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INFLUENCE OF SOIL APPLICATION OF ZINC AND BORON ON POST-HARVEST QUALITY ATTRIBUTES AND SHELF LIFE OF DRAGON FRUIT (*HYLOCEREUS POLYRHIZUS* L.)

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ABSTRACT

The present study was conducted during 2023-24 and 2024-25 at college of agriculture, IGKV, Raipur, with the objective to know the Influence of soil application of zinc and boron on post-harvest quality attributes and shelf life of Dragon Fruit (*Hylocereus polyrhizus* L.). As far as post-harvest during parameters of dragon fruits was concerned, were stored up to 9th day after harvest to analysis the physico-chemical composition parameters and shelf life. All the data were recorded at 9th day after harvest. The minimum acidity (0.239, 0.246 and 0.248 %) recorded under factor A (zinc) Z_1, factor B (boron) B_3 and their treatment interaction T_8 (Z_1B_3) - Zinc sulphate @ 3 g per pole + Boron @ 6 g per pole and maximum non-reducing sugar (3.16, 3.35 and 3.59 %) recorded under factor A (zinc) Z_2, factor B (boron) B_3 and their treatment interaction T_{12} (Z_2B_3) - Zinc sulphate @ 6 g per pole + Boron @ 6 g per pole. The maximum TSS (17.55, 18.46 and 18.83 ^{0}Brix), maximum ascorbic acid (9.163, 9.198 and 9.216 mg/100g), total sugar (9.66, 10.06 and 10.29 %), reducing sugar (6.59, 6.71 and 6.87 %), minimum physical loss in weight (4.260, 2.548 and 2.533 %), maximum retention of marketable fruits (81.66, 92.50 and 93.33 %), minimum fruit decay (18.33, 7.50 and 6.66 %), maximum specific gravity (1.003, 1.082 and 1.113 g/cc), maximum anthocyanin (116.82, 116.93 and 116.99 mg/g) and maximum shelf life (12.50, 13.50 and 14.33 Days) recorded under factor A (zinc) Z_3, factor B (boron) B_3 and their treatment interaction T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole.
***Keywords* :** Boron, Dragon fruits, Post-harvest and Zinc.

Introduction

Dragon fruit, otherwise called pitaya or pitahaya, is an edible fruit of the *Hylocereus* genus. *Hylocereus spp*. is diploid (2n = 22) and belongs to the genus *Hylocereus* of the family Cactaceae and subfamily Cactoideae. *Hylocereus* species are herbaceous perennial climbing cactus mainly distributed in subtropical and tropical regions and highly tolerant to drought. It is a native of Southern Mexico, Guatemala, and Costa Rica (Mizrahi *et al*., 1997; Wichienchot *et al.,* 2010). Dragon fruit is a exotic fruit crop in India. Dragon fruit has red or pink thornless skins, while its juicy flesh can range from white to magenta. The skin is covered with bracts or scales. Dragon fruit is considered a promising crop to be grown commercially in dry regions (Vaillant *et al.,* 2005). Usually, dragon fruit is propagated sexually by seed and asexually by grafting and stem cutting. The easiest, cheapest and convenient method of propagating dragon fruit is by stem cutting. Though seed propagation method is very simple but seeds are not true to type due to cross pollination (Andrade *et al.,* 2005). It has expanded globally in Central and tropical South America, Southeast Asia and China (Wichienchot *et al.,* 2010). It is a long day plant and due to the beauty of their large creamy white coloured flower that bloom at night, the fruit is also known as “Noble women” or “Queen of the night” (Kumar *et al*., 2019). Among micronutrients, horticultural crops suffer from zinc deficiency worldwide (Suman *et al.,* 2017). Zinc is essential for energy transmission, nitrogen metabolism and oxidation reduction reactions. Many enzymes in plants like carbonic anhydrase, hydrogenase, cytochrome synthesis and ribosomes is affected by zinc (Tisdale *et al.,* 1984). Zinc also plays an important role in photosynthesis and related enzymes resulting in increasing sugar and decreasing acidity (Sangeeta *et al.* 2019). Boron also influences fruit development and improves fruit quality by regulating biochemical processes (Storey, 2007). Boron is involved in several metabolic pathways including sugar transport during fruit development and maturation. It also stimulates the synthesis of sucrose by upregulating the activity of sucrose synthase. Boron is also involved in maintenance of fruit firmness by reducing the activity of cell wall degrading enzymes (Muengkaew *et al.,* 2018). Boron is essential for cell wall and protein synthesis, sugar transport, cell division and differentiation, membrane functioning, root elongation, regulation of plant hormone levels and generative plant growth (Anonymous, 2012). Unlike other micronutrients, boron has restricted mobility in plant system, hence application is commonly followed in fruit crops to improve fruit quality attributes (Ali *et al.,* 2017). Boron is also involved in maintenance of fruit firmness by reducing the activity of cell wall degrading enzymes (Muengkaew *et al.,* 2018). The roles of B in plants primarily include; sugar transport, cell wall synthesis, lignification, carbohydrate metabolism, ribose nucleic acid metabolism, indole acetic acid metabolism, and phenol metabolism (Ahmad *et al.*, 2009). Zn and B help in obtaining higher yield due to good preservation of fruits by improving fruit set and reducing fruit drop (Noor *et al.,* 2019) micronutrient in relation to growth, yield and quality of dragon fruits.

