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Effect of pre-harvest treatments on yield and postharvest quality of banana (*Musa acuminata*) cv. red banana

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Abstract

A field experiment was conducted in the farmer's field located at Erasakkanaickanur, Chinnamannur block, Theni district, Tamil Nadu, India during 2021-2022 to evaluate the effect of pre-harvest treatments on yield and postharvest quality of banana (*Musa spp.*) cv. Red Banana with 12 treatments, three replications in Randomized Block Design. The treatments consist of T_1 (K_2SO_4 1.0% + $MnSO_4$ 0.5%), T_2 (K_2SO_4 1.0% + $CaCl_2$ 0.5%), T_3 (K_2SO_4 1.0% + Boric acid 0.1%), T_4 ($MnSO_4$ 0.5% + $CaCl_2$ 0.5%), T_5 ($MnSO_4$ 0.5% + Boric acid 0.1%), T_6 ($CaCl_2$ 0.5% + Boric acid 0.1%), T_7 (K_2SO_4 1.0% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5%), T_8 (K_2SO_4 1.0% + $MnSO_4$ 0.5% + Boric acid 0.1%), T_9 (K_2SO_4 1.0% + $CaCl_2$ 0.5% + Boric acid 0.1%), T_{10} ($MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%), T_{11} (K_2SO_4 1.0% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%) and T_{12} (Control). Three sprays of pre-harvest treatments were imposed at immediately after denavelling one month after denavelling and two months after denavelling in the standing crop. The results of the study revealed that the maximum values for number of hands bunch^{-1} (5.90), number of fingers hand^{-1} (15.78), number of fingers bunch^{-1} (89.84), finger length (25.81 cm), finger girth (16.87 cm), fruit weight (175.38 g), bunch weight (20.19 kg), TSS (20.19 °brix), total sugars (18.19%), reducing sugars (15.67%), non-reducing sugars (2.52%), β carotene (23.14 mg 100 g^{-1}), anthocyanin (222.90 mg kg^{-1}) and shelf life (9.30 days) were recorded in the treatment combination of T_{11} (K_2SO_4 1% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%) in banana cv. Red Banana. The minimum values for titratable acidity (0.50%), physiological loss in weight (3.57%), finger drop (11.50%) and finger rotting (30.75%) were also recorded in the same treatment. Whereas the highest values for bunch weight, finger length, finger girth, fruit weight, TSS, total sugars, reducing sugars, non-reducing sugars and anthocyanin and the lowest for titratable acidity, physiological loss in weight, finger drop and fruit rotting were registered in the treatment T_{12} (control).

Keywords: Banana, pre-harvest, postharvest, potassium sulphate, calcium chloride, manganese sulphate, boric acid, denavelling, shelf life and finger drop

Introduction

Red Banana (*Musa spp.*) is a monocotyledonous perennial, giant herb belonging to the family Musaceae and order Zingiberales. It is one of the fourth key food resources in the world after rice, wheat and maize (Ngamau *et al.*, 2014) [20]. Banana is a native of the tropical regions of Southeast Asia (Fuller and Madella, 2009) [10] and mostly grown in tropical and subtropical locales of the world (Dodo, 2014) [8]. There are around 1000 different varieties of banana around the world. Red banana is one of the important varieties of banana with reddish- purple skin, Plumpier and sweeter than the common Cavendish banana. Red banana, also called as red Dacca banana. At fully ripening stage, the flesh of red banana is cream to light pink in colour having a slight raspberry flavour with higher nutritive and calorific value, containing large amounts of potassium, iron, Vitamin C and β- carotene. The fruits are available throughout the year and tend to cost about 50% more than yellow bananas.

Red bananas provide many essential nutrients and the health benefits are rich in essential nutrients, lower blood pressure, support eye health, rich in antioxidants, support immune system, improve digestive and heart health and delicious diet. As compared to yellow bananas, red bananas will ripen in a few days at room temperature. They are frequently eaten raw, whole or chopped and added to desserts and fruit salads and also be baked, fried and toasted. It is grown in few countries like India, Australia, Central America and Brazil etc. In India, banana is cultivated in an area of 878 thousand ha with a production of 31504 thousand MT. (NHB, 2020). It is normally found in Kerala and some parts of Tamil Nadu.

