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Foliar Application of Micronutrients on the Morpho-agronomic Characterization and Fruit Quality in Papaya (*Carica papaya* L.) Cv. Red Lady

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ABSTRACT

The present study was conducted during April, 2023 to March, 2024 at farmers field adjoining to College of Horticulture, Sirsi (Location), Karnataka, India to evaluate the effect of micronutrients, time / period, frequency and concentration of foliar application of micronutrient mixture (iron, boron and zinc) on plant growth, yield and fruit quality in papaya Cv. Red Lady. Results indicated that the time of foliar application of micronutrients was highly significant on all reproductive, yield and quality traits recorded. The treatment with foliar spray at 1, 3, 5, 7 months was the best as it recorded reduced number of days taken for flower initiation, increased number of flowers, number of fruits set, fruit weight, yield, TSS and shelf life of fruits and vary less percent of deformed fruits (13.12 days, 25.62%, 41.65%, 36.28%, 91.82%, 21.69%, 45.45% and 3.39%, respectively), which indicated continues supply of micronutrients is favorable for both increased yield and quality of fruits. In another experiment the frequency and concentration of foliar application of micronutrient significant influence on most of reproductive parameters. Further, yield parameters (weight of fruit, length, cavity diameter, fruit plant^{-1} and hectare) (highest of the was1.52 kg, 24.50cm, 46.08 kg and 144.13 t ha^{-1}, respectively) and quality parameters were also significantly influenced and the highest of them was noticed in with spraying fruit special containing (at 5 g l^{-1}) at 30 days interval. In conclusion, extended application of micronutrients up to eight month was useful for improved yield and quality parameters in papaya cv. Red lady.

KEYWORDS: Papaya, red lady, micronutrients, fruit size, yield, quality

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1. INTRODUCTION

Papaya (*Carica papaya* L.) is known as 'wonder fruit of tropics' due to its productivity and nutritional resources. It is very important tropical crop as it produces fruits throughout the year for 2- years with highest productivity among commercial fruit crops. Moreover, it has very important therapeutic value which includes leaf juice curing dengue fever. The fruits and it's by products has various uses in the beverage, food, pharmaceutical and tanning industries. India is the first largest producer of papaya in the world with total area of 1,33,360 ha and production of 56.39 lakh t of fruits with a productivity of 42.30 mt (Anonymous, 2015). In crop production, cultural operations, including irrigation, fertilizer application, pruning, and harvesting systems, also affects enormously the crop quality (Raza et al., 2019). Iron (Fe), Boron (Bo), Zinc (Zn), Cupper (Cu), Molybdenum (Mo), Manganese (Mn) and Chlorine (Cl) in minute or micro quantities for regulation of plant growth and development. Micronutrients play crucial roles in maintaining the overall health and vitality of crops. They are involved in several physiological and biochemical activities, each of it contributs uniquely to crop health and productivity (Tariq Aftab, 2020). For example, iron, a micro element indispensable for several enzymatic processes in crops, can considerably increases the postharvest quality of fruits (Khakpour et al., 2022). By managing optimal zinc levels resulted in improved in fruit quality and its composition including phenolic compounds, antioxidants, and overall fruit yield and quality (Ahmed et al., 2024). Further, borax application can bring about enhanced sugar content, good taste, and high vibrant color (Walli et al., 2022). Hence, every micro element engages in several reactions that underscore growth and development of plants (Stanton et al., 2022). Although the necessarily these trace elements required at minute level, their shortage or imbalance can critically affect plant growth, development, and fruit yield. Usually, the micronutrient requirements are met out through foliar nutritional sprays during important developmental phases to improve plant growth, development, health (Dass et al., 2022). The micronutrients application should be balancely managed to reduce any potential environmental problems (Mathur et al., 2022). Nevertheless, overuse of these trace elements can cause negative consequences on entire eco-system (Zulfiqar et al., 2019). In this view, Papaya is very responsive to the application of inorganic fertilizes along with organic manures. Also, as papaya grows and sets flowers and fruits continuously and hence, the nutrition of papaya differs from other fruit crops. So, it appears, frequent manuring of papaya plant with major nutrients is highly essential to maintain health and to obtain profitable yield. The choice of method for application of micronutrients depends upon the crop type (Arevalo-Gardini et al., 2015). Several other studies on soil and foliar (Bhaleroa and Patel, 2015; Subedi et al., 2019) application of micronutrients individually and mixtures have been taken up in papaya and other crops (Farid et al., 2020; Ilyas et al., 2015; Singh et al., 2022 Haider et al., 2019). In spite of those studies, there is very meager information particularly about time and concentrations of micronutrients in papaya. Furthermore, its nutrient requirement varies with region and hence systematic study is required in all agroclimatic zones (Bindu and Bindu, 2017). A well balanced schedule of trace elements application may even very effective in viral disease management (Kudada and Prasad, 2002). In this view, the present study has been planned to evaluate the effect mixture of micronutrients (iron, boron and zinc), time/ period, frequency and concentration of foliar application of micronutrients on plant growth, yield and fruit quality in papaya Cv. Red Lady.

