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Original article

Synchronization of zinc and boron application methods and rates for improving the quality and yield attributes of *Mangifera indica* L. on sustainable basis



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ABSTRACT

Deficiency of micronutrients is a major hurdle for achieving good quality mango fruit and sustainable optimum yield. High soil pH and phosphorus fertilizers are major causes that restrict the bioavailability of micronutrients, such as zinc (Zn) and boron (B). In addition, low or no micronutrient application may create severe Zn and B deficiency in fruits, especially mango. The judicious use of Zn and B is critical to overcoming this problem. Application of both nutrients in the form of soil and foliar application can increase the uptake of Zn and B and the yield of mango fruit on a sustainable basis. However, time is needed to synchronize micronutrients to application methods. Therefore, the current experiment was conducted to explore the best application rate of both micronutrients to the application method in mango orchards. There were 14 treatments applied with three replications. For micronutrient application, soil and foliar methods were chosen. Results showed that 75SB + 0.8FB + 150SZn + 1.0FZn perform significantly best for the improvement in the fruit length (62 %), fruit width (57 %), pulp fresh weight (92 %), stone weight (72 %). Furthermore, a significant increase in total soluble solids (45 %) and a decrease in acidity (50 %) confirmed the imperative functioning of 75SB + 0.8FB + 150SZn + 1.0FZn over control. Furthermore, a significant reduction in total phenolic contents and juice pH validated the effectiveness of 75SB + 0.8FB + 150SZn + 1.0FZn over control in mango. In conclusion, Zn and B soil and foliar

Abbreviations: Zn, Zinc; B, Boron; OM, Organic Matter; EC, Electrical Conductivity; K, Potassium; P, Phosphorus; TSS, Total Soluble Solids.

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application is a better approach for achieving good quality mango fruit. Treatment 75SB + 0.8FB + 150SZn + 1.0FZn is best for mango growers to achieve maximum fruit yield. However, more investigation is suggested in different climatic zones to declare 75SB + 0.8FB + 150SZn + 1.0FZn as the best application amendment to maximize the yield and quality of mango.

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1. Introduction

Micronutrients are essential for the achievement of sustainable yield in different crops. These micronutrients are involved in the assimilation and biosynthesis of photosynthate and the activation of many enzymes. Besides global deficiency of micronutrients in soils, Pakistan's soils are also deficient in zinc (Zn) and boron (B). Less uptake of Zn and B can severely damage the quality and production of fruits (Ahmed et al. 2020). In addition, B and Zn severe deficiency resulted in poor fruit setting, low quality and dropping of fruits at different developmental stages (Siddiq et al. 2017).

Most farmers apply imbalance phosphatic fertilizers that create Zn deficiency symptoms in plants (Brennan 1991; Fageria et al. 2009; Randall and Bouma 1973; Tahir et al. 2018). Furthermore, higher pH is another major cause of B and Zn deficiency. It has been documented that soil's phosphorus contents decrease Zn mobilisation (Bibi et al. 2020; Ova et al. 2015). Besides, soil texture, contents of calcium carbonate, structure, iron and aluminium oxides, nutritional status, organic matter, soil fauna, flora, bicarbonate, sulfur, soil redox potential, poor irrigation and management practices restrict the translocation and accumulation of micronutrients in consumable parts of crops subsequently reducing the yield (Bibi et al. 2019; White and Broadley 2001).

Insufficient availability of Zn induces abnormalities and stresses at the physiological stage of plants, due to which deficiency symptoms appear on the leaves. Small leaves, stunted growth, less fertile spikelet's, and chlorosis are some of the major symptoms that usually appear due to the deficiency of Zn in the different crops (Cakmak et al., 1996; McCauley et al., 2009; Randall and Bouma, 1973).

On the other hand, less B availability in floral structure resulted in less fruit setting from flowers. It also minimized percent fruit retention on panicles (Bibi et al. 2019). Optimum B uptake increases the thickness of the cell wall through specific complexes. In addition, an increase in flower number and retention, germination, pollen tube elongation, seed and fruit development are other benefits associated with balance B uptake. Boron also controls the translocation of photosynthates and less indole acetic acid oxidation (Bibi et al. 2019; Dutta 2004; Jatav et al. 2020; Moheyuddin et al. 2013; Rashid et al. 1997). To overcome the deficiency of B and Zn, scientists mostly suggest the application of inorganic fertilizer in the soil and on mango trees as foliar. These fertilizers compensate for the deficiency pool of micronutrients in soil created due to intensive agriculture and imbalance in the application of inorganic fertilizers (Rajendran et al. 2009).

