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Influence of Pre-harvest Application of NAA, Ca, and B on Fruit Drop, and Yield of Thailand Ber (*Ziziphus mauritiana*)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study was carried out to investigate the beneficial effects of the pre-harvest spray of NAA, calcium, and boron on fruit drop and yield of Thailand ber (*Ziziphus mauritiana*) at the Experimental Farm, Department of Horticulture, AAU, Jorhat-13 during 2022-2023. The treatment T_4 i.e. spraying with NAA @ 20 ppm + B @ 0.5% resulted in maximum fruit set (4.68%), lesser fruit drop (53.28%), the highest yield per tree (18.12 kg/tree), yield per hectare (24.16 t), the maximum thickness of pulp (1.94 mm) and pulp weight (62.25 g). Spraying of NAA 20 ppm in combination with Boron 5% is the most profitable approach for minimizing fruit drop and maximizing production.

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Keywords: Calcium; boron; fruit drop; fruit retention NAA.

1. INTRODUCTION

One of the oldest and most popular fruits native to China and India is the ber (*Zizyphus mauritiana* Lamk.), which is in the family Rhamnaceae and genus *Zizyphus.* Genus *Zizyphus* consists of 50 genera and more than 600 species [1]. Ber fruits are packed with vitamins, carotenoids, pectin, and minerals. They have higher ascorbic acid content than citrus and are second only to guava among tropical fruits [2]. In recent years, Thailand developed a crossbreed (green apple x jujube) variety of ber called “Thailand ber” or “Thai Apple ber” that is rapidly gaining popularity worldwide. The new cultivar has an apple-like appearance [3]. Thailand ber plants bear large round to ovate fruits. It outperforms in terms of both quality and economic benefits. As a result, Thailand ber cultivation is growing in popularity across India, especially in Assam. Round green and roundish ovate reddish varieties are commonly grown in Assam [4]. It also bears fruit within 6 to 8 months of planting and is very nutritious. Delicious fruits have a crunchy texture and are very juicy and sweet.

Fruit drop is the separation of premature fruits from the attached plant. When pollination occurs in ber, there is a significant loss of blooms and ovaries due to various reasons. The majority of fruit drop occurs at an early stage of fruit development (pea stage). Numerous factors, including hormonal instability, embryonic abortion, and unfavourable weather are responsible for immature fruit drop in ber [5].

The growth regulators and micronutrients play a significant role in vegetative propagation, inducing seedlessness, increasing fruit set, preventing pre-harvest fruit drop, regulating flowering, controlling fruit size, thinning flowers and fruits, and improving fruit quality and yield in many fruit crops. Mineral nutrients also play a role in the flowering and fruiting processes, pollen germination, cell division, and glucose metabolism. Exogenous application of plant growth regulators can effectively prevent fruit drop in ber.

Keeping all the above-mentioned facts and issues into consideration, the present investigation has been undertaken with the objective to study the influence of NAA, Ca, and B on premature fruit drop and yield in Thailand Ber.

2. MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat 13 during 2022- 2023. The standing crop of Thailand Ber (*Ziziphus mauritiana*) with a spacing of 2.5 m x 3m was selected for this experiment. The experiment was laid out in a Randomized Block Design with seven treatments and four replications. The crop was sprayed with seven treatments *viz.,* T_0- Control, T_1-NAA @ 20ppm, T_2-Borax @ 0.5%, T_3-$CaCl_2$ @ 1%, T_4-NAA @ 20ppm + Borax @ 0.5%, T_5-NAA @ 20ppm + $CaCl_2$ @ 1%, T_6-NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%. The foliar application of the treatments was done thrice at 45-day intervals after flower initiation. Ten litres of the solution, which was determined to be sufficient to completely soak the foliage, were sprayed over each tree.

Using a pneumatic foot sprayer equipped with a nozzle, the spraying was carried out in the afternoon between 3 and 5 PM. Each tree's five uniform branches were tagged. Before the first spray, the flower buds in the chosen cymes were counted. At seven days following the second spray, the number of little fruits that had been set on each marked branch was counted. The plants were covered with nylon nets to protect the entire experimental area from birds.

