



RESEARCH ARTICLE

Impact of foliar application of naphthaleneacetic acid (NAA), boron (B) and gibberllic acid (GA₃) on fruit drop, yield and quality attributes of aonla (*Emblica officinalis* Gaertn. cv. NA-7)

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Abstract

The aonla is an important high value indigenous fruit crop an experiment on impact of foliar application of naphthaleneacetic acid (NAA), boron (B) and gibberllic acid (GA₃) on fruit drop, yield and quality attributes of aonla (*Emblica officinalis* Gaertn. cv. NA-7) was conducted at the Horticulture Garden, Chandra Sekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India, during 2024. Employing a randomized block design (RBD), with the one-way analysis of variance (ANOVA) the research involved 10 different treatments and 3 replications. Result revealed that the minimum fruit drop (63.47 %) and highest fruit retention (36.53 %) was observed in plants treated with T₆ (NAA at 30 ppm). Treatment T₈ (GA₃ at 50ppm) resulted in a maximum (4.38 cm) length, width of (4.96 cm), highest fruit weight (37.67 g), maximum fruit volume (35.21 cc), highest pulp weight (36.34 g), minimum stone weight (1.32 g), highest pulp: stone ratio (27.43), highest specific gravity (1.07 g/cc) and maximum fruit yield (96.92 kg/plant). The highest total soluble solids (15.16 °Brix), lowest titratable acidity (1.63 %), maximum ascorbic acid (607.67 mg/100g), highest total sugar (12.97 %) and highest moisture (94.11 %) with the foliar application of T₈ (GA₃ at 50 ppm). Thus, the information generated will help to develop the scientific package of practices for aonla cultivation, which in turn will help to improve the economy of farmers.

Keywords: aonla; foliar application; NA-7; quality attributes; yield improvement

Introduction

Aonla (*Emblica officinalis* Gaertn.) is a member of the Euphorbiaceae family has chromosomal number 2n = 28. It is mostly found in the tropical region of Southeastern Asia, specifically in the Central and Southern Indian peninsulas (1). It has been grown and known in India for more than 3500 years. It finds a special mention in the ancient Indian text 'Ayurveda' by Sushruta, the father of ancient medicine during 1500–1300 BC. India ranks first in the production of aonla, which occupies an area of 94000 ha with a production of 10.98 lakh metric tonnes. In Uttar Pradesh, aonla cultivation is maximum in nearby belts of the Pratapgarh and Ayodhya Districts. The area under the production of aonla is 15.75 ('000 ha), with 63.00 ('000 MT) of production and about 4.0 (MT per ha) productivity (2). The fruit is frequently used to make pickles, candies, jams, sauces, canned food (murabba) and other goods. It has more vitamin C (600 mg/100 g pulp) than citrus and guava fruits combined and it also includes phenols, polyphenols, tannins and alkaloids. Among other ailments, fruits are used as blood purifiers, antioxidants, laxatives, liver tonics and antibiotics. The nutritional composition of the fruit reveals its richness in moisture (81.2 %) along with moderate amounts of fibre (3.4 %) and carbohydrates (14.0 %). It contains 0.5 %, protein 0.1 % fat and 0.7 % mineral matter with calcium (Ca) present at 0.05 % and

iron (Fe) at 1.20 %. The calorific value is measured at 5 g/100 g. Notably, the fruit is an excellent source of vitamin C (600 mg/100 g) and also contains vitamin B (30 mg/100 g) and nicotinic acid (0.2 mg/100 g) emphasizing its nutritional importance while, the roots are enriched with lupeol and ellagic acid. The NA-7 is a mid-season and abundant regular bearer variety, seedling selection from Francis. Medium-sized to giant fruits have a conical tip a tiny bit more fibre is present than in NA-6. Foliar application of micronutrients and plant growth regulators (PGRs) plays a crucial role in enhancing fruit quality, yield and fruit set. These applications also help fruit crops overcome nutritional deficiencies and physiological disorders, thereby improving overall plant health and productivity.