Finger drop is one of the problems often encountered upon the attainment of the table ripe stage especially in red banana. Finger drop is a physiological disorder wherein ripe fruits readily fall off from the crown and is associated with the weakening and softening of the pedicel during ripening which causes individual fruits to separate or dislodge very easily (Paull, 1996; Dadzie and Orchard, 1997) [23, 6]. This limits its shelf life and results in reduced marketability, hence the need to develop methods of controlling finger drop.

Banana requires large amounts of nutrients for proper growth and production. Red Banana is one of the leading banana cultivars of Southern India. Yet, poor filling and development of fruits is often reported with this cultivar, which might be related to inadequate or non-availability of nutrients just prior to the shooting stage occurring 7 months after planting. High nutrient availability is important at that stage to support plant requirements until harvest since large quantities of photosynthates are beginning to move from the source to the sink i.e. developing fruit bunches. Any limitation in the supply of nutrients at this time will negatively affect bunch size and quality. However, it has not been wise to apply fertilizers basally at finger development stage, since the uptake is slow and low (Buragohain *et al.*, 1986) [7].

Potassium plays a major role in carbohydrate synthesis, translocation, synthesis of protein, phloem loading, unloading of sucrose, syntheisis of amino acids, starch and neutralization of physiologically important organic acids. Potassium is responsible for energy production in the form of ATP and NADPH in chloroplasts by maintaining balanced electric charges (Mengel and Kirkby, 1987) [18]. Foliar application also favours the conversion of starch into simple sugars during ripening by activating the sucrose synthase enzyme. In plants well-supplied with potassium, the osmotic potential of the phloem sap and the volume flow rate are higher than in plants grown under low potassium fertility (Marschner, 1995) [17].

Calcium has been reported to improve fruit texture by maintaining cell wall integrity and changing the physical properties of the cell membrane (Brett and Waldron, 1990) [4]. Calcium improves stem-end peel firmness and it serves as an intermolecular bonding agent that stabilizes the pectin protein complex of the middle lamella.

Manganese is mainly used to improve the colour of the fruit. The role of manganese in plant came from its involving in photosynthesis, membrane function, as well as activator of numerous enzymes in the cell. Also found that banana bunch sprayed with $MnSO_4$ had increased fruit yield as well as TSS, fruit thickness and weight of fruits. Manganese sulphate also is also a heavy metal micronutrient, the functions of which are fairly known. It is involved in the oxygen-evolving step of photosynthesis and membrane function, as well as serving as an important activator of numerous enzymes in the cell (Wiedenhoeft, 2006) [35].

Tariq *et al.*, 2007 [33] reported that foliar application of 0.25% each of manganese sulphate and combined with 0.15% boric acid, significantly increased fruit yield and juice content of pomegranate fruit. In addition, foliar application of Mn alone or in combination with each other showed significant increase in fruit yield of sweet oranges.

More than 90% of the boron in plants is found in cell wall and it's most important role is associated with cell wall formation, functioning and strength. Boron requirement is much higher during reproductive growth than vegetative growth in most plant species because high demand of boron by reproductive organs containing pectin. Immobile nature of boron in plant which produced various deficiency disorders in growing and reproductive parts in fruit crops under its unavailability in soils. The availability of boron in soils as influenced by many factors like pH, soil texture, soil moisture, organic matter, type of clay, lime content, quality of irrigation water and nutrient interaction etc. Therefore, foliar application of boron is the best option for fruit crops. With this background, this study is formulated with different pre-harvest treatments to alleviate the problems associated with postharvest life and to enhance the shelf life of banana cv. Red Banana.