Materials and Methods

The experiment was conducted in the Centre of Excellence Protected Cultivation and Precision Farming, Department of Fruit Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.), during the years 2023-2024 and 2024-2025. The experiment was laid out in a Factorial Randomized Complete Block Design on dragon fruits of variety Red into Red with two factors with four Level and of sixteen treatment combination with three replications *viz.*, Factor A (Zinc)-Z_0-No zinc sulphate ($ZnSO_4$), Z_1 - Zinc sulphate ($ZnSO_4$) @ 3 g per pole, Z_2 - Zinc sulphate ($ZnSO_4$) @ 6 g per pole, Z_3 - Zinc sulphate ($ZnSO_4$) @ 9 g per pole and Factor B (Boron) B_1 - No boron ($Na_2B_8O_{13}.4H_2O$), B_2-Boron ($Na_2B_8O_{13}.4H_2O$) @ 2 g per pole, B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole, B_4 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole and their treatment combination T_1 (Z_0B_0) - No zinc sulphate + No boron (Control), T_2 (Z_0B_1) - No zinc sulphate + Boron @ 2 g per pole, T_3 (Z_0B_2) - No zinc sulphate + Boron @ 4 g per pole, T_4 (Z_0B_3) - No zinc sulphate + Boron @ 6 g per pole, T_5 (Z_1B_0) - Zinc sulphate @ 3 g per pole + No boron, T_6 (Z_1B_1) - Zinc sulphate @ 3 g per pole + Boron @ 2 g per pole, T_7 (Z_1B_2) - Zinc sulphate @ 3 g per pole + Boron @ 4 g per pole, T_8 (Z_1B_3) - Zinc sulphate @ 3 g per pole + Boron @ 6 g per pole, T_9 (Z_2B_0) - Zinc sulphate @ 6 g per pole + No boron, T_{10} (Z_2B_1) - Zinc sulphate @ 6 g per pole + Boron @ 2 g per pole, T_{11} (Z_2B_2) - Zinc sulphate @ 6 g per pole + Boron @ 4 g per pole, T_{12} (Z_2B_3) - Zinc sulphate @ 6 g per pole + Boron @ 6 g per pole, T_{13} (Z_3B_0) - Zinc sulphate @ 9 g per pole + No boron, T_{14} (Z_3B_1) - Zinc sulphate @ 9 g per pole + Boron @ 2 g per pole, T_{15} (Z_3B_2) - Zinc sulphate @ 9 g per pole + Boron @ 4 g per pole, T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole. Firstly clean the research field. All the cultural practices, like weeding, application of basal dose of primary nutrient, irrigation and plant protection were taken up timely intervals. After uniform dragon fruits poles from each treatment were selected. The packed prepared 3g, 6g and 9g of zinc and 2g, 4g and 6g boron. Research work based soil application of zinc and boron on dragon fruit root zone and used media vermicompost. The observation were recorded 9^{th} day after harvest (DAH) of dragon fruits.

TSS (^{0}Brix)

Total soluble solids, in the juice of representative sample were determined by using "Hand Refractometer" (range of 0-32°brix) and expressed as total soluble in solid, degree Brix (^{0}B) following the procedure given in A.O.A.C. (1980).

Acidity (%)

Acidity was estimated by adopting the procedure described by Ranganna (1986). Ten grams of sample was ground well and transferred to volumetric flask and volume was made up to 100ml with distilled water. The contents were filtered through whatman No.1 filter paper. An aliquot of 10ml was taken into a conical flask and 2-3 drops of phenolphthalein indicator was added and then titrated against 0.1N NaOH. Appearance of light pink colour denotes the end point. It was calculated using the following formula and expressed in percentage. (Eq. wt. of citric acid = 0.064).

$$\textbf{Acidity (\%)} = \frac{\text{Titre x Normality of NaOH x Eq. wt. of acid x volume made up}}{\text{Weight of sample x Aliquot taken}} \times 100$$

Ascorbic acid (mg/100g)

Ascorbic acid was estimated by Indophenol method (Ranganna, 1986). Ten grams of fresh fruit pulp was ground well and blended with 3% Meta phosphoric acid (HPO_3) and the volume was made up to 100ml with HPO_3 solution. An aliquot of 10ml was taken and titrated against standard dye solution (2, 6 dichlorophenol indophenol dye) till light pink colour persist for at least 15 seconds. Standardization of dye (dye factor) was done by titrating it against standard ascorbic acid diluted in 3% HPO_3 solution. The ascorbic acid was calculated using the following formula and expressed as mg ascorbic acid per 100 g fresh weight.

$$\textbf{Ascorbic acid (mg/100g)} = \frac{\text{Titre x Day factor x volume made up}}{\text{Weight of sample x Aliquot taken}} \times 100$$

$$\textbf{Day factor} = \frac{0.5}{\text{Titre value}} \times 100$$

Total sugar (%)

Total sugars were also determined by Lane and Eynon method (Ranganna, 1986). A quantity of 50ml lead free filtrate was taken in a 100ml volumetric flask and 5ml of concentrated HCl was added to it, mixed well and kept for 24 hours at room temperature. Acid was then neutralized with NaOH using a drop of phenolphthalein as an indicator till the pink colour persisted for at least few seconds. Then volume was made up to 100ml. Total sugars were then estimated by taking this solution into a burette and titrating it against standard Fehling's solution mixture of A and B (1:1) using methylene blue as an indicator to a brick red colour as an end point. The results were calculated and expressed as percent total sugars with the following formula. (10ml Fehling's solution = 0.052g glucose).

$$\textbf{Total sugar (\%)} = \frac{\text{Factor x Dilution 1 x Dilution 2}}{\text{Titre value x Weight of sample x Aliquot taken}} \times 100$$

Reducing sugar (%)

The per cent reducing sugars in fully matured dragon fruit pulp were determined by Lane and Eynon method (AOAC, 1984). 25 grams of the sample of fruit juice was taken into 250 ml volumetric flask and add 100 ml of distilled water. Two ml of lead acetate solution (45%) was added to the flask to precipitate colloidal matter and wait for 30 mins. Later two ml of potassium oxalate (22%) was added to the solution to precipitate the lead acetate and the volume was made up to 250 ml by using distilled water. The contents were then filtered through Whatman No. 1 filter paper. A little of filtrate was tested for its freedom of lead acetate by adding a drop of potassium oxalate. The filtrate was taken into a burette and titrated against 10 ml of standard Fehling's solution mixture of A and B (1:1) by using methylene blue as an indicator till the formation of brick red precipitate. The titration was carried out by keeping the Fehling's solution mixture on boiling waterbath. The per cent reducing sugars in dragon fruit juice was calculated by using the following formula.

$$\textbf{Reducing sugar (\%)} = \frac{\text{Factor x Volume made up x 100}}{\text{Titre value x Weight of sample taken (g) x 1000}}$$

Non reducing sugar (%)

The percentage of non-reducing sugars was obtained by subtracting the percentage of reducing sugars from the total sugars and expressed in percentage.

