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Effect of foliar nutrition of calcium and sulphur on growth and yield of papaya (*Carica papaya* L.)

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Abstract
A field experiment was carried out to assess the effect of foliar nutrition of calcium and sulphur on growth and yield parameters of papaya at the Horticultural College and Research Institute, TNAU, Coimbatore. The study involved the foliar application of calcium ($Ca(NO_3)_2$) and sulphur (K_2SO_4) independently or in combination at two levels (0.25 % and 0.5 %) with micronutrients (zinc sulphate @ 0.5% and boric acid @ 0.1%) at 3rd, 5th and 7th months after planting along with the recommended dose of fertilizers (50:50:50 g NPK /plant @ bimonthly interval) in randomized block design with three replications. The results showed that the plants treated with foliar application of calcium (0.5% $Ca(NO_3)_2$), sulphur (0.5% K_2SO_4) and micronutrients (zinc sulphate @ 0.5% and boric acid @ 0.1%) along with the recommended dose of fertilizers (T_7) registered significantly the highest number of fruits (34.21), fruit weight (1.39 kg), fruit length (29.96 cm) and fruit circumference (41.34 cm). The fruit yield (47.54 kg/plant) registered in this treatment (T_7) was 28.21% higher than control in spite of the incidence of PRSV (31.26 %). The same treatment also registered the highest leaf area (2473.45 cm^2) and chlorophyll content (1.970 mg g^{-1}).

Keywords: papaya, foliar spray, calcium, sulphur, growth and yield attributes

Introduction

Papaya (*Carica papaya* L.), a native fruit of Tropical America was introduced to India in the 16th century from Malacca and it belongs to the family Caricaceae (Singh, 1990). High nutritional value and its richness in vitamin A content (2020 IU/100g) make papaya an important fruit crop. India is the largest producer of papaya in the world producing 61.07 lakh tonnes of fruits from an area of 1.36 lakh hectares with productivity of 44.86 MT/ ha (NHB, 2018) [19]. It is commercially cultivated in Andhra Pradesh, Gujarat, Karnataka, West Bengal, Madhya Pradesh, Maharashtra and Tamil Nadu. The importance of this crop lies not only in the yield potential of delicious fruits but also for the extraction of a valuable proteolytic enzyme ‘papain’ from the unripe matured fruit. Papain is used in pharmaceutical, food processing, textile and cosmetic industries. Besides, being used as a table fruit, it is also used in the preparation of various products such as jam, jelly, tutti-frutti, marmalade, nectar, wine, syrup, dehydrated flakes and baby foods.

Papaya is a fast growing crop and can bear fruits continuously once it starts flowering. Therefore, it needs moisture stress free environment and periodical judicious nutrient supply at regular intervals for optimum productivity. Shanmugavelu *et al*. (1973) [29] reported that application of different macro and micronutrients in papaya recorded a positive influence in yield and fruit quality. However, the studies pertaining to understand the influence of the important secondary nutrients *viz*., calcium and sulphur independently or in combination on papaya is limited. 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 influences the cell wall strength during fruit development. Sulphur is another essential nutrient known for its role as a structural component for amino acids *viz*., methionine and cysteine and also necessary for chlorophyll formation. Of late, the papaya crop is also affected by a serious viral disease caused by Papaya Ring Spot Virus (PRSV). The virus causes severe yield reduction. Application of micronutrients could help to manage the disease problem to certain extent. Hence, this study was taken up to investigate the influence of the two secondary nutrients *viz.*, calcium and

Micronutrients could help to manage the disease problem to certain extent. Hence, this study was taken up to investigate the influence of the two secondary nutrients *viz.*, calcium and sulphur when applied through foliar application on growth and yield of papaya grown under field conditions.

