Effect of Foliar Spray of Boron and Zinc on the Fruit Quality of Papaya (*Carica papaya* L.) cv. Red Lady in Chitwan, Nepal

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Abstract
A field experiment was carried out at the commercial papaya farm, Chanauli, Chitwan, from January 2016 to December 2016 to find out the effect of foliar spray of boron and zinc on the quality of papaya (*Carica papaya* L.) cv. Red Lady. The experiment consisted of eleven treatments viz., “T1-Control (No spray), T2-Water Spray, T3-Borax at 0.1 % and ZnSO₄ at 0.1 %, T4-Borax at 0.1 % and ZnSO₄ at 0.2 %, T5-Borax at 0.1 % and ZnSO₄ at 0.3 %, T6-Borax at 0.2 % and ZnSO₄ at 0.1 %, T7-Borax at 0.2 % and ZnSO₄ at 0.2 %, T8-Borax at 0.2 % and ZnSO₄ at 0.3 %, T9-Borax at 0.3 % and ZnSO₄ at 0.1 %, T10-Borax at 0.3 % and ZnSO₄ at 0.2 % and T11-Borax at 0.3 % and ZnSO₄ at 0.3 %.” Post-harvest analysis of the harvested fruits was done at the post-harvest laboratory of Agriculture and Forestry University, Rampur, Chitwan. Significantly the highest values were observed for the quality parameters like ascorbic acid content (4.67 mg/100 g pulp), TSS (11.68 ° Brix), pH of fruit juice (5.53), TSS/TA ratio (101.63), and fruit firmness (2.73 Kg/cm²) with the application of borax at 0.3 % and ZnSO₄ at 0.2 %. Similarly, the lowest values for titratable acidity (0.115 %) and physiological loss in weight during 3 days (1.60 %), 5 days (2.00 %), 7 days (3.05 %), and 9 days (4.75 %) after storage at room temperature were found in the same treatment.

Keywords: Boron, Zinc, Papaya, Quality, Foliar Spray, Red Lady

1 Introduction
Papaya (*Carica papaya* L.) is an evergreen herbaceous commercial fruit crop of tropical and subtropical regions. It belongs to the family Caricaceae. Over the years, it has become an important commercial fruit crop. The ripe fruits of papaya are used for table purposes; raw fruits are cooked and used as vegetable and immature fruits are used for extraction of papain. Papaya has occupied a unique place in the diet of people worldwide because of its striking nutritional and medicinal value. It is a rich source of carbohydrates, minerals, and vitamins (carotene, riboflavin and vitamin A). Papaya is also known to contain high amounts of photolytic enzymes (captoprine, which have many applications in pharmaceutical, tanning, and silk industries (Chadha, 1992). Red Lady is gynodioecious in nature, early, vigorous, productive, and tolerant to papaya ring spot virus (PRSV). The flesh is thick, red, and 13% sugar content with unique aroma (Tyagi and Datt, 2004). Micronutrients can tremendously boost crop yield, improve quality and post-harvest life of produce. They play an important role in disease resistance since they function as enzyme activators and also play a role in lignin biosynthesis (Edward Raja, 2009). Foliar application of micronutrients has gained importance in recent years because the nutrients are sprayed directly to leaves and can be made available to the plants at proper time when needed. Zinc and Boron occupy an important place due to their ability to positively influence plant growth and development and to impart resistance to biotic and abiotic stresses (Cakmak, 2008). Boron is a constituent of cell membrane and is essential for cell division. It acts as a regulator of potassium/calcium ratio in the plant and helps in nitrogen absorption and translocation of sugars in plants. Zinc is the important constituent of several enzymes, which regulates various metabolic reactions in the plant and also essential for auxin and protein synthesis (Trivedi et al., 2012). The present investigation was carried out to find the influence of boron and zinc on the quality of papaya fruits from January 2016 to December 2016.
2 Results
All the treatments containing the combinations of different concentrations of boron and zinc have significant effect on the ascorbic acid content, TSS, TA, TSS/TA ratio, pH, and firmness of papaya fruits as compared to control (Table 1). Foliar application of borax @ 0.3 % along with ZnSO₄ @ 0.2 % have produced maximum ascorbic acid content, TSS, TSS/TA ratio, pH, and firmness and minimum TA of the papaya fruits.

Similarly, the application of different concentrations of borax and ZnSO₄ in combination through foliar spray has significantly reduced the physiological loss in weight of papaya fruit (Table 2). Foliar application of borax @ 0.3 % along with ZnSO₄ @ 0.2 % have minimum physiological loss in weight (PLW) during 3 days, 5 days, 7 days and 9 days after storage at room temperature.

