FOLIAR NUTRITION WITH CALCIUM AND MICRONUTRIENTS FOR GROWTH AND YIELD ENHANCEMENT IN PAPAYA (*Carica papaya* L.)

by

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(2018-12-009)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE VELLAYANI,

THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2020

DECLARATION

I, hereby declare that this thesis entitled **“FOLIAR NUTRITION WITH CALCIUM AND MICRONUTRIENTS FOR GROWTH AND YIELD ENHANCEMENT IN PAPAYA (*Carica papaya* L.)”** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"FOLIAR NUTRITION WITH CALCIUM AND MICRONUTRIENTS FOR GROWTH AND YIELD ENHANCEMENT IN PAPAYA (*Carica papaya* L.)"** is a record of research work done independently by Ms. Anju P. (2018-12-009) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Acknowledgement

With immense pleasure, I would like to express my sincere gratitude to my major advisor **Dr. Bindu B,** Assistant Professor (Horticulture), Farming system Research Station, Sadanandapuram, Chairperson of my advisory committee for the constructive guidance, constant inspiration, critical scrutiny of the manuscript and valuable suggestions which render me to accomplish the research work successfully. I extend my sincere gratitude for providing a stress-free situation by the open-minded approach and for the care and affection bestowed on me throughout the study period.

I express my sincere gratitude to **Dr. M. Rafeekher**, Assistant Professor and Head, Department of Fruit Science, College of Agriculture, Vellayani and member of Advisory Committee, for his valuable advice, constant encouragement, critical assessment, realistic suggestions, technical advice and timely help for the successful completion of my thesis work.

I humbly express my gratitude to **Dr. T. Sajitha Rani,** Professor and Head**,** Instructional farm, College of Agriculture, Vellayani and Member of my advisory Committee for her encouragement, guidance, incessant motivation, unstinting support, passionate approach rendered during the period of research work.

I convey my heartfelt thanks to **Dr .Naveen Leno,** Assistant Professor**,** Department of Soil Science and Agricultural Chemistry**,** College of Agriculture, Vellayani, and a member of my advisory committee for his ever-willing help, technical advice and support.

I would express my sincere gratitude to **Dr. Sheela V.L.,** Professor and former Head, Department of Fruit Science, College of Agriculture, Vellayani for her valuable suggestion and constant inspiration.

I would like to thank **Dr. Priyakumari I**, **Dr. Reshmi C R**, **Ajith Sir** (Farm officer) **Rani chechi** (non-teaching staff), Department of Fruit Science, for their sincere cooperation and kindly approach and inspiration offered during the study period. A very special thanks to **Shaji chettan** and all the workers, Department of Fruit Science for their help and support during the

course of my field work.

I express my thanks and whole hearted cheers to my batch mates for their help, love, encouragement and support which made my days more blissfull.

Words are inadequate to express my thanks to my dear **Uchudu** and **Karishma chechi** for their constant support, love and for the happiest moments we cherished together. I deeply express my gratitude to, **Akhi**, **Smera** and **Ajin** who were there with my journey of bighearted support and for their unbound love.

It's my pleasure to express my special thanks to my batch mate **Sharanesh** and all my batchmates. Special thanks to my friends **Arya, Sherin, Sree** for their support throughout the study period. I extend my gratefulness to Arya chechi, Anawara chechi for their valuable encouragement and support. I owe my sincere gratitude to my seniors **Reshma chechi, Anushma chechi, Dhanya sree chechi, Sruthi chechi** and **Vipinettan** for their timely advice and help rendered for me when I was in need.

I express my heartfelt thanks to my juniors **Ananaya, Akshara, Deepa, Akshay, Sooraj** and **Gazel** for their love, care and support.

I am beholden beyond words to express my indebtedness to my **Achan**, **Amma**, **Ettan**, **Ammamma** and my all relatives for their unconditional love, sacrifices and support bestowed on me during my hard periods.

Anju P.

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LIST OF ABBREVIATIONS

AOAC	Association of Official Agricultural Chemists
B	Boron
B: C	Benefit cost ratio
Ca	Calcium
CD	Critical difference
Cm	Centimeter
cv.	Cultivar
EC	Electrical Conductivity
et al.	Co-workers/co-authors
Fe	Iron
Fig.	Figure
FYM	Farm yard manure
Ha	Hectare
ha^{-1}	Per hectare
K	Potassium
KAU	Kerala Agricultural University
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare
L	Litre
M	Metre
m^2	Square metre
MAP	Month after planting
N	Nitrogen
NS	Non-significant
No.	Number
P	Phosphorus
$Plant^{-1}$	Per plant
POP	Package of practices
RBD	Randomized block design
Sem	Standard Error of mean
T	Tons
t ha^{-1}	Tons per hectare
TSS	Total soluble solids
Zn	Zinc

LIST OF SYMBOLS

@	At the rate of
º C	Degree Celsius
%	Per cent

Introduction

1. INTRODUCTION

Papaya (*Carica papaya* L.) is an important fruit crop grown widely in tropical and subtropical regions of the world belonging to genus Carica and family Caricaceae. It is the most extensively cultivated species and commonly called as mamao (Brazil), tree melon (China) and papaw or pawpaw (Australia). It is widely consumed as a fresh dessert fruit, and the green fruit is often used as cooked vegetable and salad. Several preparations like jam, soft drinks, crystallized fruits and ice-cream flavours are prepared from ripe fruits of papaya. Papain, a proteolytic enzyme is recovered from the latex of green fruit and it has various uses in cosmetics, beverages, food and pharmaceutical industries. Papaya is a nutritious fruit containing carbohydrates, proteins, and minerals in particular iron, calcium and phosphorus. Its delightful fruits are not only nutritious and digestive also aid as a mild laxative. Although fruits are delicious and rich in nutritional vitamins A and C, the fruit is fragile, a trait limiting large-scale exportation to temperate countries. Progress in postharvest and shipping technologies should augment commercialization of this crop.

Papaya is one of the major fruit crop suited for both commercial orchards and nutrition gardens. Short pre-bearing period, high nutritive value, year-round fruiting behaviour and high yield potential make papaya unique among fruit crops (Bindu and Bindu, 2017). In Kerala, it is slowly emerging from the status of a homestead crop to that of commercial crop due to its multifold uses. India ranks first in papaya production, occupying an area about 0.14 million ha and 5.98 million MT annual production with 42.71 MT ha^{-1} average productivity during (NHB, 2019).

Papaya is an emerging nutraceutically important fruit crop of Kerala. Even though the market demand of this fruit is increasing day by day, our state is lagging behind in production and productivity. In Kerala, papaya is grown in an area of 19694 ha with an annual production of 116.26 MT (FIB, 2019). Lack of proper crop management is one of the reasons behind it. Adoption of suitable nutrient management practices, including micronutrient and secondary nutrient application will lead to an increase in fruit yield and quality and it is also essential for the successful raising of papaya.

Micronutrients and secondary nutrients like calcium play a vital role in crop production due to their essentiality in plant metabolism and manifest a contrary effect due to their deficiency. Besides promoting plant growth attributes, they also play a major role in disease resistance in cultivated crop species. So, an efficient and judicious use of fertilizers along with micronutrient and secondary nutrient application is essential for attaining higher yield per unit area. It is also efficient in correcting both visual deficiency symptoms and hidden hunger of micronutrients.

A number of studies conducted in papaya indicated that there was a positive impact of various micronutrients and secondary nutrient along with a standard package of macronutrient application in papaya's performance, yield, and quality as well as disease resistance. Foliar application of nutrients often gives a quicker response than soil application.

Among micronutrients, boron and zinc deficiencies are commonly observed in papaya orchards (Meena, 2013b). Zinc deficiency reduces the growth, yield potential, fruit size and fruit number (Manjunatha *et al*., 2014). Boron deficiency in papaya cause bumpy fruits having uneven shape, retard the growth of apical growing point and reduction in fruit set (Nishina, 1991). Foliar sprays of boron and zinc in papaya increases plant growth, fruit yield, latex yield apart from improving the fruit quality characters (Saini *et al*., 2019). Zinc is an essential element for several enzyme systems that regulate various metabolic activities in plant (Modi *et al*., 2012). Calcium, a secondary nutrient has a great role in enhancing the post-harvest quality of papaya fruits (Bhalerao and Patel, 2015). Calcium deficiency is responsible for premature ripening, softening of the fruit pulp and peel, which results in problems in transportation and a short commercial shelf life of fruits (Madani *et al*., 2016).

Alleviation of nutrient deficiency symptoms that are manifested on papaya plant as well as on fruit, a major problem encountered in papaya cultivation, can be achieved through systematic experimentation which will generate adoptable technological practices. Therefore, considering the above-mentioned issues, the present study is proposed to find out the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya.

Review of Literature

2. REVIEW OF LITERATURE

Papaya (*Carica papaya* L.) often considered as common man's fruit is one of the commercially important fruit crops of the tropics. High productivity and ability to produce fruits all over the year offered popularity and commercial importance for this crop. For attaining proper growth, yield and quality of papaya fruits, balanced nutrition is essential, including the application and management of deficient nutrients to the crop in adequate amounts irrespective of secondary or micronutrients. Besides affecting plant growth and quality determination, micronutrients and secondary nutrients also play a important role in disease resistance and the post-harvest life of harvested produce, thereby increasing the market value of the produce. Application of micronutrients as foliar spray has become important now a days, as the nutrients are easily accessible to the plants at appropriate time when sprinkled directly onto the leaves.

The current experiment was carried out to study the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya. The review of literature highlights on the following aspects.

2.1 BIOMETRIC CHARACTERS

2.1.1 Height of plants

Perez -Lopez and Reyes-Jurado (1983) found that tallest (1.99 m) plants of papaya variety P.R. 7-65 were obtained through the application of 340 kg ha^{-1} N along with 2.3 kg ha^{-1} boron compared to plants those were fertilized alone with nitrogen.

