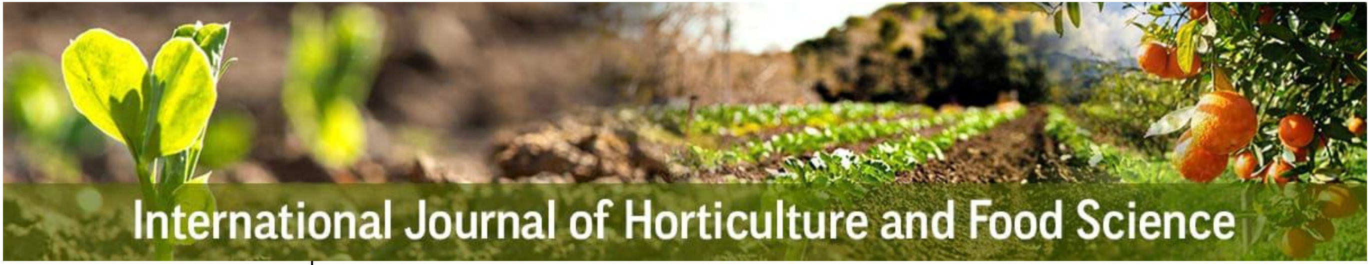
International Journal of Horticulture and Food Science 2024; 6(2): 15-19



E-ISSN: 2663-1067
P-ISSN: 2663-1075
www.hortijournal.com
IJHFS 2024; 6(2): 15-19
Received: 19-05-2024
Accepted: 28-06-2024

Effects of zinc and boron application in soil on growth and yield of *Papaya* cv. red lady

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DOI: https://doi.org/10.33545/26631067.2024.v6.i2a.223

Abstract

An experiment was conducted in 2021-2022 at the Ishwardi upazila in Pabna, Bangladesh to assess the impact of zinc and boron soil application on *Papaya* cv. Red Lady for growth and yield. Where the experiment was lied in RCBD design with 13 treatments, *viz:* T_0-Control (RDF), T_1-4 g Zinc, T_2- 8 g Zinc, T_3-12 g Zinc, T_4-16 g Zinc, T_5-3 g Boron, T_6 -6 g Boron, T_7-9 g Boron, T_8-12 g Boron, T_9-8 g Zn + 6 g B, T_{10}-8 g Zn + 9 g B, T_{11}-12 g Zn + 6 g B and T_{12}-12 g Zn + 9 g B. The highest yield (144.62 t/ha) and fruit set (29.33 fruit/plant) were found for the treatment T_{11}-12 g Zn + 6 g B. Among the micronutrient treatments, the *Papaya* cultivar Red Lady treated with T_{11}-12 g Zn + 6 g B shown to be the most effective for enhancing growth and productivity.

Keywords: Zinc, boron, *Papaya*, red lady, yield

Introduction

The *Papaya* (*Carica Papaya* L.), also referred to as the "wonder fruit of the tropics," is a significant fruit crop in the tropical regions of the world. Due to its highest productivity and year-round fruit production, it has become more well-known and significant economically. According to BBS, (2022) [2] Bangladesh produced around 0.46 million ton of *Papaya*. Aside from this, *Papaya* is a healthful fruit with a high nutritional and medicinal value. The fruit is rich in iron, vitamin C, and vitamin A (Rashid *et al.*, 1987) [14]. Green fruits are frequently used in salads, pickles, and cooked vegetable preparations, but ripe fruits are primarily served as a fresh desert. The beverage, culinary, pharmaceutical, and tanning industries employ papain, a proteolytic enzyme found in latex that is primarily extracted from fruits, for a variety of purposes. *Papaya* leaves provide therapeutic benefits as well. *Papaya* has earned the moniker "common man's fruit" as a result. Because of their importance to plant metabolism and the negative consequences of micronutrient deficiencies, micronutrients are crucial to crop productivity. In farmed crop species, these trace elements are also crucial for disease resistance. Additionally, these micronutrients aid in the absorption of larger nutrients and actively participate in the entire spectrum of plant metabolism, from the development of cell walls to respiration, photosynthesis, the synthesis of chlorophyll, enzyme activity, hormone synthesis, nitrogen fixation and reduction, and other processes (Das, 2003) [5]. Micronutrients, however, can significantly increase the yield of horticulture crops as well as the quality and post-harvest life of horticulture produce (Raja, 2009) [13]. Therefore, for plants to grow, yield, and have higher quality, micronutrients are almost as important as macronutrients. Very little is known about the micronutrients in *Papaya*, despite the fact that very few studies have been conducted on the topic of *Papaya* nutrition. Furthermore, the nutrient content of soils will vary greatly among agroclimatic zones. Furthermore, it seems that information about the necessary quantity of each micronutrient must be generated as *Papaya* grows and consistently produces flowers and fruits. With this perspective in mind, the current study was conducted to examine the impact of Zn, B, and Fe soil application quantity on *Papaya* cv. Red Lady growth and yield.