2. MATERIALS AND METHODS

2.1. Field preparation, planting and management

The present study was conducted during April, 2023 to March, 2024 at farmers field adjoining to College of Horticulture, Sirsi. The land was properly ploughed twice and harrowed to bring it to fine tilth. The experiments pertaining to the present study was conducted in Randomized Block Design (RBD) with 13 and 14 micronutrient treatments along with a control, in two replications. The disease free seedling of papaya cv. Red Lady were raised in portrays under insect proof net house and 45 days old uniform size and vigours seedlings were selected for planting. Pits of 45 cm^3 were dug one month before the planting at a spacing of 1.8×1.8 m^2 and filled with planting mixture of sand, soil and FYM in the ratio of 1:1:1. 250 g neem cake and 15–20 g of Carbofuran was added to the pit at the time of planting. Soil application fertilizers (NPK: 250; 250;500 g $plant^{-1}$ in four equal split doses at 2, 4, 6 and 8 months after transplanting) was carried out as per package of practice. Basin irrigation method was adopted and irrigated once in seven to ten days to keep the soil wet. Hand weeding was done at fortnight intervals after transplanting to keep the plot free from weeds. The plant protection chemicals like confider (0.5 ml l^{-1}), kemstar (4 g l^{-1}) metalaxyl (1 g l^{-1}), bavistin (2 g l^{-1}) and neem oil (1000 ppm, 0.5 ml l^{-1}) were sprayed on the foliage to manage sucking pests and viral infection at regular intervals.

2.2. Experiment on time of foliar application of micronutrients

Foliar application of fruit special (Zn- 3%, Fe- 2% and B- 0.5%) as T_1- at planting, T_2-first, T_3-second, T_4-third, T_5-fourth, T_6-fifth, T_7-sixth, T_8-seventh, T_9-1,3,5,$7^{th,}$ T_{10}-$1–3^{rd}$, T_{11}-$4–6^{th}$ months after planting, T_{12}-$6–9^{th}$ months after planting along with T_{12} (control; zero micronutrients $(water\ spray)^{-1}$) was applied as treatments.

2.3. Experiment on frequency and concentration of foliar application of micronutrients

Foliar application of fruit special (Zn- 3%, Fe- 2% and B- 0.5%) as T_1: 2 g at 15 days interval; T_2: 3 g at 15 days interval, T_3: 5 g at 15 days interval, T_4: 7.5 g at 15 days interval, T_5: 10 g at 15 days interval, T_6: 12.5 g at 15 days interval, T_7: 2 g at 30 days interval, T_8: 3 g at 30 days interval, T_9: 5 g at 30 days interval, T_{10}: 7.5 g at 30 days interval, T_{11}: 10 g at 30 days interval, T_{12}: 12.5 g at 30 days interval and T_{13}: Control as per POP (5 g l^{-1} at 1st , 3rd and 5th month) along with a control (T_{14}: Water spray) was applied as treatments.

2.4. Observation recorded

In the experiment on time of foliar application of micronutrients only reproductive, yield and quality parameters were recorded. The percentage reduction in number of days taken for flower initiation, increased number of flowers, number of fruits set, fruit weight, yield, TSS and shelf life of fruits and vary less percent of deformed fruits has been calculated and used in statistical analysis. The experiment on frequency and concentration of foliar application of micronutrients, the observations at an interval of 30 days on vegetative growth parameters like plant height (m), stem girth (cm), number of leaves were recorded up to 9th month after transplanting. The reproductive parameters such as days taken to first flowering, number of flowers $plant^{-1}$, days taken to first fruit set, number of days to fruit harvest after fruit set were recorded after flower and fruit set initiation. The yield attributes such as yield $plant^{-1}$ (kg $plant^{-1}$), ha^{-1} (t ha^{-1}) and fruit characteristics (weight of fruits, fruit length, width and cavity) were recorded after harvest. The observations of quality parameters such as TSS (^{O}brix) and acidity (%) and post- harvest shelf life (days) were made after the harvesting of fruits from each treatment.