Mango (*Mangifera indica* L.) is a fruit crop of the family Anacardiaceae. Tropical and subtropical areas of the world are most suitable for its cultivation. Delicious flavour, taste and lovely fragrance are a major cause of its position as king in fruits. However, low fruit retention, setting and poor quality of fruits are serious problems in mango. The role of micronutrients is very important in this regard. Their acute deficiencies sometimes cause lower fruit yield and quality of mango (Patil et al. 2018). Therefore, the current study aimed to examine the improvement in mango quality and yield attributes by selecting the best application method and rate of B and Zn fertilizer. It is hypothesized that combining B and Zn, i.e.,

foliar and soil, can improve mango quality and yield characteristics. The current study will help the farming community manage B and Zn in mango trees to achieve better fruit quality and yield.

2. Materials and methods

2.1. Experimental design and treatments

A field experiment was conducted based on a randomized complete block design for optimal use of micronutrients in improving the productivity of mango fruit. The climatic data of experimental site is provided in Fig. 1. The soil was calcareous in nature with pHs = 8.20, electrical conductivity (ECe) = 2.14 dS m⁻¹, organic matter (OM) = 0.45 %, total nitrogen = 0.0225 %, available phosphorus (P) = 6.32 mg/kg dry soil, extractable potassium (K) = 111 mg/kg dry soil, extractable zinc (Zn) = 0.30 mg/kg dry soil and extractable boron (B) = 0.25 mg/kg dry soil.

Fourteen treatments with three replications were evaluated in this research. Each treatment was applied on 4 healthy plants that make one block (594 sq. feet). The treatments include: T1 = control, T2 = 75 g Borax plant⁻¹ (75SB), T3 = 0.8 % H₃BO₃ plant⁻¹ foliar (0.8FB), T4 = 150 g ZnSO₄ plant⁻¹ (150SZn), T5 = 1.0 % ZnSO₄ plant⁻¹ foliar (1.0FZn), T6 = 75SB + 150SZn, T7 = 75SB + 1.0FZn, T8 = 0.8FB + 150SZn, T9 = 0.8FB + 1.0FZn, T10 = 75SB + 0.8FB + 150SZn, T11 = 75SB + 0.8FB + 1.0FZn, T12 = 75SB + 150SZn + 1.0FZn, T13 = 0.8FB + 150SZn + 1.0FZn and T14 = 75SB + 0.8FB + 150SZn + 1.0FZn. All the suggested doses of Zn and B are optimal doses which were selected based on previous screening experiments.

2.2. NPK application

Based on the soil test of the study area, micronutrients of N, P and K were used in the ratio of 1.5, 1.0 and 1.0 kg per plant per year, respectively. Total required phosphorus was used at the end of July, and then nitrogen and potassium were added (½ at the end of July and the other ½ before 1st week of February), respectively.

2.3. Boron and zinc application

Soil application of B and Zn was done before flowering. Foliar spraying of B and Zn was done twice a year (total of 24 L/tree applied in 2 splits), once at the time of emergence of inflorescence and the second time when the fruit reached the size of a pea. At the end of the experiment, soil and leaf samples were collected, stored and processed for further analysis (Bibi et al. 2019).

2.4. Irrigation practices

The trench was made with a radius 1 (r1) = 12 feet and a radius 2 (r2) 14 feet apart from the tree's main trunk. The depth of the trench was 2 feet. A total of eight irrigations were applied to each tree with trench during the growing period of mango at the experimental site.