Materials and methods

A field experiment was conducted during 2021-2022 to investigate the effect of pre-harvest treatments on yield and postharvest quality of banana (*Musa spp.*) cv. Red Banana with 12 treatments, three replications in Randomized Block Design at Erasaikkanaickanur, Chinnamannur block, Theni district, which lies at the foot slopes of the Western Ghats of India between 9.84˚12' of North and 77˚ 58'of East longitude. Soil of the experimental site is red loam belonging to 'Erasai series'. All recommended cultural practices were followed after plantation of banana. The treatments consisted of T_1 (K_2SO_4 1.0% + $MnSO_4$ 0.5%), T_2 (K_2SO_4 1.0% + $CaCl_2$ 0.5%), T_3 (K_2SO_4 1.0% + Boric acid 0.1%), T_4 ($MnSO_4$ 0.5% + $CaCl_2$ 0.5%), T_5 ($MnSO_4$ 0.5% + Boric acid 0.1%), T_6 ($CaCl_2$ 0.5% + Boric acid 0.1%), T_7 (K_2SO_4 1.0% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5%), T_8 (K_2SO_4 1.0% + $MnSO_4$ 0.5% + Boric acid 0.1%), T_9 (K_2SO_4 1.0% + $CaCl_2$ 0.5% + Boric acid 0.1%), T_{10} ($MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%), T_{11} (K_2SO_4 1.0% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%) and T_{12} (Control). Three sprays of pre-harvest treatments were imposed at immediately after denavelling, one month after denavelling and two months after denavelling in the standing crop. The nutrient mixtures were sprayed on all sides of the bunch. The recommended dose of fertilizers (150: 35: 330 N, P_2O_5 and K_2O g plant^{-1}) were applied as urea, single super phosphate and muriate of potash. The nitrogen and potassium were applied in four splits i.e. at 2, 4, 6 and 8 months after planting while the entire dose of phosphorus was applied as basal. The plants were planted at a recommended spacing of 1.8 x 1.8 m. The postharvest study was undertaken at the ambient storage condition in the Department of Postharvest Technology, Horticultural College and Research Institute, TNAU, Periyakulam.

Yield parameters

Yield parameters *viz*., number of hands bunch^{-1}, number of fingers hand^{-1}, number of fingers bunch^{-1}, finger length (cm), finger girth (cm), individual fruit weight (g) and bunch weight (kg) were recorded at unripe stage. Representative random samples of ten fruits per replication were collected to record data on finger length, finger girth and individual fruit weight. The middle fingers in the top and bottom rows of the second hand were selected as representative fingers to record average weight of the finger and expressed in gram (g). Weight of the bunch including the peduncle upto first bract leaf node above the first hand was recorded and expressed in kilogram (kg).

Quality and biochemical parameters

The total soluble solids were calculated by using hand refractometer (0-32 per cent range) and expressed in ºBrix (Ranganna, 1986) [26]. Titratable acidity was determined by titrating the fruit sample against 0.1N NaOH (Ranganna 1986) [26]. Total sugar content was estimated by the anthrone method suggested by Hedge and Hofreiter (1962) [12]. Reducing sugar content was analysed by Nelson- Somogyi (1952) [31] method. Non reducing sugar content of banana fruits was determined by subtracting the reducing sugar content from total sugars and multiplied with necessary factor 0.95 expressed in per cent. Non reducing sugars (%) = (Total sugars – Reducing sugars) x 0.95. The β carotene content was determined as per the method suggested by Ranganna (1986) [26]. The anthocyanin content was quantified by the procedure described by Swain and Hillis (1959) [32].

Postharvest quality parameters

Shelf life (days)

Shelf life of fruits was observed by visual inspection of fruits on alternate days. Then it was calculated by the number of days between the day of harvesting and the end consumption level of the fruit. These days considered as the final stage of shelf-life and expressed in days.

Physiological Loss in Weight (%) (PLW)

The fruit weight reduction was recorded once in every three days. The physiological weight loss was calculated using the formula given below and expressed in percentage (Aboud, 1974).

$$\text{Physiological Loss in Weight (\%)} = \frac{\text{Initial bunch weight} - \text{Final bunch weight}}{\text{Initial bunch weight}} \times 100$$

Finger drop (%)

The method was modified from Semple and Thompson (1988) [29]. A hand of banana was held at 15 cm above a table for 10 s, and the number of dislodged fingers were recorded, and expressed as a percentage of total number of fingers on the hand (Wachiraya *et al.*, 2006) [13]

Fruit rotting (%)

Fruit rotting of red banana during storage was calculated using the number of rotten fruits counted at each storage interval and reported as percentage. To prevent future contamination, the rotten fruits were removed.

$$\text{Fruit rotting (\%)} = \frac{\text{Weight of rotted fruits}}{\text{Total bunch weight}} \text{X100}$$

Statistical analysis

The data recorded were subjected to statistical scrutiny (Panse and Sukhatme 1985) [21].