2.5. Statistical analysis

The design adopted was randomized block design. The data on all the growth parameters yield and quality parameters was tabulated and subjected to statistical analysis using method of analysis of variance (ANOVA) for randomized complete block design (RBD). Whenever 'F' test was found significant for comparing the means of two treatments, critical difference (C. D. at p=0.05) were worked.

3. RESULTS AND DISCUSSION

A few studies have been taken up on effect of foliar application of micronutrients in papaya. However, in most of those studies, lower concentrations of Bo (0.01–0.03%), Zn (0.2–0.5%) and Fe (0.2–0.5%) were used at 60, 90 and 120 days or later after planting and results differed with concentration and time of foliar application which insisted for further detailed investigation on effect of higher concentration, shorter intervals and longer duration of application of micronutrients. Further, now-a-days, most of micronutrient formulations for fruit crops contain zinc (2%), (3%) iron and boron (0.5%) which is recommended at 5 g l^{-1} of water in foliar sprays. Hence, we have examined varied time foliar spray and different concentrations of fruit special micronutrient mixture at two intervals viz., at 15 and 30 days regularly after planting up to nine months to elucidate the exact effect of time, interval and frequency of application the micronutrient mixtures. Further, we tried to compare results of our study with other earlier studies wherever possible to provide a detailed insight on impact of application of micronutrients in papaya, continues flowering and fruiting horticultural crop.

3. 1. Time of foliar application of micronutrients

Time of foliar application of micronutrients was highly significant on all reproductive, yield and quality traits recorded (Figure 1). The treatment T_9 (foliar spray at 1,3,5,7 months) was the best as it recorded most reduction in number of days taken for flower initiation, increase in number of flowers, number of fruits set, fruit weight, yield, TSS and shelf life of fruits and vary less percent of deformed fruits(13.12 days, 25.62%, 41.65%, 36.28%, 91.82%, 21.69%, 45.45% and 3.39%, respectively), which indicated continues supply of micronutrients was favorable for both increased yield and quality of fruits. Application of micronutrients at single dose every month was not useful. Further, it was found that application of micronutrients during initial period of planting up to six months was highly beneficial than later, which might be because of crucial period flower differentiation in papaya. It was also indicated from observations in plants supplied micronutrients later than six months of planting. Similarly, foliar application (1% Grade–IV micronutrient) at 2nd, 4th, 6th and 8th month after planting significantly increased Fe as well as Zn content in leaves. The plants absorbed nutrients and water present in the soil through active salt absorption. However, the

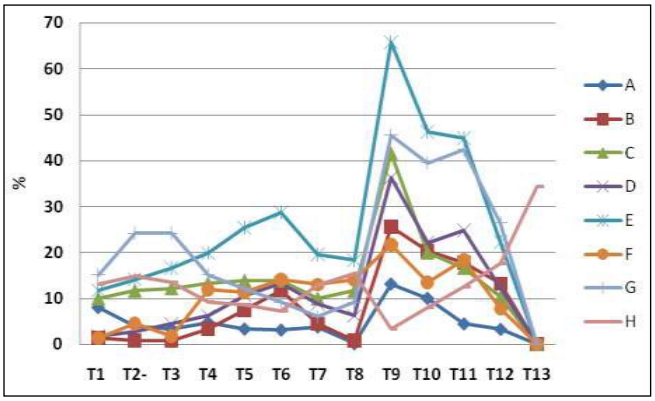

Figure 1: Effect of time of foliar spray of micronutrients on reproductive, yield and quality parameters in Papaya cv. Red Lady

nutrient content in soil might or might not be available to the plant at each and every stage of growth and development. This situation might lead to the deficiency resulting into reduction or inactivation in different physiological processes and thereby controlled the flowering and fruiting in plants and similar observations have been recorded in papaya by Kavitha et al. (2000a) and Kavitha et al. (2000b). However, the present study was exclusive in testing foliar application of micronutrients at various period right from planting to ninth month of planting and it has provided a clear picture of continues requirement of micronutrients in papaya for good yield and quality fruits.