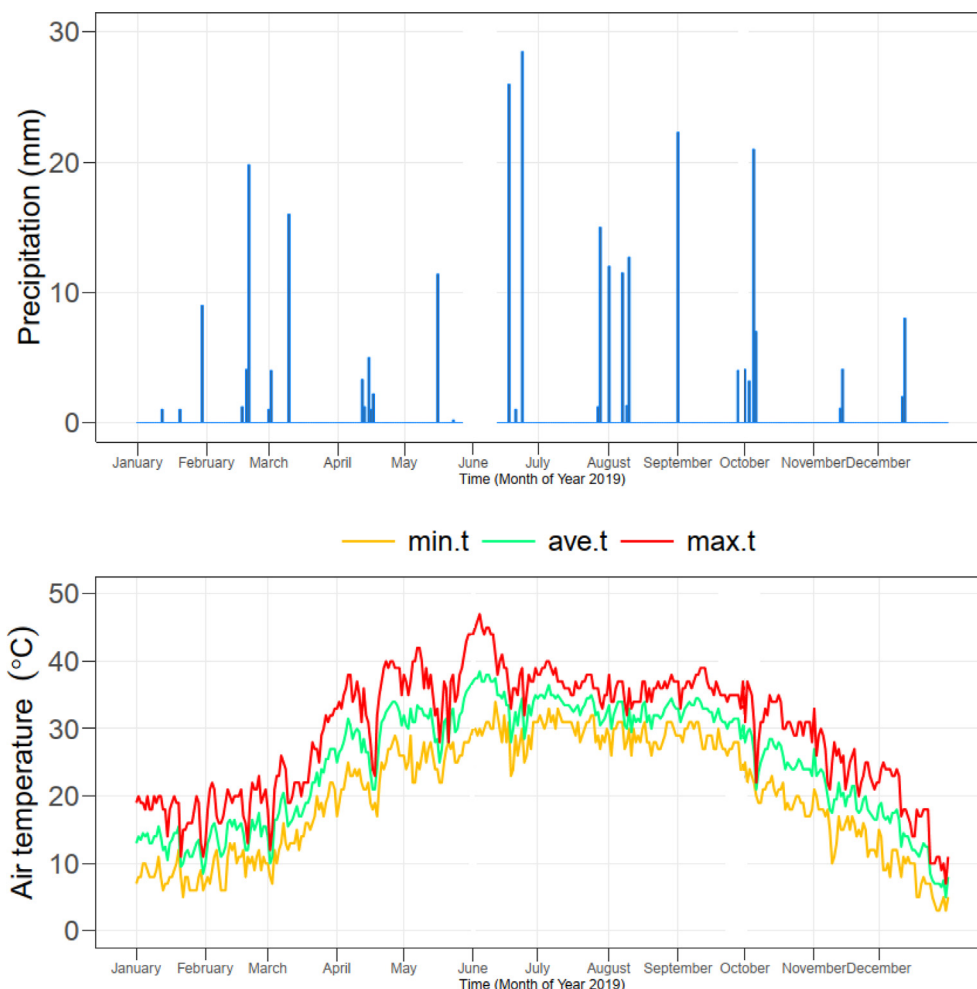


Fig. 1. The daily minimum, maximum and average temperature and rainfall in Multan, Pakistan, during 2019 (Majid et al. 2020).

2.5. Plant sampling

To prepare leaf samples, 15 healthy mango plants (age 10 years ± 5 months) were randomly introduced from the garden. About 20 grown leaves (4–6 months old) were randomly collected from each side of the mango canopy from fruiting and non-fruiting branches. Collect of samples was performed during July and August. Then leaves were washed with distilled water and then dried, placed in an oven at a temperature of 70 °C for 48 h. After Taking out the samples from the oven, they were ground with the help of John Wiley mill and then passed through a 40-mesh screen.

2.6. Plant analyses

The leaf samples were digested in a di-acid mixture with a B concentration (Gaines and Mitchell 1979). Zinc and iron were also measured using atomic absorption spectrophotometer (Hettiarachchi et al. 2004). P content of leaves was determined using the spectrophotometer (Benton et al. 1991) and K and Na by flame photometer (Pratt, 1965). Finally, nitrogen analysis was performed using the Kjeldhal’s method (Bremner, 1996).

2.7. Fruit retention

A 1.0 square meter area was identified from the four sides of the tree to evaluate the fruit holding rate. Fruit retention was observed

between mustard and marble stages with standard protocol adoption.

2.8. Acidity

The titratable acidity was evaluated as the percentage of citric acid in fresh mango juice. Sample titration was performed at pH 8.2 with sodium hydroxide (0.1 N)(Rangana 1979).

$$Acidity(\%) = \left(\frac{Volume\ of\ 0.1N\ NaOH(ml) \times 0.067}{Volume\ of\ juice(mL)} \right) \times 100$$

2.9. Total soluble solids (TSS)

“Medline Scientific Ltd., digital hand refractometer model SELECT045”, was used for total soluble solids (Brix°). Twenty grams of the pulp of each fruit was extracted and homogenized in 80 ml of distilled water for 60 s. Finally, 1 ml of homogenate was placed on a refractometer to evaluate TSS (Drake et al. 1988).

2.10. Sugar contents

The total amount of mango pulp sugar was determined calorimetrically using the Antron method (Jayaraman and Jayaraman 1981).

2.11. Total phenolic contents and Vitamin C

The total phenolic content of the liqueurs was determined by the spectrophotometric method with Folin-Ciocalteu (“Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid reagents,” 1965). Vitamin C content in mango fruit was determined by adopting the methodology of Spencer et al. (1956).

2.12. Statistical analysis

Data analysis was conducted by applying homogeneity of variance and normality of distribution followed by an analysis of variance (ANOVA). The means were compared by using Fisher LSD test at p-value of 0.05. A statistical computer software package (Origin 2020b) was used for the statistical analysis (Steel et al. 1997).