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Materials and Methods

Study Location

In Pabna, Bangladesh, the experiment was conducted at the Ishwardi upazila between September 2021 and September 2022. The position was between latitudes 24.12°N and 89.06°E, and it was 16 inches above sea level. The soil type of the trial area is clay loam, which is characteristic of the Low High Ganges River Flood Plain Alluvial Tract (Table 1).

Table 1: Physico-chemical characteristics of the initial soil

1. Sand (%) (0.2-0.02 min)	:	25
2. Silt (%) (0.02-0.002 min)	:	37
3. Clay (%) (<0.002 min)	:	38
4. Soil textural class	:	Clay loam
5. pH	:	7.23
6. Organic matter (%)	:	2.25
7. Total nitrogen (%)	:	0.15
8. Available sulphur (ppm)	:	14.2
9. Available phosphorus (ppm)	:	20.25
10. Available zinc	:	0.64
11. Available boron	:	0.36
12. Exchangeable potassium (me %)	:	0.18

***Source*:** Mechanical analysis of soil sample in the Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

Climatic Condition

The experimental area had a subtropical climate from September 2021 to April 2022, with medium to little rainfall and significant rainfall from May 2022 to September 2022. During the growing season, 148.30 mm of rain fell on the region overall. The highest and lowest average temperatures were 31.5 °C and 19.20 °C, respectively. Figure 1 shows that the average relative humidity was 62.65% and the average number of sunshine hours was 159.72.