Results and Discussion

Effect of pre-harvest treatments on yield attributes

Pre-harvest treatmental effect of calcium, potassium, manganese and boron on various yield parameters were recorded and presented in table 1. The data on yield parameters *viz.*, number of hands bunch^{-1}, number of fingers hand^{-1} and number of fingers hand^{-1} were not affected significantly by the different pre-harvest treatments indicating that the application of pre-harvest chemicals immediately after denavelling, one month after denavelling and two months after denavelling had no effect but it showed statistically significant variation on finger length, finger girth, individual fruit weight and bunch weight from different treatments showed significant variations. The experimental results exhibited the highest values for finger length (25.81 cm), finger girth (16.87 cm), individual fruit weight (175.38 g), bunch weight (20.19 kg), in the treatment T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). While the treatment T_{12} (control) expressed the lowest values for yield parameters *viz.*, number of hands bunch^{-1} (4.79), number of fingers hand^{-1} (12.20), number of fingers bunch^{-1} (60.40), finger length (17.22 cm), finger girth (12.94 cm), individual fruit weight (158.18 g) and bunch weight (14.01 kg) in both the seasons.

The yield enhancement in banana is due to the cumulative effect of potassium, calcium, manganese and boron. The potassium plays a major role in increasing bunch weight mainly, due to its catalytic activity in many biological processes of the plant which reflect on the nutritional status of the trees (Baiea *et al*., 2015) [2].

Increasing the finger length, finger girth, individual fruit weight and bunch weight of red banana is might be due to the positive influence of potassium and calcium on cell division, cell elongation, calcium deposition, finger turgor, osmotic pressure and strengthening of cell wall. The sulphate has synergistic effect with potassium, which is essential for cell elongation by increasing the cell permeability to water and osmotic solutes of the cells. Increased finger length and girth and other finger characteristics due to the spray of nutrients can be attributed to its impact on cell development and cell division. Similar results were found in the findings of Mustaffa *et al*., (2004) [19], in banana cv. Ney poovan. Calcium has been reported to improve fruit texture by maintaining cell wall integrity and changing the physical properties of the cell membrane (Brett and Waldron, 1990) [4]. Calcium improves stem-end peel firmness and it serves as an intermolecular bonding agent that stabilizes the pectin protein complex of the middle lamella. Tariq *et al.*, 2007 [33] reported that foliar application of 0.25% each of manganese sulphate and combined with 0.15% boric acid, significantly increased fruit yield and juice content of pomegranate fruit. In addition, foliar application of Mn alone or in combination with each other showed significant increase in fruit yield of sweet oranges. Hence it is concluded that the combined effect of potassium, manganese and boron showed positive response on banana yield.

Table 1: Effect of pre-harvest treatments on yield parameters of banana cv. Red Banana.

Treatments	Number of hands bunch^{-1}	Number of fingers hand^{-1}	Number of fingers bunch^{-1}	Finger length (cm)	Finger girth (cm)	Fruit weight (g)	Bunch weight (kg)
T_1	5.20	13.75	81.00	22.55	13.99	161.44	15.41
T_2	5.50	14.75	81.15	21.23	14.81	162.27	16.76
T_3	5.39	15.00	81.02	23.56	15.21	157.97	16.37
T_4	5.59	14.55	81.50	23.46	14.68	158.04	17.11
T_5	5.30	13.70	82.62	22.74	14.08	164.93	16.23
T_6	5.10	14.40	83.76	21.40	13.34	160.57	14.71

