



RESEARCH ARTICLE

Enhancing yield and quality of mango cv. Amrapali through foliar and soil application of boron

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Abstract

This experiment was conducted at Bangladesh Agricultural University Germplasm Centre (BAU-GPC) and Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during November 2023 to July 2024 to explore the effects of boron (B) on reduction of fruit cracking and improvement of yield and quality of mango cv. Amrapali. The experiment was laid out in randomised complete block design (RCBD) with 3 replications. The study comprised of eight treatments viz., T₁: Control, T₂: 50 g/plant of boric acid (BA) by soil application (SA), T₃: 100 g/plant of BA by SA, T₄: 150 g/plant of BA by SA, T₅: 0.5 % of BA by foliar application (FA), T₆: 1 % of BA by FA, T₇: 1.5 % of BA by FA, T₈: 50 g of BA by SA + 0.5 % BA by FA. Boron was applied in December, while FA was done in twice at pea and marble sizes of fruits. Results show that number of fruits per plant (182.67), fresh weight (188.83 g/fruit), length (10.31 cm), diameter (7.02 cm), weight of fruits (19.73 kg/plant), weight of marketable fruits (19.64 kg/plant), marketable yield (7.86 t/ha) and total sugar content (16.11 %) were the highest, while fruit cracking (0.37 %), titratable acidity (TA) (0.21 %) were the lowest in treatment T₆ (1 % of BA by FA) as compared to control. The control plants exhibited the maximum fruit cracking, lowest total sugar, highest TA with lower fruit quality and smaller fruits, whereas treatment T₆ performed successful for nominal cracked fruits, highest marketable fruit yield and better quality of mango cv. Amrapali.

Keywords: boric acid; improving marketable yield; reducing fruit cracking; titratable acidity; total sugar

Introduction

Mango (*Mangifera indica* L.), is a very significant fruit in Bangladesh, is also known as the "king of fruits" and belongs to the family Anacardiaceae. It originated on the Indian subcontinent during prehistoric times (1). Plant nutrients are essential chemical elements required for plant growth, development and metabolic activities. The external application of mineral nutrients can modify and regulate physiological processes when applied directly to the foliage in low concentrations. Plants can absorb essential elements through the stomata and epidermal cells of the leaves. Nutrients supplied through foliar application are generally absorbed more quickly and efficiently than those applied to the soil.

Mangoes grow abundantly in Bangladesh. Rajshahi and Chapai Nawabgonj mangoes are popular both domestically and internationally. The climate and soil of Rajshahi are ideal for growing mangoes. Mango thrives in somewhat acidic (pH: 5.5–7.5) and well-drained soil, whether sandy, loam, or clay. Mango is also drought resistant and can tolerate the rare flood.

Bangladesh has significant potential for mango production and export, especially in the north, where considerable amounts of mango are produced each year. However, there is significant potential for producing and exporting high-quality mango (2). The mango is one of the most delicious fruits in the world. However, each variety has its own distinct taste and flavour. Mango is best

consumed in its fresh condition. The current daily availability of fruits per person in Bangladesh is around 85 g, while the daily requirement for an adult is 250 g, indicating a significant deficit of fruits (3). It also contains a considerable amount of carbohydrates (4). Furthermore, each 100 g edible chunk of mango has up to 74 Kcal, which is roughly equal to the energy content of boiling rice of comparable weight (5).

Mango is one of the most cultivated, traded and popular fruits in Bangladesh and throughout the world. It is one of the world's most significant tropical and subtropical fruits, popular in both fresh and processed versions. Bangladesh produces 1482937.04 metric tonnes of mangoes from 306274.32 ha. of cultivated land (6). Mango is an important and popular fruit in Bangladesh. It has achieved a unique position in terms of nutritional content, flavour and customer choice among the approximately 50 varieties of fruit crops cultivated in Bangladesh. In addition, mango is today regarded as one of the top fruits on the global market. Mango is currently grown commercially in many areas across the world.

However, in recent years, mango output has declined due to a lack of micronutrients, notably boron (B), as well as other environmental pressures (7). Mango trees are susceptible to a variety of illnesses and disorders, which may negatively impact productivity, quality, market value and exports. A variety of physiological diseases can potentially harm trees (8). Fruit cracking is a severe economic concern in many fruit crops and the extent of the damage varies by cultivar (9). In subtropical portions of Uttarakhand, India, the primary

mango cultivars include 'Dashehari', 'Langra' and 'Chausa', with Dashehari being the highest to fruit cracking. Typically, the skin and flesh split, revealing the stone or seed and the damaged fruits are unmarketable (10). The breaking might be rather superficial, yet the fruit remains unmarketable. There were three types of main cracking detected in general: longitudinal, star and horizontal. In the instance of longitudinal fruit cracking, the stone was completely exposed, but in star cracking, the damaged fruits had star-shaped breaks in their skin. Cracking may begin at the calyx end of the fruit, although it is more commonly observed on the side.

Cracking might be caused by a lack of water, Boron, or calcium. Extreme temperatures, humidity and rainfall may all add to the condition. It decreases production by up to 20 % in 'Dashehari' mango cultivars (7). The current study gives information on the kind of cracking, the timing of cracking, the morphology of the damaged fruits and the potential impacts of weather on the disease. The data was gathered over several seasons on trees of the vulnerable cultivar 'Dashehari'. Mango quality production, market value and export are limited by a variety of issues, including nutritional problems. Boron, among other minerals, has a significant impact in the decline of mango quality and output potential (11).