The auxin as naphthaleneacetic acid (NAA) improved the quality of various fruits by increasing fruit set and decreasing fruit drop. Abscission is prevented in plants by an increase in auxin content (3). It has been demonstrated that the NAA significantly increases the production of synthetic auxin and cellulose fibre in plants. Fruit drop is managed by applying of NAA.

Boron (B) plays a vital role in pollen tube growth, ovule development and successful fruit set. Gibberellins are widely used in horticulture to enhance stalk elongation and increase fruit production. Their application improves fruit quality and storage life,

ensures uniform crop emergence and promotes cell division and elongation, leading to increased fruit size. Gibberellins (GA₃) also help delay fruit maturity, reduce fruit cracking and premature drop, improve fruit retention, induce seedless fruit development and enhance sugar content in various fruit crops when applied at appropriate concentrations (4).

Keeping the view of above fact, the present investigation was undertaken to comprehensively evaluate the influence of these factors on the overall performance of aonla trees. The scope of the study includes assessing their role in improving fruit retention, physical characteristics, biochemical quality and overall productivity, as well as addressing physiological disorders associated with fruit drop. The findings are expected to provide scientifically validated recommendations for the effective use of PGRs and micronutrients in aonla cultivation, thereby contributing to enhanced fruit quality, higher yields and improved economic returns for farmers.

Materials and Methods

A field experiment was carried out on a 24-year old orchard of aonla cv. NA-7 is located at Horticulture Garden, Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during 2024–25. Geographically, Kanpur district is located in a subtropical zone, between 25°26 to 26° 58 N latitude and 79.31° to 80.34° E longitudes. It is semi-arid with hot dry summers and severe cold winters. It is located at the alluvial belt of the Gangetic plains of Central Uttar Pradesh at 135 m above mean sea level. The annual rainfall of the district is 627.3 mm. The treatments includes, (T₁); Borax 0.2 %, (T₂); Borax 0.4 %, (T₃); Borax 0.6 %, (T₄); NAA 10 ppm, (T₅); NAA 20 ppm, (T₆); NAA 30 ppm, (T₇); GA₃ 25 ppm, (T₈); GA₃ 50 ppm, (T₉); GA₃ 75 ppm and (T₁₀) control (water spray) replicated thrice in randomized block design (RBD) were used to study their influence on fruit retention, yield and quality. The solution of NAA (10 ppm) was prepared by dissolving 10 mg NAA in small quantity of alcohol. The volume was made up to 1000 mL by adding distilled water. Similarly, (20 ppm) and (30 ppm) NAA solution was also prepared by dissolving 20 mg and 30 mg NAA in small quantity of alcohol respectively. The volume was made up to 1000 mL by adding distilled water. The solution of borax (0.2 %) was prepared by dissolving 20 g borax in 10 L of distilled water. Similarly, the solution of borax (0.4 %) and (0.6 %) was prepared by dissolving 40 g and 60 g borax in 10 L of distilled water respectively. The volume was made up to 1000 mL by adding distilled water. The solution of GA₃ (25 ppm) was prepared by dissolving 25 mg GA₃ in small quantity of alcohol. The volume was made up to 1000 mL by adding distilled water. Similarly, (50 ppm) and (75 ppm) GA₃ solution was also prepared by dissolving 50 ppm and 75 ppm small quantity of alcohol respectively. The volume was made up to 1000 mL by adding distilled water. The foliar sprays of NAA, B and GA₃ were applied once after the fruit set on 9th August 2024. Selected trees were sprayed with 10 L of solution which was found adequate to drench the entire foliage. The spraying was done in the morning using a pneumatic foot sprayer fitted with a nozzle and observations were recorded after foliar application till harvesting on fruit drop and fruit retention percentage. The physical characters of fruits i.e. fruit size (length and width of fruits), weight, fruit volume (cc), specific gravity, stone and pulp weight, pulp: stone ratio per cent, fruit yield and the chemical characteristics i.e., total soluble solids (TSS), titrateable acidity, ascorbic acid, total sugars, fruit moisture content. The TSS was

determined by hand refractometer in the 0–32° range. The values were corrected at 20 °C with the help of a temperature correction chart and expressed as °Brix. The acid content in aonla fruit was found by crushed 5 mL fruit juice in a warring blender taken in a 100 mL volumetric flask and volume made up to 100 mL with distilled water. Then 5 mL aliquot was taken for titration against standard N/10 NaOH solution using phenolphthalein as an indicator. The pink colour appearance and persistence were considered the endpoint. The result was calculated by following the formula and expressed in percentage.

