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Effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) Cv. Taiwan Red Lady

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Abstract
The present investigation on "effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) Cv. Taiwan Red Lady" was carried out during 2019 - 2020 in farmer's field, Pittalagudem village of Nalgonda District, Telangana. The experiment was laid out in Randomized Block Design (RBD) with nine treatments and three replications. Results revealed that the combined foliar application of plant nutrients significantly increased the total soluble solids (12.26 ^{0}Brix), total sugars (7.91%), reducing sugars (6.07%), non-reducing sugars (1.84%) and ascorbic acid (23.56 mg 100g^{-1}) and reduced physiological loss in weight PLW% (15.62%), titrable acidity (0.011%) at the same time increased fruit firmness (6.93 kg cm^{-2}) and shelf life (6.83 days) was obtained with the treatment T_4: KNO_3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%) per tree.

Keywords: papaya, foliar application, plant nutrients, quality parameters and shelf life

Introduction
Papaya (*Carica papaya* L.) is a native fruit of Tropical America was introduced to India in the 16th century from Malacca and belongs to the family Caricaceae (Singh, 1990) [24]. It is one of the commercially important fruit crop of the tropics and is often considered as common man's fruit, also known as papita, papaw and true melon. The high productivity and ability to produce fruits throughout the year has added to gain popularity and commercial importance. It is rich in carotene (2020 IU 100g^{-1} precursor of vitamin A), vitamin 'C' and minerals such as calcium, phosphorus and iron (Chadha, 1992) [5] makes papaya an important fruit crop. A new papaya cultivar Taiwan Red Lady was introduced to India from Taiwan which has replaced the traditional varieties like Pusa selections, Coorg Honey Dew and Coimbatore Selections due to its gynodioecious nature, high productivity and red colour flesh. India is the largest producer of papaya in the world, producing 61.07 lakh tonnes of fruits from an area of 1.39 lakh hectares with productivity of 58.31 lakh MT ha^{-1} (NHB, 2018-19) [16]. It is commercially cultivated in Telangana in an area of 1184.68 hectares with productivity 79274.46 MT ha^{-1} (Telangana State Horticulture Department, 2018-19) [27]. Papaya crop needs moisture stress free environment and judicious nutrient supply at regular intervals for optimum productivity and application of different macro and micronutrients in papaya recorded a positive influence in fruit quality (Shanmugavelu *et al*., 1973) [20].
Potassium (K) is involved in quality related characteristics of fruit and is called a quality element (Ahmad *et al*., 2018) [1]. It is crucial for many bio-chemical reactions that are essential for enzyme activation and physiological processes in cell. These reactions play a major role in ion transport between cells and stomatal conductance under different climatic variables (temperature, light, humidity), thus affects the fruit quality (Eisenacha and Angeli, 2017) [7]. Fruit size, soluble solids, acidity, as well as shelf-life are significantly influenced by an adequate supply of K (Tohidloo *et al*., 2018) [29].
In addition to recommended dose of macro-nutrients, monthly application of micronutrient sprays like zinc and boron are very important for its growth and development. Boron is necessary for calcium metabolism. Calcium sprays given during plant growth improves the establishment of root system, increases the fruit set along with fruit retention and also provides a safe mode of supplementing endogenous calcium to fresh fruits which improves the cell wall strength during fruit development, reducing respiration rate and ethylene evolution and there by reduces rotting of fruit (Monika *et al*., 2018) [15].
Zinc enhances the vegetative growth due to the presence of tryptophan, which is the precursor of auxin and stimulates flowering and to obtain good fruit set and size.

It also helps in the process of translocation of metabolites to the bud itself or to the site of bud development. Zinc is a component or a functional co-factor of several enzymes including auxin. It also plays an important role in carbohydrate metabolism, protein synthesis and internodes elongation (Ryugo, 1988) [19].