3.2. Frequency and concentration of foliar application of micronutrients

3.2.1. Plant height, stem girth and number of leaves

The frequency and concentration of foliar application of micronutrient had significant influence on plant height, stem girth and number of leaves from 2nd to 7th month. The highest of them at 8th MAT were recorded in plants foliar sprayed with T_9 [fruit special containing Zn-3%, Fe-2% and B-0.5%) and 5 g l^{-1} at 30 days interval] 1.65 m, 35.75 cm and 43.83 respectively (Table 1), whereas the lowest of them was recorded in control (T_{14}-Water spray) with 1.36 m, 29.97 cm and 38.00, respectively. No significant difference was observed during 1st and 8th months after transplanting.

In the studies conducted by Bhalerao and Patel (2015) with foliar sprays of micronutrients in cv. Tiwan Red Lady, plant height and stem girth was 136.20 cm and 39.46 cm, receptively (in plants treated with calcium nitrate 1000 mg l^{-1}+borax 30 mg l^{-1}+zinc sulphate 200 mg l^{-1}+ferrous sulphate 200 mg l^{-1}). Our results were in line with this study. Further, we have data up to 8th month after planting, the trend of increase in plant height up to 8th month was remained same compared to that study. This might be due to the synergistic effect of different micronutrients as they directly take part in many physiological processes and activity of many enzymes for greater gathering of food materials. Zinc helps in prevention of abscission layer formation and increase the synthesis of tryptophan which is the precursor of auxin synthesis and this facilitates the ovary to remain intact with the shoot, ensuring in minimizing the flower and fruit drop and maximize the retention of fruits in the plants (Gurjar et al., 2015). Similar increase in plant girth was observed with the foliar application of micronutrients (zinc and boron) when applied alone or in combination in papaya cv. Ranchi by Singh et al. (2010). Our results were also revealed that both zinc and iron play a significant role which is also supported by Singh et al. (2015) and Farid et al. (2020), who showed that both $FeSO_4$ and $ZnSO_4$ improve vegetative and fruiting parameters.

Table 1: Effect of concentration and frequency of foliar spray of micronutrients on growth and reproductive parameters in papaya cv. Red Lady

Treatments details		Plant height	Stem girth	Days taken for flowering
T_1	2 g l^{-1} at 15 days interval	1.53	35.08	104.30
T_2	3 g l^{-1} at 15 days interval	1.54	35.47	102.32
T_3	5 g l^{-1} at 15 days interval	1.61	34.22	102.02
T_4	7.5 g l^{-1} at 15 days interval	1.46	36.15	99.80
T_5	10 g l^{-1} at 15 days interval	1.52	34.57	108.83
T_6	12.5 g l^{-1} at 15 days interval	1.51	34.32	111.17
T_7	2 g l^{-1} at 30 days interval	1.45	35.82	106.33
T_8	3 g l^{-1} at 30 days interval	1.45	35.58	105.50
T_9	5 g l^{-1} at 30 days interval	1.65	37.09	104.82
T_{10}	7.5 g l^{-1} at 30 days interval	1.64	36.33	106.00
T_{11}	10 g l^{-1} at 30 days interval	1.64	35.59	107.33
T_{12}	12.5 g l^{-1} at 30 days interval	1.54	35.12	107.50
T_{13}	Control as per POP 5 g l^{-1} at 1st, 3rd and 5th month	1.52	34.53	104.67
T_{14}	Water spray	1.41	32.47	112.17
	SEm±	0.07	1.72	1.72
	CD (p=0.05)	NS	NS	NS

3.2.2. Reproductive parameters

The frequency and concentration of foliar application of micronutrient mixture had significant influence on reproductive parameters (days taken for first flowering, fruit set and harvest and number of flowers) (Table 2). First flower (99.00 days) and fruit set (125.00 days) were utmost advanced (required minimum days) with application of T_4 (containing Zn-3%, Fe-2% and B-0.5% applied at 7.5 g l^{-1} at 15 days interval) and taken highest days (112.17 days and 144.71 days, respectively) T_{14} (Water spray). The lowest number of days for first fruit harvest (146.50 days) was recorded in T_9 (containing Zn-3%, Fe-2% and B-0.5% applied at 5 g l^{-1} at 30 days interval) and highest for it was recorded in control T_{14} (Water spray; 160.50 days). Similarly, Bhalerao and Patel et al. (2015) has recorded lowest number of days 93.40 for first flowering in papaya cv. Red Lady with foliar application of micronutrients mixture of zinc, boron and iron and Modi et al. (2012) recorded the lowest days of 74.22 for fruit harvest after fruit set in boron applied plants in cv. Madhu Bindu. This confirms application of micronutrients assures early flowering, fruit set and harvesting. Similar findings were in conformity with