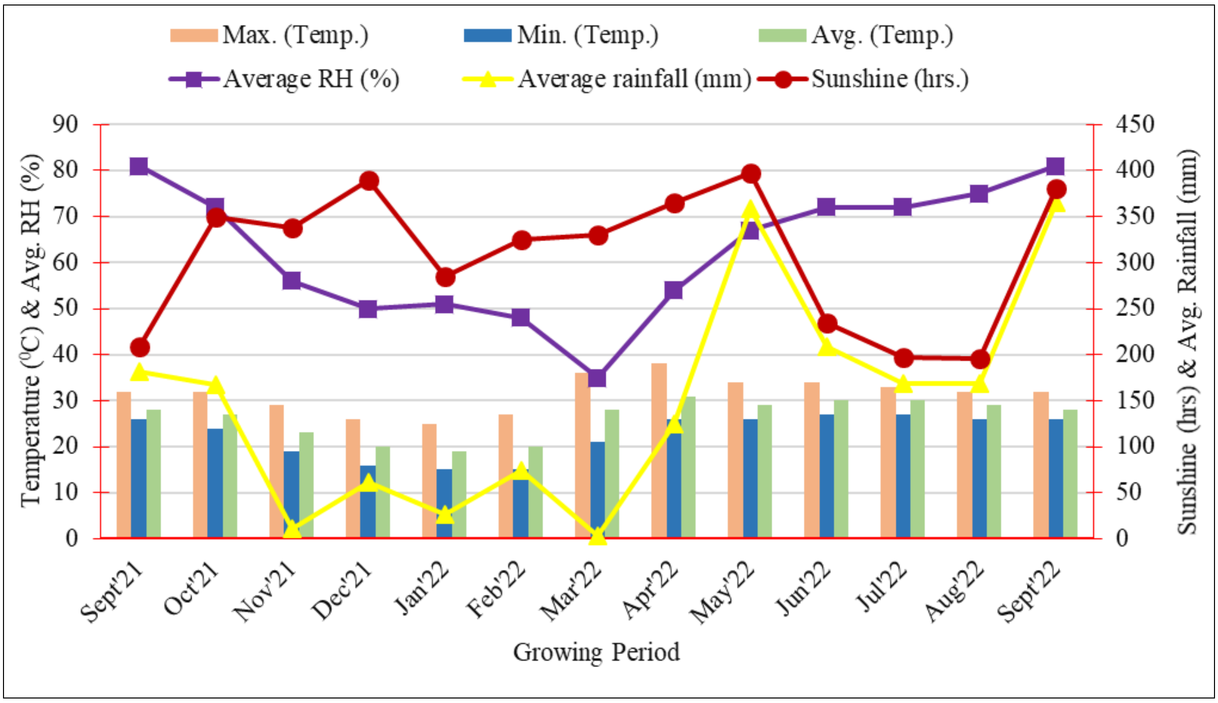

Fig 1: Climatic conditions during crop growing period

Experimental design and data collection

The field trial was carried out in Bangladesh's Ishwardi upazila in Pabna. *Papaya* (var. Red Lady) seeds were planted in tiny polythene bags. 45-day-old seedlings with equal size and vigor were sown in the field during the first week of July in the morning. The pits measured 45 × 45 × 45 cm and were spaced 1.8 meters apart in both directions. Beginning with seedling transplantation, four equal split doses of fertilizer (250 g N, 250 g P, and 500 g K per plant) were applied to the soil every two months. Thirteen treatments total, each of which was duplicated three times, were arranged in a Randomized Block Design (RBD) experiment. These were the treatments: T_0-Control (RDF only), T_1-4 g Zinc, T_2- 8 g Zinc, T_3-12 g Zinc, T_4-16 g Zinc, T_5-3 g Boron, T_6 -6 g Boron, T_7-9g Boron, T_8-12 g Boron, T_9-8 g Zn + 6 g B, T_{10}-8 g Zn + 9 g B, T_{11}-12 g Zn + 6 g B, and T_{12}-12 g Zn + 9 g B. Three, five, and seven months after transplanting, the soil was treated with micronutrients. Eight months after transplanting, observations on plant height, stem girth, and number of leaves; reproductive parameters (number of flowers and fruits per plant); fruit parameters (weight of fruits); and yield parameters (kg plant^{-1} and tha^{-1})

were made. Plant height was measured with a scale. Ten centimeters above the ground, a reference point was marked in the trunk. From this point of reference to the growing shoot's tip, the plant's height was measured. Using a measuring tape, the stem girth was determined. Visual counting was used to record the number of leaves and flowers. After the fruit reached maturity, the number of fruits per plant was physically counted and reported as numbers per tree. Using a digital analytical balance, five *Papaya* fruits that were chosen at random were weighed. The average fruit weight was reported in kilograms. When the fruit was harvested, it was measured and reported in kilograms per plant. The fruit yield per hectare was calculated in tons per hectare by multiplying the yield per plant by the total number of plants that could be grown in one hectare.

Statistical analysis

Using the MSTAT computer program, a statistical analysis was performed on the mean value of the collected data. Duncan's Multiple Range Test (DMRT) was used for the examination of variance and the mean differences (Gomez and Gomez, 1984) [11]. Functional correlations between yield and yield attributes were created using the program Past 4.03.