Micronutrients helps in absorption of major nutrients thus increases fruit quality (Thirupathaiah *et al.*, 2017) [28], decrease of weight loss is by the application of calcium and its role in the maintenance of fruit firmness, retardation of respiratory rates as well as transpiration and delayed senescence (Singh *et al.*, 1982) [22]. Therefore, present investigation was carried out to know the effect of plant nutrients on quality and shelf life of papaya.

Materials and Methods

A field experiment was conducted at farmer's field, Pittalagudem, Konda Mallepally, Nalgonda, Telangana on seven months old plants of papaya. The experiment was laid out in Randomized Block Design (RBD) with nine treatments and three replications *viz.*, T_1: 19:19:19 (0.5%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%), T_2: 19:19:19 (1%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) +$ZnSO_4$ (0.5%), T_3: KNO_3 (1%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%), T_4: KNO_3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%), T_5: $ZnSO_4$ (0.25%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%), T_6: $ZnSO_4$ (0.5%) +Borax (0.5%) + Ca $(NO_3)_2$ (0.5%), T_7: $ZnSO_4$ (0.25%) + Borax (0.3%) + KNO_3 (1%), T_8: $ZnSO_4$ (0.5%) + Borax (0.5%) + KNO_3 (1.5%), T_9: Control (water spray). Plant nutrients are applied eight times in monthly interval during July, 2019 to March, 2020. Data regarding total soluble solids, total sugars, reducing sugars, non-reducing sugars, ascorbic acid, titrable acidity physiological loss in weight (PLW%), fruit firmness and shelf life was recorded as per standard procedure.

Results and Discussion

Physiological loss in weight (PLW%)

Reduce in weight loss of fruits per tree might be due to combined foliar application of plant nutrients the minimum weight loss T_4 (15.62%), which was on par with T_1 (16.13%) and the maximum weight loss is in T_9 control (18.92%) was depicted in Table 1.

Physiological weight loss (PLW%) is one of the important factors which govern the fruit quality. The decrease in weight loss by the application of calcium might be ascribed due to its consistency in the cell wall resulting in fruit firmness, retardation of respiratory rate and delay in senescence (Singh *et al*., 2010) [23]. Similar findings of low physiological loss in weight of fruits during storage has been reported by Bhalerao *et al*. (2014) [3] and Manjunatha *et al*. (2014) [11] in papaya.

Table 1: Effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) Cv. Taiwan Red Lady

Treatments	(PLW%)	Fruit firmness (kg cm^{-2})	TSS (^{0}Brix)	Ascorbic acid (mg $100g^{-1}$)	Titrable acidity (%)
T_1-19:19:19 (0.5%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%)	16.13	6.66	11.83	22.53	0.013
T_2 -19:19:19 (1%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) +$ZnSO_4$ (0.5%)	17.02	6.53	11.53	22.30	0.015
T_3 - KNO_3 (1%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%)	16.45	5.96	12.16	22.86	0.012
T_4 - KNO_3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%)	15.62	6.93	12.26	23.56	0.011
T_5 -$ZnSO_4$ (0.25%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%)	18.02	4.93	10.53	20.63	0.021
T_6 - $ZnSO_4$ (0.5%) +Borax (0.5%) + Ca $(NO_3)_2$ (0.5%)	17.57	5.66	11.30	21.76	0.018
T_7 - $ZnSO_4$ (0.25%) + Borax (0.3%) + KNO_3 (1%)	18.48	4.40	9.76	20.53	0.023
T_8 - $ZnSO_4$ (0.5%) + Borax (0.5%) + KNO_3 (1.5%)	17.17	5.26	10.93	21.60	0.016
T_9 - Control (water spray)	18.92	4.10	9.36	19.83	0.035
S.Em. (±)	0.57	0.21	0.23	0.33	0.003
C. D. at 5%	1.72	0.63	0.71	1.01	0.009

Fruit firmness (kg cm^{-2})