Non-reducing sugars (%) = Total sugars (%) - Reducing sugars (%)

Physical loss in weight (%)

For determination of Physiological loss in weight the marked and labeled fruits in each treatment were weighed prior to storage. Their weight was determined on 9th days after harvest. The reduction in weight of stored fruits was calculated in relation to initial weight of fruits and expressed in percentage.

$$\textbf{PLW (\%)} = \frac{W1-W2}{W1} \times 100$$

Where,

W1 = Initial weight of fruits.

W2 = Weight of fruits after 9th days after storage.

Retention of marketable fruits (%)

Number of marketable fruits remained during storage under various treatment was recorded at (i.e., 9th day after harvest). Retention of marketable fruits was calculated by given formula and expressed in terms of percentage.

$$\textbf{No. of marketable fruits (\%)} = \frac{\text{Number of marketable fruits}}{\text{Total number of fruits kept for storage}} \times 100$$

Fruit decay (%)

At 9th days after harvest, the number of fruits that had decayed from infection of fungus or other microorganism was counted and calculated to a percentage of the total fruit using the following equation.

$$\textbf{Fruit decay (\%)} = \frac{\text{Number of decayed fruits}}{\text{Initial number of harvested fruits}} \times 100$$

Specific gravity (g/cc)

For determination of specific gravity, the marked and labelled fruits in each treatment were weighed prior to harvest. Their specific gravity was determined by water displacement method on 9^{th} days after storage.

$$\textbf{Specific gravity} = \frac{\text{Density of fruit}}{\text{Density of water}}$$

Where,

$$\textbf{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Anthocyanin (mg/g)

2-5 grams of sample was homogenized with AM (Acidic methanol) and incubated for 72 h. The mixture was squeezed and the residue was re-extracted 2-3 times to extract all anthocyanins. Pooled extract was made up to 25ml. The intensity of colour was read at 540 nm adjusting 100% transmission against AM. Amount of anthocyanin in unknown sample was calculated using cyanidin hydrochloride as standard and expressed as mg/100g fresh weight. w/w of total anthocyanins in the sample (Lee *et al.,* 2005).

$$w/w = \frac{A}{\varepsilon L} \times MW \times DF \times \frac{V}{Wt} \times 100$$

Where:

A = Absorbance

ε = Cyd-3-glu molar absorbance (26,900)

MW = anthocyanin molecular weight (449.2)

DF = dilution factor

V = final volume (mL)

Wt = sample weight (mg)

L = cell pathlength (usually 1 cm)

Shelf life (Days)

Shelf life of the fruits was determined by recording the number of days the fruits remained in good condition in storage. The stage where in more than 50 per cent of the stored fruits became unfit for consumption was considered as end of shelf life in that particular treatment and expressed as mean number of days (Padmaja and Bosco, 2014).

Results and Discussion

The fruit storage quality traits during pooled mean years of different treatments are mentioned in Table 1 and 2, which revealed a significant variation in 9^{th} day after harvest of fruit quality attribute Total Soluble Solids (^{0}Brix), acidity (%), ascorbic acid (mg/100g), total sugar (%), reducing sugar (%), non-reducing sugar (%), physical loss in weight (%), retention of marketable fruits (%), fruit decay (%), specific gravity (g/cc), anthocyanin (mg/g) and shelf life (Days) among treatments.

Total soluble solids (^{0}Brix)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed and the maximum TSS (17.55 ^{0}Brix) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (17.27 ^{0}Brix). However, minimum TSS (16.74 ^{0}Brix) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum TSS (18.46 ^{0}Brix) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (17.94 ^{0}Brix). However, minimum TSS (15.74 ^{0}Brix) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$) and the treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum TSS (18.83 ^{0}Brix) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was found statistically at par with T_{12} (Z_2B_3) (18.48 ^{0}Brix), T_{15} (Z_3B_2) (18.46 ^{0}Brix) and T_8 (Z_1B_3) (18.30 ^{0}Brix). However, minimum TSS (15.06 ^{0}Brix) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. The increase in TSS content might be due to application of micronutrients. Zinc plays a crucial role in the hydrolysis of complex polysaccharides into simple sugars, the synthesis of metabolites, and the efficient translocation of photosynthates and minerals from other parts of the plant to developing fruits. These functions ultimately contribute to an increase in TSS content observed on the 9^{th} day of storage. The results from the present study are similar with the finding of Kumar *et al.* (2021), Kumar *et al.* (2024) in papaya, Rajkumar (2014) in guava. Similar finding were also reported by Sahu *et al*. (2022), Sahu *et al*. (2022a), Chakma *et al.* (2014), Lalduhsangi and Mandal (2021), Baruah *et al.* (2024), Prashanth *et al.* (2022), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits.

Acidity (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the minimum acidity (0.239 %) was recorded under Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (0.260 %). However, maximum acidity (0.263 %) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the minimum acidity (0.246 %) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_1 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 2 g per pole (0.254 %).

However, maximum acidity (0.268 %) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the minimum acidity (0.248 %) was noticed in T_8 (Z_1B_3) - Zinc sulphate @ 3 g per pole + Boron @ 6 g per pole which was found statistically *at par* with T_4 (Z_0B_3) (0.250 %), T_7 (Z_1B_2) (0.251 %), T_{15} (Z_3B_2), T_{12} (Z_2B_3) (0.255 %) and T_{14} (Z_3B_1), T_{11} (Z_2B_2) (0.258 %). Which was significantly difference with T_3 (Z_0B_2) (0.261%). However, maximum acidity (0.288 %) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. High boron levels may enhance sugar accumulation in dragon fruits by reversing glycolysis, activating biochemical pathways. This alters metabolic processes, slowing the decrease in fruit acidity and influencing overall fruit quality and sugar-acid balance during maturation. Similar reports were reported by Sahu *et al.* (2022), Prashanth *et al.* (2022), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits and similar finding were observed in other fruit crops Patel *et al.* (2017) in aonla, Kumar *et al.* (2024a), Kumar *et al.* (2021) and Rajkumar *et al.* (2014).