The monthly spray of $ZnSO_4$, $FeSO_4$ and borax @ 0.1% with or without combination were effective in improving the plant height compared to control in papaya (Veena and Lavania, 1998).

Application of borax at 0.50% and $ZnSO_4$ at 0.25% at two months interval from transplanting was observed as the best treatment which aided in maximum plant growth (171.62 cm) in papaya cv. Ranchi (Singh *et al.*, 2000).

Modi *et al*. (2012) recorded maximum plant height (169.87 cm and 175.69 cm) during final harvest in papaya cv. Madhu Bindu with individual application of $ZnSO_4$ 0.5% and borax 0.3% respectively at 30, 60 and 90 DAT.

Madani *et al*. (2013) conducted an experiment in papaya cv. Eksotika II and they suggested that Calcium nitrate at a rate of 180 mg l^{-1} was applied 4 times every two weeks in the form of foliar spray recorded maximum plant height of 154.6 cm.

Highest plant height (205.47 cm) in papaya cv. Red Lady was noticed by Manjunatha *et al*. (2014) as a result of foliar spray of $ZnSO_4$, Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively at 9 months after treatment of plants.

Bhalerao and Patel (2015) proved that the foliar application of calcium nitrate 1000 mgL^{-1}along with borax 30 $mgL^{-1}$and zinc sulphate 200 $mgL^{-1}$and ferrous sulphate 200 mgL^{-1} resulted in highest plant height of 98.58 cm, 123.40 cm and 136.20 cm on 90, 120 and 150 days respectively on papaya var. Taiwan Red Lady.

2.1.2 Girth of plants

Veena and Lavania (1998) studied the effect of micronutrients on girth of papaya plants and concluded that spraying of $FeSO_4$, $ZnSO_4$ and borax @ 0.1% alone or in combination at monthly intervals was efficient in increasing the plant girth compared to control.

Singh *et al*. (2000) noticed that application of borax (0.50%) and $ZnSO_4$ (0.25%) at bimonthly intervals from transplanting resulted in highest plant girth (39.74 cm) in papaya cv. Ranchi.

An inference made by Modi *et al*. (2012) while conducting an experiment using papaya cv. Madhu Bindu showed that individual application of $ZnSO_4$ (0.5%) and borax (0.3%) at 30, 60 and 90 DAT resulted in highest plant girth (42.18 cm and 36.48 cm) respectively at final harvest.

Madani *et al*. (2013) revealed hat highest stem diameter of 29.9 cm in papaya variety Eksotika II was resulted due to application of $Ca(NO_3)_2$ at the rate of 180 mgL^{-1} 4 times in every two weeks.

Manjunatha *et al.* (2014) noted that highest stem diameter (113.59 mm) in papaya cv. Red Lady was observed at 9 months after planting in plants that were treated with $ZnSO_4$, Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively.

Bhalerao and Patel (2015) identified that papaya plants which were sprayed with $Ca(NO_3)_2$1000 mg L^{-1}, borax 30 mg L^{-1}, $ZnSO_4$ 200 mg L^{-1} and $FeSO_4$ 200 mg L^{-1} showed highest stem girth of 23.85 cm, 33.18cm and 39.46 cm on 90, 120 and 150 days respectively in papaya var. Taiwan Red Lady.

2.1.3 Number of leaves

Chattopadhyay and Gogoi (1988) observed that foliar application of boron 30 ppm in the form of borax lead to production of greater number of leaves (72.27) in papaya cv. Ranchi.

Jeyakumar *et al*. (2001) applied micronutrients in papaya which resulted in an increment in the number of leaves plant^{-1} in papaya cv.CO-5 due to the staggered application of $ZnSO_4$ (0.5%) in combination with borax (0.5%) at 4 and 7 months after planting.

Individual application of $ZnSO_4$ (0.5%) and borax (0.3%) respectively at 30, 60 and 90 DAT of papaya cv. Madhu Bindu significantly increased the number of leaves (54.09 and 58.01) at final harvest (Modi *et al.*, 2012).

A study by Meena (2013) on effects of micronutrient application in papaya cv. Red Lady, reported that foliar application of $ZnSO_4$ (0.5%) and Borax (0.2%) at 6th month and 8th month gave highest leaf count per plant (24).

Manjunatha *et al*. (2014) inferred that highest number of leaves (40.41) was seen in the plants which were treated with $ZnSO_4$ along with Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively in papaya cv. Red Lady.

The foliar sprays of $Ca(NO_3)_2$ 1000 mgL^{-1} along with borax 30 mgL^{-1}, $ZnSO_4$ 200 mgL^{-1} and $FeSO_4$ 200 mgL^{-1} resulted in highest leaf area of papaya var. Taiwan Red Lady (Bhalerao and Patel, 2015).

2.1.4 Height at first flowering

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that foliar application of boron 0.2 percent per plant resulted in lowest plant flowering height of 1.21 m.

An experiment carried out by Meena (2013) on micronutrient application in papaya revealed that plants that received 50g Zinc sulphate and 20g Borax had flowering at lower node (14) compared to control (20) in papaya cv. Red Lady at 6 months after planting.

2.1.5 Days to flowering

Alila *et al.* (2004) reported that foliar application of boron @ 0.1 per cent hastened flower opening in papaya cv. Ranchi andnumber of days was taken for flowering was minimum when compared to control.

Reddy (2010) conducted an investigation and found that foliar application of boron 0.2 percent resulted in minimum days to flowering (137.27 days) in papaya cv. Sunrise Solo.

Shekhar *et al*. (2010) reported that foliar application of $CuSO_4$ 0.25 per cent along with $MnSO_4$ 0.25 per cent and borax 0.1 per cent decreased the days to flowering (186.33 days) compared to control (208 days) in papaya cv. Washington.

In another study Singh *et al*. (2010) recognized that foliar application of 0.50% borax resulted in minimum days to flowering (104.42 days) in papaya cv. Ranchi.

Modi *et al*. (2012) concluded that individual application of zinc sulphate (0.5 per cent) and borax (0.3 per cent) exerted great influence on earlier initiation of flower bud in papaya cv. Madhu Bindu.

Bhalerao and Patel (2015) proved that Borax 30 mgL^{-1}, when applied as foliar spray resulted in advancement in flower initiation (93.40 days) in papaya variety Taiwan Red Lady.

2.1.6 Sex expression of plant

Reduction in the production of staminate flowers to the extent of 34.26% in papaya cv. Coorg Honey Dew and increase in hermaphrodite flowers when sprayed with boron @ 2ppm was studied by Shanmugavelu *et al*. (1973).

Foliar application of boron (0.1%) at 2^{nd} and 3^{rd} MAP of papaya cv. Ranchi recorded the highest number of hermaphrodite flowers which increased femaleness and in turn increased fruit yield (Ghanta *et al*., 1992).

2.1.7 Sex ratio of plants

Foliar applications of boron (0.1%), Manganese (0.25%) and Copper (0.25%) singly and in combination at 2^{nd} and 3^{rd} MAP increased femaleness of papaya cv. Ranchi (Ghanta *et al*., 1994)

Veena and Lavania (1998) observed a significant increase in the percentage of female plants in Pant papaya-1 upon treatment with foliar spray of $ZnSO_4$ (0.15 per cent) along with $FeSO_4$ (0.15 %).

Farid *et al*. (2007) recorded that application of B (15 g $tree^{-1}$) on jack fruit trees of 20 years old produced the highest number of female spikes (157).

2.1.8 Number of flowers per cluster

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that foliar application of boron 0.05 percent per plant resulted in the production of highest number of flowers (114.75) and in another experiment proved that soil incorporation of boron @ 10 g per plant resulted in the production of highest number of flowers (48.88) compared to control (23.5).

Meena (2013) studied the micronutrient application in papaya and came to conclusion that foliar application of 0.5% zinc sulphate and 0.2% borax at 8 months after planting resulted in the production of highest number of flowers per plant (92.40) in papaya cv. Red lady.

Manjunatha *et al.* (2014) noted highest number of flowers (53.13) were found in plants treated with $ZnSO_4$+ Borax+ $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively in papaya cv. Red Lady at 9 MAP.

Sachin *et al*. (2019) observed that foliar application of Zinc sulphate (1%) + Borax (1%) + Copper sulphate (1%) resulted in maximum number of flowers per shoot (29.87) compared to control (13.93) in guava cv. Lalit.

2.1.9 Fruit set percentage

A study conducted by Mansour and El-Sied (1981) reported that $ZnSO_4$ at 0.5 or 1.0 per cent applied to guava at full bloom stage improved fruit set and yield from 160 to 373 fruits per tree in untreated to 206 to 964 fruits in treated ones.

Dutta *et al*. (2000) noticed that pre-anthesis period spraying of boron at 164 mg l^{-1} produced highest fruit set (63.00) in litchi cv. Bombai.

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and noted that foliar application of boron 0.2 percent per plant resulted in the highest fruit set percent of 59.42 and soil application of boron @ 10 g per plant resulted highest fruit set of 73.48 compared to control (45.98).

Meena (2013) recorded higher fruit set of 58.89% in papaya cv. Red Lady which was treated with 0.25% $ZnSO_4$ and 0.1% borax at 6 months after planting.

Sachin *et al*. (2019) noticed that foliar application of Zinc sulphate (1%) + Borax (1%) + Copper sulphate (1%) resulted in maximum fruit set percentage (79.28%) compared to control (57.36) in guava cv. Lalit.

2.1.10 Time for harvest

Modi *et al*. (2012) observed that individual application of borax at 0.3% recorded minimum days of 74.22 taken for fruit setting to the first harvest in papaya cv. Madhu Bindu.

Meena (2013) revealed that a lesser number of days for fruit setting to harvest was recorded for soil incorporation of Zinc sulphate (50g) and borax (20 g) at 6 month after planting of papaya cv. Red Lady.

Yadav *et al*. (2017) observed that foliar application of Boric acid (0.4%) and Zinc sulphate (0.4%) resulted in the lowest number of days to harvest of 59.26 days and 59.15 days respectively compared to control (62.10 days) in Strawberry Cv. Winter Dawn.