During fruit growth, an appropriate B supply becomes challenging, especially in locations with acid sandy soils that receive a lot of rain. Furthermore, B is easily leached under these circumstances (12). From the above review it is found that application of Boron either in soil or foliar may significantly reduce fruit cracking in mango by improving cell wall strength and peel elasticity. Therefore, this study was undertaken to determine the optimum dose of boric acid (BA) for reducing fruit cracking and improving yield and quality of mango cv. Amrapali.

Materials and Methods

Experimental site and plant materials

The experiment was conducted at Bangladesh Agricultural University Germplasm Centre (BAU-GPC) and Postharvest Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh, from November 2023 to July 2024. The experimental site is located at 24°25' N latitude and 90°50' E longitude, at an elevation of 18 m above sea level. The plant materials were approximately 16 years old mango plants cv. Amrapali, grown at the Bangladesh Agricultural University Germplasm Centre.

Weather status of the experimental area

The temperature data represents a clear seasonal pattern, with air temperature declining from November to a minimum in January (mean ~17.5 °C), followed by a steady increase, reaching peak levels during April–May (mean ~29–30 °C). Maximum temperature ranged from 21.7 °C (January) to 35.1 °C (April), while minimum temperature varied from 13.0 °C (January) to 27.5 °C (July). These conditions are critical for mango cv. Amrapali, where cooler temperatures during December–January favour floral induction and the subsequent rise in temperature supports flowering, fruit set and development (Fig. 1).

Relative humidity shows moderate seasonal variation, with maximum relative humidity remaining consistently high (92.7–97.7 %) throughout the study period. Minimum relative humidity ranged from 47.8 % (February) to 75.0 % (June), while mean relative humidity varied between 74–86 %, showing relatively lower values during February–April and higher levels during the monsoon months (June–July). Such humidity conditions, characterised by moderate levels during flowering and higher levels during fruit development, are favourable for the mango cv. Amrapali (Fig. 2).

Rainfall distribution exhibits a distinct seasonal pattern, with negligible precipitation during winter months (November–January; 0–26.5 mm) and a gradual increase from February (17.3 mm) to March (72 mm), followed by a sharp rise during the monsoon period, peaking in June (413.6 mm). Such rainfall dynamics indicate dry conditions during floral induction and early flowering, which are favourable for the mango cv. Amrapali, while increased precipitation during later stages supports fruit development (Fig. 3).

Sunshine hours show a clear fluctuating trend, with a maximum in November (235.2 hr) and a secondary peak during March–April (214.9–215.7 hr), while minimum values were recorded in June (84.1 hr) and January (92.9 hr). The overall pattern showed a decline from November to January, followed by a gradual increase up to April and a sharp decrease towards June, indicating a seasonal flow of solar radiation availability during the experimental period (Fig. 4).

Experimental design and treatments

The experiment was laid out in randomised complete block design (RCBD) with 3 replications and 8 treatments. A single plant was considered as a replication. So, the total number of the plants was 24. The treatments were T₁: control (without BA application), T₂: 50 g/plant of BA by soil application (SA), T₃: 100 g/plant of BA by SA, T₄: 150 g/plant of BA by SA, T₅: 0.5 % of BA by foliar application (FA), T₆: 1 % of BA by FA, T₇: 1.5 % of BA by FA, T₈: 50 g of BA by SA + 0.5 % BA by FA

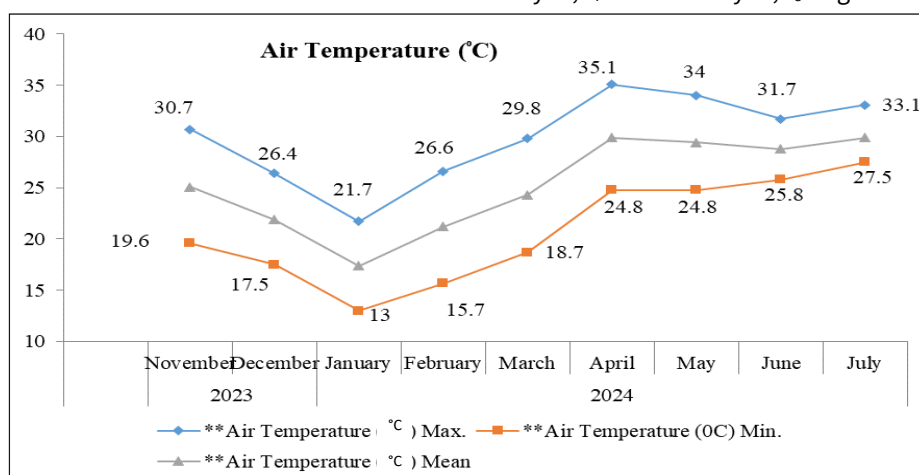


Fig. 1. Month wise maximum, minimum and mean temperature during the experimental period at BAU-GPC, Mymensingh, Bangladesh