Materials and Methods

A field trial was conducted at the college orchard, Horticultural College and Research Institute, TNAU, Coimbatore to assess the effect of calcium and sulphur on growth and yield parameters of papaya with the variety "TNAU papaya CO.8". Soil type of the experimental field was sandy clayey loam with pH and EC of 7.93 and 0.69 dS/m respectively. The initial status of available N, P, K in the experimental field was 213 kg/ha, 11 kg/ha and 705 kg/ha respectively. The study involved eight treatments *viz.*, T_1 - Recommended NPK dose (bimonthly dose of 50:50:50 g /plant) + Micronutrients (zinc sulphate @ 0.5% and boric acid @ 0.1%), T_2 - T_1+ 0.25 % Ca $(NO_3)_2$, T_3 - T_1+ 0.5 % Ca $(NO_3)_2$, T_4 - T_1+ 0.25 % K_2SO_4, T_5 - T_1 + 0.5 % K_2SO_4, T_6 - T_1 + 0.25 % Ca $(NO_3)_2$ + 0.25 % K_2SO_4, T_7 - T_1 + 0.5 % Ca $(NO_3)_2$ + 0.5 % K_2SO_4 and T_8-Recommended dose of NPK alone, with three replications in randomized block design. Calcium nitrate and potassium sulphate were used as sources for calcium and sulphur respectively. Transplanting of 45 days old seedlings of papaya was done in the field with a spacing of 1.8 m X 1.8 m. Regular cultural operations were followed as per the recommendations given in the Crop Production Guide (TNAU, 2014). The micronutrient sprays as well as calcium and sulphur sprays were given through foliar application at 3rd, 5th and 7th month after planting.

Observations were recorded on growth and yield parameters of papaya. Growth characters such as plant height (cm), stem girth (cm), days to first flowering (days), days to first harvest (days), first fruiting height (cm) and number of leaves were recorded. Leaf area was calculated using the prediction method as described by Karikari (1973) [13]. Chlorophyll content (mg g^{-1}) was estimated in physiologically active leaves as per the procedure suggested by Yoshida *et al.* (1971) [35]. Leaf petiole analysis were estimated out in the sixth fully opened leaves from growing point for calcium (%), sulphur (%), magnesium (%) and zinc (ppm) as per Jackson, 1973 while boron (ppm) was estimated as per Berger and Troug, 1939. The yield attributing characters such as number of fruits per plant, fruit length (cm), fruit circumference (cm), fruit weight (kg) and fruit yield (kg/plant) were also recorded.

Papaya Ring Spot Virus (PRSV) disease incidence was recorded using the following score chart:

Score chart for papaya ring spot virus (PRSV) disease incidence

Score	Symptoms
0	No symptoms
1	Mild mosaic or oily spots, streaks on petioles or stem, oily spots on fruits
3	Mild mosaic and oily streaks / spots on petiole or stem and ring spots on fruits
5	Oily spots /streaks on petiole (or) stem (or) ring spots on fruits
7	Oily spots/streaks on petioles, stem,(or) on fruits, (ring spots), severe mosaic or blistening on leaves and leaf deformation and severe leaf reduction or mild fruit deformation with ring spots
9	Oily spots/streaks on petiole or stem and shoe string formation or severe fruit deformation with ringspots and stunted plants

Disease severity was calculated using the following formula:

$$\text{PRSV \%} = \frac{\text{Total score of all plants}}{\text{Total number of plants}} \times \frac{100}{\text{maximum score}}$$

For disease rating, the scores were transformed to arc sine values for estimating the analysis of variance (ANOVA). Statistical analysis was performed on the data of the above mentioned growth and yield attributes (Panse and Sukhatme, 1978) [20].

Results and Discussion

Growth characters

In the present study, it was evident that the foliar application of calcium and sulphur influenced plant height, stem girth, days to first flowering, days to first harvest, first fruiting height, number of leaves and leaf area (Table. 1) significantly at first flowering and first harvest. The plant height at first flowering was lowest in T_6 (88.17cm) indicating the application of micronutrients along with 0.25 % each of Ca and S can result in early flowering. It is possible that micronutrient application containing zinc could have stimulated auxin synthesis leading to better plant growth as implied by Hanamanth (2002) [9]. Application of calcium proved to improve seedling height of papaya in an earlier study by Madani *et al.* (2013) [16]. A positive effect for stem girth was also pronounced with the application of calcium as 0.25 % or 0.50 % Ca $(NO_3)_2$ (T_2 and T_3) as compared to other treatments at the time of first harvest.

The results obtained are in agreement with earlier works (Mengel *et al.*, 2001; Ehret *et al.*, 2005 and Shams *et al.*, 2012) [17, 4, 18], reporting that calcium application increased plant height and diameter.

Days for first harvest were delayed up to 35.5 days in T_7 and 25.5 days in T_6 among the treatments as compared to control (Table. 1). Though the delay appeared to be a negative influence as compared to control, there was a significant build up of resources as could be deduced from subsequent increase in leaf number and higher leaf area in these two treatments than control. These treatments were also high yielding at the later stage. The first fruiting height ranged from 92.38 cm to 106.17 cm (Table. 1). However, no definite influence of the nutrients could be attributed for this parameter in the present study as control plants have also recorded lower first fruiting height.