3 Discussion
Boron and zinc are reported to act as activators in the biosynthesis of ascorbic acid thus increased the ascorbic acid content of fruit juice. The positive influence of borax and ZnSO₄ in improving the ascorbic acid content have also been reported by Singh and Chonkkar (1983), Sharma et al. (1991), Wahid et al. (1991) in guava, and Rai et al. (1988) in orange. Micronutrients like boron and zinc help in catalytic action and their combined synergetic effect particularly at higher concentrations helps in accumulation of more photosynthates into sink. Zinc helps in conversion of starch into soluble sugars. Boron helps in rapid translocation of soluble sugars into developing fruits. Similar results of increment in TSS content due to foliar spray of boron and zinc have also been reported by Kavitha et al. (2000) and Singh et al. (2010) in papaya and Rawat et al. (2010) in guava. Firmness (Kg/cm²) is an important characteristic of fruits. Boron and zinc involve in the synthesis and integrity of cell wall, cell wall lignification, and metabolism of RNA, carbohydrate, phenol, and indole acetic acid (IAA), respiration and cell membrane integrity (Parr and Loughman, 1983). Similarly, boron content influences calcium metabolism and its accumulation in the cell wall as a calcium pectate and other derivatives (Yamaguchi et al., 1986) resulting into higher firmness as calcium is the structural integrity of both the call wall and plasma membrane (Tandel, 2014).
Similar results were reported by Yadav et al. (2010) in papaya. The reduction in titratable acidity of papaya fruits and increase in pH of papaya juice due to application of different levels of boron and zinc in combinations might be due to positive influence of boron and zinc on rapid conversion of acids into sugars and their derivatives by the reaction involving the reversal of glycolic pathway or might have been used as substrate in the respiration or both (Pandey et al., 2008). The results were in close conformity with the findings of Singh et al. (2010) in papaya, who also reported reduction in acidity of fruits with foliar application of boron and zinc in combination with other nutrients.

The lower physiological loss in weight due to application of different levels of boron and zinc in combinations might be due to increase in fruit firmness. It might also be due to the beneficial effect of zinc and boron on hormonal metabolism, photosynthesis, and water relations in plants. Further, boron and zinc involve in slower conversion of starch to sugars and also less and delayed incidence of papaya ring spot virus, which deteriorates the fruit quality. Appreciable enhancement in physiological loss in weight of papaya fruits by foliar application of boron and zinc in field condition has also been reported by Ratananukul et al. (1988), Kavitha et al. (2000), Singh et al. (2005) as well as Kudada and Prasad (2006) in papaya.

4 Materials and Methods
The field experiment was conducted in the net house at Chanauli, Chitwan from January 2016 to December 2016 following randomized complete block design (RCBD) with three replications and post-harvest analysis of the harvested fruits was done at post-harvest laboratory of Agriculture and Forestry University, Rampur, Chitwan. Mulching by black polythene plastic was done and set-up was made by spreading the plastic pipes along the row with perforation in the certain spacing for the drip irrigation and fertigation purpose. Healthy, disease free, and uniform Red Lady papaya seedlings were planted in the experimental field on 11-01-2016 (2nd week of January)
Table 1 Effect of foliar spray of boron and zinc on fruit quality parameters of papaya cv. Red Lady in Chitwan, Nepal, 2016

| Treatments                      | Ascorbic acid (mg/100g pulp) | TSS (°Brix) | TA (%) | TSS/TA ratio | pH | Firmness (Kg/cm²) |
|--------------------------------|-------------------------------|-------------|--------|--------------|----|------------------|
| Control                        | 3.36a                         | 8.33a       | 0.1923 | 43.34a       | 4.60a | 1.48a            |
| Water spray                    | 3.36a                         | 8.33a       | 0.1923 | 43.32a       | 4.60a | 1.46a            |
| Borax @ 0.1% + ZnSO₄ @ 0.1%   | 3.52ab                        | 9.24b       | 0.1640 | 56.40b       | 4.80ab | 1.50a            |
| Borax @ 0.1% + ZnSO₄ @ 0.2%   | 3.61abc                       | 9.38b       | 0.1628 | 57.65b       | 4.90bc | 1.60ab           |
| Borax @ 0.1% + ZnSO₄ @ 0.3%   | 3.62abc                       | 9.41b       | 0.1620 | 58.17b       | 5.10cd | 1.60abc          |
| Borax @ 0.2% + ZnSO₄ @ 0.1%   | 3.70abc                       | 9.78bc      | 0.1408 | 69.51c       | 5.20de | 1.75abcd         |
| Borax @ 0.2% + ZnSO₄ @ 0.2%   | 3.86abc                       | 9.86bc      | 0.1401 | 70.45c       | 5.33ef | 1.87abcd         |
| Borax @ 0.2% + ZnSO₄ @ 0.3%   | 3.97abc                       | 10.12bc     | 0.1390 | 72.92c       | 5.40ef | 1.93abcd         |
| Borax @ 0.3% + ZnSO₄ @ 0.1%   | 4.33abc                       | 10.67cd     | 0.1280 | 83.91d       | 5.40ef | 2.06bd           |
| Borax @ 0.3% + ZnSO₄ @ 0.2%   | 4.67d                         | 11.68e      | 0.1150 | 101.63f      | 5.53f  | 2.73c            |
| Borax @ 0.3% + ZnSO₄ @ 0.3%   | 4.47cd                        | 11.00bc     | 0.1180 | 93.33c       | 5.46f  | 2.10d            |
| LSD                            | 0.783                         | 0.918       | 0.005984 | 6.72       | 0.2090  | 0.421            |
| SEM                            | 0.265                         | 0.311       | 0.002029 | 2.28       | 0.0709  | 0.143            |
| CV %                           | 11.9                          | 5.5         | 2.3     | 5.80        | 2.4    | 13.5             |
| Grand mean                     | 3.86                          | 9.80        | 0.15039 | 68.19       | 5.121  | 1.83             |