3. Results

Effect of treatments were significant on fruit length, fruit width, pulp fresh weight and stone weight of mango (Table 1). Application of control, 75SB, 0.8FB, 150SZn and 1.0FZn remained statistically alike to each other for fruit length. Treatments 75SB + 150SZn, 75SB + 1.0FZn, 0.8FB + 150SZn, 0.8FB + 1.0FZn differed significantly over control, 75SB, 0.8FB, 150SZn and 1.0FZn for fruit length. It was noted that 75SB + 0.8FB + 150SZn, 75SB + 0.8FB + 1.0FZn, 75SB + 150SZn + 1.0FZn, 0.8FB + 150SZn + 1.0FZn also gave significantly better results for the improvement in fruit length over control, 75SB, 0.8FB, 150SZn and 1.0FZn. Maximum significant increase of 62 % in fruit length was noted in 75SB + 0.8FB + 150SZn + 1.0FZn from control. For fruit width 75SB, 0.8FB, 150SZn and 1.0FZn did not differ significantly over control. A significant enhancement in fruit width was observed in 75SB + 150SZn, 75SB + 1.0FZn, 0.8FB + 150SZn, 0.8FB + 1.0FZn over control. Application of 75SB + 150SZn and 75SB + 1.0FZn gave significantly better fruit width over 0.8FB + 150SZn, 0.8FB + 1.0FZn. Highest fruit width was observed in 75SB + 0.8FB + 150SZn + 1.0FZn (57 %) followed by 75SB + 0.8FB + 150SZn (31 %), 75SB + 0.8FB + 1.0FZn (29 %), 75SB + 150SZn + 1.0FZn (45 %), 0.8FB + 150SZn + 1.0FZn (49 %) than control. No significant change was noted in pulp fresh and stone weight where control, 75SB, 0.8FB, 150SZn and 1.0FZn were applied. An increasing trend of was noted in pulp fresh and stone weight where treatments 75SB + 150SZn, 75SB + 1.0FZn, 0.8FB + 150SZn, 0.8FB + 1.0FZn were applied. Maximum pulp fresh and stone weight was noted in 75SB + 0.8FB + 150SZn + 1.0FZn fol-

lowed by 75SB + 0.8FB + 150SZn, 75SB + 0.8FB + 1.0FZn, 75SB + 150SZn + 1.0FZn, 0.8FB + 150SZn + 1.0FZn.

According to the results, experimental treatments significantly affected the number of flowers per panicle, number of fruits matured per panicle, average fruit weight, and yield (Table 2). Among the treatments, the highest and lowest number of flowers per panicle equal to 800 and 595 were observed from 75SB + 0.8FB + 150SZn + 1.0FZn and control, respectively, which were significantly different from each other. Treatment 75SB + 0.8FB + 150SZn + 1.0FZn increased the number of flowers per panicle by 25.70 % compared to the control. In examining the number of fruits matured per panicle, treatments of control, 75SB, 0.8FB, 150SZn and 1.0FZn were not significantly different from each other. Subsequently, a significant increase in the number of fruits matured per panicle was observed where treatments of 75SB + 150SZn, 75SB + 1.0FZn, 0.8FB + 150SZn were applied. The highest number of fruits matured per panicle was observed with application 75SB + 0.8FB + 150SZn + 1.0FZn followed by 0.8FB + 150SZn + 1.0FZn, 75SB + 150SZn + 1.0FZn and 0.8FB + 1.0FZn. The average fruit weight was not affected by any of the treatments of control, 75SB, 0.8FB, 150SZn and 1.0FZn. While 75SB + 150SZn, 75SB + 1.0FZn, 0.8FB + 150SZn and 0.8FB + 1.0FZn caused a slight improvement in the average fruit weight. Application of 75SB + 0.8FB + 150SZn + 1.0FZn had the highest average fruit weight. Mango yield is affected by its components, and there is a direct relationship between yield and number of flowers per panicle, number of matured fruits per panicle and average fruit weight. Application of control, 75SB, 0.8FB, 150SZn and 1.0FZn did not significantly affect mango yield. The highest mango yield was obtained with the application of 75SB + 0.8FB + 150SZn + 1.0FZn and increased the mango yield by 50.75 % compared to the control.

Traits shelf life, total sugars, reducing sugars, and non-reducing sugars were affected by experimental treatments (Table 3). In the study, shelf life, treatments of control, 75SB, 0.8FB, 150SZn and 1.0FZn had no significant effect on this trait. Application of 75SB + 150SZn, 75SB + 1.0FZn and 0.8FB + 150SZn significantly increased shelf life, and these three treatments were not statistically different. Maximum shelf life was obtained in 75SB + 0.8FB + 150SZn + 1.0FZn, which was no different from 0.8FB + 150SZn + 1.0FZn and is followed by 75SB + 150SZn + 1.0FZn, 75SB + 0.8FB + 150SZn, 75SB + 0.8FB + 1.0FZn and 0.8FB + 1.0FZn. All treatments except control caused a significant increase in total sugars. Treatments 75SB + 0.8FB + 150SZn + 1.0FZn, 0.8FB + 150SZn + 1.0FZn and 75SB + 150SZn + 1.0FZn had the highest total sugars, respectively, and there was no statistical difference with each

Table 1
Effect of Zn and B application rates through foliar and soil application on fruit length, fruit width, pulp fresh weight and stone weight of mango. Means are an average of 3 replicates ± standard error. Different letters on bars showed a significant difference at p ≤ 0.05.