Ascorbic acid (mg/100g)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum ascorbic acid (9.163 mg/100g) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (9.133 mg/100g). However, minimum ascorbic acid (9.053 mg/100g) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum ascorbic acid (9.198 mg/100g) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (9.169 mg/100g). However, minimum ascorbic acid (8.981 mg/100g) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum average ascorbic acid (9.216 mg/100g) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was found statistically at par with T_{12} (Z_2B_3) (9.206 mg/100g). Which was significantly difference with T_4 (Z_0B_3) (9.190 mg/100g). However, minimum ascorbic acid (8.866 mg/100g) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Boron and zinc enhance ascorbic acid in fruits by aiding polysaccharide hydrolysis, metabolite synthesis, and translocation of nutrients. However, prolonged storage reduces ascorbic acid due to ascorbinase activity, converting L-ascorbic acid into dehydroascorbic acid. Similar reports were reported by Sahu *et al.* (2022), Sahu *et al.* (2022a), Lalduhsangi and Mandal (2021), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits and similar finding were observed in other fruit crops Anju *et al.* (2022), Kumar *et al.* (2021), Rajkumar *et al.* (2014) and Patel *et al.* (2017).

Total sugar (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on maximum total sugar (9.66%) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was statistically at par with Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (9.59%) which was followed by Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole (9.30%). However, minimum total sugar (8.74%) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum total sugar (10.06%) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (9.56%). However, minimum total sugar (8.39%) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum total sugar (10.37%) was noticed in T_{12} (Z_2B_3) - Zinc sulphate @ 6 g per pole + Boron @ 6 g per pole which was found statistically *at par* with T_{16} (Z_3B_3) (10.29%). However, minimum total sugar (7.70%) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Boron and zinc enhance total sugar content in fruits by promoting tryptophan synthesis, a precursor of IAA, which stimulates physiological processes. Zinc acts as a catalyst in sugar metabolism, while boron aids sugar translocation and membrane transport by forming complexes with sugars, enhancing their movement into fruit tissues. The present results are parallel with the finding of other fruit crops Kumar *et al.* (2021), Rajkumar *et al.* (2014), Patel *et al.* (2017) and Khan and Ahmed (2022). Similar results were reported by Prashanth *et al.* (2022), Sangeeta (2023) and Lalduhsangi and Mandal (2021) in dragon fruits.

Reducing sugar (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum reducing sugar (6.59%) was recorded under Z_3–Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was statistically *at par* with Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (6.43%) and Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole (6.34%). However, minimum reducing sugar (5.77%) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum average reducing sugar (6.71%) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (6.39%) and B_1 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 2 g per pole (6.25%). However, minimum reducing sugar (5.78%) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum reducing sugar (6.87%) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was significantly difference with T_{10} (Z_2B_1) (6.34%). However, minimum reducing sugar (5.07%) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Increase in reducing sugar content might be due to zinc and boron causes conversion of starch and polysaccharides into simple sugar with the advancement of storage was responsible for the increase of reducing sugar as reported by Kumar *et al.* (2021). Similar results were reported by Sahu *et al.* (2022), Sahu *et al.* (2022a), Prashanth *et al.* (2022) and Sangeeta (2023) in dragon fruits and similar finding were observed on other fruit crops Rajkumar *et al.* (2014), and Khan and Ahmed (2022).

Non reducing sugar (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum non-reducing sugar (3.16%) was recorded under Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole. However, minimum non-reducing sugar (2.96%) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum non-reducing sugar (3.35%) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was statistically *at par* with B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (3.17%). However, minimum non-reducing sugar (2.61%) was noticed in B_0-No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum non-reducing sugar (3.59%) was noticed in T_{12} (Z_2B_3) - Zinc sulphate @ 6 g per pole + Boron @ 6 g per pole. Which was significantly difference with T_9 (Z_2B_0) (2.79%). However, minimum non-reducing sugar (1.44%) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. The increase in non-reducing sugar content may result from zinc's catalytic role in oxidation and sugar metabolism, while boron aids in sugar translocation. Borate ions may form complexes with sugars, facilitating their membrane transport and accumulation in the fruit pulp. The present results are parallel with the finding of other fruit crops Kumar *et al.* (2021), Rajkumar *et al.* (2014) and Khan and Ahmed (2022). Similar results were reported by Sahu *et al.* (2022a), Prashanth *et al.* (2022) and Sangeeta (2023) in dragon fruits.

Table 1 : Effect of zinc and boron on post-harvest quality attributes of dragon fruits

Notations		9^{th} day after post-harvest quality attributes					
		TSS (^{0}Brix)	**Acidity (%)**	**Ascorbic acid (mg/100g)**	**Total sugar (%)**	**Reducing sugar (%)**	**Non-reducing sugar (%)**
Factor A Zinc							
Z_0		16.74^{c}	0.263^{c}	9.053^{d}	8.74^{c}	5.77^{b}	2.96^{a}
Z_1		17.10^{b}	0.239^{a}	9.076^{c}	9.30^{b}	6.34^{a}	2.96^{a}
Z_2		17.27^{b}	0.260^{b}	9.133^{b}	9.59^{a}	6.43^{a}	3.16^{a}
Z_3		17.55^{a}	0.262^{b}	9.163^{a}	9.66^{a}	6.59^{a}	3.07^{a}
SE(m)±		**0.10**	**0.002**	**0.003**	**0.09**	**0.09**	**0.14**
CD at 5%		**0.22**	**0.006**	**0.008**	**0.26**	**0.25**	**0.42**
Factor B Boron							
B_0		15.74^{d}	0.268^{c}	8.981^{d}	8.39^{d}	5.78^{c}	2.61^{b}
B_1		16.51^{c}	0.254^{b}	9.077^{c}	9.27^{c}	6.25^{b}	3.01^{ab}
B_2		17.94^{b}	0.257^{b}	9.169^{b}	9.56^{b}	6.39^{b}	3.17^{a}
B_3		18.46^{a}	0.246^{a}	9.198^{a}	10.06^{a}	6.71^{a}	3.35^{a}
SE(m)±		**0.10**	**0.002**	**0.003**	**0.09**	**0.09**	**0.14**
CD at 5%		**0.22**	**0.006**	**0.008**	**0.26**	**0.25**	**0.42**
Treat.	**Inter. (AxB)**						
T_1	$Z_0 B_0$	15.06^{h}	0.288^{g}	8.866^{k}	7.70^{f}	5.07^{h}	1.44^{f}
T_2	$Z_0 B_1$	15.66^{g}	0.275^{f}	9.013^{i}	7.98^{e}	5.72^{g}	2.25^{e}
T_3	$Z_0 B_2$	17.40^{de}	0.261^{bcde}	9.143^{f}	9.47^{c}	5.83^{g}	3.57^{ab}