T_7	5.65	15.59	82.52	20.40	15.31	161.26	17.28
T_8	5.80	15.64	83.64	21.27	15.24	165.44	17.19
T_9	5.89	15.69	84.56	25.78	16.29	172.29	19.23
T_{10}	5.86	15.20	82.70	19.42	14.91	172.05	18.01
T_{11}	5.90	15.78	89.84	25.81	16.87	175.38	20.19
T_{12}	4.79	12.60	60.40	17.22	12.94	158.18	14.01
SE(d)				0.262	0.156	2.566	0.785
CD(p=0.05)	NS	NS	NS	0.746*	0.449*	5.158*	1.578*

*- Significant at (p<0.05); NS Non Significant

T_1 (K_2SO_4 1% + $MnSO_4$ 0.5%)
T_2 (K_2SO_4 1% + $CaCl_2$ 0.5%)
T_3 (K_2SO_4 1% + Boric acid 0.1%)
T_4 ($MnSO_4$ 0.5% + $CaCl_2$ 0.5%)
T_5 ($MnSO_4$ 0.5% + Boric acid 0.1%)
T_6 ($CaCl_2$ 0.5% + Boric acid 0.1%),
T_7 (K_2SO_4 1% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5%)
T_8 (K_2SO_4 1% + $MnSO_4$ 0.5% + Boric acid 0.1%)
T_9 (K_2SO_4 1% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{10} ($MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{11} (K_2SO_4 1% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{12} (Control).

Table 2: Effect of pre-harvest treatments on biochemical and postharvest quality parameters of banana cv. Red Banana.

Treatments	TSS (ºbrix)	Titratable acidity (%)	Total sugar content (%)	Reducing sugar content (%)	Non-reducing sugar content (%)	β Carotene content (mg 100 g^{-1})	Anthocyanin content (mg kg^{-1})	Physiological loss in weight (%)	Finger drop (%)	Fruit rotting (%)	Shelf life (days)
T_1	17.83	0.65	15.43	13.37	2.06	20.26	177.34	6.62	47.50	75.00	6.90
T_2	18.19	0.63	15.99	13.88	2.11	20.01	160.59	4.28	40.00	47.50	7.90
T_3	18.03	0.63	15.63	13.60	2.03	20.70	166.62	5.21	52.00	63.25	7.25
T_4	17.60	0.67	15.30	13.01	2.29	20.17	187.71	4.79	37.50	51.50	7.35
T_5	17.46	0.57	15.16	13.06	2.10	20.14	191.44	4.64	56.50	61.75	7.35
T_6	18.56	0.71	16.36	14.35	2.01	20.63	171.08	4.42	31.99	56.25	7.44
T_7	18.87	0.67	16.57	14.36	2.21	19.98	199.95	4.17	27.00	58.50	8.00
T_8	19.52	0.67	17.32	15.09	2.23	20.54	206.28	4.35	59.50	43.25	7.75
T_9	19.86	0.52	17.76	15.61	2.15	21.31	183.67	7.46	16.50	35.50	6.34
T_{10}	19.18	0.58	16.98	14.84	2.14	19.76	213.84	7.31	21.00	41.00	6.40
T_{11}	20.19	0.50	18.19	15.67	2.52	23.14	222.90	3.57	11.50	30.75	9.30
T_{12}	17.23	0.85	15.03	13.26	1.70	19.52	141.67	8.28	68.50	91.25	4.70
SE(d)	0.425	0.029	0.347	0.169	0.033	0.255	2.990	0.265	0.70	0.974	0.123
CD(p=0.05)	0.887*	0.059*	0.725*	0.354*	0.067*	0.512*	6.010*	0.754*	1.40*	2.033*	0.246*

*- Significant at (p<0.05)

T_1 (K_2SO_4 1% + $MnSO_4$ 0.5%)
T_2 (K_2SO_4 1% + $CaCl_2$ 0.5%)
T_3 (K_2SO_4 1% + Boric acid 0.1%)
T_4 ($MnSO_4$ 0.5% + $CaCl_2$ 0.5%)
T_5 ($MnSO_4$ 0.5% + Boric acid 0.1%)
T_6 ($CaCl_2$ 0.5% + Boric acid 0.1%),
T_7 (K_2SO_4 1% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5%)
T_8 (K_2SO_4 1% + $MnSO_4$ 0.5% + Boric acid 0.1%)
T_9 (K_2SO_4 1% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{10} ($MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{11} (K_2SO_4 1% + $MnSO_4$ 0.5% + $CaCl_2$ 0.5% + Boric acid 0.1%)
T_{12} (Control).