$$\text{Acidity (\%)} = \frac{\text{Total weight of pulp titrate value} \times 0.1 \times 64 \times 100}{\text{Aliquot taken} \times \text{weight of sample taken} \times 1000}$$

To estimate ascorbic acid a 5 mL fruit juice sample was taken into a 50 mL volumetric flask with a volume of up to 50 mL with 3% metaphosphoric acid (HPO₃) solution. Thereafter, 5 mL aliquot was titrated against 2, 6- Dichlorophenol indophenol dye solution. The endpoint was marked by the appearance of pink colour which persisted for at least 15 sec. The content of ascorbic acid was expressed in mg/100 g fruit pulp sample after calculation using the following formula:

$$\text{Ascorbic acid (mg/100 g pulp)} = \frac{\text{Titrate value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot taken} \times \text{weight of sample taken}}$$

The modified Lane and Eynon approach as explained was employed to find the total amount of sugar in the fresh fruits. A 250 mL graduated flask was filled with 25 mL juice and 50 mL distilled water. 1 N NaOH was used to neutralise the contents. The material was then deproteinized by adding 2 mL of a 45 % (w/v) lead acetate solution. 2 mL of a 22 % (w/v) potassium oxalate solution was added to precipitate excess lead acetate. Distilled water was added to get the volume up to 250 mL and what man filter paper was used to filter the contents. After transferring 50 mL of the filtrate to a 250 mL volumetric flask 10 mL of 50 % HCl was added and the mixture was left at room temperature for a 24 hr. After neutralising the contents with a saturated NaOH solution the volume was increased to 250 mL. Using methyl blue as an indicator it was titrated against Fehling solution to ascertain the overall sugar content. The total sugars content in the samples was calculated as follows:

$$\text{Total sugars (\%)} = \frac{\text{Milligram of invert sugar} \times \text{dilution}}{\text{Titrate volume} \times \text{volume of sample} \times 1000}$$

The fruit moisture (%) was determined by using a sharp knife; the fruit was split transversely to determine the fruit moisture percentage. The stones were then removed and the remaining pulp was oven dried for 16 hr at 95 °C. The data recorded during the investigation were statistically analysed following the analysis of variance (ANOVA) for randomized block design (RBD) as suggested (5). Statistical significance was tested with an 'F' value at a 5 % level of probability by using Microsoft Excel.

Results and Discussions

Impact of foliar application of naphthaleneacetic acid (NAA), boron (B) and gibberlic acid (GA₃) on fruit drop, retention, physical and yield character

The fruit drop, retention, physical and yield character of aonla as reflected by various foliar applications of NAA, B and GA₃ acid is given in Table 1. Significant variation was recorded in fruit drop, fruit retention, fruit length (cm), fruit width (cm), fruit weight (g), fruit volume (cc), specific gravity (g/cc), fruit pulp weight (g), fruit stone weight (g), pulp: stone ratio and fruit yield (kg/plant). Among the different treatments, the minimum fruit drop (63.47 %) was observed under treatment T₆ (NAA at 30 ppm) closely followed by T₅ (NAA at 20 ppm) with (64.31 %). In contrast the maximum fruit drop (82.78 %) occurred in the control treatment (water spray) and the treatments T₆ (NAA at 30 ppm) recorded the highest fruit retention (36.53 %) followed by T₅ (NAA at 20 ppm) with 35.69 %. The lowest fruit retention (17.22 %) was recorded under the control treatment (T₁₀). The effectiveness of NAA in reducing fruit drop could be attributed to its role in enhancing endogenous auxin production thereby delaying abscission processes. These outcomes are in agreement with earlier research findings that emphasised the utility of PGRs in minimising fruit drop and the improvement in fruit retention may be associated with increased auxin levels, released by elongating pollen tubes, promoting fruit set and development (6, 7). Additionally, role in tryptophan biosynthesis, which subsequently elevates endogenous auxin levels, may have further contributed to reducing fruit drop and improving retention. These findings align with early reports (8, 9).