Treatments	Fruit Length (cm)	Fruit Width (cm)	Pulp Fresh Weight (g)	Stone DryWeight (g)
Control	9.36 ± 0.06 g	4.87 ± 0.009i	195 ± 1.8i	142 ± 0.5i
75SB	9.48 ± 0.01 g	4.92 ± 0.006hi	199 ± 0.6i	145 ± 0.2hi
0.8FB	9.53 ± 0.01 g	4.95 ± 0.003hi	201 ± 0.7i	145 ± 0.3hi
150SZn	9.54 ± 0.01 g	4.98 ± 0.009hi	204 ± 0.7i	146 ± 0.2hi
1.0FZn	9.56 ± 0.02 g	5.02 ± 0.065 h	204 ± 0.9i	149 ± 0.8 h
75SB + 150SZn	10.96 ± 0.04f	5.29 ± 0.018 g	216 ± 2.3 h	162 ± 1.9 g
75SB + 1.0FZn	11.25 ± 0.15e	5.94 ± 0.033f	240 ± 2.9 g	174 ± 1.2f
0.8FB + 150SZn	11.31 ± 0.12e	6.00 ± 0.023ef	257 ± 4.3f	184 ± 2.3e
0.8FB + 1.0FZn	12.51 ± 0.08d	6.11 ± 0.018e	278 ± 1.4e	203 ± 1.9d
75SB + 0.8FB + 150SZn	13.32 ± 0.17c	6.39 ± 0.026d	288 ± 1.8d	204 ± 2.2d
75SB + 0.8FB + 1.0FZn	13.57 ± 0.06c	6.30 ± 0.131d	280 ± 2.6de	205 ± 3.4d
75SB + 150SZn + 1.0FZn	14.15 ± 0.10b	7.09 ± 0.087c	316 ± 2.0c	225 ± 2.2c
0.8FB + 150SZn + 1.0FZn	14.27 ± 0.12b	7.26 ± 0.045b	335 ± 5.2b	233 ± 1.3b
75SB + 0.8FB + 150SZn + 1.0FZn	15.20 ± 0.10a	7.66 ± 0.061a	374 ± 8.0a	244 ± 0.9a

Table 2

Effect of different application rates of Zn and B through foliar and soil application on number of flowers panicle⁻¹, number of fruits matured panicle⁻¹, average fruit weight and yield of mango. Means are an average of 3 replicates ± standard error. Different letters on bars showed a significant difference at p ≤ 0.05.

Treatments	No. of Flowers (Panicle ⁻¹)	No. of Fruits Matured (Panicle ⁻¹)	Average Fruit Weight (g)	Yield (kg Tree ⁻¹)
Control	592 ± 1.4j	1.22 ± 0.01j	438 ± 0.58j	134 ± 0.70 k
75SB	602 ± 1.5i	1.25 ± 0.01ij	441 ± 0.88ij	136 ± 0.76i-k
0.8FB	602 ± 4.7i	1.30 ± 0.01ij	440 ± 0.33j	139 ± 0.43ij
150SZn	606 ± 2.6i	1.33 ± 0.01i	437 ± 1.20j	139 ± 0.46i
1.0FZn	608 ± 2.4hi	1.35 ± 0.02i	445 ± 2.03i	135 ± 0.97jk
75SB + 150SZn	616 ± 2.2 h	1.93 ± 0.04 h	453 ± 1.45 h	161 ± 1.49 h
75SB + 1.0FZn	640 ± 3.2 g	2.10 ± 0.03 g	463 ± 1.73 g	171 ± 0.79 g
0.8FB + 150SZn	650 ± 1.5f	2.28 ± 0.02f	474 ± 2.19f	172 ± 2.25 g
0.8FB + 1.0FZn	688 ± 4.4e	3.11 ± 0.08d	488 ± 1.53e	179 ± 0.69f
75SB + 0.8FB + 150SZn	707 ± 3.8d	2.75 ± 0.03e	526 ± 1.76d	196 ± 2.23d
75SB + 0.8FB + 1.0FZn	712 ± 4.3d	2.76 ± 0.03e	525 ± 3.18d	188 ± 1.50e
75SB + 150SZn + 1.0FZn	761 ± 4.0c	3.25 ± 0.05c	541 ± 2.08c	202 ± 2.35c
0.8FB + 150SZn + 1.0FZn	793 ± 2.6b	3.44 ± 0.05b	559 ± 3.48b	225 ± 1.67b
75SB + 0.8FB + 150SZn + 1.0FZn	815 ± 2.2a	3.70 ± 0.03a	567 ± 1.53a	232 ± 1.60a

Table 3

Effect of different application rates of Zn and B through foliar and soil application on shelf life, total sugar, reducing sugar and non-reducing sugar of mango. Means are an average of 3 replicates ± standard error. Different letters on bars showed a significant difference at p ≤ 0.05.