Result and Discussion

Significant differences were observed in the vegetative parameters, including plant height and stem girth, eight months after transplanting. Additionally, the number of leaves showed a significant difference with micronutrient treatments (Table 2). However, with the treatment T_{11} (12 g Zn + 6 g B), the maximum plant height (155 cm), stem girth (36.46 cm), highest number of leaves (38.50), maximum number of flowers per plant, and fruit set per plant were recorded as 51.30 and 29.33, respectively, while no micronutrient treatment recorded the minimum values of vegetative parameters. Micronutrients like zinc and boron have been applied, which has improved the plant's respiration and photosynthetic efficiency while also influencing growth characteristics and increased vegetative parameters. According to Singh *et al.* (2010) [20], zinc plays a role in the synthesis of tryptophan, which is the precursor of auxin, and this may explain why zinc sulphate promotes vegetative growth in *Papaya*. Combining zinc and boron enhanced the activities of metabolites, which in turn enhanced the metabolites in plants that are in charge of cell division, elongation, and growth (Bhalerao and Patel, 2015) [3]. The outcomes closely align with the research conducted by Ram and Bose (2000).

In contrast, the treatment receiving 6g (105.00), 8 g (121.67), and 9 g (145.33) of boron was found to have the most advanced days for flowering, fruit set, and fruit harvest following fruit set (Table 2). This promptness could be because in the early stages of flower initiation, the formation of flower buds, and the synthesis of native and florigenic substances, boron is essential. In addition to promoting pollen germination, pollen tube growth, and fertilization, it also plays a role in the metabolism of glucose and the transport of hydrocarbons. Similar results were obtained in the case of Singh *et al.* (2010) [20] in Ranchi. In terms of reproductive parameters, eight months after transplanting, the plants treated with soil application of T_{11} (12 g Zn + 6 g B) displayed a higher number of flowers plant-1 (51.30) (Table 2). It might be because zinc and boron have a beneficial combined effect on flowering. According to Ryugo (1988) [16], zinc improved the synthesis of auxin in plants, which promotes flowering. Per Pandey and Sinha (2006), iron is recognized as having a specific function in the synthesis of the chlorophyll molecule. According to Brown *et al.* (1995) [4], boron controls metabolism, which includes the translocation of carbohydrates, the formation of cell walls, and RNA synthesis. Venu *et al.* (2014) [22] found similar outcomes with kagzi lime.

Table 2: Effect of micronutrients on growth parameters at eight months after transplanting

Treatment	Plant height (cm)	Stem girth (cm)	Leaves plant^{-1}	Flowers plant^{-1}	Fruits plant^{-1}
T_0	125 i	28.20 f	25.33 h	31.33 k	21.33 h
T_1	127 hi	29.58 ef	28.67 fg	33.30 i	24.30 efg
T_2	132 fgh	31.33 cdef	30.10 efg	36.32 h	25.17 def
T_3	140 cde	32.72 bcde	34.62 bc	38.71 g	27.67 abc
T_4	145 bc	33.48 abcd	32.71 cde	40.67 e	28.33 ab
T_5	127 hi	30.76 def	28.23 gh	32.17 j	22.67 gh
T_6	129 ghi	32.51 bcde	29.00 fg	39.52 f	24.56 efg
T_7	135 efg	34.24 abc	31.53 cdef	40.17 ef	25.33 cdef
T_8	137 def	34.52 abc	30.65 defg	38.58 g	23.72 fgh
T_9	140 cde	35.34 ab	32.82 cde	42.67 d	26.67 bcde
T_{10}	143 cd	35.82 ab	33.67 bcd	46.23 c	27.36 abcd
T_{11}	155 a	36.46 a	38.50 a	51.30 a	29.33 a
T_{12}	150 ab	36.10 a	36.23 ab	47.67 b	26.17 bcde
CV (%)	2.61	5.97	6.12	1.10	5.63
LSD (0.05)	6.04	3.33	3.28	0.74	2.43

Values in a column that share the same letter (s) do not significantly differ at the 5% level using LSD

Table 3: Effect of micronutrients on days to first flowering, fruit set fruit and fruit yield of *Papaya*