Higher number of leaves were registered in T_2 (20.50), T_6 (19.75) and T_4 (19.53) at first flowering and in T_3 (32.45), T_5 (31.88) and T_2 (31.17) at first harvest as compared to control indicating a positive influence of the application of calcium or sulphur which may be involved in build-up of resources essential for the increase in number of leaves (Table. 1). At flowering, the leaf area was highest in the treatment T_7 (1389.29 cm^2) and T_6 (1372.47 cm^2) with a per cent increase of 36.06 and 34.41 respectively as compared to control (T_8). The highest leaf area at the time of first harvest was also observed in T_7 (2473.45 cm^2) with 46.96 per cent increase as compared to control (T_8) (Table. 1). The enlarged leaf area might be due to the influence of calcium involved in cell wall binding along with other micronutrients which could have enhanced cell division and growth (Tuteja and Mahajan, 2007 and Raja, 2010).

In the present study, total chlorophyll content ranged from 1.017 (T_8) to 1.957 (T_7) mg/g at 5th MAP and 1.021 (T_8) to 1.970 (T_7) mg/g at 7th MAP (Table.2). Chlorophyll levels were generally higher in all the treatments compared to control and were much better in T_6

Table 1: Influence of different treatments on plant growth parameters at first flowering and fruiting of papaya

Treatments	Plant height (cm)		Stem girth (cm)		Days to first flowering	Days to first harvest	First fruiting height (cm)	Number of leaves		Leaf area at first flowering (cm^2)	Leaf area at first harvest (cm^2)
	At first flowering	At first harvest	At first flowering	At first harvest				At first flowering	At first harvest		
T_1	93.00	193.69	16.83	29.62	124.08	267.00	92.38	19.00	27.62	1033.77	1793.18
T_2	91.07	188.00	17.77	32.09	126.58	255.50	99.83	20.50	31.17	1129.61	1890.09
T_3	94.84	202.38	17.30	31.94	135.50	244.00	103.44	19.08	32.45	1279.66	2037.06
T_4	91.12	191.15	20.10	30.46	141.00	248.67	95.42	19.53	28.00	1295.15	2106.23
T_5	98.54	231.72	19.98	30.43	126.50	266.00	106.17	19.17	31.88	1321.60	2302.40
T_6	88.17	185.00	20.53	30.10	133.17	268.50	97.03	19.75	27.73	1372.47	2327.31
T_7	93.98	186.50	20.03	29.70	129.50	278.50	96.79	18.25	28.08	1389.29	2473.45
T_8	91.25	181.63	21.60	28.70	119.17	243.00	93.42	18.08	26.43	1021.12	1683.12
SE d	2.20	3.32	0.86	0.78	2.83	7.03	2.26	0.50	1.21	25.41	34.11
CD p=0.05)	4.72*	7.12*	1.85*	1.68*	6.07*	15.08*	4.85*	1.08*	2.59*	54.50*	73.16*
CV (%)	2.91	2.08	5.49	3.16	2.68	3.32	2.82	3.22	5.08	2.53	2.01

***** - Significant at 5% level

Table 2: Influence of different treatments on chlorophyll content and plant nutrient analysis of papaya

Treatments	Total chlorophyll content (mg/g)		Ca (%)		S (%)		Mg (%)		Zn (ppm)		B (ppm)	
	5th MAP	7th MAP	5th MAP	7th MAP	5th MAP	7th MAP	5th MAP	7th MAP	5th MAP	7th MAP	5th MAP	7th MAP
T_1	1.216	1.225	0.232	0.253	0.118	0.123	0.131	0.139	20.96	22.02	33.45	38.66
T_2	1.328	1.342	0.456	0.519	0.123	0.127	0.164	0.186	19.27	21.35	33.75	39.48
T_3	1.490	1.528	0.569	0.642	0.125	0.119	0.147	0.159	19.80	21.02	33.96	39.62
T_4	1.211	1.220	0.248	0.290	0.143	0.159	0.179	0.213	22.23	24.15	39.45	41.31
T_5	1.246	1.253	0.234	0.271	0.212	0.257	0.167	0.178	22.65	24.83	39.75	41.96
T_6	1.660	1.684	0.365	0.373	0.150	0.213	0.154	0.162	21.55	22.41	37.59	40.72
T_7	1.957	1.970	0.351	0.366	0.158	0.223	0.168	0.172	21.26	21.98	37.81	41.00
T_8	1.017	1.021	0.186	0.192	0.117	0.118	0.118	0.119	19.13	20.17	32.85	37.80
SE d	0.038	0.029	0.022	0.019	0.004	0.004	0.003	0.004	0.53	0.34	0.52	0.78
CD p=0.05)	0.081*	0.062*	0.048*	0.040*	0.008*	0.008*	0.007*	0.008*	1.13*	0.73*	1.12*	1.71*
CV%	3.30	2.51	4.96	3.95	3.32	2.78	2.56	2.85	3.10	1.87	1.77	2.44