In case of fruit length and width, the longest fruit length (4.38 cm) was observed under treatment T₈ (GA₃ at 50 ppm) followed by T₇ (GA₃ at 25 ppm) with (4.31 cm) and T₆ (NAA at 30 ppm) with (4.28 cm). In contrast, the shortest fruit length (3.33 cm) was recorded under the control treatment (T₁₀). It was also evident from Table 1 that reduced nutrient concentration corresponded with a significant decrease in fruit length and widest fruits (4.96 cm) were recorded under treatment T₈ (GA₃ at 50 ppm) followed by T₇ (GA₃ at 25 ppm) with (4.54 cm). The narrowest fruit width (3.41 cm) was observed in the control treatment (T₁₀). The application of NAA, B and GA₃ likely enhanced the translocation of nutrients from source tissues to sink tissues (fruit), facilitating increased cell elongation and fruit enlargement. These results are consistent with previous findings (10, 11).

The increase in fruit width under NAA, B and GA₃ treatments attributed to enhanced cell division and cell elongation along with the improvement in nitrogen (N) metabolism, leading to larger fruit dimensions without negatively affecting yield and micronutrients that support the growth and development, improving the quality of the plant. These findings corroborate the early results (12, 13).

The data revealed that the highest fruit weight (37.67 g) was observed under T₈ (GA₃ at 50 ppm), followed by T₇ (GA₃ at 25 ppm) with (35.41 g). The lowest fruit weight (25.67 g) was recorded in the control treatment (T₁₀). Fruit weight was significantly affected by the foliar application of NAA, B and GA₃. The observed enhancement in fruit weight may be due to the increased cell division, cell enlargement and improved mobilisation of photosynthates toward the developing fruits under NAA, B and GA₃ treatments. These findings are supported by early observations (13, 14).

T₈ (GA₃ at 50 ppm) recorded statistically highest fruit volume (35.21 cc) which was found at par with T₇ (GA₃ at 25 ppm) at (33.39 cc). The minimum fruit volume (24.93 cc) was noted in the control (T₁₀) and the highest specific gravity (1.07 g/cc) was recorded under T₈ (GA₃ at 50 ppm), while the minimum (1.02 g/cc) was observed in the control treatment (T₁₀) which mentioned below (Table 2). The GA₃ significant increase in fruit volume may be attributed to the direct influence cells to divide and expand rapidly, directly increasing the fruit's dimensions on growth and its indirect impact on the accumulation and translocation of essential nutrients ultimately resulting in large fruit sizes. The findings align with the results of the early research findings (15, 16). The increased specific gravity observed due to enhanced pulp development and reduced stone weight resulting in heavier fruits. These observations are supported by the previous studies (6, 17–19).

The maximum pulp weight (36.34 g) was obtained with T₈ (GA₃ at 50 ppm) followed by T₇ (GA₃ at 25 ppm) with 34.04 g (Table 2). The minimum pulp weight (23.82 g) was recorded in the control treatment (T₁₀) and minimum stone weight (1.32 g) was observed under T₈ (GA₃ at 50 ppm), followed by T₇ (GA₃ at 25 ppm) with (1.38 g). The maximum stone weight (1.85 g) was recorded in the control (T₁₀). The application of NAA likely enhanced the biochemical activities and nutrient mobilisation within the developing fruit, resulting in higher pulp accumulation. These results are consistent with the early findings (5, 13, 28). The reduction in stone weight might be attributed to the metabolic stimulation caused by GA₃ which enhances sink strength and modulates enzymatic activities such as invertase and NAD dependent sorbitol dehydrogenase during fruit development. These findings align with the previous studies (12, 16).