The maximum fruit firmness was recorded with application of T_4 (6.93 kg cm^{-2}) which was on par with T_1 (6.66 kg cm^{-2}) and the minimum fruit firmness in T_9 control (4.10 kg cm^{-2}) was shown in Table 1. Appreciable increase of fruit firmness might be due to combined foliar feeding of plant nutrients led to thickening of middle lamella of fruit cell owing to increase formation and deposition of calcium pectate (Gupta *et al*., 1984) [8]. Another reason for higher fruit firmness according to Mastrangelo *et al*. (2000) [12] is that calcium is forming the cross link with carboxylic group of polygalacturo polymerase present in middle lamella of cell and also reduce the activity of polygalacturonase, thus stabilizing and strengthening the cell wall. The proportion of calcium pectate in cell walls is very important for the ripening of fruit. The increase of fruit calcium content leads to the increase of fruit firmness and delays fruit ripening or prevents calcium-related disorders (Khurshid *et al*., 2019) [9] in apple. Similar findings has been documented by Singh *et al*. (1982) [22] and Robson *et al*. (1989) [18] in peach.

Total soluble solids (^{0}Brix)

Data presented in Table 1 indicated that the combined foliar application of plant nutrients had significant effect on total soluble solids, the maximum total soluble solids (12.26 ^{0}Brix) T_4 followed by T_3 (12.16 ^{0}Brix) and the minimum total soluble solids in T_9 control (9.36 ^{0}Brix). The increase in TSS content might be due to application of micronutrients, which may be attributed to an increased photosynthetic activities and production of more sugars and also attributed to the hydrolysis of polysaccharides, conversion of organic acids into soluble sugars and enhanced solublization of insoluble starch and pectin present in cell-wall and middle lamella. Zinc improves the auxin content and it also acts as a catalyst in oxidation-reduction processes in plants. It also helps in other enzymatic reaction like transformation of carbohydrates, activity of hexokinase and formation of cellulose and change in sugars are considered due to its action on zymohexose and the other reason might be transfer of organic acid into sugars led to increasing the TSS content of fruits (Shivanand *et al*. 2017) [21]. During ripening carbohydrate converts into simplest form of sugars which may ultimately increase the TSS content of fruits and also appreciable increase of TSS is due to high level of potassium content of fruit. These findings were similar with findings of Manjunatha *et al*. (2014) [11] and Bhalerao *et al*. (2014) [3] in papaya.

Total sugars (%)

The maximum total sugars observed with application of T_4 (7.91%) which was on par with application of T_3 (7.49%) and minimum total sugars in T_9 control (6.03%) was shown in Table 2. Significant increase in TSS content, might be due to accumulation of higher level of water-soluble compounds like total sugars, vitamins, minerals, which were synthesized, translocated and accumulated due to chemical changes during the fruit development and maturity of fruits. Foliar feeding of micronutrients especially boron and zinc are also found to be effective in increasing the total sugar content of fruit, due to active synthesis of tryptophan in presence of zinc, which is a precursor of IAA and stimulates the various physiological processes in plant tissue. Further, zinc acts as a catalyst in oxidation process and its presence is of great importance in sugar metabolism. Boron plays a major role in sugar metabolism and translocation of available photosynthates to fruit pulp rather than to other parts and borate ion may be associated with the cell membrane where it could be complex with sugar molecules and facilitates its passage across the membrane that might be the reason of increased total sugars, higher levels of potassium increased the total sugar content (Bisht *et al*. (2010) [4] in papaya. The present findings are also in agreement with the observations done by Meena *et al*. (2005) [13] in guava Cv. Sardar and Bhalerao *et al*. (2014) [3] in papaya.