Effect of pre-harvest treatments on quality, physiological and bio chemical parameters

Various quality and biochemical parameters were recorded and presented in table 2. Among various treatments, T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%) expressed the maximum values for total soluble solids (20.19 ºbrix) with minimum titratable acidity (0.50%), total sugars (18.19%), reducing sugars (15.67%) non-reducing sugars (2.52%) β carotene (23.14 mg 100 g^{-1}) and anthocyanin content (222.90 mg kg^{-1}). Whereas the treatment T_{12} (control) recorded the lowest values for total soluble solids (17.23 ºbrix), total sugars (15.03%), reducing sugars (13.26%) non-reducing sugars (1.70%), β carotene (19.52 mg 100 g^{-1}) and anthocyanin content (141.67 mg kg^{-1}). The next best treatment was T_9 (potassium sulphate 1.0% + calcium chloride 0.5% + boric acid 0.1%) for all the quality parameters.

In the present study, the total soluble solids (TSS) was high in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). Potassium plays a vital role in sugar accumulation, photosynthetic activity, transport of sugars and mitigating senescence (Arora *et al.*, 2006) [1]. The increased total soluble solids might be due to the positive effect of potassium on sugar accumulation. Owing to the positive effect of sugar transport and lower organic acids accumulation resulted in higher TSS. The similar results were also reported by Arora *et al.*, (2006) [1] and Karimi (2017) [14] in peach.

In the present study, the titratable acidity was lower in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). Neutralization of organic acids due to high potassium level in tissues could have also resulted in a reduction in acidity (Tisdale and Nelson, 1966) [34]. Titratable acidity of banana is primarily used to indicate consumption quality. The titratable acidity showed a constant decrease during the storage period. The decline in acidity may be attributed to the utilization of acids in the process of ripening in the presence of reduced supply of sugar as a substrate of respiration, which might be due to lower rate of starch degradation during the ripening. The finding of the present study is in accordance with the result of Macwan (2012) [15] in banana.

In the present study, the total sugars, reducing sugars and non-reducing sugars was higher in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). The increased total sugars in fruits may be due to the hydroxylation of starch into simple sugars and translocation of sugar from source to sink (Scavroni *et al.*, 2018) [28]. Reis *et al.* (2004) [27] reported that combined spray increased the TSS of banana pulp and also found that sugar level were dependent on the K_2SO_4 and boric acid in sugar accumulation. Potassium is responsible for energy production in the form of ATP and NADPH in chloroplasts by maintaining balanced electric charges. Besides, potassium is involved in phloem loading and unloading of sucrose and also amino acids, and storage in the form of starch in developing fruits by activating the enzyme starch synthase (Mengel and Kirkby, 1987) [18].

In the present study, β carotene content was higher in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%) and lower in T_{12} (control). The decrease in carotenoids towards the later part of the storage period may be due to the degradation of carotenoid pigments. Oxidative protection of carotenoids by ascorbic acid has previously been reported. The decline in the content of natural ascorbic acid during red banana fruit ripening may, therefore, also have led to the degradation of carotenoids. The observations of Rajkumar *et al*. (2005) [25] in papaya and Patel and Padhiar (2010) [22] in banana lend support to the hypothesis that the prevention of chlorophyll degradation may have delayed the synthesis of carotenoids in banana.

Calcium was assumed to strengthen cellular tissue and increase the green life of fruits. Calcium was further shown to modify pectin hemicelluloses, which are known to influence the physical properties of fruits. Manganese sulphate is involved in the oxygen-evolving step of photosynthesis and membrane function, as well as serving as an important activator of numerous enzymes in the cell (Wiedenhoeft, 2006) [35].