2.2 YIELD CHARACTERS

2.2.1 Fruit weight

Chattopadhyay and Gogoi (1988) compared the yield of 40 ppm boron treated and untreated papaya cv. Ranchi and found that average fruit weight was more than 1000 g with more than 100 tonnes per ha yield for treated and 89.26 tonnes for untreated plants respectively.

Lokhande and Moghe (1991) inferred that the plants of papaya cv. Honeydew receiving 200g N and 100g P through soil and foliar spray of 1% urea along with 0.2% B and 50 ppm IAA at 90 days interval recorded highest fruit weight (1.828 kg $fruit^{-1}$).

A study by Reddy (2010) in papaya cv. Sunrise Solo noticed that foliar application of boron 0.2 percent per plant resulted in highest fruit weight of 290.72 g and soil application of boron @ 10 g per plant resulted in highest fruit weight of fruits 962.70 g compared to control (806.16 g).

Meena (2013) followed foliar application in papaya cv. Red Lady and revealed that highest fruit weight of 1.03 kg was obtained as a result of application of 0.5% $ZnSO_4$ and 0.25% borax at 8 months after planting.

Highest values for mean weight of fruits (1.73 kg) was noticed in the plants treated with $ZnSO_4$ along with Borax and $FeSO_4$,0.25%, 0.1% and 0.5% respectively in papaya cv. Red Lady (Manjunatha *et al*., 2014).

Bhalerao and Patel (2015) proved that highest number of fruits in papaya var. Taiwan Red Lady resulted when plants were sprayed with a combination of calcium nitrate 1000 mgL^{-1} + borax 30 mgL^{-1} + zinc sulphate 200 mgL^{-1}+ ferrous sulphate 200 mgL^{-1}.

2.2.2 Fruit length

According to Reddy (2010), highest fruit length of 16.52 cm was reported in papaya cv. Sunrise Solo due to the foliar application of boron 0.2 percent and also found that soil application of boron @ 10 g per plant resulted in highest fruit length of 20.63 cm when compared to the control plant (15.24 cm).

Manjunatha *et al*. (2014) noticed that highest fruit length (21.17 cm) in papaya cv. Red Lady was recorded in the plants which were treated with foliar application of $ZnSO_4$ along with Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively.

Bhalerao and Patel (2015) identified that when papaya var. Taiwan Red Lady sprayed with a combination of calcium nitrate 1000 mgL^{-1}+ borax 30 mgL^{-1} and zinc sulphate 200 mgL^{-1}along with ferrous sulphate 200 mgL^{-1} resulted in the highest fruit length of 25.39 cm.

2.2.3 Fruit girth

Veena and Lavania (1998) observed that foliar sprays of ferrous sulphate, zinc sulphate and Borax singly or zinc sulphate in combination with ferrous sulphate or borax produced significant increase in the fruit diameter in papaya.

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that foliar application of boron 0.2 percent per plant resulted in highest fruit girth of 12.29 cm and soil application of boron @ 10 g per plant resulted in highest width of fruit (14.03 cm) compared to control (11.71 cm).

An investigation carried out by Meena (2013) revealed that papaya cv. Red Lady received 50g Zinc sulphate and 20g Borax gave higher fruit diameter of 16.4 cm compared to control plant (16 cm).

Manjunatha *et al*. (2014)) observed that highest fruit diameter (17.47 cm) in papaya cv. Red Lady was recorded in the plants which were treated with $ZnSO_4$ along with Borax and $FeSO_4$ at the rate of 0.25%, 0.1% and 0.5% respectively.

In an experiment carried out by Bhalerao and Patel (2015) recognized that highest fruit diameter in papaya var. Taiwan Red Lady was seen in plants sprayed with calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 $mgL^{-1}$and ferrous sulphate 200 mgL^{-1}.

2.2.4 Fruit volume

Awasthi and Lal (2009) reported that guava produced with the foliar application of 1.5% $ZnSO_4$ was found to have highest value of fruit volume of 164.5

ml.

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that soil application of boron @ 10 g per plant resulted in highest fruit circumference (31.90 cm) compared to control (27.06 cm).

In a study conducted by Meena (2013) proved that highest fruit volume of 24 cc in papaya cv. Red Lady was due to the foliar application of 0.2% $ZnSO_4$ and 0.5% borax at 8 MAP.

Manjunatha *et al*. (2014) registered that highest fruit volume of 2446.67 ml was observed for plants treated with $ZnSO_4$, Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively in papaya cv. Red Lady.

2.2.5 Pulp percentage

Dutta *et al*. (2000) noticed that the proportion of peel weight was minimum (18.98%) with Boron (328 mg l^{-1}) application in litchi cv. Bombai.

Singh *et al*. (2007) observed the effect of combined spray of $ZnSO_4$ (0.5%), NAA (10 ppm) and GA_3 (25 ppm) in aonla cv. NA-10 and found the significant improvement in pulp weight (47.85 g) and pulp: stone ratio (21:10).

Reddy (2010) noticed that in papaya cv. Sunrise Solo foliar application of boron 0.2 percent per plant resulted in highest pulp weight of 314.51 g compared to control (266.38g), lowest peel weight of 53.71 g when compared to control plant (73.98 g) and highest pulp to peel ratio of 5.85.

Higher dose of $CaCl_2$ (3%) and Borax (1.5%) increased pulp weight from minimum (14.88 g) in control to a maximum of 15.69 g in litchi cv. China was noticed by Haq *et al*. (2013).

Highest pulp: peel ratio (14.88) was recorded in the fruits treated with borax at 0.50% along with $ZnSO_4$ at 0.25% in papaya cv. Ranchi (Singh *et al*., 2010).

Waskela *et al*. (2013) noted that high pulp (96.91%) of fruit was observed in guava cv. Dharidar which was treated with foliar application of 0.75% zinc sulphate in

2.2.6 Flesh thickness

An investigation was carried out by Reddy (2010) in papaya cv. Sunrise Solo suggested that foliar application of boron 0.2 percent per plant resulted in highest pulp thickness of 1.90 cm compared to control 1.35 cm.

Singh *et al*. (2010) inferred that highest pulp thickness (3.12 cm) and pulp weight of 1288.23 g were noticed in papaya cv. Ranchi treated with borax at 0.50% + $ZnSO_4$ at 0.25%.

Meena (2013) recorded that foliar spray of zinc sulphate (0.5%) and borax (0.2%) at 8 MAP gave highest flesh thickness of 2.7 cm in papaya cv. Red Lady.

Waskela *et al*. (2013) noticed that maximum pulp: seed ratio (32.09), of fruit was obtained with the foliar application of 0.75% $ZnSO_4$ in guava cv. Dharidar.

2.2.7 Number of fruits per plant

Shanmugavelu *et al*. (1973) under took a field experiment to determine the effect of foliar application of boron on number of fruits produced in papaya cv. Coorg Honey Dew. In their study they revealed that boron @ 2ppm induced cluster bearing elongated fruit stocks with slender and smooth surface.

Increment in the mean number of fruits per plant for both female and hermaphrodite plants along with the raising of boron levels was studied by Perez-Lopez and Reyes-Jurado (1983) in papaya variety P.R. 7-65.

Ahmed *et al*. (1992) detected that soil application of 1 kg of lime along with 5 to 10 g boron per plant in papaya cv.P-011 increased the number of fruits plant^{-1}, yield and provided uniform shape to fruit as compared to control.

Foliar sprays of Zn @ 0.5% along with boron @ 0.1% at 4th, 8th, 12th and 16th MAP improved the fruit characters, total number of fruits per tree, fruit and latex yield in papaya cv.CO-5 (Kavitha *et al*., 2000b).

Modi *et al*. (2012) opined that individual application of borax (30,60 and 90 days after transplanting) at 0.3% recorded highest average fruit weight of 0.739 kg in papaya cv. Madhu Bindu.

Meena (2013) said that foliar application of 0.5% zinc sulphate and 0.2% borax at 8 months after planting of papaya cv. Red Lady reported highest number of fruits per plant (40.5).

Bhalerao and Patel (2015) revealed that the papaya plants sprayed with calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 mgL^{-1}along with ferrous sulphate 200 mgL^{-1}thrice at one-month interval from 60 DAP, significantly increased the number of fruits per plant resulting in higher yield in papaya var. Taiwan Red Lady.

Vasanthu *et al.* (2015) from their study reported that foliar application of 0.3%

borax at every 60 days from date of planting to harvest resulted in 29% more number of fruits per plant in papaya cv. Red Lady.

2.2.8 Number of seeds per fruit

In Surya and Red Lady cultivars of papaya, fruits treated with boron showed healthy seeds whereas seeds were a few, aborted and small size in control (Raja, 2010).

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that foliar application of boron 0.2 percent per plant resulted in lowest number of seeds per fruit (608), highest seed weight (67.98 g) and highest dry seed weight (15.14 g).

Singh *et al*. (2010) realized that lowest seed weight (50.12 g) was observed in treatment where plants of papaya cv. Ranchi were sprayed with borax at 0.50%.

A study conducted to evaluate the effect of foliar application of micronutrients (Fe, B and Zn) on the quality of mango (*Mangifera indica* L.) cv. Dushehari was conducted by Anees *et al* (2011) and found that foliar application of 0.4% $FeSO_4$, 0.8% H_3BO_3 and 0.8% $ZnSO_4$ before flowering and at full bloom stage showed less stone weight (28.13 g).

Foliar application of $ZnSO_4$ @ 0.5% resulted in minimum seed (3.09%) in guava cv. Dharidar (Waskela *et al*., 2013)

2.2.9 Total yield per plant

Ahmed *et al*. (1992) reported that foliar spray of boron in papaya cv. P-011 at the rate of 5g and 10g per litre significantly increased the production of uniform and healthy fruits and resulted in production of highest number of fruits plant^{-1} (47.2) which in turn resulted in higher fruit yield ha^{-1}.