T_4	**$Z_0 B_3$**	18.23^{bc}	0.250^{ab}	9.190^{bc}	9.80^{bc}	6.47^{abcde}	3.32^{abc}
T_5	**$Z_1 B_0$**	15.70^{g}	0.271^{ef}	8.926^{j}	8.23^{e}	5.94^{fg}	2.29^{de}
T_6	**$Z_1 B_1$**	16.36^{f}	0.268^{def}	9.030^{i}	9.66^{c}	6.19^{cdefg}	3.47^{abc}
T_7	**$Z_1 B_2$**	18.03^{bc}	0.251^{ab}	9.170^{de}	9.52^{c}	6.52^{abcd}	2.99^{abcde}
T_8	**$Z_1 B_3$**	18.30^{abc}	0.248^{a}	9.178^{cd}	9.78^{bc}	6.71^{ab}	3.07^{aabcd}
T_9	**$Z_2 B_0$**	15.73^{g}	0.271^{ef}	9.040^{h}	8.79^{d}	6.00^{efg}	2.79^{bcde}
T_{10}	**$Z_2 B_1$**	17.00^{e}	0.268^{def}	9.110^{g}	9.68^{c}	6.34^{bcdef}	3.34^{abc}
T_{11}	**$Z_2 B_2$**	17.88^{cd}	0.258^{abcd}	9.176^{cd}	9.51^{c}	6.59^{abc}	2.94^{abcde}
T_{12}	**$Z_2 B_3$**	18.48^{ab}	0.255^{abc}	9.206^{ab}	10.37^{a}	6.78^{ab}	3.59^{a}
T_{13}	**$Z_3 B_0$**	15.86^{fg}	0.268^{def}	9.093^{g}	8.85^{d}	6.10^{defg}	2.75^{cde}
T_{14}	**$Z_3 B_1$**	17.03^{e}	0.258^{abcd}	9.156^{ef}	9.76^{bc}	6.76^{ab}	3.00^{abcde}
T_{15}	**$Z_3 B_2$**	18.46^{abc}	0.255^{abc}	9.186^{bcd}	9.74^{c}	6.63^{abc}	3.10^{abc}
T_{16}	**$Z_3 B_3$**	18.83^{a}	0.265^{cdef}	9.216^{a}	10.29^{ab}	6.87^{a}	3.42^{abc}
SE(m)±		**0.20**	**0.004**	**0.006**	**0.18**	**0.17**	**0.28**
CD at 5%		**0.59**	**0.012**	**0.017**	**0.53**	**0.48**	**0.80**

Physical loss in weight (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the minimum physical loss in weight (4.260 %) was recorded under Z_3–Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (4.344 %). However, maximum physical loss in weight (5.204 %) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the minimum physical loss in weight (2.548 %) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_1 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 2 g per pole (4.336 %). However, maximum physical loss in weight (6.573 %) was noticed in B_0-No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the minimum physical loss in weight (2.533 %) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was found statistically *at par* with T_{12} (Z_2B_3) (2.540 %) and T_8 (Z_1B_3) (2.550 %). Which was significantly difference with T_4 (Z_0B_3) (2.570 %). However, maximum physical loss in weight (8.070 %) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Dragon fruit contains high water content, leading to increased physiological weight loss during storage due to transpiration. However, zinc and boron may reduce this loss by decreasing tissue permeability, thereby minimizing water loss and maintaining fruit weight over the storage period. Similar finding were reported by Sangeeta (2023), Lata *et al.* (2023) and Prashanth *et al.* (2022) in dragon fruits and other fruit crops Patel *et al.* (2017).

Retention of marketable fruits (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum retention of marketable fruits (81.66 %) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was statistically *at par* with Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole and Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole (80.00 %). Whereas, Z_2 and Z_1 did not differ with each other. However, minimum retention of marketable fruits (71.66 %) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum retention of marketable fruits (92.50 %) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (85.83 %). However, minimum retention of marketable fruits (59.16 %) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum average retention of marketable fruits (93.33 %) was noticed in T_{16} (Z_3B_3), T_{15} (Z_3B_2), T_{12} (Z_2B_3) and T_8 (Z_1B_3) which was found statistically *at par* with T_4 (Z_0B_3) (89.99 %). Which was followed by T_{14} (Z_3B_1), T_{10} (Z_2B_1) and T_6 (Z_1B_1) (80.00 %) while, did not differ with each other. However, minimum retention of marketable fruits (56.66 %) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Marketable fruit retention was 100% at 3^{rd} DAS but declined after 6^{th} DAS due to factors like water loss from transpiration and increased fruit decay, both of which negatively affected quality and reduced the percentage of marketable dragon fruits during storage. The results are close conformity with the findings of Prashanth *et al.* (2022), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits.

Fruit decay (%)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the minimum fruit decay (18.33 %) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was statistically at par with Z_2 and Z_1 – (20.00 %). Whereas, Z_2 and Z_1 did not differ with each other. However, maximum fruit decay (28.33 %) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the minimum fruit decay (7.50 %) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (14.16 %). However, maximum fruit decay (40.83 %) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the minimum fruit decay (6.66 %) was noticed in T_{16} (Z_3B_3), T_{15} (Z_3B_2), T_{12} (Z_2B_3) and T_8 (Z_1B_3). Which was significantly difference with T_3 (Z_0B_2) (23.33 %). However, maximum fruit decay (43.33 %) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. The present investigation were finding there was increasing pattern of decay and degradation of fruits as number of storage days increases due to the occurrence of senescence phase, accompanied by fruit softening and an observed escalation in microbial growth. The results are close conformity with the findings of Prashanth *et al.* (2022), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits.