Treatments	Shelf Life (Days)	Total Sugar (%)	Reducing Sugar (%)	Non-Reducing Sugar (%)
Control	7 ± 0.02f	16.63 ± 0.63f	13.68 ± 0.34 h	7.04 ± 0.04e
75SB	7 ± 0.01f	18.37 ± 0.32e	14.29 ± 0.29gh	7.48 ± 0.29de
0.8FB	7 ± 0.01f	18.74 ± 0.26e	14.64 ± 0.32f-h	7.82 ± 0.18 cd
150SZn	7 ± 0.03f	18.74 ± 0.63e	14.71 ± 0.36 fg	7.83 ± 0.19 cd
1.0FZn	8 ± 0.02f	18.73 ± 0.27e	14.65 ± 0.33f-h	7.83 ± 0.17 cd
75SB + 150SZn	10 ± 0.25e	19.88 ± 0.48d	15.38 ± 0.25ef	8.14 ± 0.18 cd
75SB + 1.0FZn	10 ± 0.30e	21.21 ± 0.21c	15.82 ± 0.43de	8.41 ± 0.30c
0.8FB + 150SZn	10 ± 0.04e	21.31 ± 0.16c	16.63 ± 0.32d	8.38 ± 0.20c
0.8FB + 1.0FZn	12 ± 0.28d	21.33 ± 0.33c	17.67 ± 0.34c	8.55 ± 0.29c
75SB + 0.8FB + 150SZn	13 ± 0.15 cd	22.41 ± 0.30b	18.05 ± 0.58c	9.33 ± 0.16b
75SB + 0.8FB + 1.0FZn	12 ± 0.97d	22.67 ± 0.33b	19.48 ± 0.29b	9.96 ± 0.55b
75SB + 150SZn + 1.0FZn	13 ± 0.43bc	23.99 ± 0.01a	19.96 ± 0.04b	11.63 ± 0.32a
0.8FB + 150SZn + 1.0FZn	14 ± 0.55ab	24.27 ± 0.27a	20.17 ± 0.44b	11.85 ± 0.15a
75SB + 0.8FB + 150SZn + 1.0FZn	15 ± 0.32a	24.73 ± 0.37a	21.42 ± 0.30a	12.34 ± 0.33a

other. Among the studied factors, treatments of control, 75SB, 0.8FB and 1.0FZn did not significantly reduce sugars. Treatment of 75SB + 0.8FB + 150SZn + 1.0FZn had the highest reducing sugars (22 %) and was significantly different from other treatments. In the study of non-reducing sugars, it was observed that the most non-reducing sugars were obtained from 75SB + 0.8FB + 150SZn + 1.0 FZn, and there was no significant difference with 0.8FB + 150SZn + 1.0FZn and 75SB + 150SZn + 1.0FZn; the lowest non-reducing sugars were obtained from the control treatment.

The effect of treatments was significant on plant physiological traits such as photosynthetic rate, stomatal conductance, and transpiration rate (Table 4). The plant's photosynthetic rate was affected by experimental factors, and the highest photosynthetic rate was observed from 75SB + 0.8FB + 150SZn + 1.0FZn. The lowest photosynthetic rates were observed from control and 75SB, respectively, and there was no significant difference with each other. No significant change was observed in stomatal conductance where control, 75SB, 0.8FB, 150SZn, and 1.0FZn were applied. An increasing trend in stomatal conductance was observed where 75SB + 150SZn, 75SB + 1.0FZn, and 0.8FB + 150SZn were applied. The highest stomatal conductance was observed in 75SB + 0.8FB + 150SZn + 1.0FZn, which was in a statistical group with 0.8FB + 150SZn + 1.0FZn. The results showed that mango transpiration rate was affected by the treatments. The control treatment had the lowest transpiration rate and had no statistical difference with 75SB. A significant increase in transpiration rate was observed from 1.0FZn that with 75SB + 150SZn, 75SB + 1.0FZn and 0.8FB + 150SZn, which

were placed in a statistical group. The highest transpiration rate was also observed with application 75SB + 0.8FB + 150SZn + 1.0FZn.