Ghanta *et al*. (1992) found that papaya cv. Ranchi produced higher yield when there was foliar spray of 0.1 per cent boron at 60 and 90 days after transplanting.

Kavitha *et al*. (2000b) reported that foliar spray of zinc @ 0.5 per cent or soil application of 10 g plant^{-1} and boron @ 0.1 per cent foliar spray or soil application of 5 g plant^{-1} during the fourth, eighth, twelfth and sixteenth month after planting increased the yield parameters of papaya cv. CO.5.

An investigation carried out by Singh *et al.* (2000) revealed that application of borax at 0.50% along with $ZnSO_4$ at 0.25% was considered as the best which caused the highest fruit yield (37.20 kg/plant) in papaya cv. Ranchi.

A field experiment was conducted by Jeyakumar *et al*. (2001) to determine the effect of B and Zn on the fruit yield of papaya cv. Co 5. Results revealed that highest fruit yield was obtained from foliar application of zinc sulphate @ 0.5 percent in combination with borax @ 0.1 per cent.

An increase in fruit yield with acceptable fruit weight for local and export market, improved the quality of fruits and reduction in bumpiness of fruits in papaya cv. Sunrise Solo was resulted due to the application of borax @ 5.0kg hectare^{-1} (Tyagi and Datt, 2004).

Bhalerao and Patel (2015) noticed uppermost fruit yield of 80.76 t ha^{-1} was recorded for papaya cv. Taiwan Red Lady by foliar application of calcium nitrate 1000 ppm, borax 30 ppm and zinc sulphate 200 ppm along with ferrous sulphate 200 ppm at 60, 90 and 120 DAP.

Modi *et al.* (2012) observed that individual application of borax (30, 60 and 90 days after transplanting) at the rate of 0.3% recorded the highest yield of fruit per plant (30.76 kg) in papaya cv. Madhu Bindu.

Vasanthu *et al.* (2015) registered that foliar application of 0.3% borax at every 60 days from planting to harvest resulted 37% higher yield in papaya cv. Red Lady.

2.2.10 Days taken for maturity

Reddy (2010) opined that in papaya cv. Sunrise Solo, foliar application of boron at the rate of 0.2% resulted in minimum days for fruit maturity (247.50 days) compared to control plants (267.50 days).

Sachin *et al*. (2019) reported that foliar application of Zinc sulphate 1%), Borax (1%) and Copper sulphate (1%) resulted in minimum days to fruit maturity (116.33 days) compared to control plants (130.33 days) in guava cv. Lalit.

2.3 QUALITY CHARACTERS

2.3.1 Total soluble solids

Increment in brix: acid ratio of papaya cv. Coorg Honey Dew sprayed with 2ppm boron was found by shanmugavelu *et al*. (1973).

TSS increased remarkably, when $ZnSO_4$, $FeSO_4$ and borax applied at monthly interval as foliar spray singly or in combinations over control (Veena and Lavania, 1989).

Singh *et al*. (2000) identified that in papaya cv. Ranchi, application of borax at 0.50% along with $ZnSO_4$ at 0.25% was considered as the best treatment which resulted in highest total soluble solids content (6.81°B).

According to Jeyakumar *et al*. (2001), foliar application of $ZnSO_4$ (0.5%) and H_3BO_3(0.1%) at 4th and 8th month of planting in papaya cv. CO5 resulted in highest total soluble content of 14.8^0 brix.

Modi *et al*. (2012) revealed that individual application of borax (30, 60 and 90 days after transplanting) at 0.3% recorded highest TSS of 11.19 % in papaya cv. Madhu Bindu.

Highest TSS content (11.62 ^{0} brix) was reported in papaya cv. Red Lady due to the application of $ZnSO_4$ (0.5%) and borax (0.2%) at 8 months after planting (Meena, 2013).

2.3.2 Acidity

Acidity increased remarkably, when $ZnSO_4$, $FeSO_4$ and borax applied at monthly interval as foliar spray singly or in combinations over control (Veena and Lavania, 1989).

Singh *et al*. (2000) conducted studies and reported that in papaya cv. Ranchi, application of borax (0.50%) along with $ZnSO_4$ (0.25%) was considered as the best treatment which caused the highest TSS- acid ratio of 58.41.

Ramakrishna *et al*. (2001) applied $CaCl_2$ and $Ca(NO_3)_2$ in the preharvest phase increased titratable acidity in papaya fruits.

Bakshi *et al*. (2013) after conducting an investigation on Strawberry cv. Chandler suggested that the plants treated with 0.6 per cent $ZnSO_4$ showed lowest acidity (0.716%).

Meena (2013) noticed that combined spray of $ZnSO_4$ (0.5%) and borax (0.2%) at 8 months after planting recorded minimum acidity (1.3%) in papaya cv. Red Lady.

A significant decrease in titrable acidity in papaya var. Taiwan Red Lady was found due to the combined foliar application of calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 $mgL^{-1}$and ferrous sulphate 200 mgL^{-1} (Bhalerao and Patel 2015).

2.3.3 Total carotenoids

Singh *et al*. (2000) reported that in papaya cv. Ranchi, application of borax at 0.50% along with $ZnSO_4$ at 0.25% was considered as the best treatment which resulted in highest β-carotene content (3327.14 µg100 g^{-1}).

Reddy (2010) registered that foliar application of boron (0.2 percent) per plant resulted in highest carotene content of 2.17 mg $100g^{-1}$ in papaya cv. Sunrise Solo.

2.3.4 Ascorbic acid content

Chandrashekhar *et al*. (2010) noticed that an increase in ascorbic acid content of papaya cv. Washington due to the foliar application of copper sulphate (0.25%), $MnSO_4$ (0.25%) along with borax (0.25%).

Modi *et al*. (2012) proved that individual application (30, 60 and 90 days after transplanting) of borax at 0.3% recorded minimum ascorbic acid content of 51.16 mg $100g^{-1}$ in papaya cv. Madhu Bindu.

Bakshi *et al*. (2013) reported that the plants treated with 0.6 per cent $ZnSO_4$ showed highest ascorbic acid (60.88 mg 100 g^{-1}) of strawberry cv. Chandler.

In an investigation carried out by Meena (2013) revealed that application of $ZnSO_4$ (0.5%) and borax (0.2%) resulted in the production of significantly higher ascorbic acid content of 59.23 mg $100g^{-1}$ in papaya cv. Red Lady.

A study conducted by Bhalerao and Patel (2015) revealed that when calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 mgL^{-1} and ferrous sulphate 200 mgL^{-1} applied as foliar spray resulted in maximum ascorbic acid content in papaya var. Taiwan Red Lady.

Increasing calcium concentrations caused a significant increase in ascorbic acid content in papaya cv.Eksotika -2 was reported by Madani *et al*. (2016).

2.3.5 Total sugars

Shanmugavelu *et al*. (1973) opined that when papaya cv. Coorg Honey Dew sprayed with 2ppm boron improved the total sugar content of the fruit.

Veena and Lavania (1989) noticed that sugar increased remarkably in papaya fruits, when $FeSO_4$, $ZnSO_4$ and borax when applied at monthly interval as foliar spray singly or in combinations over control.

Foliar spray of Zinc (0.5%) and Boron (0.1%) at 4^{th}, 8^{th}, 12^{th} and 16^{th} months after planting increased total sugars in association with bio-chemical traits in papaya cv. CO-5 (Kavitha *et al*., 2000a).

Singh *et al*. (2000) noted that in papaya cv. Ranchi, application of borax (0.50%) and $ZnSO_4$ (0.25%) was considered as the best treatment caused the highest total sugar (6.88%).

Modi *et al*. (2012) registered that individual application of borax at 0.3% recorded highest total sugar content (8.12 %) in papaya cv. Madhu Bindu.

Bhalerao and Patel (2015) inferred that combined foliar application of calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 $mgL^{-1}$and ferrous sulphate 200 mgL^{-1} in papaya var. Taiwan Red Lady resulted in higher sugar percentage.

2.3.6 Reducing sugar

Shanmugavelu *et al*. (1973) found that foliar application of 2ppm boron improved the reducing sugar percentage in papaya cv. Coorg Honey Dew.

Foliar spray of Zinc (0.5%) and Boron (0.1%) at 4^{th}, 8^{th}, 12^{th} and 16^{th} months after planting increased, reducing sugar content in papaya cv. CO-5 (Kavitha *et al*., 2000a)

An investigation followed by Modi *et al*. (2012) revealed that individual application of borax (0.3%) recorded highest reducing sugar of 6.74 % in papaya cv. Madhu Bindu.

Meena (2013) found that combined foliar spray of $ZnSO_4$ (0.5%) and borax (0.2%) at 8 months after planting registered higher reducing sugar content (12.28%) over control in papaya cv. Red Lady.

According to Bhalerao and Patel (2015), foliar application of calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 mgL^{-1} and ferrous sulphate 200 mgL^{-1} in papaya var. Taiwan Red Lady resulted in highest reducing sugar percentage of 5.27%.

2.3.7 Non reducing sugar

Foliar spray of Zinc (0.5%) and Boron (0.1%) at 4^{th}, 8^{th}, 12^{th} and 16^{th} months after planting increased non-reducing sugar content in papaya cv. CO-5 (Kavitha *et al*., 2000a).

In an experiment conducted by Alila *et al*. (2004) found that aqueous solutions of boric acid (0.1%) and zinc sulphate (0.2%) applied twice (at 2 and 4 months after planting) to papaya cv. Ranchi resulted in highest non-reducing sugar content.

Modi *et al.* (2012) recognized from a study that individual application of borax at 0.3% recorded highest reducing sugar content of 1.38% in papaya cv. Madhu Bindu.

2.3.8 Colour of pulp and peel

A study conducted by Manjunatha *et al*. (2014)) in papaya cv. Red Lady revealed that plants treated with $ZnSO_4$ (0.25%) + Borax (0.1%), $ZnSO_4$ (0.25%) + Borax (0.1%) + $FeSO_4$(0.5%) and Borax (0.1%) six days after harvest of fruits showed good colour development with 98.33 %, 95.00% and 96.67% respectively.