Specific gravity (g/cc)

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum specific gravity (1.003 g/cc) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (0.991 g/cc). However, minimum specific gravity (0.941 g/cc) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum specific gravity (1.082 g/cc) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (1.035 g/cc). However, minimum specific gravity (0.860 g/cc) was noticed in B_0-No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum specific gravity (1.113 g/cc) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was significantly followed by T_{12} (Z_2B_3) (1.083 g/cc). Whereas, T_{12} (Z_2B_3), T_8 (Z_1B_3) and T_4 (Z_0B_3) statistically *at par* with each other. However, minimum specific gravity (0.836 g/cc) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. The results were finding and clearly indicates a consistent decrease in specific gravity as the storage period. Which can be attributed to its ability to reduce transpiration and respiration rate. This, in turn, mitigates weight loss and shrinkage of the fruits during storage. The results are close conformity with the findings of Sangeeta (2023) in dragon fruits. Similar finding were observed in other fruit crops Singh *et al.* (2017) and Kaur *et al.* (2019) and Pareek *et al.* (2009).

Anthocyanin (mg/g) 24-25

At 9 DAH of dragon fruits the effect of factor A (Zinc) were observed on the maximum anthocyanin (116.82 mg/g) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was statistically at par with Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (116.79 mg/g) and Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole (116.73 mg/g). However, minimum anthocyanin (116.70 mg/g) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). The effect of factor B (Boron) were observed on the maximum anthocyanin (116.93 mg/g) was recorded under B_3 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was statistically *at par* with B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (116.91 mg/g) which was followed by B_1 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 2 g per pole (116.74 mg/g). However, minimum anthocyanin (116.47 mg/g) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum anthocyanin (116.99 mg/g) was noticed in T_{16} (Z_3B_3) -Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was found statistically *at par* with T_{12} (Z_2B_3) (116.95 mg/g), T_{15} (Z_3B_2) (116.93 mg/g), T_{11} (Z_2B_2) (116.96 mg/g), T_8 (Z_1B_3) (116.91 mg/g), T_7 (Z_1B_2) (116.90 mg/g), T_4 (Z_0B_3) (116.87 mg/g), T_3 (Z_0B_2) (116.87 mg/g) and T_{14} (Z_3B_1) (116.80 mg/g). Which was significantly difference with T_{10} (Z_2B_1) (116.74 mg/g). However, minimum anthocyanin (116.35 mg/g) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Anthocyanin in dragon fruit pulp was significant influenced by application of zinc and boron. Similar results were reported by Yasmin *et al.* (2024) and Saenjum *et al.* (2021) in dragon fruits.

Shelf life (Days) 24-25

Among the factor A (Zinc), maximum shelf life (12.50 days) was recorded under Z_3 – Zinc sulphate ($ZnSO_4$) @ 9 g per pole which was significantly followed by Z_2 – Zinc sulphate ($ZnSO_4$) @ 6 g per pole (11.91 days) and Z_1 – Zinc sulphate ($ZnSO_4$) @ 3 g per pole (11.75 days). However, minimum shelf life (10.41 days) was noticed in Z_0 – No zinc sulphate ($ZnSO_4$). Similarly, among the factor B (Boron), maximum shelf life (13.50 days) was recorded under B_3-Boron ($Na_2B_8O_{13}.4H_2O$) @ 6 g per pole which was significantly followed by B_2 - Boron ($Na_2B_8O_{13}.4H_2O$) @ 4 g per pole (12.58 days). However, minimum shelf life (9.25 days) was noticed in B_0 - No boron ($Na_2B_8O_{13}.4H_2O$). The treatments interaction between factor A (Zinc) and factor B (Boron) were observed on the maximum shelf life (14.33 days) was noticed in T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole which was found statistically *at par* with T_{12} (Z_2B_3) (13.66 days) and T_8 (Z_1B_3) (13.66 days). Which was significantly difference with T_{15} (Z_3B_2) (13.33 days). However, minimum shelf life (8.33 days) was recorded under treatment T_1 (Z_0B_0) - No zinc sulphate + No boron (Control) during pooled mean data, respectively. Increased shelf life of fruits may result from zinc and boron's effects on hormonal balance, photosynthesis, and water regulation, along with slower starch-to-sugar conversion and delayed ripening. Boron strengthens cell walls by accumulating in the middle lamella, enhancing fruit firmness and longevity reported by Kumar *et al.* (2021) and Anju *et al.* (2022) and Patel *et al.* (2017) in other fruit crops. The results are close conformity with the findings of Prashanth *et al.* (2022), Lata *et al.* (2023) and Sangeeta (2023) in dragon fruits.

Table 2 : Effect of zinc and boron on post-harvest quality attributes of dragon fruits

