(5):42-45.
7. Daramola B, Asunni OA. Preparation, physiochemical and sensory assessment of pawpaw red ginger food drink. American-Eurasian Journal of Scientific Research. 2007; 2(2):101-105.
8. Ghosh SN, Bera B, Roy S, Kundu A, Roy SKD. Effect of nutrients and plant growth regulators on fruit retention, yield and physicochemical characteristics in aonla cv. NA-10. Journal of Horticultural Sciences. 2009; 4(2):164-166.
9. Gomez KA, Gomez AA. Statistical procedures for agricultural research, 2nd edition. John Wiley and sons, New York, 1984.
10. Goyal RK, Patil RT, Kinglsly ARP, Walia H, Kumar P. Status of post harvest technology of aonla in India - A Review. American Journal of Food Technology. 2008; 3:13-23.
11. Kadam SS. New products from the arid and semiarid fruits. Indian Journal of Horticulture. 2001; 58(2):170-177.
12. Krishnamoorthy HN. Physiology of plant growth and development. Atma Ram and Sons Publishers, New Delhi, India, 1993.
13. Kumar A, Singh A, Dora J. Essentials Perspectives for *Emblica officinalis*. International Journal of Pharmaceutical and Chemical Sciences. 2012; 1(1):11-18.
14. Patel JS, Dhruve JJ, Motka GN, Patel AD. Influence of plant growth regulators and boron on nutritional quality and shelf-life of aonla fruit. International Journal of Current Microbiology and Applied Sciences. 2017; 6(4):2533-2540.
15. Pathak RK. Status Report on Genetic Resources of aonla *(Emblica officinalis* Gaertn.) in South and Southeast Asia. In Mal, B., Rao, V. R. and Arora, R.K. (Eds.). IPGRI Office for South Asia, New Delhi, India, 2003.
16. Patil SR, Sonkamble AM, Ganvir MM. Studies on flower and fruiting behaviour of aonla cultivars. The Asian Journal of Horticulture. 2012; 7(2):615-616.
17. Prakash O, Yadav AL, Singh Y. Effect of Foliar Feeding of Urea, Zinc Sulphate and Plant Growth Regulator on Physical Parameter and Yield of aonla Fruit (*Emlica officinalis* Gaertn) cv. Chakaiya. International Journal of Pure and Applied Bioscience. 2017; 5(3):62-66.
18. Shukla HS, Kumar V, Tripathi VK. Effect of gibberellic acid and boron on development and quality of aonla fruits 'Banarasi'. Acta Horticulture. 2011; 890:375-380.
19. Singh A, Singh HK. Application of Plant Growth Regulators to improve Fruit Yield and Quality in aonla (*Emblica officinalis* Gaertn.). Journal of Agri Search. 2015; 2(1):20-23.
20. Singh G. Checklist of Commercial Varieties of Fruits, 1st edition. New Delhi: Department of Agriculture and Cooperation, 2012.
21. Singh JK, Prasad J, Singh HK. Effect of micro-nutrients and plant growth regulators on yield and physico-chemical characteristics of aonla fruits in cv. NA-10. Indian Journal of Horticulture. 2007; 64(2):216-218.
22. Singh JK, Prasad J, Singh HK, Singh A. Effect of micro-nutrients and plant growth regulators on plant growth and fruit drop in aonla (*Emblica officinalis* Gaertn.) fruits cv.NA-10. Plant Archives. 2008; 8:911-13.
23. Singh S, Singh AK, Joshi HK. Standardization of maturity indices in aonla (*Emblica officinalis* Gaertn)

under semiarid conditions of Gujarat. Indian Journal of Agricultural Sciences. 2006; 76:591-595.
24. Srivastava CP, Singh HK, Vishwanath, Pratap B. Efficacy of foliar feeding of plant growth regulators along with urea on yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. 'NA-7' fruits. Annals of Horticulture. 2009; 2(1):77-79.
25. Taylor JE, Whitelaw CA. Signals in abscission. New Phytologist. 2001; 151(2):323-339.
26. Westwood MN. Plant efficiency: Growth and yield measurements. In: Temperate zone Pomology, W. H. Freeman and Company (San Francisco), 1978, 119-120.
27. Yadav S, Shukla HS, Ram RA. Studies on foliar application of NAA, $GA_3$, boric acid, and $Ca(NO_3)_2$ on fruit retention, growth, yield and quality of aonla (*Emblica officinalis* Gaertn.) cv. Banarasi. The Horticulture Journal. 2010; 23(2):64-67.
28. Zhang C, Tanabe K, Tani H, Nakajima H, Mori M, Itai A *et al*. Biologically active gibberellins and abscisic acid in fruit of two late-maturing Japanese pear cultivars with contrasting fruit size. Journal of the American Society for Horticultural Science. 2007; 132:452-458.