2.3.9 Firmness of pulp

Ramakrishna *et al*. (2001) applied $CaCl_2$ and $Ca(NO_3)_2$ to papaya fruits during preharvest phase enhanced firmness of fruits.

Reddy (2010) revealed that in papaya cv. Sunrise Solo foliar application of boron (0.2 percent) resulted in highest firmness of fruit (3kg cm^{-2}).

Studies also indicated that foliar application of calcium decreased fruit decaying and increased firmness and storage duration of papaya (Madani *et al*., 2013).

Highest fruit firmness of 7.17 kg cm^{-2} in papaya var. Taiwan Red Lady was noted by Bhalerao and Patel (2015) when the plants were applied with a spray solution containing combination of calcium nitrate 1000 mgL^{-1}, borax 30 mgL^{-1}, zinc sulphate 200 mgL^{-1} and ferrous sulphate 200 mgL^{-1}.

2.3.10 Organoleptic evaluation of fruits

Ratananukul *et al.* (1988) identified that there was an improvement in the fruit quality interms of appearance and shape when there was an addition of borax at the rate of 10-40 g per papaya plant.

Nishina (1991) noted that ‘Boron’ deficiency in papaya led to bumpy skin surface and deformed fruits.

Reddy (2010) conducted an experiment in papaya cv. Sunrise Solo and found that foliar application of boron 0.2 percent resulted in minimum number of bumpy fruits (6.25).

Fruits harvested from plants, sprayed with B and Ca 0.4% had significant low fruit deformation (0.8%), blossom and fruit drop (32.6%) than control plants (2.8% and 79.2%, respectively) in Indian goose berry (Shukla, 2011).

Madani *et al*. (2015) registered that texture and flavor of papaya fruits (Eksotika II) were improved with preharvest calcium application at the rate of 4000 or 5400 mg l^{-1}.

Vasanthu *et al*. (2015) reported that foliar application of 0.3% borax at every 60 days from planting to harvest resulted in significant decline in deformed fruits (13.58 %) than control (21.38 %) in papaya cv. Red Lady.

2.4 SHELF LIFE OF FRUITS AT AMBIENT CONDITIONS

Reduction in gloesporioide's spore germination in papaya cv. Eksotika-2 was studied by Eryani-Raqeeb *et al.* (2007). They found that combined effect of Ca at various concentration (1.5, 2.5 and 3.5%) with chitosan amended with PDA (Potato dextrose agar) showed better effect on mycelial growth and controlling anthracnose during storage.

In papaya cultivars, Red Lady and Surya, fruits treated with boron exhibited smooth skin, healthy seeds and bigger size compared to control where the seeds were few, aborted and size was small. (Raja, 2010).

Meena (2013) noticed that the application of $ZnSO_4$ (0.5%) along with borax (0.2%) recorded 24.35% higher shelf life of fruits over control in papaya cv. Red Lady at 8 months after planting.

Madani *et al* (2014) inferred from an experiment that increasing calcium content in papaya fruits by calcium sprays of 1.5% and 2% concentration reduced the anthacnose incidence during 5 weeks of storage and delayed initiation of symptoms by 4 weeks.

Highest shelf life (8.67 days) was observed in the fruits of papaya cv. Red Lady which was sprayed with $ZnSO_4$, Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively (Manjunatha *et al*., 2014).

According to Bhalerao and Patel (2015), reduction in physiological loss in weight (PLW) with respect to foliar application of calcium nitrate 1000 mg L^{-1}, borax 30 mg L^{-1}, zinc sulphate 200 mg L^{-1} and ferrous sulphate 200 mg L^{-1} in papaya var. Taiwan Red Lady helped in the development of higher firmness of fruit resulting in higher shelf life.

Increase in calcium concentrations of fruit caused a significant reduction in ethylene production and decrease in anthracnose diameter in papaya cv. Eksotika -2 was found by Madani *et al*. (2016).

2.5 SOIL ANALYSIS

Rahman *et al*. (2002) detected that foliar feeding of micronutrient resulted in less available boron 0.45 μg g^{-1} and available zinc 0.85 μg g^{-1} compared to control which were 0.49 and 0.90 respectively in rice-wheat system.

A study conducted by Lalithya *et al*. (2014) realized that foliar application of boron @ 3g l^{-1} in sapota resulted in 171.33 kg ha^{-1}, 11.19 kg ha^{-1} and 154.86 kg ha^{-1} available soil N, P and K respectively, after harvest and micronutrient spray of 4ml l^{-1} resulted in organic carbon content of 1.52% which were lower than control (1.68%).

2.6 PLANT ANALYSIS

Single spray of Boron in banana cv. Giant Governor showed the highest amount of N (3.11%), P (0.175%) and K (3.13%) in leaf (Ghanta and Mitra, 1993).

Foliar application of $FeSO_4$ (0.4%), $ZnSO_4$ (0.25%) and borax (0.2%) individually or in combination in pomegranate significantly increased the Fe, Zn and B content in leaves (Afria *et al*., 1999).

Jeyakumar *et al.* (2001) concluded that application of $ZnSO_4$ (0.5%) and H_3BO_3(0.1%) as foliar spray at 4th and 8th month of planting of papaya cv. CO5 resulted in high concentration of the micronutrients in leaves compared to soil incorporations.

Dutta and Dhua (2002) noticed that leaf nitrogen and zinc status of mango was increased. with application Zn (0.1 and 0.2%).

In an experiment conducted by Madani *et al*. (2015) revealed that leaf calcium concentration in the papaya was highest at a concentration of 180 mg l^{-1} when foliar application of $Ca(NO_3)_2$ was given to papaya cv. Eksotika II

Foliar application of 0.03 % borax at every 60 days interval had effect on the leaf boron status and the mean boron content which were increased significantly from 18.44 mg kg^{-1} to 26.62 mg kg^{-1} in papaya cv. Red Lady (Vasanthu *et al*., 2015).

2.7 FRUIT ANALYSIS

Garcia *et al*. (1996) found that calcium chloride (1%) treated strawberry fruits showed a significant rise in calcium content about 37% than the control.

Calcium contents in flesh of papaya fruits increased from 1.09 to 1.86% with the application of calcium at 1.5 to 3.5% respectively when compared with the control (0.73%) (Eryani-Raqeeb *et al*., 2009).

Foliar spray of $ZnSO_4$ (0.5%), $FeSO_4$ (0.5%) and Borax (0.2%) resulted in 6.36% Zinc content and 1.56% boron content compared to control (4.40% and 0.95% respectively) in mango cv. Amrapali (Patel, 2015).

Asad *et al*. (2013) revealed that application of 100g micronutrients along with 0.3 ml phosphoric acid l^{-1} at full bloom and at fruit set significantly enhanced all mineral contents (Fe, Zn, Mn, Cu and B) in fruits of Le Conte pear.

Foliar application of Calcium carbonate (0.6%) + Borax (0.4%) + Zinc sulphate (0.8%) resulted in maximum calcium (0.072%) and Zinc (0.00399%) in Aonla cv. NA-7 (Meena, 2013).

A study conducted by Madani *et al* (2015) found that preharvest applications of calcium (0, 4000, and 5400 mgL^{-1}) showed that increasing concentrations improved fruit Ca content of Papaya fruit peel and pulp.

2.8 PEST AND DISEASES INCIDENCE

Nishina (1991) found that reduction in the symptom of milky latex exudation from young fruit of papaya when applied with commercial fertilizer mix (14:14:14 + 0.30% B) includes 1lb of elemental boron when applied at a rate of 350 lb fertilizer per acre once in a year.

Reddy (2010) observed that foliar application of boron (0.2%) showed less papaya ring spot disease incidence, less number of infected plants, maximum days taken to disease appearence (12.25 days), maximum days taken for appearance of papaya mite (198.75) on papaya cv. Sunrise solo.

According to Madani *et al*. (2014) six pre-harvest foliar calcium sprays (0.5%) applied at biweekly intervals to papaya cv. Eksotika-2 reduced anthracnose incidence during storage

Madani *et al*. (2015) compared postharvest disease incidence in calcium treated and untreated papaya and concluded that control fruit (0 mgL^{-1}) had 100% disease incidence after storage compared with 8.8% and 0% when papaya was treated with foliar calcium at 4000 $mgL^{-1}$and 5400 mgL^{-1}respectively.

In a study on management of papaya ring spot virus conducted at Kerala

Agricultural University, Harish (2018) noticed that application of micronutrients helped in masking the appearance of disease severity in papaya.

2.9 ECONOMIC ANALYSIS

2.9.1 Net income

Maximum gross returns (Rs 600750) and maximum net returns (Rs 427655 Rs/ha) were obtained under the treatment of $ZnSO_4$ (0.5%) along with borax (0.2%) (at 8 months treated plants) application in papaya cv. Red Lady (Meena, 2013).

Reddy (2010) opined that in papaya cv. Sunrise Solo net returns was highest in treatment where plants were sprayed with boron 0.2 percent which gave 3.28 lakh compared to 0.08 lakh in control.

Lokesh (2014) noticed that foliar application of Borax (0.50%) and $ZnSO_4$ (0.25%) was superior in terms of net returns (Rs 343716.6) where control gave Rs 70476.

Manjunatha (2012) noted that foliar application of $ZnSO_4$ (0.25%) + Borax (0.1 %) + $FeSO_4$ (0.5%) resulted in highest net income of Rs 561548 in papaya cv. Red Lady compared to control (Rs 283856).

2.9.2 B:C ratio

Meena (2013) found that in papaya var. Red Lady at 8 months stage treatment with $ZnSO_4$ (0.5%) and borax (0.2%) recorded highest B:C ratio of 3.47 over control (1.44).

Highest B:C Ratio of 3.35 was reported by Reddy (2010) while conducting an experiment using papaya cv. Sunrise Solo when plants were treated with 0.2% foliar application of boron.