Table 2: Effect of plant nutrients on quality and shelf life of papaya (*Carica papaya* L.) Cv. Taiwan Red Lady

Treatments	Total sugars (%)	Reducing sugars (%)	Non-Reducing sugars (%)	Shelf life (days)
T_1-19:19:19 (0.5%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%)	6.85	5.76	1.68	6.66
T_2 -19:19:19 (1%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) +$ZnSO_4$ (0.5%)	7.09	5.60	1.61	5.66
T_3 - KNO_3 (1%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%) + $ZnSO_4$ (0.25%)	7.49	5.81	1.77	6.50
T_4 - KNO_3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%)	7.91	6.07	1.84	6.83
T_5 -$ZnSO_4$ (0.25%) + Borax (0.3%) + Ca $(NO_3)_2$ (0.25%)	6.44	4.82	1.16	4.50
T_6 - $ZnSO_4$ (0.5%) +Borax (0.5%) + Ca $(NO_3)_2$ (0.5%)	6.60	5.45	1.79	5.83
T_7 - $ZnSO_4$ (0.25%) + Borax (0.3%) + KNO_3 (1%)	6.21	4.40	1.15	4.00
T_8 - $ZnSO_4$ (0.5%) + Borax (0.5%) + KNO_3 (1.5%)	6.63	5.15	1.43	5.50
T_9 - Control (water spray)	6.03	4.25	1.08	3.83
S.Em.(±)	0.03	0.13	0.15	0.39
C. D. at 5%	0.10	0.40	0.47	1.19

Reducing sugars (%)

The maximum reducing sugars recorded with application of T_4 (6.07%), followed by spraying of T_3 (5.81%) and minimum reducing sugars in application of T_9 control (4.25%) was depicted in Table 2. Thus the conversion of starch and polysaccharides into simple sugars with the advancement of storage was responsible for the increase of reducing sugar, and onward decline was due to the utilization of sugar in evapo-transpiration and other bio-chemical activities (Arvind *et al*., 2012) [2]. However increased potassium levels also increased the reducing sugars (Bisht *et al*., 2010) [4] and Modi *et al*. (2012) [14] in papaya Cv. Madhu Bindu.

Non-reducing sugar (%)

Combined foliar application of plant nutrients had shown significant effect on non-reducing sugars, the maximum non reducing sugars (1.84%) in T_4, followed by spraying of (1.77%) and minimum non-reducing sugars in T_9 control (1.08%) was presented in Table 2. Foliar application of micronutrients especially zinc and boron are also found to be effective in increasing the total sugar content of fruit and this may be due to active synthesis of tryptophan in the presence of zinc, which is precursor of IAA and stimulates the various physiological processes in plant tissue. Further, zinc acts as a catalyst in oxidation process and its presence is of great importance in sugar metabolism.

Boron plays a major role in sugars metabolism and translocation. Improvement in non-reducing sugars is conversion of starches and polysaccharides into simple sugar with the advancement of storage and onward decline was due to the utilization of sugar in evapo-transpiration and other bio-chemical activities, as recorded by Arvind *et al*. (2012) [2] in mango. These results are in congruence with the findings of Waskela *et al*. (2013) [30] in guava and Makhmale *et al*. (2016) [10] in custard apple.

Titrable acidity (%)

The minimum titrable acidity (Table 1) with application of T_4 (0.011%) which was on par with spraying of T_3 (0.012%) and maximum titrable acidity in T_9 control (0.035%). The reduction in titrable acidity of papaya fruits might be due to application of different levels of boron, zinc and their different combinations has probably has positive influence of boron and zinc in rapid conversion of acids into sugars and their derivatives by the reaction involving the reversal of glycolytic pathway or might have been used as substrate in the respiration or both reduction of acidity in fruits with foliar application of micronutrients (zinc and boron) alone or in combination with other nutrients. Thus the reduction in acid content may be based on the fact that mineral compounds reduced the acidity in fruits, since it is neutralized in parts during metabolic pathways and or used in respiratory process as a substrate.