The effect of treatments on acidity, juice pH, total soluble solids and total phenols were significant (Table 5). Among the treatments studied, control, 75SB, 0.8FB, 150SZn, and 1.0FZn increased mango acidity were not significantly different from each other. A significant reduction in acidity was observed through application of 75SB + 150SZn followed by 75SB + 1.0FZn, 0.8FB + 150SZn, 0.8FB + 1.0FZn, 75SB + 0.8FB + 150SZn, 75SB + 0.8FB + 1.0FZn, 75SB + 150SZn + 1.0FZn, 0.8FB + 150SZn + 1.0FZn, and 75SB + 0.8FB + 150SZn + 1.0FZn. Most of the juice pH was obtained by application 75SB, which was not significantly different from 0.8FB, and 150SZn. The lowest juice pH was obtained from 75SB + 0.8FB + 150SZn + 1.0FZn, and which was in a statistical group with 0.8FB + 150SZn + 1.0FZn whilst other treatments were not significantly different from each other. Application of 75SB + 0.8FB + 150SZn + 1.0FZn, and 0.8FB + 150SZn + 1.0FZn remained statistically alike to each other for total soluble solids. The control treatment also had the lowest total soluble solids. The highest total phenols content was obtained by control, 75SB, 0.8FB, 150SZn, and 1.0FZn. A significant decreasing trend was observed with the application of 75SB + 150SZn, which was statistically similar to 75SB + 1.0FZn. The lowest total phenols were observed from 75SB + 0.8FB + 150SZn + 1.0FZn, which was in a statistical group with 0.8FB + 150SZn + 1.0FZn, 75SB + 150SZn + 1.0FZn, and 75SB + 0.8FB + 1.0FZn.

Table 4

Effect of different application rates of Zn and B through foliar and soil application on photosynthetic rate, transpiration rate and stomatal conductance in mango leaves. Means are an average of 3 replicates ± standard error. Different letters on bars showed a significant difference at p ≤ 0.05.

Treatments	Photosynthetic Rate (µmol/m/s)	Transpiration Rate (mmol/m/s)	Stomatal Conductance (mol/m/s)
Control	13.96 ± 0.08i	4.28 ± 0.04i	0.18 ± 0.003 g
75SB	14.30 ± 0.30i	4.34 ± 0.02hi	0.20 ± 0.003 fg
0.8FB	14.94 ± 0.13 h	4.48 ± 0.02gh	0.21 ± 0.003f
150SZn	15.11 ± 0.07gh	4.57 ± 0.04 g	0.22 ± 0.003f
1.0FZn	15.40 ± 0.16 g	5.27 ± 0.16f	0.21 ± 0.003f
75SB + 150SZn	16.23 ± 0.13f	5.08 ± 0.09f	0.25 ± 0.006e
75SB + 1.0FZn	16.79 ± 0.05de	5.16 ± 0.05f	0.26 ± 0.009e
0.8FB + 150SZn	16.91 ± 0.04de	5.22 ± 0.04f	0.27 ± 0.022e
0.8FB + 1.0FZn	16.63 ± 0.05e	5.48 ± 0.05e	0.31 ± 0.009d
75SB + 0.8FB + 150SZn	17.13 ± 0.07d	5.86 ± 0.09d	0.34 ± 0.012 cd
75SB + 0.8FB + 1.0FZn	17.95 ± 0.05c	6.04 ± 0.03 cd	0.36 ± 0.010c
75SB + 150SZn + 1.0FZn	18.04 ± 0.11c	6.20 ± 0.03c	0.39 ± 0.006b
0.8FB + 150SZn + 1.0FZn	18.76 ± 0.13b	6.53 ± 0.06b	0.41 ± 0.009ab
75SB + 0.8FB + 150SZn + 1.0FZn	19.27 ± 0.16a	6.77 ± 0.07a	0.43 ± 0.009a

Table 5

Effect of Zn and B application rates through foliar and soil application on acidity, juice pH, total soluble solids, and total phenols in mango. Means are an average of 3 replicates ± standard error. Different letters on bars showed a significant difference at p ≤ 0.05.

Treatments	Acidity (%)	Juice pH	TSS (°Brix)	TP (mg/100 g fw)
Control	0.28 ± 0.006a	4.50 ± 0.3b-e	20.43 ± 0.4 h	180 ± 5.9bc
75SB	0.28 ± 0.003a	5.05 ± 0.1a	21.96 ± 0.5 g	185 ± 2.6ab
0.8FB	0.29 ± 0.009a	4.70 ± 0.1a-c	22.66 ± 0.3 fg	187 ± 3.0ab
150SZn	0.28 ± 0.003a	4.83 ± 0.1ab	23.52 ± 0.3ef	191 ± 2.9ab
1.0FZn	0.29 ± 0.006a	4.58 ± 0.2b-d	23.71 ± 0.3e	192 ± 4.5a
75SB + 150SZn	0.24 ± 0.006b	4.29 ± 0.2c-e	25.10 ± 0.5d	169 ± 6.1 cd
75SB + 1.0FZn	0.21 ± 0.006c	4.50 ± 0.1b-e	24.96 ± 0.0d	158 ± 5.9de
0.8FB + 150SZn	0.20 ± 0.006 cd	4.48 ± 0.1b-e	25.63 ± 0.4d	156 ± 6.3ef
0.8FB + 1.0FZn	0.18 ± 0.006de	4.39 ± 0.1c-e	25.32 ± 0.3d	150 ± 3.1e-g
75SB + 0.8FB + 150SZn	0.16 ± 0.009ef	4.19 ± 0.1de	26.72 ± 0.3c	145 ± 2.7f-h
75SB + 0.8FB + 1.0FZn	0.16 ± 0.012ef	4.32 ± 0.2c-e	27.84 ± 0.2b	140 ± 2.7 g-i
75SB + 150SZn + 1.0FZn	0.16 ± 0.009ef	4.22 ± 0.1de	28.75 ± 0.3b	136 ± 3.7 h-i
0.8FB + 150SZn + 1.0FZn	0.15 ± 0.007 fg	4.12 ± 0.1ef	28.79 ± 0.2ab	139 ± 1.9 g-i
75SB + 0.8FB + 150SZn + 1.0FZn	0.14 ± 0.009 g	3.76 ± 0.2f	29.72 ± 0.3a	130 ± 3.0i