* Significant at 5% level

And T_7. Comparatively higher chlorophyll levels were observed in those treatments receiving calcium nitrate than those supplied with potassium sulphate. The increase in chlorophyll content may be due to the influence of calcium nitrate (Swietlik, 2006) [32] and has an indirect and positive effect on nitrogen assimilation (Lopez-Lefebre *et al*., 2000) [15]. Coupled with higher chlorophyll contents, higher leaf area can lead to enhanced reserves in the plant.

Leaf petiole nutrient content

In the present study, highest calcium concentrations at 5th and 7th MAP were recorded in T_3 (0.569 % and 0.642 % respectively) and followed by T_2. This signifies that application of 0.5% and 0.25% Ca source may have increased the calcium content in the petiole. Among the eight treatments, the calcium content was found to be lowest in T_8 at both 5th and 7th MAP. This indicates that when combined with potassium sulphate, the calcium uptake is reduced. The treatment T_5 recorded higher levels of sulphur at 5th and 7th MAP (0.212% and 0.257 %) followed by T_6 and T_7 compared to control indicating calcium nitrate may interfere in sulphur assimilation and foliar spray of potassium sulphate at 0.5 per cent is favourable for enhancing sulphur concentration. The results are in agreement with the findings of Ganeshamurthy (1996) [5].

Increase in magnesium content was observed in T_4 at both the stages as compared to control and increase in boron and zinc content was observed highest in the treatment, T_5 and T_4 along with the micronutrient spray at 5th and 7th MAP (Table. 2). All the other treatments also had higher micronutrient contents compared to control. This indicates that potassium sulphate sprays may have influenced uptake of magnesium, boron and zinc synergistically. The results support the findings of Shaaban *et al*. (2004) [27] and Hosseini *et al*. (2007) [10].

Yield parameters

Number of fruits per plant (34.21), fruit weight (1.39 kg) and yield per plant (47.54 kg/plant) were found to be the highest by the application of 0.5 % Ca $(NO_3)_2$ +0.5% K_2SO_4 (T_7) along with micronutrients (Table. 3). Increase in fruit yield in T_7 was about 28.21% higher than control (T_8) and 16.81% higher than micronutrients (T_1). It can be inferred that combined influence of calcium or potassium sprays along with micronutrients could have helped in improving yield by enhanced photosynthetic assimilation favoured by higher leaf number and leaf area, improved flowering, improved fruit set and fruit retention. Boron is generally involved in increased fruit set by the stimulation of pollen germination, growth and development of pollen tube, stimulation of fertilization process and higher synthesis of metabolites (Perez-Lopez and Reyes-Jurdo, 1983) [21]. Zinc has a direct influence on auxin (IAA) synthesis in plants, reducing the cellulose and polygalacturonase in abscission zone leading to better fruit set and retention (Modi *et al.*, 2012 and Ghanta *et al.*, 1992) [18, 21]. Zehler *et al*. (1981) [36] also reported that potassium sulphate resulted in higher yield and better quality fruits in pineapple. Potassium sprays resulted in improved fruit weight, number of fruits per bunch and increased the yield of banana and grapes (Ganeshamurthy *et al.*, 2011) [6]. The results in the present study is also in agreement with the findings of Sarrwy *et al*. (2012) [25] who obtained increased fruit set using 1 % and 2 % Ca $(NO_3)_2$ with H_3BO_3 at 500 ppm in date palm.