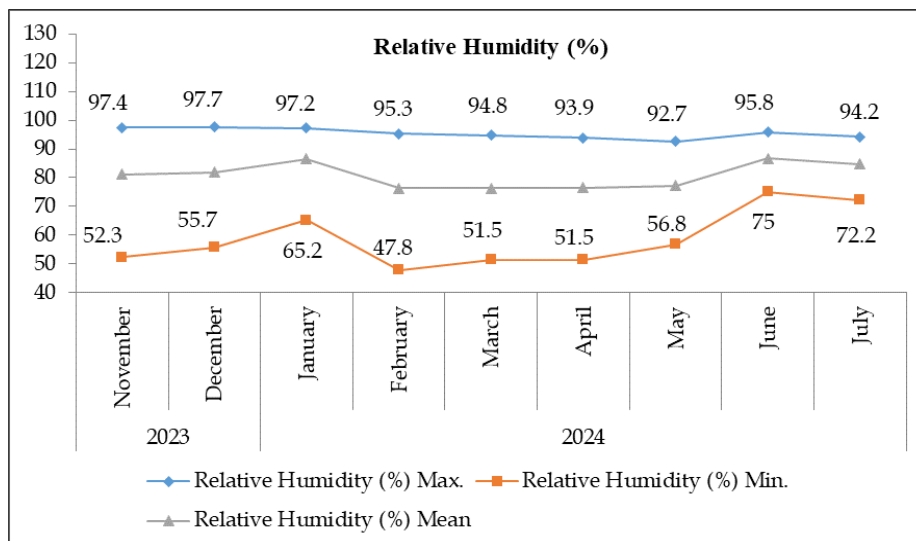


Fig. 2. Month wise maximum, minimum and mean relative humidity during the experimental period at BAU-GPC, Mymensingh, Bangladesh.

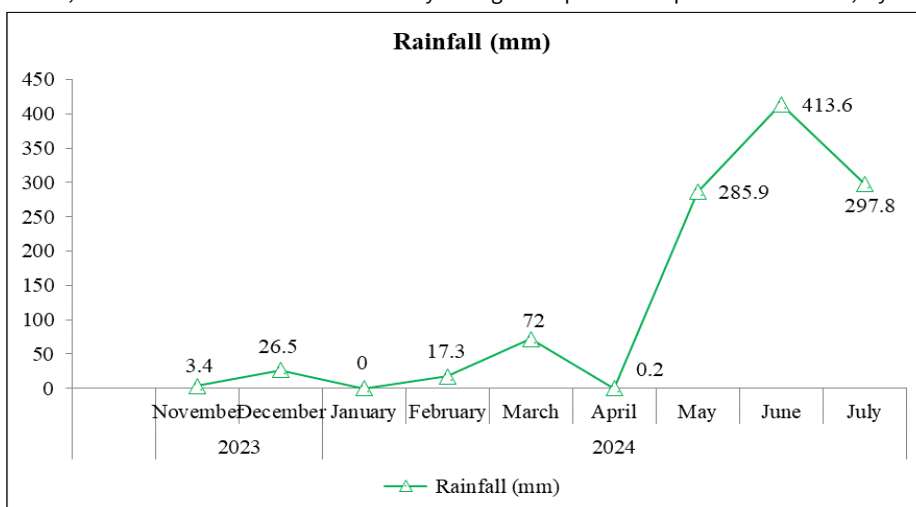


Fig. 3. Month wise rainfall status during the experimental period at BAU-GPC, Mymensingh, Bangladesh

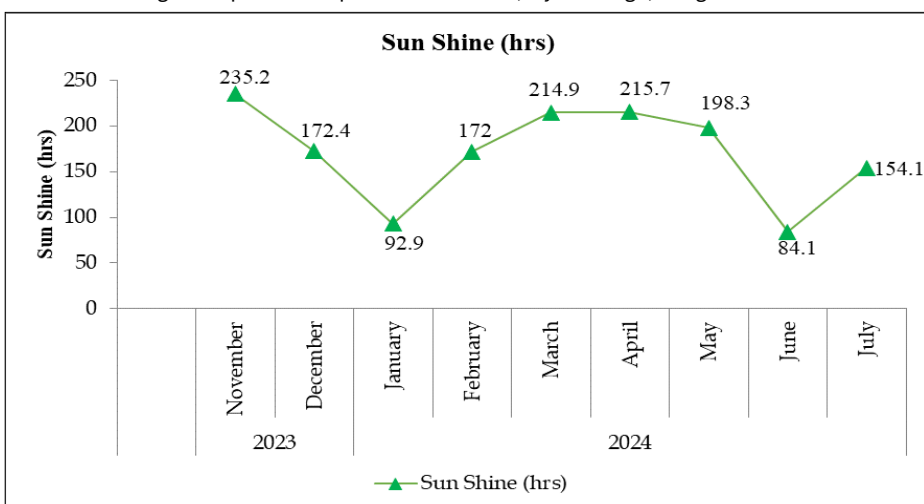


Fig. 4. Month wise sun shine (hr) during the experimental period at BAU-GPC, Mymensingh, Bangladesh. * Monthly total, ** Monthly average. Source: Weather yard, Department of Irrigation and Water Management, Record of Climatologically observation, Bangladesh Agricultural University, Mymensingh-2202.

per plant.

Application of manures and fertilisers

The recommended doses of manures and fertilisers for 16 years old mango tree were applied into two instalments. Manures and fertilisers were applied at 100–120 cm away from the base of the plant and mixed well with soil followed by light irrigation. All manures and fertilisers were applied in the soil except BA. Boric acid

was applied according to treatment of the study. Soil application of BA was done in a single time in the first week of December and foliar application was done twice such as at pea stage and marble size of mango fruits.