4. Discussion

Balance uptake of micronutrients in fruiting trees increases crop growth and yield and enhances fruits' quality (Ahmed et al. 2020; Marschner 2011; Rafiullah et al. 2020; Rahi et al. 2021). In the current experiment, it is clear from the control treatment plants that micronutrients are important in the growth and yield aspects. The control shows minimum fruit length, fruit width, pulp fresh weight, and stone weight among all the treatments. A significant increase in the fruit length, pulp fresh weight and stone weight was observed where combined B and Zn were applied using swine and their applications. Many scientists documented that proper update of B played an imperative role in forming a pollen tube, developing anther and pollen germination. Improvement in the number of flowers through B significantly enhances the yield of fruiting trees (Bibi et al. 2019; Mozafar 1989). Previous investigations also concluded that Zn is very important for tryptophan biosynthesis. This tryptophan acts as a precursor for the manufacturing of indole acetic acid (Ali et al. 2012). In the current study, significant improvement in the fruit length, fruit width, pulp fresh weight and stone weight might be due to improvement in the biosynthesis of indole acetic acid regulated by the balance uptake of Zn. The higher activity of dehydrogenase and proteinase enzyme also becomes slow due to the balance uptake of Zn. These enzymes induced early maturity in the fruits, resulting in less retention and poor quality (Chandra and Singh 2015). Boron improves polyphenol oxidase activity which decreases browning incidence in fruits.

This reduction in browning incidence is a major indicator of improvement in post-harvest fruit quality (Khalaj et al. 2017). Application of B becomes the part of the plant through phloem filter plates during basipetal sucrose flow. It provides strength to the nuclear membrane and regulates ribonucleic acid metabolism, which played a key role in the sugar contents assimilation (Marschner 2011). Similar findings were also noted in the current study where soil and foliar application of B significantly increased reducing and non-reducing and total sugar contents of the mango fruits. A significant improvement in the gas exchange attributes, i.e., photosynthetic rate, transpiration rate and stomatal conductance was also noted where Zn was applied through foliar and soil applications. The improvement pass might be due to balance uptake of Zn.

Many enzymes activation in photosynthesis required, zinc as a cofactor. These enzymes accelerate photosynthesis' metabolic functioning, which results in the improvement of gas exchange attributes (Kazemi 2013). It has been observed that B has a key role in phenolic metabolism. It activates the enzyme phenylalanine ammoniumlyase (PAL) under deficiency conditions which significantly increases phenolic. Higher accumulation of phenolic is catalytically oxidized by the activity of polyphenoloxidase (PPO) enzyme. Such oxidation results in the production of quinones that decrease the integrity of the cell membrane (Camacho-Cristóbal et al. 2002). The current study findings also signify that phenolic contents were decreased by increasing soil and foliar application of B.

The reduction in phenolic might be due to better uptake of B and alleviation of B deficiency in mango plants. In-plant cell wall, deficiency of B also decreases glycoproteins. Most surface proteins bind with the membrane through glycosylphosphatidylinositol anchors such as arabinogalactan proteins (AGP). These glycosylphosphatidylinositol anchors, such as arabinogalactan proteins (AGP) provide bindings sites for putative B-binding structures (Goldbach and Wimmer 2007; Redondo-Nieto et al. 2007). Similar results were also noted in the current study, where B and Zn balance application significantly decreased the phenolic content in the mango fruits compared to the control treatment. Furthermore, a significant decrease in the fruit's acidity and an increase in the total soluble solids indicate time parity functioning of combined use of B and Zn via foliar and soil application.

5. Conclusions

It is concluded that both B and Zn are necessary for maximizing mango yield. Quality attributes in mango can be improved through the combined use of B and Zn. Farmers are recommended to apply combined B and Zn through the soil and foliar methods to improve mango's growth, quality, and yield attributes. More investigations of different climatic conditions are needed to declare 75SB + 0.8F B + 150SZn + 1.0FZn as the best treatment for mango.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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