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The per cent fruit set was calculated by dividing the number of fruits by the number of flowers. The number of buds/fruitlets retained on each branch was counted at 15-day intervals after foliar application. The average number of fruit dropped from each branch was calculated in percent drop by subtracting the number of fruitlets at the initial from the number of fruit retention at harvest and dividing it by the number of fruitlets at the initial.

The fruits' length and girth was recorded using a vernier caliper and expressed in cm. The fruit volume was calculated using the water displacement method using a measuring cylinder and expressed in cc. Fruit weights were measured in grams using an electronic balance. To calculate the yield per plant in kg, the total number of fruits in each individual plant was recorded and the average fruit weight of the plant was multiplied by that number. The yield per plant was multiplied by the total number of plants for each treatment and expressed in kg/ha. The fruit surface colour was determined by HunterLab ColourQuest XE colourimeter,

The experiment was laid out in a Randomized Block Design with seven treatments and four replications. Observations obtained during field trials along with data acquired from laboratory investigations were subject to analysis of variance (ANOVA). 'F' values were used to calculate the significance and non-significance of the variance [6]. Critical differences at a 0.05 % probability level were calculated only when the 'F' value was significant.

3. RESULTS AND DISCUSSION

3.1 Flowering and Fruiting Parameter

Foliar applications of $CaCl_2$ and NAA in combination required lesser time to reach maturity than in other treatments. Calcium binds with pectin, producing calcium pectate which increases middle lamella rigidity and resistance to enzymes that break down pectin, including polygalacturonase [7]. These results are in agreement with prior reports of Schlegel and Schonherr [8] on apples and Abbasi et al*.* [9] on tomatoes.

NAA in association with boron significantly influenced the flowering and fruit set in ber as boron levels affected the pollen tube growth and pollen germination [10]. The effects of NAA on plant growth are strongly influenced by the time of application and concentration levels. NAA enhances fruit set by preventing pre-harvest fruit drop by reducing the impact of ethylene [11]. Boron regulates metabolic processes involved in the translocation of carbohydrates, the formation of cell walls, and the synthesis of RNA [12]. These factors led to an improvement in flowering and fruit set in ber during the experimentation. These results are in accordance with the reports of Shukla [13] Helal et al. [14] and Badal and Tripathi [15].

3.2 Fruit Drop and Fruit Retention

Fruit growth and development after fruit set is largely dependent on photosynthates supplied by leaves, and an increase in sink ability in fruit via increased levels of endogenous growth promoters, which regulate the mobility of nutrients and photosynthates from the source (leaves) to the sink (fruit), resulting in increased fruit growth and development and decreased fruit drop [16].

NAA and B when applied alone or in combination enhanced the fruit retention thereby preventing fruit drop. NAA's beneficial role in fruit retention could be attributed to its involvement in cell division, cell elongation, and increased volume of intercellular spaces in mesocarpic cells, which could have improved plant health and resulted in a healthy fruit, which was ultimately beneficial in fruit retention [17]. The exogenous application of NAA might delay the abscission of the fruit's outer layer, thereby increasing fruit retention. It might also have enhanced auxin levels in plants which prevented fruit drop.

Table 1. Days from flowering to harvesting, flower/plant, fruit set, fruits/plant

Treatments	Days from flowering to harvesting	Flower per plant	Fruit set %	Fruits per plant
T_0: Control	125.50	14090.00	3.99	241.25
T_1: NAA @ 20ppm	103.75	15337.50	4.23	304.75
T_2: Borax @ 0.5%	105.00	16342.50	4.48	308.00
T_3: $CaCl_2$ @ 1%	102.50	16340.00	4.26	300.50
T_4: NAA @ 20ppm + Borax @ 0.5%	103.25	17197.50	4.68	346.25
T_5: NAA @ 20ppm + $CaCl_2$ @ 1%	99.50	16160.00	4.48	325.25
T_6: NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%	102.25	16975.00	4.57	328.00
Mean	105.96	16063.21	4.43	307.75
S.Ed (±)	1.414	4.062	0.019	1.621
CD (0.05)	2.971	8.535	0.041	3.382