Lokesh (2014) noticed that foliar application of Borax (0.50%) and $ZnSO_4$ (0.25%) was superior in terms of benefit-cost ratio (2.50) compared to control (0.56).

Foliar application of $ZnSO_4$ (0.25%), Borax (0.1 %) and $FeSO_4$ (0.5%) resulted in highest B:C ratio (18.19) compared to control (11.72) in papaya cv. Red Lady (Manjunatha, 2012).

Materials and Methods

3. MATERIALS AND METHODS

The study on "Foliar nutrition with calcium and micronutrients for growth and yield enhancement in papaya (*Carica papaya* L.)" was conducted at the Department of Fruit science, College of Agriculture, Vellayani, Thiruvananthapuram during 2019-2020. The objective of the experiment was to study the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya.

3.1 EXPERIMENTAL SITE

Location of the experimental site is 8° 4' North latitude and 76° 9' East longitude at an altitude of 29 m above mean sea level. In the experimental site predominant soil is laterite belonging to Vellayani series. Texture in the experimental site is sandy clay loam with acidic nature.

3.2 EXPERIMENTAL MATERIAL

The experiment was conducted using IIHR- gynodioecious papaya variety, Surya. Characteristics such as high fruit quality, excellent taste, good keeping quality and medium sized fruits with reddish orange coloured flesh gives higher acceptability of this variety among consumers.

3.3 EXPERIMENTAL DETAILS

3.3.1 Nursery

Seeds of papaya variety surya were procured from Indian Institute of Horticlural Research, Banglore. Papaya seeds soaked in GA_3 (200 ppm) over night were sowed in a protray filled with cowdung, sand and coir pith mix and kept it under a poly house. Regular watering, weeding were done. Later, 1month old seedlings were planted in a polythene bag containing potting mixture (sand, FYM and soil in the proportion of 2:1:1). Proper pest and disease management was done when required. Two month old healthy seedlings with 4 to 6 leaf stage were transplanted in the main field.

3.3.2 Preparation of Experimental plot

Experimental plot was brought to fine tilth by tilling and levelling. After that layout was done (Fig.1).

3.3.2.1 Planting method

The pits of 50 cm^3 were taken at a spacing of 2m × 2m. Seedlings were planted in pits after 1 week of application of lime to correct the pH. Organic manure (10 kg FYM plant^{-1}) was given uniformly to all treatments as basal application as per POP (KAU, 2016).

3.3.2.2 Fertilizer application

Apart from organic manures applied as basal dose, papaya requires major nutrients such as N, P and K through Urea, Rajphos and MOP respectively. These fertilizers were applied in six splits at an interval of 2 months to obtain 240:240:480 g NPK plant^{-1} year^{-1}. For the effective absorption by plants, fertilizers were applied in basin and mixed with soil thoroughly. Irrigation should provide before or after the fertilizer application.

3.3.2.3 Treatment application

Treatments such as Borax, Calcium nitrate, Zinc sulphate and water spray were given individually and in combination according to the treatment details at 4th and 7th month after planting as foliar spray. Spraying was done during morning or evening hours.

3.3.2.3 Irrigation methods

On the basis of weather and soil condition irrigation schedules was fixed. During initial stages of establishment of seedlings, protective irrigation was carried out to avoid seedling rot.

3.3.2.4 Intercultural operations

Deep hoeing as well as cutting with bush cutter were done to check weed growth especially during monsoon season. Earthing-up were done for required plants to avoid water logging after heavy rain.

3.3.2.5 Plant protection measures

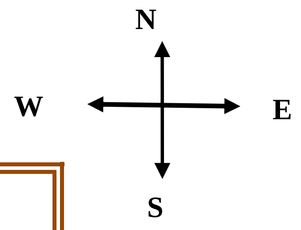
Insecticides and fungicides were applied weekly or bi-weekly interval as per requirement to control pests and diseases.

Treatment details

The design adopted for the experiment was Randomized Block Design (RBD) with nine treatments and three replications.

Number of treatments - 9

Number of replications - 3



R_1T_1	R_1T_7	R_1T_4
R_1T_9	R_1T_2	R_1T_6
R_1T_5	R_1T_3	R_1T_8
R_2T_5	R_2T_2	R_2T_8
R_2T_1	R_2T_7	R_2T_3
R_2T_9	R_2T_6	R_2T_4
R_3T_6	R_3T_9	R_3T_3
R_3T_7	R_3T_4	R_3T_8
R_3T_1	R_3T_5	R_3T_2

Fig.1 Lay out of papaya plot

1) T_1 - Borax (0.5%)
2) T_2 - Zinc sulphate (0.5%)
3) T_3 - Calcium nitrate (0.5%)
4) T_4 - Borax (0.5%) + Calcium nitrate (0.5%)
5) T_5 - Borax (0.5%) + Zinc sulphate (0.5%)
6) T_6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)
7) T_7 - Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)
8) T_8 - Water spray
9) T_9 - Control (KAU, POP)

Number of plants per plot - 6

Plot size - 24 m^2

Spacing - 2 m x 2 m

Field experiment

Variety selected for the study- Surya

Details of various treatments and spray details

1) T_1 - Borax (0.5%)

2) T_2 – Zinc sulphate (0.5%)

3) T_3 – Calcium nitrate (0.5%)

4) T_4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T_5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T_6 - $ZnSO_4$ (0.5%) + Calcium nitrate (0.5%)

7) T_7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T_8 - Water spray

9) T_9 - Control (KAU, POP)

Organic manure (10 kg FYM plant^{-1}) as per POP (KAU, 2016) will be given uniformly to all treatments as basal. T_1 to T_8 will be applied at 4th and 7th months after planting. 100% recommended dose of NPK as per KAU POP (240: 240: 480 g NPK plant^{-1} year^{-1} will be given uniformly to all treatments as soil application. Stickers will be added along with micronutrients and calcium for foliar sprays.

a) Filled pro-tray with seeds

b) Germinated seedlings

c)1 month old seedlings

d) 2 month old seedlings

Plate 1. Stages of crop growth

a) Fixing pit dimensions

b) Pit with 50 cm^3 dimension

Plate2. Pit taken for planting

a) Transplanting the seedlings

b) Irrigating transplanted crops

Plate 3. Planting operations

Plate 4. vegetative stage of papaya plants 4 months after transplanting (Field view)

Plate 5. Fruit bearing stage in papaya (Field view)

3.4 OBSERVATIONS

3.4.1 Biometric characters

3.4.1.1 Height of plants (cm)

Height of the plants were recorded in centimeters from soil level to the tip of growing point using a measuring scale at 2 months interval and average was worked out.

3.4.1.2 Girth of plants (cm)

Girth of the plant was recorded as circumference in centimeter from 5 centimeters above soil level using a thread at 2 months interval and average was worked out.

3.4.1.3 Number of leaves

Total number of fully opened leaves per plant was noted for each replication at 2 months interval and average was worked out.

3.4.1.4 Height at first flowering (cm)

Height of appearance of first flower from ground level was recorded in centimeter in each observational plant and mean height was calculated.

3.4.1.5 Days to flowering

Average of number of days from planting to opening of first flower were recorded.

3.4.1.6 Sex expression of plant

Total number of hermaphrodite and female plants were noted in each replication and expressed in percent.

3.4.1.7 Sex ratio of plants

Ratio of total number of female plants and hermaphrodite plants were found in each treatment.

3.4.1.8 Number of flowers per cluster

Total number of flowers in each cluster was counted for each observational plant and average was found.

3.4.1.9 Fruit set (%)

Total number of flowers which set into fruits in each treatment plant was noted and compared with the total number of hermaphrodite and female flowers produced and expressed in percentage.

$$\text{Percent fruit set} = \frac{\text{No. of fruits per plant}}{\text{No. of flowers per plant}} \times 100$$

3.4.1.10 Time for harvest (days)

Total number of days taken from planting to the harvest of first formed fruit of each observational plant was recorded.

3.4.2 Yield characters

3.4.2.1 Fruit weight (g)

Random selection of 5 fruits from each plant was done and its weight was taken using a weighing balance and average of fruit weight was calculated.

3.4.2.2 Fruit length (cm)

Fruit length was measured after cutting the fruits longitudinally and measuring from the stalk end to the floral end of selected fruits of each observational plant using scale or thread.

3.4.2.3 Fruit girth (cm)

Fruit girth was measured at the centre of longitudinally cut fruit, where maximum width is there and then average was found.

3.4.2.4 Fruit volume (cc)

Volume of fruits in each treatment was calculated using water displacement method. Fruits were immersed into a container fully filled with water and was placed in another container. The volume of the fruit is equal to the volume of displaced water and measured using a measuring cylinder.

3.4.2.5 Pulp percentage

Fruits were selected randomly from each treatment and the weight was taken. After removing peel and seeds again weight was taken. Pulp percentage was calculated using the formula:

$$\text{Pulp percentage} = \frac{\text{Weight of the pulp (g)}}{\text{weight of the fruit (g)}} \times 100$$

3.4.2.6 Flesh thickness (cm)

Thickness of the pulp was measured at the centre of selected fruits using a scale after making it into halves and average was worked out.

3.4.2.7 Number of fruits per plant

Total number of fruits obtained from each plant was calculated and average was worked out.

3.4.2.8 Number of seeds per fruit

Seeds were extracted from randomly selected 5 ripened fruits and numbers were counted and average was found.

3.4.2.9 Total yield per plant (kg)

For getting total yield per plant, the total number of fruits harvested from individual plant was counted and multiplied it with average fruit weight. It is expressed in kilogram $plant^{-1}$.

3.4.2.10 Days taken for maturity

It is the number of days taken from fruit set to fruit turn to harvest maturity.

3.4.3 Quality characters

3.4.3.1 Total soluble solids (°Brix)

Hand refractometer was used to measure TSS of the selected ripened fruits and expressed in degree brix. One drop of the fruit juice was put on the prism of refractometer and percent TSS were recorded directly (Ranganna, 1997).