Fruit size (length and circumference) and fruit weight are correlated to each other and are determinants of yield. In the present study, both the parameters increased in the treatment T_7 with more than 7.37 per cent increase in fruit size and 9.45 per cent increase in fruit weight as compared with the control (Table. 3). Increase in these parameters may be due to the influence of calcium or potassium. Application of potassium sulphate in grapes (Singh *et al.*, 1979) [31] and calcium nitrate (Ca $(NO_3)_2$ sprays in guava (Raychaudhary *et al.*, 1992) [23] to increase the fruit size and fruit weight are evidences that support for the results obtained in this study.

Zinc is also known to influence the cell division and cell expansion resulting in improved physical characters of the papaya fruit (Agarwala and Sharma, 1978 and Ghanta *et al.*, 1992) [1, 7]. Increase in the physical parameters of the fruit may be attributed to the role of zinc.

Table 3: Influence of different treatments on yield parameters and PRSV incidence of papaya

Treatments	No. of fruits per plant (1st crop)	Fruit weight (kg)	Fruit length (cm)	Fruit Circumference (cm)	Estimated yield (kg/plant)	Per cent increase than control (T_8)	Per cent increase than T_1	PRSV incidence (At first harvest)
T_1	31.80	1.28	25.74	38.98	40.70	9.76	-	44.03 (41.57)**
T_2	32.01	1.29	26.04	39.16	41.28	11.33	1.43	35.78 (36.74)
T_3	32.81	1.31	26.45	39.80	42.97	15.88	5.58	34.97 (36.25)
T_4	33.12	1.33	27.98	40.48	44.02	18.72	8.16	33.52 (35.38)
T_5	33.60	1.36	28.04	40.59	45.70	23.25	12.29	32.55 (34.79)
T_6	33.91	1.37	28.62	40.94	46.44	25.24	14.10	31.84 (34.35)
T_7	34.21	1.39	29.96	41.34	47.54	28.21	16.81	31.46 (34.12)
T_8	29.22	1.27	25.39	38.50	37.08	-	-	45.83 (42.61)
SE d	0.62	0.02	0.37	0.42	0.87			0.61
CD(p=0.05)	1.33*	0.04*	0.80*	0.84*	1.86*			1.31*
CV (%)	2.34	1.85	1.68	3.12	2.46			2.03

***** Significant at 5% level
** The values in the paranthesis are arc sine transformed

Which involves in regulating the semi- permeability of cell membranes thereby increasing the size of the fruit as reported in guava cv. Allahabad Safeda by Ghosh (1986) [8]. The findings obtained in this study on fruit parameters of papaya are also in corroboration with those of Kavitha *et al.* (2000) [14], Jeyakumar *et al*. (2001) [12], Alila *et al*. (2005) [2], Raja (2010) [22] and Modi *et al.* (2012) [18].

The yield increase in the best treatment (T_7) over control was nearly 28 % and this can be due to the beneficial impact of micronutrients and secondary major nutrients supplemented through foliar application preventing the tissue degeneration or adverse physiological impact caused by PRSV disease.

PRSV incidence

At the time of fruiting, the symptoms of PRSV incidence (Table. 3) on fruits was lowest in T_7 (31.46 %) and the treatments T_6 (31.84 %) and T_5 (32.55 %) also resulted in lower PRSV incidence and are on par with T_7. The highest disease incidence was observed in T_8 (45.83 %) and it was on par with T_1 (44.03 %). In spite of the presence of the disease pressure, reasonable yield (47.54 kg/plant) could be obtained with micronutrient sprays combined with 0.5% of potassium sulphate or calcium nitrate (T_7) through foliar application (Table. 3). The reason for increased yield in spite of PRSV prevalence can be attributed to availability of the essential nutrients, micronutrients (Reddy, 2010) and stimulation of proteins and enzymes required for flowering and fruit set when foliar application is given. Because of vascular deformation due to virus incidence the plant may not be otherwise able to translocate the required nutrients from the soil. Thus, the application of secondary and micronutrients might have helped to certain extent to overcome the disease stress.

Conclusion

There is a pronounced improvement in the growth and yield attributes of papaya when sprayed with Ca $(NO_3)_2$ (0.5 %) + K_2SO_4 (0.5) % along with micronutrients (zinc sulphate (0.5%) + boric acid (0.1%) and recommended dose of NPK at 50g each applied at 3rd, 5th and 7th month (T_7)). Hence, it could be concluded that both calcium and sulphur as foliar spray in combination with micronutrients zinc and boron could favourably influence the growth and yield of papaya.

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