Data recorded

Fruits were harvested manually with proper care at the mature stage and kept them separately on a plastic sheet at the Germplasm



Plate 1. Picture showing different views of experimental activity of mango at BAU-GPC, Mymensingh, Bangladesh.

Centre premises (Plate 1). The total fresh weight of fruits per plant was weighed using a digital pan balance and expressed in kilograms (kg/plant), number of fruits per plant was counted and recorded according to the treatment. Thereafter, sorting all harvested fruits to separate cracked fruits and marketable fruits (Plate 2 and Plate 3). The weight of marketable fruits was recorded by a similar digital balance and expressed in kilograms (kg) per plant.

Marketable fruit yield per hectare

The plants of the experimental mango orchard were previously planted following a spacing of 5 m × 5 m. The marketable yield per plant was estimated to find out the value of marketable yield per hectare. So, the number of plants per hectare was calculated by using the following formula:

$$\text{Number of plants/ha} = \frac{\text{Area}}{\text{Spacing}} \quad (\text{Eq.1})$$

Thereafter the number of plants per hectare was multiplied by the marketable fruit yield per plant and calculated the marketable fruit yield per hectare.

Fruit cracking (%)

After harvesting all the fruits from each plant, sorting and grading were done at the mango orchard. During sorting, the cracked fruits were separated from each treatment and the data were recorded. Fruit cracking percentage was calculated by using the following formula:

Fruit cracking (%) =

$$\frac{\text{No. of cracked fruits per plant}}{\text{Total no. of harvested fruits per plant}} \times 100 \quad (\text{Eq.2})$$

Fresh weight of individual fruit

At the same day of harvesting, 10 fresh fruits were randomly selected from each treatment and the individual fruit was measured with the help of a digital pan balance, averaged them and expressed in gram (g).

Length and diameter of individual fruit

The length and diameter of individual fruit from each treatment was measured by digital slide callipers from ten randomly selected fruits and averaged them and expressed in centimetres (cm).

Determination of titratable acidity (%)

The titratable acidity (TA) of mango pulp was determined by method of Ranganna (13). The reagents standard NaOH solution (0.1 N) and phenolphthalein (1 % solution) were used for the determination of TA. In brief, 10 g of fresh mango pulp was taken in a 250 mL beaker and then it was homogenised with distilled water using a blender. The blended materials were then filtered and transferred to 250 mL volumetric flask and volume was made up to the mark with distilled water. Thereafter, 10 mL of pulp solution was taken in a conical flask and 2 to 3 drops of phenolphthalein indicator solution were added and the conical flask was shaken vigorously. It was then titrated immediately with 0.1 N NaOH solutions from a burette till a permanent pink colour appeared. The volume of NaOH solution



Plate 2. Picture showing different types of fruits cracking (longitudinal and star) due to the boron deficiency (Control, T_1 treatment).

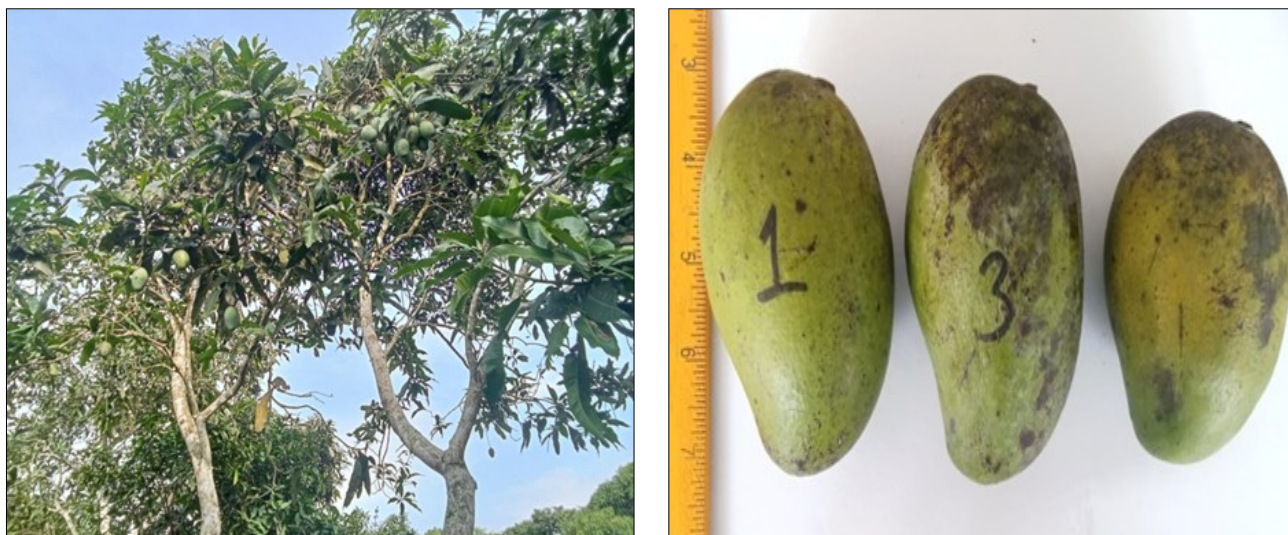


Plate 3. Picture showing non-cracked fruits after applying 1 % of boric acid by foliar application, T_6 treatment.

required for the titration was noted from burette reading. The TA percent was calculated using the following formula:

$$TA (\%) = \frac{T \times N \times V_1 \times E}{V_2 \times W \times 1000} \times 100 \quad (\text{Eq.3})$$

Here, T: titre; N: normality of NaOH; V₁: volume made up (mL), V₂: volume of extract (mL), E: equivalent weight of acid; and W: weight of sample (g).