Table 2: Effect of concentration and frequency of foliar spray of micronutrients on reproductive parameters in papaya cv. Red Lady

Treatments details		No. of flowers plant^{-1}	Days taken to first fruit set	Days to fruit harvest after fruit set	Number of fruits plant^{-1}
T_1	2 g l^{-1} at 15 days interval	43.00	127.17	153.83	25.34
T_2	3 g l^{-1} at 15 days interval	43.67	126.50	148.67	26.84
T_3	5 g l^{-1} at 15 days interval	43.00	126.83	150.17	28.67
T_4	7.5 g l^{-1} at 15 days interval	43.34	125.00	146.50	26.84
T_5	10 g l^{-1} at 15 days interval	39.50	136.00	147.17	24.50
T_6	12.5 g l^{-1} at 15 days interval	36.83	138.17	157.33	23.50
T_7	2 g l^{-1} at 30 days interval	36.84	131.00	150.67	24.17
T_8	3 g l^{-1} at 30 days interval	39.34	129.00	157.33	26.17
T_9	5 g l^{-1} at 30 days interval	52.50	130.15	149.17	33.50
T_{10}	7.5 g l^{-1} at 30 days interval	51.67	136.67	158.17	32.33
T_{11}	10 g l^{-1} at 30 days interval	51.50	135.67	157.17	32.00
T_{12}	12.5 g l^{-1} at 30 days interval	44.17	135.17	153.17	27.34
T_{13}	Control as per POP 5 g l^{-1} at 1st, 3rd and 5th month	41.34	138.33	157.67	27.17
T_{14}	Water spray	36.33	144.17	160.50	23.17
	SEm±	2.46	3.64	1.17	1.56
	CD (p=0.05)	7.52	NS	3.57	4.78

the findings of Singh et al. (2010) in cv. Ranchi. However, the difference in flowering to harvesting in different studies might be due to varied agroclimatic conditions, variety and concentration of micronutrients.

In this study, the frequency and concentration of foliar application micronutrient had significant influence on number of flowers and fruits plant^{-1} (Table 3). At 8th MAT, the highest of them (52.50 flowers and 31.50 fruits plant^{-1}, respectively) was produced in T_9 (fruit special containing Zn- 3%, Fe-2% and B-0.5% and at 5 g l^{-1} at 30 days interval), whereas lowest of them (30.50 flowers and 22.17 fruits plant^{-1}, respectively) was produced in T_{14} (Water spray). Similarly, trend in flowering and fruits pre plant was recorded by Singh et al. (2010) in papaya Cv. Ranchi. Hence, application of micronutrients, very importantly in combination found to be better for improved number of flowers and fruits. The results of the present study are also in agreement with earlier studies in lemon (Sheikh et al., 2021).

3.2.3. Yield and fruit parameters

The frequency and concentration of foliar application of micronutrient had significant influence on yield and fruit parameters (weight of fruit, length, cavity diameter, fruit plant^{-1} and hectare, Table 3). The highest of them except cavity diameter were noticed in with T_9 (fruit special containing Zn- 3%, Fe-2% and B-0.5%) and at 5 g l^{-1} at 30 days interval) 1.52 kg, 24.50 cm, 47.77 kg and 147.42 t ha^{-1} while the lowest fruit weight was recorded in T_{14} (Water spray) 1.06 kg, 15.80 cm, 23.45 kg and 72.35 t ha^{-1}, respectively. The lowest cavity diameter was noticed in the same treatment (9.50 cm) compared to control (13.40 cm).