Table1. Impact of foliar application of naphthaleneacetic acid (NAA), boron (B) and gibberlic acid (GA₃) on fruit drop, retention, fruit length, fruit weight and fruit weight character

Treatments	Fruit drop (%)	Fruit retention (%)	Fruit length (cm)	Fruit width (cm)	Fruit weigh (g)
T ₁ Borax at 0.2 %	70.2±74.22	26.58± 1.68	3.52±0.04	3.65±0.02	27.86±0.19
T ₂ Borax at 0.4 %	71.78±70.81	29.69±1.02	3.93±0.02	4.01±0.06	28.32±0.42
T ₃ Borax at 0.6 %	65.37±68.05	33.49±0.80	4.25±0.06	4.41±0.03	32.96±0.06
T ₄ NAA at 10 ppm	66.45±63.65	34.11±1.17	4.09±0.10	4.14±0.02	29.18±0.54
T ₅ NAA at 20 ppm	64.76±62.51	35.69±0.94	4.17±0.05	4.27±0.09	30.54±0.27
T ₆ NAA at 30 ppm	63.51±63.49	36.53±0.03	4.28±0.10	4.48±0.05	35.29±0.35
T ₇ GA ₃ at 25 ppm	69.08±68.94	31.13±0.15	4.31±0.09	4.54±0.11	35.41±0.75
T ₈ GA ₃ at 50 ppm	72.37±72.67	27.39±0.12	4.38±0.09	4.96±0.13	37.67±0.31
T ₉ GA ₃ at 75 ppm	73.23±74.31	25.14±1.13	4.22±0.10	4.32±0.02	32.41±0.75
T ₁₀ Control	81.92±80.23	17.22±1.77	3.33±0.06	3.41±0.04	25.67±0.34
CD	3.06	3.05	0.22	0.20	1.33
CV	2.51	5.95	3.15	2.76	2.44

NAA: naphthalene acetic acid; GA₃: gibberlic acid; CD: critical difference; CV: coefficient of variation.

Table 2. Impact of foliar application of naphthaleneacetic acid (NAA), Boron (B), gibberlic acid (GA₃) on fruit volume, specific gravity, pulp weight, fruit stone weight, pulp: stone ratio and fruit yield character

Treatments	Fruit volume (cc)	Specific gravity (g/cc)	Pulp weight (g)	Fruit stone weight (g)	Pulp : stone ratio (%)	Fruit yield (kg/plant)
T ₁ Borax at 0.2 %	26.91±0.45	1.03±0.006	26.14±0.18	1.72±0.02	15.19±0.16	75.12±0.04
T ₂ Borax at 0.4 %	27.44±0.43	1.03±0.010	26.64±0.42	1.68±0.01	15.57±0.11	76.64±1.08
T ₃ Borax at 0.6 %	30.94±0.62	1.06±0.012	31.44±0.06	1.52±0.03	21.1±0.38	80.78±0.63
T ₄ NAA at 10 ppm	28.03±0.45	1.04±0.006	27.54±0.50	1.64±0.04	16.76±0.26	77.64±1.16
T ₅ NAA at 20 ppm	29.18±0.17	1.04±0.010	28.94±0.30	1.59±0.03	18.22±0.16	78.84±1.11
T ₆ NAA at 30 ppm	33.27±0.54	1.06±0.012	33.83±0.33	1.47±0.04	23.03±0.60	82.84±0.56
T ₇ GA ₃ at 25 ppm	33.39±0.39	1.06±0.017	34.04±0.75	1.38±0.03	24.35±0.70	83.97±1.88
T ₈ GA ₃ at 50 ppm	35.21±0.57	1.07±0.012	36.34±0.30	1.32±0.03	27.43±0.77	86.92±0.59
T ₉ GA ₃ at 75 ppm	30.62±0.02	1.05±0.012	30.72±0.79	1.57±0.03	18.92±0.11	79.98±0.45
T ₁₀ Control	24.93±0.59	1.02±0.006	23.82±0.02	1.85±0.04	12.87±0.13	70.1±0.25
CD	1.21	1.33	1.33	1.27	2.88	
CV	2.35	2.57	2.57	3.82	2.10	

NAA: naphthalene acetic acid; GA₃: gibberlic acid; CD: critical difference; CV: coefficient of variation.