Treatment	Days taken for first flowering	Days taken to first fruit set	Days to fruit harvest after fruit set	Fruit weight (kg)	Yield (kg plant^{-1})	Yield (tha^{-1})
T_0	115.00 a	144.00 a	165.67 a	0.90 g	19.06 g	58.83 g
T_1	111.50 abc	137.33 bc	157.00 bc	1.20 ef	29.02 ef	89.56 ef
T_2	110.30 bcd	138.23 b	155.67 cde	1.17 f	29.32 ef	90.47 ef
T_3	111.67 abc	136.28 cd	154.33 de	1.36 bcde	37.70 bc	116.34 bc
T_4	110.50 bc	135.33 d	151.67 fg	1.38 bcd	39.03 bc	120.44 bc
T_5	108.00 cde	128.67 e	154.33 de	1.15 f	26.03 f	80.25 f
T_6	105.00 e	125.67 f	149.67 g	1.21 def	29.78 ef	91.91 ef
T_7	107.67 cde	123.83 g	145.33 h	1.30 def	32.86 de	101.42 de
T_8	110.20 bcd	121.67 h	158.33 b	1.35 cde	32.15 de	99.23 de
T_9	112.67 ab	136.33 cd	156.67 bcd	1.32 def	35.24 cd	108.75 cd
T_{10}	108.67 bcde	137.67 bc	154.33 de	1.51 abc	41.25 b	127.29 b
T_{11}	106.37 de	124.37 fg	146.67 h	1.60 a	46.86 a	144.62 a
T_{12}	110.00 bcd	135.38 d	153.33 ef	1.53 ab	39.97 b	123.36 b
CV (%)	2.20	0.76	1.00	7.94	7.52	7.53
LSD (0.05)	4.05	1.71	2.56	0.18	4.27	13.19

Values in a column that share the same letter (s) do not significantly differ at the 5% level using LSD

The treatment T_{11} (29.33) had the highest number of fruits, comparable to treatments T_4(28.33) and T_3 (27.67), while treatment T_0(Control) had the lowest number of fruits (Table 2). Auxin production may have contributed to the increase in fruits per tree as a result of the combined application of micronutrients through foliar or soil application. Auxins likely helped retain fruits by lowering flower drops, which in turn increased fruit production. The outcome supported the conclusions shown in fig. by Tamboli *et al.* (2015) [21]. Dhinesh *et al.* (2007) [6] found similar results in Kinnow Mandarin. The plants treated with 12 g Zinc + 6 g Boron (T_{11}) had the highest fruit weight values, weighing 1.60 kg, according to the results. A higher fruit weight could have been the consequence of the combined treatment of boron and zinc. Micronutrients may have contributed to the weight increase of the fruit in treated plants by facilitating the faster loading and mobilization of photoassimilates to the fruit as well as by assisting in cell division and expansion (Gurjar *et al.*, 2015) [12]. The present findings agree with similar results found by Banik *et al.* (1997) [1], Dutta and Dhua (2002) [7], Dutta (2004) [8] in the case of mango, and Ghanta and Mitra (1993) [10] in the case of banana. The data presented in Table 3 indicates that T_{11} had the highest mean fruit yield per plant (46.86 kg) and the highest yield ha^{-1} (144.62 tons) (Table 3). Conversely, T_0 had the significantly lowest values. Micronutrients have a direct impact on photosynthesis and are essential for the growth, development, and flowering of plants. As a result, there is a chance that yield and the dry matter percentage will increase. These outcomes agree with the conclusions of Tamboli *et al.* (2015) as shown in fig. The beneficial effects of micronutrients on growth and nutrition have also been reported in earlier studies on sapota (Saraswathy *et al.*, 2004) [18], kinnow mandrian (Dhinesh *et al.*, 2007) [6], mandarin orange (Saraswathi *et al.*, 1998) [17], and guava (Rathore *et al.*, 2008) [15].