The finding of present study was in line with earlier studies on micronutrient application in papaya (Kavitha et al., 2000b; Bhalerao and Patel et al., 2015). Similarly, Ilyas et al. (2015) also proved that the foliar application of Zn, Cu and B obtained the maximum number of fruits per plant and yield per tree. Various physical, physiological and metabolic functions are managed by these mineral nutrients. Bo is particularly essential in pollen germination, fe acts as an oxygen carrier and promotes chlorophyll formation, while, Zn aids plant growth hormones and enzyme system. Yield and quality of agri-horticultural products increased with application of micronutrients, hence both human and animal health is protected with feeding enriched plant materials (Sherefu and Zewide, 2021; Rathore et al., 2020). Singh et al. (2010) have also reported an appreciable increase in number of fruits plant^{-1} with the spray of micronutrients viz., borax and zinc sulphate, when they were applied in combination or alone in papaya cv. Ranchi. The appreciable improvement in fruit weight by boron and zinc application has been also reported by Subedi et al. (2019) and Singh et al. (2010) in papaya. The increase in fruit weight with

Table 3: Effect of concentration and frequency of foliar spray of micronutrients on yield and quality parameters in papaya cv. Red Lady

Treatments details		Fruit weight (kg)	Fruit length (cm)	Yield plant^{-1} (kg)	Yield ha^{-1} (T)	% yield increase over control
T_1	2 g l^{-1} at 15 days interval	1.90	19.50	34.76	107.06	17.60
T_2	3 g l^{-1} at 15 days interval	1.91	19.60	37.67	116.02	27.45
T_3	5 g l^{-1} at 15 days interval	1.98	20.13	38.94	119.92	31.73
T_4	7.5 g l^{-1} at 15 days interval	1.66	16.60	38.17	117.57	29.15
T_5	10 g l^{-1} at 15 days interval	1.89	18.25	34.58	106.51	17.00
T_6	12.5 g l^{-1} at 15 days interval	1.90	17.45	33.11	101.99	12.03
T_7	2 g l^{-1} at 30 days interval	1.69	17.88	33.47	103.07	13.22
T_8	3 g l^{-1} at 30 days interval	1.84	17.20	36.90	113.65	24.84
T_9	5 g l^{-1} at 30 days interval	2.25	24.50	46.80	144.13	58.33
T_{10}	7.5 g l^{-1} at 30 days interval	2.04	20.65	43.44	133.80	46.98
T_{11}	10 g l^{-1} at 30 days interval	2.03	20.23	42.12	129.72	42.50
T_{12}	12.5 g l^{-1} at 30 days interval	1.93	18.35	36.66	112.91	24.03
T_{13}	Control as per POP 5 g l^{-1} at 1st, 3rd and 5th month	1.75	19.65	35.81	110.29	21.15
T_{14}	Water spray	1.26	15.80	29.64	91.03	0
	SEm±	0.07	0.94	2.46	6.38	1.98
	CD (p=0.05)	0.20	2.88	7.52	20.07	6.12

the sprays of borax and zinc sulphate might be due to the involvement of these chemicals in hormonal metabolism, increase in cell division and expansion of cell wall. Boron was also known to stimulate rapid mobilization of water and sugar in the fruit which intern increased in accumulation of dry matter within the fruit (Bhatt et al., 2012). Application of zinc also improved the other physical characteristics of papaya fruits. It was probably due to the effect of zinc in regulating the semi permeability of cell walls, thus mobilizing more water into fruits resulting increase in fruit weight, fruit length and girth (Singh et al., 2010).

The significant increase in fruit yield was a cumulative effect of increase in number of fruits because of reduction in fruit drop and higher fruit weight by the direct and indirect effect of foliar spray of micronutrients in mango cv. Kesar. Promotion of starch formation followed by rapid transportation of carbohydrates in plants activated by zinc and boron were well established. Foliar spray of micronutrients might have affected the physiological processes resulting into higher production reported Nehete et al. (2011) in mango. It was possibly due to their directly or indirectly involvement in setting, retention and growth and development of fruit, their activity improved fruit characteristics such as number of fruits, size and average fruit weight (Yadav et al., 2013) in papaya.

3.2.4. Quality parameters

The frequency and concentration of foliar application micronutrient had significant influence on quality parameters (total soluble solids and acidity) (Table 4). The highest total soluble solids and ascorbic acid (11.78°Brix and 25.45 mg (100 g) pulp, respectively) were noticed in fruits from plants sprayed with T_9 (containing Zn-3%, Fe-2% and B-0.5% at 5 g l^{-1} at 30 days interval) while the lowest of them were recorded in T_{14} (Water spray) 8.55°Brix, and18.98 mg (100 g)$^{-1}$ pulp, respectively. Further, the lowest acidity was (0.110%) also noticed in the same treatment and the highest of it (0.171%) was in fruit of control.