Acidity was reduced in borax treated fruits the reason might be due to early ripening induced by plant nutrient which influenced degradation of acid. It was also observed that total soluble solids increased at the expense of acidity in fruits. The acidity under the influence of borax might have converted into sugars and their derivatives by the reaction involving the reversal of glycolytic pathway or be used in respiration, was recorded by Sukhjit kaur (2017) [27] in litchi. Increased potassium levels also decreased the acidity (Bisht *et al*., 2010) [4] in papaya. The results of the present study are in close confirmity with the findings of Yadav *et al*. (2010) [31] and Preethi *et al*. (2017) [17] in papaya.

Ascorbic acid (mg $100g^{-1}$)

Cumulative foliar application of plant nutrients had significant effect on ascorbic acid recorded the maximum ascorbic acid was observed with T_4 (23.56 mg $100g^{-1}$), followed by T_2 (22.86 mg $100g^{-1}$) and minimum ascorbic acid with application of T_9 control (19.83 mg $100g^{-1}$) was depicted in Table 1. Ascorbic acid content of fruit was found minimum in all the treatments, the reason may be due to rapid destruction of ascorbic acid during ripening of papaya fruit, and presence of active enzymes, the conversion of starch to dextrose, levulose and sucrose.

Due to the balanced absorption of macro and micro nutrients which have exerted regulatory role as an important constituent of endogenous factors in affecting the quality of the fruits. The carbohydrate reserves of the roots and stems are drawn upon heavily which might have resulted in higher sugar contents in fruits as has also been reported by Dey *et al*. (2005) [6] in guava.

The increase in ascorbic acid content of fruit juice with the application of micronutrients is due to increased synthesis of catalytic enzymes and co-enzymes (Shivanand *et al*., 2017) [21] in aonla, improvement of ascorbic acid content was due to catalytic activity of zinc, iron and boron on its bio-synthesis from its precursor glucose-6-phosphate or inhibition of its conversation into dehydro ascorbic acid by enzyme and oxidation or both. Similar results were obtained by Modi *et al*. (2012) [14] and Bhalerao *et al*. (2014) [3] in papaya.

Shelf life (days)

Results revealed that combined application of plant nutrients had significant effect on shelf life, the maximum shelf life with application of T_4 (6.83 days), followed by T_1 (6.66 days) and the minimum in T_9 control (3.83 days) was shown in Table 2. Increase in shelf life might be due to presence of higher calcium content, reduced rate of respiration and transpiration from fruit surfaces, the decreased in the respiration could be further attributed to lowering of succinate and malate dehydrogenase activities associated with TCA (Tri carboxylic acid) cycle. Presence of epicuticular wax on the fruit skin also reduces respiration and transpiration during post-harvest period by partially blocking the lenticels, cuticle and consequently retards the moisture loss caused by transpiration.

Higher availability of secondary nutrients, metabolites and reduced gaseous exchange effects delay in ripening, senescence, less tissue break down and softening of tissue which increases firmness and extends storage life.

In papaya, extension of shelf life could be ascribed to the beneficial effect of zinc and boron on hormonal metabolism, photosynthesis and water relations in plants and further, it may be due to slower conversion of starch to sugars and also less and delayed incidence of papaya ring spot virus, which deteriorates the fruit quality. Appreciable increase in shelf life of fruits might be due to increase in concentration of boron in middle lamella of cell wall of fruit which provide physical strength to cell wall and improve fruit colour development and appearance (Singh *et al*., 2017) [25] in mango. The similar results are in accordance with the findings of Singh and Varma (2012) [26] in mango and Singh *et al*. (2010) [23] in papaya.

Conclusion

From this study, it can be concluded that among the different combinations of plant nutrients T_4 - KNO_3 (1.5%) + Borax (0.5%) + Ca $(NO_3)_2$ (0.5%) + $ZnSO_4$ (0.5%) per tree can be recommended which showed positive effect on quality parameters (fruit firmness, total soluble solids, total sugars, reducing sugars, non-reducing sugars, ascorbic acid, and shelf life) and also showed decrease of physiological loss in weight and acidity.

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