3.4.3.2 Acidity (%)

A known weight of fruit sample was ground with distilled water. After filtration through muslin cloth volume was made upto 100 ml in a standard flask using distilled water and an aliquot of 10 ml from this was titrated against standard 0.1 N sodium hydroxide (NaOH). Usually Phenolphthalein is used as indicator and appearance of pink color was the end point. Titrable acidity usually expressed as per cent of citric acid (Ranganna, 1997).

$$\text{Acidity} = \frac{\text{Normality x titre value x equivalent weight x volume made up}}{\text{Weight of sample x aliquot of sample x 1000}} \times 100$$

3.4.3.3 Total carotenoids (mg 100g^{-1})

Carotenoid content in a fruit sample was estimated using petroleum ether-acetone extraction method. A known weight of sample was ground in a pestle and mortar with acetone. Then extract was poured into a conical flask. Till the residue became colourless, extraction was continued. Then transferred the extract into a separating funnel. Later to this extract add 10-15 ml of petroleum ether, little amount of distilled water and a little amount of anhydrous sodium sulphate and the separating funnel was thoroughly shaken before allowing it to stand. Then the upper layer was collected and the lower layer was re-extracted. Extraction of acetone phase was repeated with small volume of petroleum ether till it became colourless. The extract was collected into a volumetric flask by passing through cotton containing small amount of anhydrous sodium sulphate and then the volume was made up with petroleum ether. The colour was measured at 452 nm using petroleum ether as blank in spectrophotometer. Results were expressed as mg 100g^{-1} of material (Ranganna, 1997).

$$\text{Total carotenoids (mg } 100g^{-1}) = \frac{\text{Optical density x volume made up}}{\text{Weight of the sample}} \times 1000$$

3.4.3.4 Ascorbic acid content (mg 100g-1)

Estimation of ascorbic acid was done using 2,6-dichloro phenol indophenol titration method. Five grams of fruit sample was taken and extracted with four percent oxalic acid solution. Then estimation of ascorbic acid was done using standard indicator dye 2,6- dichlorophenol indophenol and expressed as mg $100g^{-1}$ of fruit (Ranganna, 1997).

3.4.3.5 Total sugar (%)

Total sugar was determined according to the procedure described by A.O.A.C (1975) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp.

3.4.3.6 Reducing sugar (%)

Estimation of reducing sugar was done using Fehling's solution and expressed as gram of glucose per 100 grams of pulp (A.O.A.C, 1975).

3.4.3.7 Non- reducing sugar (%)

The estimation of non-reducing sugars was done by subtracting the reducing sugars from the total sugars and expressed as grams of glucose per 100 grams of pulp (A.O.A.C, 1975).

3.4.3.8 Colour of pulp and peel

Color of the pulp and peel was visually identified using Universal Color Language (UCL). The Universal Color Language is a color menu defined by the Inter society Color Council, National Bureau of standards in 1946 and approved by Royal Horticultural Society (Anonymous, 1999).

3.4.3.9 Firmness of pulp

Identification of firmness of pulp was done using texture analyzer TA-HD®

(Stable micro system, Surrey, England).

3.4.3.10 Organoleptic evaluation of fruits

Sensory analysis at the laboratory level were done by fifteen members panel of judges selected from a group of teachers and students. Appearance, color, taste, texture, flavor and overall acceptability are the major quality characters included for evaluation of papaya fruit based on nine-point hedonic scale (Srivastava and kumar, 2002). The score card is presented in Appendix Π.

3.4.4 Shelf life of fruits at ambient conditions (days)

Assessment of shelf life of fruit by counting the number of days for which the fruit retained the edible qualities without decaying at normal atmospheric condition.

3.4.5 Soil analysis before and after the experiment

Soil samples were collected from the field before transplanting of crop and after harvesting the crop to analyse the following soil characters (Table 1.)

Table. 1 Initial status of soil and methods followed for soil analysis

Sl.no	Particulars	Value	Analysis method
1	Soil pH	4.5 (Very strongly acidic)	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1973)
2	Electrical Conductivity (ds m^{-1})	0.18	Soil water suspension of 1:2.5 and read in EC meter (Jackson, 1973)
3	Organic carbon (%)	0.62 (low)	Loss on ignition method (Jackson, 1973)
4	Available N (Kg ha^{-1})	163.07 (Low)	Microkjedahl digestion and distillation (Jackson, 1973)

5	Available P_2O_5(Kg ha $^{-1}$)	31.63 (High)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using spectrophotometer (Jackson, 1973)
6	Available K_2O (Kg ha $^{-1}$)	102.45 (Low)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using Flame photometer (Jackson, 1973)
7	Available B (ppm)	1.18 (Adequate)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using azomethane-H (Gupta, 1967)
8	Available Zn (ppm)	2.17 (Adequate)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using AAS (Atomic absorption spectroscopy) (Jackson, 1973)
9	Available Ca (ppm)	120 (Deficient)	Diacid (HNO_3:$HClO_4$ in the ratio 9:4) digestion and estimation using EDTA method (Jackson, 1973)

3.4.6 Plant analysis

Petiole of 6th leaf from the top of the plant (Index leaf was collected from each treatment. The collected plant samples were dried in hot air oven at 65ºC before nutrient analysis.

Index leaf analysis was done for total plant nitrogen, phosphorous and potassium estimation using modified kjeldahl method (Jackson, 1973), Vando-molybdo phosphoric yellow color spectro photometric method (Jackson, 1973) and flame photometry method respectively. Secondary nutrient (Ca) was estimated using EDTA method (Jackson, 1973), and micronutrients (B and Zn) was analysed using dry ashing, azomethane-H method (Gupta, 1967) and Atomic absorption spectroscopic method (Jackson, 1973) correspondingly.

3.4.7 Fruit analysis

Papaya fruits were collected from each replication and analysis were done for the estimation of total NPK, secondary (Ca) and micronutrients (B and Zn) using methods described by Ranganna (1997) after drying of fruit samples in hot air oven at 65ºC.

3.4.8 Pest and diseases incidence

Number of plants infected with pests and diseases were identified by frequent observation of plants in the field.

3.4.9 Economic analysis

3.4.9.1 Net income

Net income = Gross income – Cost of cultivation

3.4.9.2 B: C ratio

Benefit to cost ratio for each treatment was calculated using formula

$$\text{BCR} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.10 Statistical analysis

Statistical analysis was done for observations obtained from the experiment using Randomized Block Design and tested using analysis of variance technique (Panse and Sukhatme, 1985).

Results

4. RESULTS

The current study to find out the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya was conducted at the Department of Fruit Science, College of Agriculture Vellayani during 2019-2020. The results of the study are presented below.

4.1 BIOMETRIC CHARACTERS

4.1.1 Height of plants

The data on the plant height as influenced by the foliar application of micronutrients and calcium are presented in Table 2. The height of the plants were taken at bimonthly intervals from 2 MAP to 12 MAP and significant difference among different treatments were observed at 6 MAP, 8MAP, 10MAP and 12 MAP.

Highest plant height at 2 MAP and 4 MAP (before imposing the treatments) was observed for T_4 which was 60.60 cm at 2MAP and 80.93 cm at 4MAP. Lowest plant height at 2MAP and 4MAP was recorded for T_1 which was 54.47cm and 74.53 cm respectively.

The results of data on plant height at 6 MAP revealed that the highest plant height was found for T_7 (158.07 cm) which was significantly different from all other treatments followed by T_4 (152.40 cm) which was on par with T_6 (151.40 cm) and lowest plant height was observed for control, T_9 (103.20 cm).

At 8 MAP tallest plant was recorded in T_7 (215.13 cm) and it was significantly different from other treatments. This was followed by T_4 (192.00cm) which also differed significantly from other treatments and T_9 (155.67 cm) showed the lowest value.

During 10 MAP, T_7 (243.13 cm) recorded highest plant height which differed significantly from all other treatments. This was followed by T_4 (225.80 cm) which also differed significantly from other treatments. Whereas, the least plant height was identified for T_9 (180.40cm).

Significantly taller plant height was recorded for T_7 (281.97cm) at 12 MAP which differed significantly from all other treatments. This was followed by T_4 (265.33 cm) which also differed significantly from other treatments. However, T_9 (215.47cm) recorded lowest plant height.

Table 2. Effect of foliar application of micronutrients and calcium on plant height of papaya

Treatments	Plant height (cm) of papaya					
	2MAP	4MAP	6MAP	8MAP	10MAP	12MAP
T_1	54.47	74.53	134.33	173.60	208.73	240.87
T_2	59.00	79.07	130.00	170.60	205.53	238.00
T_3	59.13	79.40	137.27	176.47	208.93	242.50
T_4	60.60	80.93	152.40	192.00	225.80	265.33
T_5	58.80	78.93	148.27	180.33	218.33	256.20
T_6	55.07	74.73	151.40	188.47	221.27	261.67
T_7	55.53	75.47	158.07	215.13	243.13	281.97
T_8	59.47	79.40	114.80	163.00	190.73	223.60
T_9	56.53	76.60	103.20	155.67	180.40	215.47
SEm(±)	1.58	1.57	1.00	1.00	0.76	0.82
CD (0.05)	NS	NS	3.01	2.99	2.26	2.46

* MAP - Months after planting

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

In general foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) resulted in the highest plant height in papaya from 6MAP to 12MAP.

4.1.2 Girth of plants

Girth of plants as influenced by the different combination of foliar application of micronutrients and calcium are given in Table 3. Observation on the plant girth at bimonthly intervals from 2 MAP to 12 MAP showed significant difference at all stages of crop growth.

Observation recorded at 2MAP indicated that T_8 (10.73 cm) showed highest plant girth which was on par with T_4 (10.20cm) which differed significantly from other treatments. Least plant girth was found for T_5 (7.87cm) which was on par with T_1 (8.40 cm), T_2 (8.06 cm) and T_9 (8.53 cm).