Similarly, Bhalerao and Patel et al. (2015) has reported that foliar application of combined micronutrients (calcium nitrate 1000 mg l^{-1}+borax 30 mg l^{-1}+zinc sulphate 200 mg l^{-1}+ferrous sulphate 200 mg l^{-1}) has improved ascorbic acid (23.23, 22.00, 21.72 and 21.77 respectively) in fruits when compared to application of boron (borax 30 mg l^{-1}) and zinc (zinc sulphate 200 mg l^{-1}) and iron (ferrous sulphate 200 mg l^{-1}) alone in papaya cv. Red Lady.

Increase in the TSS might be due to more rapid translocation of sugars from leaves to developing fruits. It might be due to the adequate amount of zinc improved the auxin content and it also acted as a catalyst in oxidation reduction processes in plants. Besides, it also helped in other enzymatic actions like

Table 4: Effect of concentration and frequency of foliar spray of micronutrients on quality parameters in papaya cv. Red Lady

Treatments details		TSS (°Brix)	Acidity (%)	Shelf life (days)
T_1	2 g l^{-1} at 15 days interval	10.40	0.140	6.25
T_2	3 g l^{-1} at 15 days interval	10.48	0.110	6.50
T_3	5 g l^{-1} at 15 days interval	10.93	0.130	7.00
T_4	7.5 g l^{-1} at 15 days interval	9.28	0.121	7.25
T_5	10 g l^{-1} at 15 days interval	10.25	0.151	7.00
T_6	12.5 g l^{-1} at 15 days interval	10.38	0.151	7.25
T_7	2 g l^{-1} at 30 days interval	9.63	0.150	7.25
T_8	3 g l^{-1} at 30 days interval	9.35	0.150	7.00
T_9	5 g l^{-1} at 30 days interval	11.78	0.110	8.75
T_{10}	7.5 g l^{-1} at 30 days interval	10.78	0.120	8.00
T_{11}	10 g l^{-1} at 30 days interval	10.65	0.140	7.75
T_{12}	12.5 g l^{-1} at 30 days interval	10.38	0.150	7.50
T_{13}	Control as per POP 5 g l^{-1} at 1st, 3rd and 5th month	10.90	0.150	7.00
T_{14}	Water spray	8.55	0.171	5.75
	SEm±	0.27	0.02	0.43
	CD (p=0.05)	0.84	NS	1.32

transformation of carbohydrates, activity of hexokinase and formation of cellulose and change in sugar were considered due to its action on zymohexose. An increase in 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 (Sherefu and Zewide, 2021). Similar trend was also observed by Singh et al. (2022) in litchi and by Haider et al. (2019) in mango.

3.2.5. Shelf life

The frequency and concentration of foliar application of micronutrient had significant influence on shelf life of fruits. The maximum shelf life was observed in fruits harvested from plants sprayed with T_9 (5 g l^{-1} at 30 days interval; 8.75 days) and minimum of it was in T_{14} (Water spray; 5.57 days). Similarly, shelf life (6.95, 6.71, 6.25 and 6.41 days, respectively) was more in fruits applied with combination of micronutrients (calcium nitrate 1000 mg l^{-1}+borax 30 mg l^{-1}+zinc sulphate 200 mg l^{-1}+ferrous sulphate 200 mg l^{-1}) when compared to boron (borax 30 mg l^{-1}) and zinc (zinc sulphate 200 mg l^{-1}) and iron (ferrous sulphate 200 mg l^{-1}) alone in papaya cv. Red Lady (Bhalerao and Patel et al., 2015).

This might be due to biochemical reaction inside the fruit tissues in terms of cell division and application of micronutrients helped to synthesis of growth substance and metabolism. The improvement in shelf life with the application of micronutrients might be due to its role in the maintenance of fruit firmness, retardation of respiration rates as well as transpiration and delayed senescence reported by Bhatt et al. (2012) in mango.

Micronutrients were key elements in plants growth and development. These elements played very important role in various enzymatic activities and synthesis. Their acute deficiencies some time possessed the problem of incurable nature (Kumar, 2002). Our study provided clear insight on time, frequency and concentration of foliar application of micronutrients in papaya.

4. CONCLUSION

Time, frequency and concentration of foliar application of micronutrients were found to have marked influence on vegetative, yield and quality parameters. Extended application of micronutrients up to eight month was useful for improved yield and quality parameters in papaya cv. Red lady

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