Determination of total sugar content (%)

Total sugar content of the mango fruit was determined calorimetrically by the anthrone method (14). Anthrone reagent and standard glucose solution were used to determine the total sugar. Extraction of sugar from mango pulp was done by using the methods described by Loomis and Shull (15). In brief, 2 g of pulp was cut into small pieces and immediately plunged into boiling ethyl alcohol and allowed to boil for 5 to 10. The extract was filtered through two layers of cloths and ground tissue was re-extracted for 3 min in hot 80 % alcohol, using 2 to 3 mL of alcohol per g of tissue. The second extraction achieved the total elimination of alcohol using appropriate chemicals. The extract was cooled and passed through two layers of cloth. Both extracts were filtered through Whatman No. 1 filter paper. The volume of the extract was evaporated to about 25 % of the volume over a steam bath and cooled. This reduced volume of extract was transferred to a 100 mL volumetric flask and was made up to the mark with distilled water.

Thereafter, an aliquot of 1 mL of pulp extract was pipetted into test tubes and then 4 mL of anthrone reagent was added and well mixed. Glass marbles were put on top of each test tube to prevent water loss through evaporation. Then the tubes were then placed in a boiling water bath for 10 min before being retrieved and cooled. A reagent blank was prepared in a tube and treated similarly. The absorbance of blue-green solution was measured at 620 nm in a colorimeter. Glucose solutions were prepared by talking 0.0, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0 mL of standard glucose in different test tubes containing 0.0, 10, 20, 40, 60, 80 and 10 mg of glucose, respectively and the volume was made up to 1 mL with distilled water. Then, 4 mL of anthrone reagent was added to each test tube and properly mixed. The absorbance was measured at 620 nm using the blank containing 1 mL of water and 4 mL of anthrone reagent. The amount of total sugar present in the extract was measured from the standard curve of glucose. Finally, the percentage of total sugar was determined by using following formula:

$$\text{Total sugar (\%)} = \frac{\text{Amount of sugar obtained (g)}}{\text{Weight of sample (g)}} \times 100 \quad (\text{Eq.4})$$

Statistical analysis

Data on different parameters were analysed statistically using IBM SPSS software (16). Analysis of variance of different parameter was performed by (F) variance test. The mean of differences of parameter was performed by least significant difference (LSD) test at 5 % level of significant (17).

Results

Different treatments significantly impacted on the yield and yield contributing traits of mango. The maximum number of fruits per plant (183.00) was obtained from T₆ treatment (1 % of BA by FA) followed by T₇ (1.5 % of BA by FA) (166.00) and T₈ (50 g of BA by SA + 0.5 % BA by FA) (152.00), whereas, the minimum number of fruits (99.00) recorded from the control treatment (T₁) (Table 1). Similar trends were also observed in total fresh weight of fruits per plant. T₆ produced the height total fresh weight of fruit (19.73 kg/plant) followed by T₇ (18.81 kg/plant) and T₈ (17.41 kg/plant). Foliar application of 1 % BA (T₆) increased fruit length (10.31 cm) as well as diameter (7.02 cm) as compared to untreated fruits (8.96 cm) and 6.00 cm, respectively) (Table 1).

Application of BA significantly affected the fresh weight of individual fruits, marketable yield and TA. The highest fresh weight of individual fruit (188.83 g) was recorded with T₆ treatment (1 % of BA by FA) followed by T₇ (1.5 % of BA by FA) (184.03 g) and T₈ (50 g of BA by SA + 0.5 % BA by FA) (182.20 g). In contrast, the lowest fresh weight of individual fruit (160.33 g) was obtained in the control treatment (T₁) (Table 2). Marketable yield followed a similar trend. The maximum yield (7.86 t/ha) was obtained from T₆, followed by T₇ (7.39 t/ha) and T₈ (6.83 t/ha). Foliar application of 1 % BA treatment (T₆) decreases TA (0.21 %). while the highest (0.64 %) occurred in T₅ treatment (0.5 % of BA by FA) (Table 2).

The effect of BA application on fruit cracking in mango cv. Amrapali is presented in Fig. 5. Foliar applications exhibited a more pronounced effect. The lowest fruit cracking (0.37 %) was observed in T₆ (1 % of BA by FA), followed by T₇ (1.5 % of BA by FA) and T₈ (50 g of BA by SA + 0.5 % of BA by FA), which recorded 1.41 % and 1.54 %, respectively (Fig. 5). A significant reduction in fruit cracking

Table 1. Effect of different doses of boric acid on yield contributing parameters

Treatments	Number of fruits/plant	Total fresh weight of fruits (kg/plant)	Length of fruit (cm)	Diameter of fruit (cm)
T ₁	99	10.28	8.96	6.00
T ₂	112	12.70	9.16	6.16
T ₃	118	13.81	9.30	6.09
T ₄	128	15.89	9.34	6.22
T ₅	135	16.72	9.37	6.49
T ₆	183	19.73	10.31	7.02
T ₇	166	18.81	9.72	6.36
T ₈	152	17.41	9.46	6.13
LSD _{0.05}	9.93	1.33	0.34	0.41
Level of significance	**	**	**	**

** indicates significant at 1 % level of probability. T₁: control (without boric acid application); T₂: 50 g/plant of boric acid (BA) by soil application (SA); T₃: 100 g/plant of BA by SA; T₄: 150 g/plant of BA by SA; T₅: 0.5 % of BA by foliar application (FA); T₆: 1 % of BA by FA; T₇: 1.5 % of BA by FA; T₈: 50 g of BA by SA + 0.5 % BA by FA.