In the present study, the anthocyanin was maximum in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%) and minimum in T_{12} (control). It was reported that a positive correlation exists between potassium concentration and anthocyanin content which plays a crucial role in anthocyanin synthesis by increasing the translocation of sugars into fruits (Davarpanah *et al*., 2017) [7].

Manganese spray increased the TSS, which may improve anthocyanin accumulation by activating transcription factors in pomegranate (Hamouda *et al*., 2016) [11]. Ca^{2+} signal may stimulate the synthesis of jasmonic acid and ethylene which may improve accumulation of anthocyanin by increasing sugar content or activating transcription factors related to anthocyanin production.

Effect of pre-harvest treatments on postharvest quality parameters

In high value crop species like banana, quality standards have become the most important factor influencing monetary yield and farmer's income. Any management system should aim to produce quality fruits, besides maximizing the productivity. In banana, fruit quality is mainly judged by the sugar content and acidity in the pulp. Pre-harvest spray of calcium, potassium, manganese and boron on various postharvest quality parameters were recorded and presented in table 2. The shelf life (9.30 days) was maximum in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%) followed by T_7 (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5%) with the value of 8.00 days and minimum shelf life (4.70 days) was found in T_{12} (control). T_{11} expressed the minimum fruit drop (11.50%), physiological loss in weight (3.57%) and fruit rotting (30.74%), whereas T_{12} showed the maximum fruit drop (68.50%), physiological loss in weight (8.28%) and fruit rotting (89.95%).

In the present study, the physiological loss in weight was lower in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). The fruit weight gradually decreased with the increase in storage period. This was due to the combined application of K_2SO_4, $MnSO_4$, $CaCl_2$ and boric acid, which lowered the phospholipid, protein and ion leakage losses in treated fruits with maintaining the membrane functionality and integrity. So, lower weight loss was seen in this treatment. Similar findings were found in muskmelon as reported by Sharma *et al.* (1991) [30].

In this experiment, the finger drop was lower in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). Finger drop is associated with weakening of the pedicel connecting the finger to the crown of a hand. This condition limits the marketability of many banana varieties (Baldry *et al*., 1981) [3]. The biochemical changes in the pedicel associated with this weakening are unknown. Calcium has been reported to improve fruit texture by maintaining cell wall integrity and changing the physical properties of the cell membrane (Brett and Waldron, 1990) [4]. The improved stem-end peel firmness is probably due to calcium serving as an intermolecular bonding agent that stabilized the pectin protein complex of the middle lamella.

Application of 4% $CaCl_2$ as pre-harvest spray delayed the occurrence and resulted in the lowest incidence of finger drop. This might be attributed to the enhanced calcium accumulation in the pedicel of the fruit such that even though fruits were at the post climacteric phase (fruits were already past the table stage), finger drop was prevented (Esguerra *et al.*, 2008) [9]

The fruit rotting was lower in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). Fruits treated with calcium recorded lower spoilage during ambient storage might be due to retardation of senescence and decaying organism. Since Ca is the major cation of middle lamella in cell walls and modifies cell wall rigidity by thickening the middle lamella of cell wall owing to increased formation and deposition of Ca-pectate and this reduced the rate of spoilage. Similar findings with spoilage of plum at low temperature were reported by Mahajan *et al*. (2008) [16].

In this investigation, the shelf-life was higher in T_{11} (potassium sulphate 1.0% + manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%). Highly significant variations were obtained for the shelf life in different treatments. An increase in shelf life was due to better cell wall integrity because calcium infusion had thickened calcium pectate in the cell wall. Calcium was reported to be essential for structural integrity of both the cell wall and plasma membrane. Calcium treatments delayed softening and improve the fruit quality. Calcium chloride ($CaCl_2$) treatment has been shown to increase the shelf-life of fruits, mainly through making cell walls less accessible to pathogens and softening enzymes (Perera and Karunaratne, 2002) [24].

Conclusion

From the findings of the study, it is brought to line light that three pre-harvest sprays with potassium sulphate 1% +

manganese sulphate 0.5% + calcium chloride 0.5% + boric acid 0.1%) (T_{11}) at immediately after denavelling, one month after denavelling and two months after denavelling improved the yield, quality and postharvest life of banana cv. Red banana.

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