Notations		9^{th} day after post-harvest quality attributes					
		Physical loss in weight (%)	Retention of marketable fruits (%)	Fruit decay (%)	Specific gravity (g/cc)	Anthocyanin (mg/g)	Shelf life (Days)
		Pooled mean	Pooled mean	Pooled mean	Pooled mean	Pooled mean	Pooled mean
Factor A Zinc							
Z_0		5.204^d	71.66^b	28.33^b	0.941^d	116.70^b	10.41^c
Z_1		4.662^c	80.00^a	20.00^a	0.972^c	116.73^{ab}	11.75^b
Z_2		4.344^b	80.00^a	20.00^a	0.991^b	116.79^{ab}	11.91^b
Z_3		4.260^a	81.66^a	18.33^a	1.003^a	116.82^a	12.50^a
SE(m)±		**0.005**	**2.71**	**2.71**	**0.005**	**0.04**	**0.16**
CD at 5%		**0.014**	**7.86**	**7.86**	**0.014**	**0.10**	**0.22**
Factor B Boron							
B_0		6.573^d	59.16^d	40.83^d	0.860^d	116.47^c	9.25^d
B_1		5.013^c	75.83^c	24.16^c	0.932^c	116.74^b	11.25^c
B_2		4.336^b	85.83^b	14.16^b	1.035^b	116.91^a	12.58^b
B_3		2.548^a	92.50^a	7.50^a	1.082^a	116.93^a	13.50^a
SE(m)±		**0.005**	**2.71**	**2.71**	**0.005**	**0.04**	**0.16**
CD at 5%		**0.014**	**7.86**	**7.86**	**0.014**	**0.10**	**0.22**
Treat.	**Inter. (AxB)**						
T_1	$Z_0 B_0$	8.070^n	56.66^d	43.33^d	0.836^i	116.35^f	8.33^g
T_2	$Z_0 B_1$	5.686^l	63.33^d	36.66^{cd}	0.866^h	116.73^{bcd}	9.00^{fg}
T_3	$Z_0 B_2$	4.490^f	76.66^c	23.33^{bc}	1.010^e	116.87^{abc}	12.00^d
T_4	$Z_0 B_3$	2.570^b	89.99^a	10.00^{ab}	1.063^{bc}	116.87^{abc}	12.33^d
T_5	$Z_1 B_0$	6.793^m	60.00^d	39.99^d	0.860^h	116.45^e	9.00^{fg}
T_6	$Z_1 B_1$	4.893^i	80.00^{bc}	20.00^{ab}	0.936^g	116.68^{cde}	12.00^d
T_7	$Z_1 B_2$	4.416^e	86.66^{ab}	13.33^{ab}	1.033^d	116.90^{abc}	12.33^d
T_8	$Z_1 B_3$	2.550^a	93.33^a	6.66^a	1.080^b	116.91^{abc}	13.66^{ab}
T_9	$Z_2 B_0$	5.746^k	60.00^d	39.99^d	0.876^h	116.51^{de}	9.33^f
T_{10}	$Z_2 B_1$	4.803^h	80.00^{bc}	20.00^{ab}	0.963^f	116.74^{bcd}	12.00^d
T_{11}	$Z_2 B_2$	4.286^d	86.66^{ab}	13.33^{ab}	1.053^{cd}	116.96^{ab}	12.66^{cd}
T_{12}	$Z_2 B_3$	2.540^a	93.33^a	6.66^a	1.083^b	116.95^{ab}	13.66^{ab}
T_{13}	$Z_3 B_0$	5.683^j	60.00^d	39.99^d	0.873^h	116.56^{de}	10.33^e
T_{14}	$Z_3 B_1$	4.673^g	80.00^{bc}	20.00^{ab}	0.976^f	116.80^{abc}	12.00^d
T_{15}	$Z_3 B_2$	4.150^c	93.33^a	6.66^a	1.053^{cd}	116.93^{ab}	13.33^{bc}
T_{16}	$Z_3 B_3$	2.533^a	93.33^a	6.66^a	1.113^a	116.99^a	14.33^a
SE(m)±		**0.009**	**5.42**	**5.42**	**0.010**	**0.08**	**0.32**
CD at 5%		**0.027**	**15.73**	**15.73**	**0.028**	**0.23**	**0.93**

Conclusion

In an investigation carried out in the effect of zinc and boron on post-harvest quality attributes of dragon fruits, revealed that the application of micronutrients *viz.*, zinc and boron in various combinations significantly improves the quality parameters of dragon fruit plant. Under this investigation it was observed that the treatments interaction between factor A (Zinc) and factor B (Boron) which is T_{16} (Z_3B_3) - Zinc sulphate @ 9 g per pole + Boron @ 6 g per pole were found to be most promotive in improving post-harvest quality attributes and shelf-life. The following combination of zinc and boron could be used in improving quality aspects of dragon fruits.

References

A.O.A.C. (1984). Official methods of analysis. Association of official analytical chemists. *Washington. D. C.* 538 p.

A.O.A.C. (1980). Official methods of analysis. Association of the Official Analytical chemists. *Washington D.C.* 13th Edn.

Ahmad, W., Niaz, A., Kanwal, S., Rahmatullah and Rasheed, M. K. (2009). Role of boron in plant growth. A review. *J. Agric. Res.*, **4(7)**: 329-338.

Ali, M. S., Elhamahmy, M. A. and El-Shiekh, A. F. (2017). Mango trees productivity and quality as affected by boron and putrescine. *Scientia Horticulturae*, **2(16)**: 248-255.

Andrade, R. A. D., Oliveira, I. V. D. M. and Martins, A. B. G. (2005). Influence of the condition and storage period in germination of red pitaya seeds. *Revista Brasileira de Fruticultura*., **2(7)**: 168-170.

Anju, P., Bindu, B., Rafeekher, M., Naveen, L., Sajitha, R. and Anuja, R. (2022). Foliar application of calcium and micronutrients for yield, quality and fruit shelf life enhancement in papaya *var.* Surya. *Annals of plant and soil research*, **24(1)**: 146-150.

Anonymous (2012). Fertilizer recommendation guide. Dhaka, Bangladesh: Bangladesh Agricultural Research Council.

Baruah, S., Borgohain, S., Sharma, J., Mazumdar, H., Bhagawati, M., Saikia, S. and Pathak, P. K. (2024). Effect of various doses of inorganic fertilizers on growth and yield of dragon fruit (*Hylocereus polyrhizus* L.) in Assam condition. *Ecology, Environment & Conservation*, **7(9)**: 765-771.

Chakma, S. P., Harunor Rashid, A. S. M., Roy, S. and Islam, M. (2014). Effect of NPK doses on the yield of dragon fruit (*Hylocereus costaricensis* [FAC Weber] Britton & Rose) in Chittagong Hill Tracts. *American-Eurasian Journal of Agricultural & Environmental Sciences*, **14(6)**: 521-526.

Kaur, M., Singh, G. and Bakshi, M. (2019). Post-harvest treatment for improvement of shelf life in guava (*Pisidium guajava*. L) cultivar 'Allahabad Safeda' under ambient storage condition. *Indian Journal of Horticulture*, **7(3)**: 125-128.

Khan, M.M.H. and Ahmed, N. (2022). Synchronization of zinc rates through soil and foliar application with synthetic fertilizer to maximize growth, yield and quality attributes of mango. *Pak. J. Bot*., **54(2)**: 563-568.

Kumar, A., Joseph, A. V. and Bahadur, V. (2024). Effect of foliar application of nano urea, boron and zinc sulphate on growth, yield and quality of guava (*Psidium Guajava* L.) *cv*. Allahabad Surkha. *Journal of Advances in Biology and Biotechnology*, **27(6)**: 285-292.

Kumar, D. N., Kumar, T. S., Joshi, V. and Goud, C. R. (2021). Effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) *cv*. Taiwan Red Lady. *Journal of Pharmacognosy and Phytochemistry*, **10(1)**: 1912-1916.

Kumar, S., Saravanan, S.S., Mishra, S. (2019). Effect of micro nutrients and organic manures on establishment and plant growth of dragon fruit (*Hylocereus polyrhizus*) under Prayagraj agro climatic condition, *cv.* Red jaina. *Inter J. Chem. Stud*., **7(1)** :161–164.