Table 2. Effect of different doses of boric acid on yield contributing and qualitative parameters

Treatments	Fresh weight of individual fruit (g)	Marketable yield (t/ha)	Titrateable acidity (%)
T ₁	160.33	3.73	0.43
T ₂	164.30	4.87	0.37
T ₃	169.27	5.32	0.27
T ₄	173.83	6.27	0.43
T ₅	172.93	6.56	0.64
T ₆	188.83	7.86	0.21
T ₇	184.03	7.39	0.27
T ₈	182.20	6.83	0.32
LSD _{0.05}	9.72	0.53	0.13
Level of significance	**	**	**

** indicates significant at 1% level of probability. T₁: control (without boric acid application, T₂:50 g/plant of boric acid (BA) by soil application (SA); T₃: 100 g/plant of BA by SA; T₄:150 g/plant of BA by SA; T₅: 0.5 % of BA by foliar application (FA); T₆:1 % of BA by FA; T₇: 1.5 % of BA by FA; T₈: 50 g of BA by SA + 0.5 % BA by FA.

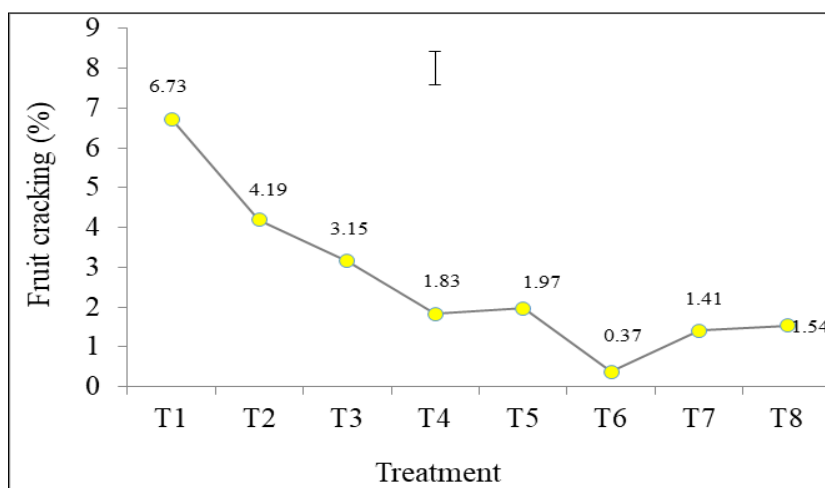


Fig. 5. Effect of boric acid application on fruit cracking of mango cv Amrapali. Vertical bar indicates LSD at 0.05 level of significance. T₁: control (without boric acid application); T₂:50 g/plant of boric acid (BA) by soil application (SA); T₃: 100 g/plant of BA by SA; T₄:150 g/plant of BA by SA; T₅: 0.5 % of BA by foliar application (FA); T₆:1 % of BA by FA; T₇: 1.5 % of BA by FA; T₈: 50 g of BA by SA + 0.5 % BA by FA.

percentage was observed with increasing levels and different modes of BA application compared to the control (T₁). The highest incidence of fruit cracking (6.73 %) was recorded in the control treatment (T₁), which received no BA. Overall, FA of BA proved more effective than SA in reducing fruit cracking in Amrapali mango, with the 1% foliar treatment (T₆) being the most effective.

The influence of BA application on marketable fruit yield of mango cv. Amrapali is depicted in Fig. 6. A significant increase in marketable yield per plant was recorded with both soil and FA of BA compared to the untreated control (T₁). The highest marketable

yield (19.64 kg/plant) was recorded under T₆ (1 % of BA by FA), followed closely by T₇ (1.5 % BA by FA) and T₈ (50 g BA by soil + 0.5 % BA by foliar spray), which yielded 18.46 kg/plant and 17.06 kg/plant, respectively (Fig. 6). The lowest marketable yield (8.50 kg/plant) was observed in the control treatment (T₁), whereas all BA treatments resulted in higher yields. Foliar application of BA proved more effective than SA in enhancing yield.