Table 2. Fruit drop, fruit retention, yield/tree, and yield/ha

Treatments	Fruit drop %	Fruit retention %	Yield/tree (kg)	Yield/ha (t)
T_0: Control	62.80	37.20	12.98	17.30
T_1: NAA @ 20ppm	54.46	45.54	16.25	21.66
T_2: Borax @ 0.5%	54.17	45.83	16.50	21.99
T_3: $CaCl_2$ @ 1%	56.84	43.16	15.81	21.08
T_4: NAA @ 20ppm + Borax @ 0.5%	53.28	46.72	18.12	24.16
T_5: NAA @ 20ppm + $CaCl_2$ @ 1%	57.74	42.26	17.50	23.33
T_6: NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%	57.71	42.29	17.60	23.46
Mean	56.71	43.29	16.39	21.85
S.Ed (±)	0.537	0.536	0.232	0.308
CD (0.05)	1.130	1.127	0.487	0.647

Boron reduced fruit drop and increased fruit retention as it played an important role in increasing pollen viability and fertilization, carbohydrate translocation, and synthesis of auxin that delayed the formation of the abscission layer in the earlier stages of fruit development [18]. The results conform with the reports of Gill and Bal [19] Sharif et al*.* [20] Tirkey et al*.* [21] Singh and Singh [22] and Badal and Tripathi [15].

3.3 Yield and Yield Attributing Parameters

The increase in yield owing to NAA and Boron applied in combination is associated with a high rate of enzymatic activity as well as biosynthesis of auxin, as well as an increase in the number and size of fruit, which ultimately increased the yield per plant [22]. As a direct correlation between the auxin content and fruit growth has been reported by Krishnamoorthy [23] the application of NAA at the preharvest stage may have increased the auxin level in fruits, which ultimately may have helped in the improvement of cell size and subsequently fruit size.

Calcium chloride has the greatest impact on fruit length and volume because it increases cell size and the strength of the carbohydrate sink [24]. The major roles that boron played in increasing fruit size and weight in the current experiment can be attributed to its ideal dose, which may have generated the desired improvement due to its involvement in hormone metabolism, accelerated cell division, elongation, and expansion of cells and it may have aided in the mobilization of food materials to the fruits, thereby boosting their size and weight [22]. The increased fruit weight might be related to the strengthening of the middle lamella and, as a result, the cell wall, which might have increased the free passage of solutes to the fruits [25]. The results are in accordance with the reports of Phookan et al*.* [26] Londe et al*.* [27] Dixit et al*.* [28] and Arora and Singh [29].

Table 3. Fruit length, fruit girth, fruit volume, and fruit weight

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cc)	Fruit weight (g)
T_0: Control	4.92	4.50	54.75	52.25
T_1: NAA @ 20ppm	5.00	4.83	66.00	65.25
T_2: Borax @ 0.5%	4.92	5.60	64.75	63.75
T_3: $CaCl_2$ @ 1%	5.65	4.80	68.00	64.25
T_4: NAA @ 20ppm + Borax @ 0.5%	5.38	4.70	62.25	65.25
T_5: NAA @ 20ppm + $CaCl_2$ @ 1%	5.25	4.88	60.75	61.25
T_6: NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%	5.20	4.75	61.25	57.25
Mean	5.19	4.86	62.54	61.32
S.Ed (±)	0.241	0.229	2.523	1.856
CD (0.05)	0.495	0.486	5.070	3.899

Table 4. Thickness of pulp, pulp weight, stone weight, and pulp stone ratio

Treatments	Thickness of pulp (cm)	Pulp weight (g)	Stone weight (g)	Pulp stone ratio
T_0: Control	1.70	47.50	4.08	11.66
T_1: NAA @ 20ppm	1.90	61.75	3.25	19.23
T_2: Borax @ 0.5%	1.85	61.00	3.00	20.33
T_3: $CaCl_2$ @ 1%	1.85	60.75	3.00	20.25
T_4: NAA @ 20ppm + Borax @ 0.5%	1.94	62.25	3.25	19.44
T_5: NAA @ 20ppm + $CaCl_2$ @ 1%	1.85	58.50	3.50	17.27
T_6: NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%	1.75	54.25	3.00	18.08
Mean	1.83	58.00	3.30	18.04
S.Ed (±)	0.051	2.021	0.251	1.541
CD (0.05)	0.105	4.245	0.527	3.238