The highest pulp:stone ratio (27.43) was recorded under T₈ (GA₃ at 50 ppm) followed by T₇ (GA₃ at 25 ppm) at 24.35. The lowest ratio (12.87) was recorded in the control (T₁₀) are presented in (Table 3). The pulp: stone ratio increase may be due to the enhanced translocation and accumulation of sugars and minerals into the pulp under the influence of plant growth regulators (PGRs) and micronutrients. Similar results were previously documented (11, 14, 17).

The maximum fruit yield (86.92 kg/plant) was achieved with T₈ (GA₃ at 50 ppm), while the minimum yield (70.11 kg/plant) was recorded under the control (T₁₀) (Table 2). The synergistic effect of GA₃ in promoting fruit set and development, combined with NAA role in reducing fruit drop, likely contributed to the enhanced yield. These findings are consistent with early findings (16, 20).

Impact of foliar application of naphthalene acetic acid (NAA), boron (B) and gibberlic acid (GA₃) on bioactive compounds

Data concerning the bioactive compounds of aonla crop under as affected by various foliar applications of NAA, Boron, GA₃ acid is presented in Table 3. The significant variation was recorded TSS (°Brix), titratable acidity (%), ascorbic acid content (mg/100g pulp), total sugar content (%) and moisture content (%). Among the different treatments the highest TSS (15.16 °Brix) was recorded under treatment T₈ (GA₃ at 50 ppm), followed by T₇ (GA₃ at 25 ppm) at (14.92 °Brix). In contrast the minimum TSS (12.84 °Brix) was observed under the control treatment (T₁₀). The enhancement in TSS under these treatments could be attributed to the activation of enzymatic activities, particularly those involved in the hydrolysis of starch into soluble sugars. Furthermore, the application of NAA may have enhanced auxin biosynthesis, promoting metabolic activities that favour sugar accumulation. These findings are in line with those previously reported (16, 21, 22).

The proximate composition, titratable acidity (1.63 %) was observed under treatment T₈ (GA₃ at 50 ppm) closely followed by T₇ (GA₃ at 25 ppm) with 1.65 %. No significant difference was noted between T₈ and T₇. Meanwhile, the maximum titratable acidity (2.00 %) was recorded in the control treatment (T₁₀). The reduction in acidity levels could be attributed to the breakdown of organic acids via reverse glycolysis, leading to increased sugar accumulation. Additionally, PGRs may stimulate vegetative growth, resulting in metabolic shifts that lower acidity levels within the fruit. These observations are consistent with early findings (23, 24).

The highest ascorbic acid content (616.32 mg/100 g pulp) was recorded under treatment T₆ (NAA at 30 ppm), followed by T₅ (NAA at 20 ppm) with 611.33 mg/100 g pulp. The minimum ascorbic acid content (582.32 mg/100 g pulp) was observed in the control treatment (T₁₀). It is proposed that the foliar application of PGRs such as NAA and GA₃ enhances metabolic activities that favour the biosynthesis and accumulation of ascorbic acid. Gibberlic acid is known to promote cell elongation and division stimulating overall physiological activity. At the same time NAA enhances nutrient uptake and supports biochemical pathways responsible for vitamin C production. Boron plays an important role in the development of pollen tubes, ovules, fruit formation and quality of aonla fruits. These findings are corroborated by previous studies (21, 25, 26). The maximum total sugar content (12.97 %) was recorded under T₈ (GA₃ at 50 ppm) followed by T₇ (GA₃ at 25 ppm) with 12.54 % and T₆ (NAA at 30 ppm) with 12.34 %. The minimum total sugar (11.11 %) was observed in the control treatment (T₁₀). The increase in sugar content could be attributed to improved metabolic activity, particularly enhanced starch to sugar conversion during fruit ripening, under the influence of PGRs. The findings are in agreement with those early reported (6, 27, 28).