Kumar, V., Chakraborty, A., Bhowmick, N., Medda, P. S., Mukhopadhyay, D. and Mandal, S. (2024a). Response of boron and zinc on growth, yield and quality of papaya cv. Red Lady. *International Journal of Minor Fruits, Medicinal and Aromatic Plants*, **10(1)**: 84-88.

Lalduhsangi, R. C. and Mandal, D. (2021). Performance of dragon fruit under integrated nutrient management at Mizoram. *Science and technology journal*, **9(1)**: 2321-3388.

Lata, D., Narayana, C.K., Anand, A. Rao, S., Ranjitha, K., Azeez, S. and Karunakaran, G. (2023). Effect of Ambient Storage on Postharvest Quality and Shelf Life of White Pulp (*Hylocereus undatus*) and Red Pulp Dragon Fruit (*Hylocereus polyrhizus*). *Erwerbs-Obstbau*, **65(2)**: 2469–2478.

Lee, J., Durst R.W., Wrolstad, R.E., Collaborators, Eisele, T., Giusti, M.M., Hach, J., Hofsommer, H., Koswig, S. (2005). Determination of total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines by the pH differential method: collaborative

Mizrahi, Y., Nerd, A. and Nobel, P. S. (1997). Cacti as crops. *Horticultural Reviews*, **1(8)**: 291-319.

Muengkaew, R., Whangchai, K. and Chaiprasart, P. (2018). Application of calcium–boron improves fruit quality, cell characteristics, and effective softening enzyme activity after harvest in mango fruit (*Mangifera indica* L.). *Horticulture, Environment and Biotechnology*, **59(4)**: 537-546.

Noor, Y., Shah, Z. and Tariq, M. (2019). Effect of zinc and boron using different application methods on yield of citrus (Sweet Orange) in calcareous soils. *Sarhad Journal of Agriculture*, **35(4)**: 1247–1258.

Padmaja, N. and Bosco, S. J. D. (2014). Preservation of jujube fruits by edible Aloe vera gel coating to maintain quality and safety. *Indian Journal of Scientific Research and Technology*, **2(3)**: 79-88.

Pareek, S., Kitinoja, L., Kaushik, R. A. and Paliwal, R. (2009). Postharvest physiology and storage of ber. *Stewart Postharvest Review*, **5(5)**: 1-10.

Patel, J. S., Dhruve, J. J., Motka, G. N. and Patel, A. D. (2017). Influence of plant growth regulators and boron on nutritional quality and shelf life of aonla fruit. *Int. J. Curr. Microbiol. App. Sci*., **6(4)**: 2533-2540.

Prashanth, R., Kumar, A. K., Rajkumar, M. and Aparna, K. (2022). Studies on postharvest quality and shelf life of pink fleshed dragon fruit (*Hylocereus* spp.) coated with Chitosan and stored at ambient temperature. *In Biol. Forum*., **14(3)**: 340-347.

Rajkumar, J. P., Tiwari, J.P. and Lal, S. (2014). Effect of foliar application of zinc and boron on fruit yield and quality of winter season guava (*Psidium guajava*) *cv*. Pant Prabhat. *Annals of Agri Bio Research*, **19(1)**:105-108.

Ranganna, Shamanna (1986). Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education.

Saenjum, C., Pattananandecha, T. and Nakagawa, K. (2021). Antioxidative and anti-inflammatory phytochemicals and related stable paramagnetic species in different parts of dragon fruit. *Molecules*, **26(12)**: 3561-3565.

Sahu, A., Kishore, K., Dash, S. N., Sahoo, S. C., Nayak, R. K. and Barik, S. (2022a). Calcium nutrition influencing yield and fruit quality of dragon fruit. *Indian Journal of Horticulture*, **79(3)**: 317-322.

Sahu, A., Kishore, K., Sahoo, S. C., Nayak, R. K., Baidya, B. K., Shukla, K. K. and Barik, S. (2022). Foliar feeding of boron influencing biochemical attributes and enzyme activity in dragon fruit (*Selenicereus monacanthus*). *Notulae Botanicae Horti. Agrobotanici Cluj-Napoca*., **50(4)**: 12777-12777.

Sangeeta (2023). Effect of post-harvest treatments on the shelf life and quality of dragon fruit (*hylocereus costaricensis*) under ambient storage condition. M.Sc. Thesis submitted to Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh.

Sangeeta, Panigrahi, H. K., Lodhi, Y. and Saha, M. (2019). Growth, yield and quality improvement in strawberry through foliar application of calcium, iron and zinc: A review. *J. Pharmacogn. Phytochem*., **8**: 734-737.

Singh, J., Prasad, N. and Singh, S. K. (2017). Postharvest treatment of guava (*Psidium guajava* L.) fruits with boric acid and NAA for quality regulation during ambient Storage. *International Journal of Bio-Resource and Stress Management*, **8(2)**: 201-206.

Storey, J. B. (2007). Zinc. In: Barker AV, Pilbeam DJ (Eds). Handbook of Plant Nutrition, CRC Press, New York.

Suman, M., P.D. Sangma and D. Singh. (2017). Role of Micronutrients (Fe, Zn, B, Cu, Mg, Mn and Mo) in Fruit Crops. Int. J. Curr. Microbiol. *App. Sci*., **6(6)**: 3240-3250.

Tisdale, S. L., Nelson, W. L. and Beaten, J. D. (1984). Zinc in soil fertility and fertilizers. Fourthedition, Macmillan Publishing Company, New York, **2(1)**: 382-391.

Vaillant, N., Monnet, F., Hitmi, A., Sallanon, H. and Coudret, A. (2005). Comparative study of responses in four Datura species to a zinc stress. *Chemosphere*, **59(7)**: 1005-1013.

Wichienchot, S., Jatupornpipat, M. and Rastall, R. A. (2010). Oligosaccharides of pitaya (dragon fruit) flesh and their prebiotic properties. *Food chemistry*, **120(3)**: 850-857.

Yasmin, A., Sumi, M. J., Akter, K., Rabbi, R. H. M., Almoallim, H. S., Ansari, M. J. and Imran, S. (2024). Comparative analysis of nutrient composition and antioxidant activity in three dragon fruit cultivars. *Peer J*., **12(1)**: 17711-17719.