Table 5. CIE L*, CIE a*, CIE b*, CIE H* and CIE C* value

Treatments	CIE L*	CIE a*	CIE b*	CIE H*	CIE C*
T_0: Control	65.21	-10.00	45.30	-1.35	46.44
T_1: NAA @ 20ppm	62.78	-9.82	45.42	-1.36	46.48
T_2: Borax @ 0.5%	64.09	-9.67	43.54	-1.35	44.64
T_3: $CaCl_2$ @ 1%	63.62	-9.08	44.12	-1.37	45.09
T_4: NAA @ 20ppm + Borax @ 0.5%	61.12	-12.08	44.29	-1.30	45.91
T_5: NAA @ 20ppm + $CaCl_2$ @ 1%	63.62	-11.13	44.11	-1.32	45.51
T_6: NAA @ 20ppm + Borax @ 0.5% + $CaCl_2$ @ 1%	62.55	-9.92	44.50	-1.35	45.63
Mean	63.28	-10.24	44.47	-1.34	45.67
S.Ed (±)	1.890	1.368	1.217	0.021	1.200
CD (0.05)	NS	NS	NS	0.045	NS

3.4 Physical Characteristics of Fruit

Combined application of NAA and boron had a stimulatory effect on the plant metabolism which enhanced the thickness and weight of pulp. Boron, either alone or in combination, also contributed to the maximum increase in pulp by accelerating the transport of photosynthates from the leaf to the fruits [30]. Similar results were reported by Tirkey et al*.* [21] Gaur et al*.* [31].

The decrease in stone weight in NAA-treated fruits could be attributed to auxins inducing a parthenocarpic effect, resulting in decreased stone weight [32]. NAA possibly enhanced solid deposition, which increased cell size by increasing water storage in intracellular space, which might have reduced stone weight [25]. The application of boron increased the pulp weight while decreasing the stone weight, resulting in a high pulp/stone ratio. Similar results were reported by Bankar and Prasad [33] Bal et al*.* [34] Singh et al*.* [35] and Brahmachari and Kumar [36].

3.5 Fruit Surface Colour

All fruits reached a point of maximum ripeness, followed quickly by decomposition. Colour can help determine the ripeness of fruits. It is also necessary to evaluate how pre- and post-harvest treatments affect fruit colour. Colour features include hue, which is a visual phenomenon in which a region appears to have characteristics of one or more proportions of the four recognized colors - red, yellow, green, and blue and so hue angle value is the actual observed colour [37]. The angle between 0°and 360° of the colour wheel is represented by hue. The saturation level of colour is measured by chroma.

The L* (lightness) axis is 0 for black and 100 for white. L* value ranged from 61.12 (darkest) in T_4 to 65.21 (lightest) in T_0. For a* axis, positive values are shown as red, negative values as green, and 0 is the neutral value. The a* value ranged from -9.08 (less green) in T_3 to -12.08 (more green) in T_4. The negative value of 'a*' indicates the greenness of ber fruits. For the b* axis, positive values are shown as yellow, negative values as blue, and 0 is the neutral value. The b* value ranged from 43.54 (less yellow) in T_2 to 45.42 (slightly more yellow) in T_1. The a* and b* values of all the fruits lied in the second quadrant with H* value ranging from -1.30 in T_4 to -1.37 in T_3.

The hue angle ranged from 105° in T_4 and 102° in T_3 which indicated that the green fruits had a tinge of yellow colour in them. C* value was in the range of 44.64 (less intense) in T_2 to 46.48 (more intense) in T_1. A study of fruit skin colour in the apple variety 'Granny Smith, revealed that colour changes were primarily caused by variations in green pigment concentrations (chlorophylls) and were almost independent of yellow pigment concentrations (carotenoids and flavonoids). Since the human eye is particularly sensitive to the presence of green colour, the consequent yellower fruit hue might have been partially caused by decreased chlorophyll levels unmasking yellow pigments [38].

4. CONCLUSION

The treatment T_4 (NAA @ 20 ppm + B @ 0.5 %) was best in terms of fruit set, fruit drop, and various yield parameters. It is evident from the data that using exogenous plant growth regulators and nutrients can yield positive outcomes if the proper spraying interval and dose of growth regulator and nutrients are employed. Growth regulators, micro and macronutrients show economic viability and ease of administration for farmers with low concentration and one-time application. Therefore it can be recommended for practice to increase production. In Assam, areas under Thailand ber cultivation is increasing due to its high demand. Fruit drop is a limiting factor as it causes yield losses. Foliar application of PGR's and nutrients can be utilized for improved production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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