Among the different treatments, the maximum total sugar content was recorded in treatment T₆ (1 % of BA by FA) (16.11 %), followed by T₂ (50 g/plant of BA by SA) (15.54 %) and T₄ (150 g/plant

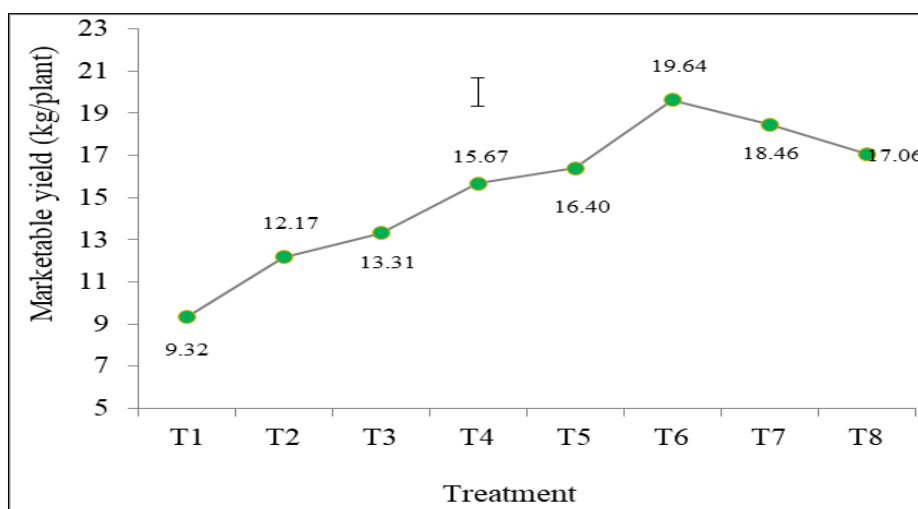


Fig. 6. Effect of boric acid application on total marketable yield of mango. Vertical bar indicates LSD at 0.05 level of significance. T₁: control (without boric acid application); T₂:50 g/plant of boric acid (BA) by soil application (SA); T₃: 100 g/plant of BA by SA; T₄:150 g/plant of BA by SA; T₅: 0.5 % of BA by foliar application (FA); T₆:1 % of BA by FA; T₇: 1.5 % of BA by FA; T₈: 50 g of BA by SA + 0.5 % BA by FA.

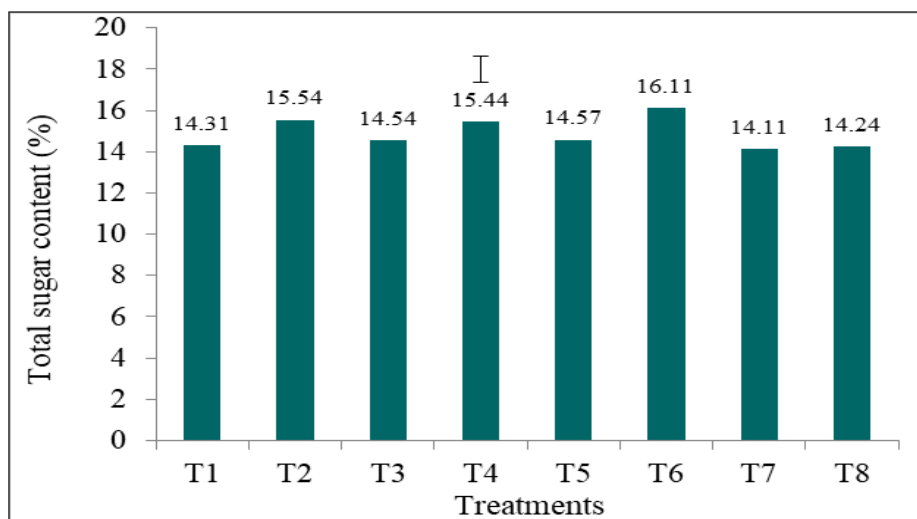


Fig. 7. Effect of boric acid application on total sugar content of mango. Vertical bar indicates LSD at 0.05 level of significance. T₁: control (without boric acid application); T₂: 50 g/plant of boric acid (BA) by soil application (SA); T₃: 100 g/plant of BA by SA; T₄: 150 g/plant of BA by SA; T₅: 0.5 % of BA by foliar application (FA); T₆: 1 % of BA by FA; T₇: 1.5 % of BA by FA; T₈: 50 g of BA by SA + 0.5 % BA by FA.

of BA by SA) (15.44 %). In contrast, the minimum total sugar content (14.31 %) was observed in the control treatment (T₁) (Fig. 7), which received no BA application. These findings imply that BA, particularly when applied as a foliar spray at 1 % concentration, can effectively enhance the sweetness and overall fruit quality of mango cv. Amrapali.

Discussion

Boric acid application exerted a significant influence on key yield and quality parameters, including number of fruits per plant, total fruit weight per plant, individual fruit fresh weight, fruit cracking percentage, length of individual fruits, diameter of individual fruits, marketable fruit weight per plant, marketable fruit yield per hectare, total sugar content and TA.

Among the treatments, T₆ (1 % BA applied through foliar application) produced the most significant improvement in yield attributes, recording the highest number of fruits per plant (183.00), total fresh fruit weight per plant (19.73 kg) and fresh weight of individual fruits (188.83 g). In contrast, the control treatment (T₁) resulted in the lowest performance, with (99.00) fruits per plant, total fruit weight of 10.28 kg per plant and fresh weight of individual fruit (160.33 g), as presented in Tables 1 and 2, respectively. These findings indicate that FA of BA at 1 % concentration markedly enhances fruit yield and associated traits compared to untreated plants. Regarding the number of fruits per plant, it is close to previous studies (18). They noticed in the cv. Amrapali mango used pre-harvest FA of borax sprayed at doses of 0.75 % at West Bengal, India. These results in the number of fruits per tree 158.83 at the time of harvest of fruits. Previous researchers also reported the findings which were close to the present findings, in the case of the total number of fruits per plant (19). They found that treatment T₄ (B) has a 160.00 final number of fruits per plant in the cv. Amrapali mango in Bangladesh. Previous studies also reported results close to the present results in terms of the total weight of fruits per plant. They reported that in control, 10.95 kg yield/plant and treatment T₅ Chemibor-P (5 g) obtained 25.39 kg yield per plant in cv. Amrapali mango in India (20).