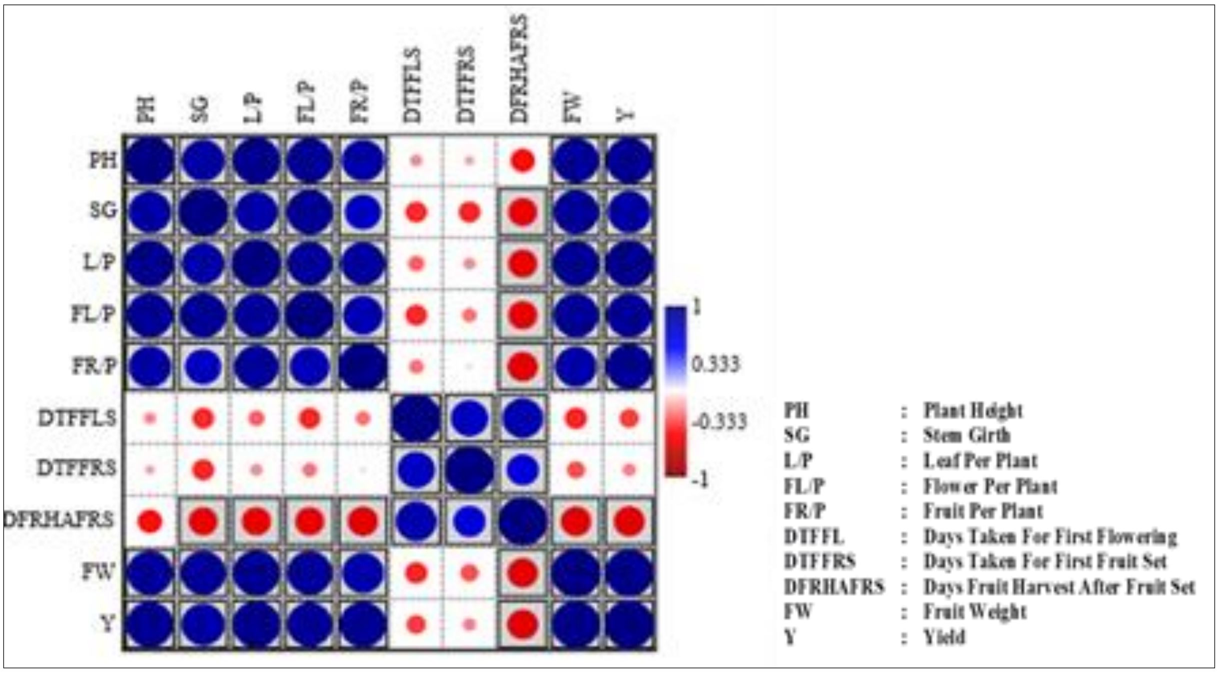

Fig 2: Correlation among the studied traits of the *Papaya* genotype

Correlations among the traits

Avery significant positive correlations were found among the most of the parameters. Prominently, yield had very significant positive correlations with plant height, stem girth, leaves per plant, flowers per plant, fruits per plant and fruit weight. And very natural significant negative correlations were found among days to fruit harvest after fruit set to stem girth, leaves per plant, and flowers per plant, fruits per plant, fruit weight and yield (Figure 2). Silva *et al.* (2007) [19], suggesting that, plants that present higher yield will also have higher stem diameter, fruits per plant but lower internal cavity diameter. Moreover, he also explored that selecting plants with larger stem diameter may improve yield due to high genetic correlation between those traits. Ferreira *et al.* (2012) [9] also evaluated correlations between morpho-agronomic traits of different *Papaya* accessions; stating that the increase in fruit matter and fruit numbers were correlated with higher stem diameter.

Conclusion

In order to increase the yield (144.62 t/ha) of *Papaya* cv. Red Lady in Bangladesh, the results of this study shown that the T_{11} treatment had a substantial effect on plant height, flowering, and fruiting of *Papaya* at the dose of 12 g Zn + 6 g B. The number of fruits produced per plant, the duration from flowering to fruit maturity, and the weight of the fruits (g) all demonstrated noteworthy benefits during this treatment. For the *Papaya* cv. Red Lady to yield excellent results, more research is necessary to identify a more precise combination.

Acknowledgments

The authors would like to express their gratitude to the scientists of the Horticulture Division at BINA in Mymensingh for their cooperation during the investigation.

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