Table 3. Impact of foliar application of naphthaleneacetic acid (NAA), Boron (B), gibberlic acid (GA₃) on total soluble solids (TSS), titratable acidity, ascorbic acid, total sugar and fruit moisture character

Treatments	TSS (brix)	Titratable acidity (%)	Ascorbic acid (mg/100g fruit pulp)	Total sugar (%)	Fruit moisture (%)
T ₁ Borax at 0.2 %	13.12±0.23	1.99±0.03	587.7±1.80	11.38±0.31	91.16±0.98
T ₂ Borax at 0.4 %	13.78±0.13	1.97±0.05	592.6±10.49	11.64±0.11	91.64±0.57
T ₃ Borax at 0.6 %	14.14±0.09	1.78±0.02	596.4±2.95	12.13±0.03	92.84±0.05
T ₄ NAA at 10 ppm	13.96±0.17	1.95±0.04	609.4±0.63	11.81±0.16	91.84±1.86
T ₅ NAA at 20 ppm	13.97±0.23	1.91±0.03	611.3±2.86	11.94±0.16	92.12±0.09
T ₆ NAA at 30 ppm	14.44±0.19	1.74±0.04	616.3±4.50	12.34±0.07	93.52±0.30
T ₇ GA ₃ at 25 ppm	14.92±0.36	1.65±0.02	602.3±6.90	12.54±0.16	93.91±0.30
T ₈ GA ₃ at 50 ppm	15.16±0.28	1.63±0.04	604.3±7.23	12.97±0.09	94.11±1.03
T ₉ GA ₃ at 75 ppm	14.02±0.03	1.84±0.03	600.1±4.37	12.01±0.09	92.44±1.05
T ₁₀ Control	12.84±0.12	2±0.04	582.3±7.88	11.11±0.10	89.42±0.70
CD	0.64	0.10	17.81	0.40	2.37
CV	2.65	3.28	1.71	1.94	1.49

NAA: naphthalene acetic acid; GA₃: gibberlic acid; CD: critical difference; CV: coefficient of variation.

Data concerning to the highest fruit moisture content (94.11 %) was observed under treatment T₈ (GA₃ at 50 ppm), followed by T₇ (GA₃ at 25 ppm) at (93.91 %) and T₆ (NAA at 30 ppm) at (93.52%). The minimum fruit moisture (89.42 %) was recorded in the control treatment (T₁₀). Although limited published reports discuss the direct influence of foliar applied growth regulators on fruit moisture content in aonla, the observed increase could be associated with improved physiological processes like water uptake and retention promoted by GA₃ and NAA treatments. This aspect merits further detailed investigation (4).

Conclusion

This study confirmed that foliar application of naphthalene acetic acid (NAA), Borax and gibberlic acid (GA₃) significantly improves fruit retention, physical attributes, biochemical quality and overall yield in aonla cv. NA-7. Among all treatments GA₃ at 50 ppm emerged as the most effective for enhancing yield and chemical quality attributes, while NAA at 30 ppm was superior for minimising fruit drop and maximising fruit retention. The results suggest that the strategic foliar application of plant growth regulators (PGRs) and micronutrients can be a sustainable horticultural practice to improve productivity and fruit quality of aonla under semiarid conditions. The findings highlight the crucial importance of PGRs and micronutrients in enhancing aonla production. Future research should focus on optimising these treatments to maximise their effectiveness providing greater benefits to the agricultural community and promoting sustainable practices in fruit.

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Authors' contributions

ST conducted the experiment, curate the data, performed the formal analysis and wrote the original draft of the manuscript. VKT provided substantial guidance, supervised the research and facilitated the work by providing necessary laboratory facilities, data analysis, experimental guidance and manuscript drafting, conceptualisation, supervision and validation. Visualisation carried out by ST and VKT. The writing review and editing were done by SP and VKT. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: All authors declare that they have no conflict of interest.

Ethical issues: None

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