The application of varying concentrations of BA had a statistically significant effect on fruit cracking percentage. The lowest

incidence of fruit cracking (0.37 %) was recorded in treatment T₆ (1 % BA through FA), whereas the highest fruit cracking (6.73 %) was observed in the control treatment (T₁). These findings, as illustrated in Fig. 5, indicate that FA of BA, particularly at 1 % concentration, effectively reduces fruit cracking and enhances fruit quality compared to untreated plants. Other studies reported similar results with the findings of this study in terms of fruit cracking percent (7). They noticed 0.73 % fruit cracking in the mango cv. Amrapali. Another study reported that FA of B and calcium nitrate decreased fruit cracking and improved quality in pomegranate in treatment with calcium (CaNa₂) at 0.2 % and borax at 0.30 % and observed 19.99 % fruit cracking in the two-year average findings (21).

In the present experiment, significant variations were observed in fruit size and marketable yield as influenced by boric acid application. The treatment T₆ (1 % BA applied through foliar application) resulted in the highest values for length of individual fruit per plant (10.31 cm), diameter of individual fruit (7.02 cm), weight of marketable fruits per plant (19.64 kg) and marketable fruit yield per hectare (7.86 t). In contrast, the control treatment recorded the lowest length of individual fruit per plant (8.96 cm), diameter of individual fruit (6.00 cm), weight of marketable fruits per plant (9.32 kg) and marketable fruits yield per hectare (3.73 t), as presented in Table 1, Fig. 6 and Table 2, respectively. The enhanced performance under T₆ indicates that FA of BA significantly improves fruit development and overall marketable productivity compared to untreated plants. The finding on the total marketable yield per hectare was close to the result of previous studies (18). They reported that used zinc and boron on cv. Amrapali mango fruit dose of borax at 0.75 % in treatment T₆ and yield was 11.01 t/ha. Regarding the length and diameter of individual fruits was very close to the results of earlier reports (19). They noticed that treatment T₄ applied boron, results were observed in length of fruit was 9.03 cm and diameter of fruit was 6.45 cm.

The highest total sugar content (16.11 %) in treatment T₆ (1 % BA by FA) and lowest total sugar content (14.11 %) was in treatment T₇ (1.5 % BA by FA), highest TA (0.64 %) in treatment T₅ (0.5 % BA by FA) and lowest TA (0.21 %) was in treatment T₆ (1 % BA by FA) as presented in Fig. 7 and Table 2, respectively. Suggest that BA concentration plays a crucial role in modulating fruit biochemical composition, particularly sugar accumulation and acidity balance.

Regarding the total sugar and TA, the present observations were close to earlier researchers (22). They observed that total sugar 17.30 % and TA 0.25 % in cv. Amrapali mango. The observations of other researchers were also like the present findings (18). Similar results were reported in a previous study, where total sugar (17.85 %) and TA (0.27 %) were found to be highest in cv. Amrapali (23). Likewise, the highest total sugar content (26.85 %) in mango cv. Amrapali was also reported earlier (24).

The increased fruit output caused by the FA of BA (micronutrients) can be linked to an increase in fruit quantity, weight and minimum fruit cracking. It might be related to the better physicochemical quality of the fruits. The physiological involvement of BA in the formation of pectic compounds in the cell wall may have contributed to the reduction in fruit cracking by strengthened the tissues and prevented fruit cracking. The role of calcium in binding tissues, particularly in the middle lamella, is significant in minimising fruit cracking. This can also be attributed to BA synergism, which may aid in calcium metabolism in the cell wall, as well as elongation and division. Similar findings were reported earlier (21). During fruit growth, maintaining an adequate B supply is often challenging, particularly in acidic sandy soils exposed to high rainfall. In the present study, the soil at the Bangladesh Agricultural University Germplasm Centre was sandy loam and slightly acidic in nature. Furthermore, boron is readily leached under such conditions (12). Therefore, FA of BA was effective in reducing fruit cracking and increasing marketable yield.

Conclusion

The purpose of the study was to explore the optimum dose of boric acid (BA) with application method to reduce the cracking in mango cv. Amrapali. The findings indicate that different levels of BA and application methods had a significant impact in reducing fruit cracking and increasing marketable fruit yield with better quality. Among the treatments, T₆ (1 % BA by foliar application (FA)) provides the superior results on growth, yield and quality traits of Amrapali. Based on the findings of this study, it can be recommended that foliar application of 1 % BA at the pea and marble stage of growth of mango would reduce fruit cracking and increase yield and quality of mango cv. Amrapali.

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Authors' contributions

MKST and MMH contributed to conceptualisation and methodology. MKST was responsible for investigation, data curation and statistical analysis. MMH contributed to supervision, project administration, funding acquisition, writing review and editing, resources and validation. MHR contributed to supervision, writing review and editing and validation. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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