Note: Means are separated by DMRT and columns represented with same letter (s) are non-significant at 5 % level of significance.

Table 2 Effect of foliar spray of boron and zinc on Physiological loss in weight of papaya cv. Red Lady in Chitwan, Nepal, 2016

| Treatments                      | Physiological loss in weight (%) |
|--------------------------------|----------------------------------|
|                                | 3 days | 5 days | 7 days | 9 days |
| Control                        | 2.39f  | 3.50f  | 5.00f  | 6.50f  |
| Water spray                    | 2.39f  | 3.50f  | 5.00f  | 6.50f  |
| Borax @ 0.1% + ZnSO₄ @ 0.1%   | 2.00d  | 3.00f  | 4.50f  | 6.00d  |
| Borax @ 0.1% + ZnSO₄ @ 0.2%   | 1.96d  | 2.90e  | 4.40ef  | 5.70bc |
| Borax @ 0.1% + ZnSO₄ @ 0.3%   | 1.89d  | 2.70d  | 4.20d ef | 5.45bc |
| Borax @ 0.2% + ZnSO₄ @ 0.1%   | 1.83bcd | 2.63cd | 4.01bcd | 5.22b  |
| Borax @ 0.2% + ZnSO₄ @ 0.2%   | 1.76bc | 2.45bc | 3.81abcde | 5.00e  |
| Borax @ 0.2% + ZnSO₄ @ 0.3%   | 1.70b  | 2.33b  | 3.55abcd | 4.90b  |
| Borax @ 0.3% + ZnSO₄ @ 0.1%   | 1.65s  | 2.13s  | 3.30bc | 4.81s  |
| Borax @ 0.3% + ZnSO₄ @ 0.2%   | 1.60s  | 2.00s  | 3.05s | 4.75s  |
| Borax @ 0.3% + ZnSO₄ @ 0.3%   | 1.64s  | 2.10s  | 3.20ab | 4.80s  |
| LSD                            | 0.1561 | 0.1918 | 0.8130 | 0.6428 |
| SEM                            | 0.0529 | 0.0650 | 0.2756 | 0.2179 |
| CV %                           | 4.8    | 4.2    | 11.9   | 7.0    |
| Grand mean                     | 1.895  | 2.659  | 4.004  | 5.422  |

Note: Means are separated by DMRT and columns represented with same letter (s) are non-significant at 5 % level of significance.
with a spacing of 2.0 m X 1.80 m. FYM @ 5 Kg per plant were applied in a pit before planting the seedlings. Recommended dose of major nutrients for papaya @ 250:250:500 g NPK per plant per year were applied in 6 splits doses at a two-month interval through fertigation. Different concentrations of zinc (0.1%, 0.2% and 0.3%) and boron (0.1%, 0.2% and 0.3%) were combined and applied through foliar spray of borax and ZnSO₄ in five split doses at 15, 30, 60, 90, and 120 days after planting, respectively. The mature fruits were harvested and transported to post-harvest laboratory of Agriculture and Forestry University, Rampur, Chitwan for post-harvest analysis. The post-harvest analysis was done collecting the data on ascorbic acid content, total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, pH, firmness, and physiological loss in weight (PLW). Experimental data were analyzed using GenStat Software of 15th edition and treatment means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance.

5 Conclusion

The combined applications of boron and zinc through foliar spray in field condition have improved the quality parameters (ascorbic acid content, TSS, TA, TSS/TA ratio, pH, firmness, and PLW) in papaya. So, the foliar application of boron in combination with zinc increased the quality of papaya in Chitwan condition.

Authors' contributions
A. Subedi and A.K. Shrestha conceived and designed the analysis. A. Subedi collected the data. A. Subedi, A.K. Shrestha, K.M. Tripathi, and B. Shrestha contributed data and analysis tool. A. Subedi performed the analysis. And A. Subedi wrote the paper. All the authors read and agreed to the final text.

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