Similar results were found at 4MAP where highest stem girth was found for T_8 (12.80cm) which was on par with T_4 (12.20 cm) and lowest stem diameter was found for T_5 (9.87cm) which was on par with T_1 (10.40cm), T_2 (10.00cm) and T_9 (10.53cm).

At 6 MAP, T_7 (34.40 cm) showed the thicker plant stem which had significant difference from other treatments and was followed by T_4 (28.80 cm) which was on par with T_6 (28.47cm) and least value was noted for T_9 (18.47 cm) which also had significant difference over other treatments.

Similar pattern of result was observed for 8 MAP where maximum plant girth was recorded for T_7 (43.33 cm) which was significantly different from other treatments. This was followed by T_4 (37.73cm) which also differed significantly from other treatments and least plant girth was found for T_9 (24.87cm), which had significant difference over other treatments.

At 10 MAP, highest mean girth was noticed for T_7 (49.33cm) followed by T_4 (45.60cm) where both were significantly differed from other treatments and the least plant girth was noticed with T_9 (34.60 cm) which also had significant difference over other treatments.

The values for stem girth at 12 MAP indicates that T_7 (56.47 cm) showed highest plant girth which has showed significant difference from other treatments and followed by T_4 (50.60cm) which was on par with T_6 (50.27 cm) and lowest value of

Table 3. Effect of foliar application of micronutrients and calcium on plant girth of papaya

Treatments	Plant girth (cm) of papaya					
	2MAP	4MAP	6MAP	8MAP	10MAP	12MAP
T_1	8.40	10.40	25.87	33.87	42.40	43.80
T_2	8.06	10.00	25.33	33.33	42.27	43.73
T_3	9.20	11.20	26.53	34.2	42.73	44.53
T_4	10.20	12.20	28.80	37.73	45.60	50.60
T_5	7.87	9.87	27.47	34.47	44.20	49.20
T_6	9.53	11.20	28.46	35.80	44.53	50.27
T_7	9.33	11.33	34.40	43.33	49.33	56.47
T_8	10.73	12.80	20.53	28.87	39.07	40.40
T_9	8.53	10.53	18.47	24.87	34.60	38.20
SEm(±)	0.35	0.37	0.22	0.29	0.17	0.18
CD (0.05)	1.05	1.11	0.65	0.87	0.51	0.54

* MAP - Months after planting

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

stem girth was reported from T_9(38.20 cm) which had significant difference over other treatments.

It was noticed that significant variation in plant girth was observed at 6MAP, 8MAP, 10MAP and 12MAP due to the foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%).

4.1.3 Number of leaves

The data regarding the number of leaves as influenced by the foliar application of micronutrients and calcium are given in the Table 4. The observation on number of leaves were taken at bimonthly intervals from 2MAP to 12MAP and found that there were significant difference in number of leaves produced at 6MAP, 8MAP, 10MAP and 12MAP.

No significant difference was noticed in the number of leaves produced at 2MAP and 4MAP in papaya.

The plants treated with T_7 produced the highest number of leaves (21) at 6 MAP which was significantly different from other treatments. This was followed by T_4 (18.67) which was on par with T_6 (18.33) and T_5 (17.67) and differed significantly from other treatments. Least number of leaves produced were recorded from control, T_9 (14.67) which was on par with T_8 (15.33) and differed significantly from other treatments.

AT 8 MAP the highest number of leaves was identified for T_7 (24.00) which differed significantly from other treatments followed by T_4 (22.33) which was on par with T_6 (21.67) and T_5 (21.33) which also differed significantly from other treatments. T_9 (17.33) produced lowest number of leaves which was on par with T_8 (18.33) and differed significantly from other treatments.

The data recorded for number of leaves at 10 MAP indicated that highest number was reported from T_7(26.33) which had significant difference from other treatments. This was followed by T_4 (24.33) which was on par with T_6 (23.67) and T_5 (22.67) which also showed significant difference over other treatments. The lowest number of leaves was noticed in T_9 (19.00) which was on par with T_8 (20.00) and differed significantly from other treatments.

Number of leaves found at 12 MAP showed that T_7 (27.67) recorded the highest number of leaves which had significant difference over other treatments. This was

Table 4. Effect of foliar application of micronutrients and calcium on number of leaves of papaya

Treatments	Number of leaves					
	2MAP	4MAP	6MAP	8MAP	10MAP	12MAP
T_1	10.33	13.00	16.67	19.33	22.00	22.33
T_2	9.67	12.00	16.33	19.00	21.00	21.33
T_3	9.67	12.00	17.00	20.33	22.33	23.00
T_4	10.67	12.67	18.67	22.33	24.33	25.33
T_5	10.33	12.67	17.67	21.33	22.67	23.00
T_6	10.33	12.67	18.33	21.67	23.67	24.33
T_7	10.00	12.33	21.00	24.00	26.33	27.67
T_8	11.00	13.00	15.33	18.33	20.00	19.67
T_9	10.67	13.33	14.67	17.33	19.00	18.67
SEm(±)	0.78	0.75	0.39	0.46	0.52	0.65
CD (0.05)	NS	NS	1.18	1.38	1.55	1.95

* MAP - Months after planting

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Followed by T_4 (25.33) which was statistically on par with T_6 (24.33) and differed significantly from other treatments. The control, T_9 (18.67) showed the least value for number of leaves which was on par with T_8 (19.67) and differed significantly from other treatments.

It was observed that foliar application of Borax, Zinc sulphate along with Calcium nitrate @ 0.5% significantly increased the number of leaves per plant in papaya.

4.1.4 Height at first flowering

The data presented in the Table 5. revealed that lowest height at first flowering was observed for T_7 (72.13 cm) which was significantly different from other treatments and was followed by T_4 (75.40 cm) which also showed significant difference over other treatments. The highest height at first flowering was found for T_8 (96.20 cm) which differed significantly from other treatments.

Foliar application of Borax (0.5%), Zinc sulphate (0.5%) and calcium nitrate (0.5%) spray had a significant effect on reducing height at first flowering.

4.1.5 Days to flowering

The data regarding the days to flowering as influenced by the foliar application of micronutrients (boron and zinc) and calcium is described in Table 5.

Significant variation in days to flowering was seen in papaya. Less number of days for flowering was reported from T_7 (152.13 days) which differed significantly from other treatments. This was followed by T_4 (157.73days) which was on par with T_6 (158.00 days). The highest number of days for flowering was noted in T_9 (183.93 days), which also differed significantly from other treatments.

It was found that foliar application of micronutrients and calcium had effect on reducing the days to flowering.

4.1.6 Sex expression of plant

Sex expression of the plants as influenced by the foliar application of micronutrients and calcium are presented in Table 6.

Data from the table indicates that percentage of female plants were highest in T_7 (77.78%) which was on par with all other treatments except T_8 (38.89%) and T_9 (33.33%), where T_9 (33.33%) showed the lowest value and it was on par with T_8 (38.89%) and T_5 (55.56%).

Table 5. Effect of foliar application of micronutrients and calcium on height at first flowering and days to flowering in papaya

Treatments	Height at first flowering (cm)	Days to flowering
T_1	84.53	170.53
T_2	87.37	174.27
T_3	86.20	172.67
T_4	75.40	157.73
T_5	78.50	161.47
T_6	76.80	158.00
T_7	72.13	152.13
T_8	96.20	180.20
T_9	94.13	183.93
SEm(±)	0.14	0.21
CD (0.05)	0.42	0.63

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

The percentage of bisexual plants were found to be highest for T_9 (66.67) which was on par with T_8 (61.11%) and T_5 (44.44%). Lowest value for the percentage of bisexual plants was noted with T_7 (22.22%) which was on par with all other treatments except T_8 (61.11%) and T_9 (66.67%).

In general, foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) increased the femaleness in papaya. So, it has a significant effect on sex expression of papaya plants.

4.1.7 Sex ratio of plants

There was no significant difference noticed in the sex ratio of plants as result of foliar spray of different combination of micronutrients (B and Zn) and calcium are inscribed in the Table 6.

4.1.8 Number of flowers cluster^{-1}

A perusal of data presented in the Table 7. revealed the following findings on the number of flowers per cluster as influenced by the foliar spray of micronutrients and calcium.

Results of the statistical analysis revealed that number of flowers per cluster was the highest for T_7 (2.89) which was on par with T_6 (2.56), T_4 (2.56) and T_5 (2.33). The lowest value was found for T9 (1.22) which was on par with T_8 (1.44), T_1 (1.78) and T_3 (1.78).

It was noted that number of flowers per cluster was influenced by foliar application of micronutrients and calcium.

4.1.9 Fruit set percentage

Fruit set % of plants as influenced by the foliar application micronutrients and calcium are depicted in the Table 7.

Highest fruit set percentage was recorded for T_7 (85.07%) which differed significantly from other treatments. This was followed by T_4 (79.73%) which was on par with T_6 (79.07%) and lowest value was observed for T_9 (63.40%) which differed significantly from other treatments.

Increment in fruit set % was noted due to the foliar application of micronutrients and calcium in papaya.

4.1.10 Time for harvest

It was evident from the data in Table 7. indicated the influence of foliar application of

Table 6. Effect of foliar application of micronutrients and calcium on sex expression and sex ratio of plants of papaya

Treatments	Sex expression		Sex Ratio (F/B)
	Female plants (%)	Bisexual plants (%)	
T_1	66.67	33.33	2.67
T_2	72.22	27.78	3.00
T_3	66.67	33.33	2.67
T_4	66.67	33.33	2.67
T_5	55.56	44.44	1.33
T_6	66.67	33.33	2.67
T_7	77.78	22.22	4.00
T_8	38.89	61.11	0.67
T_9	33.33	66.67	0.57
SEm(±)	8.07	8.07	0.95
CD (0.05)	24.20	24.20	NS

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 7. Effect of foliar application of micronutrients and calcium on number of flowers cluster $^{-1}$, fruit set percent and time for harvest in papaya

Treatments	No. of flowers cluster $^{-1}$	Fruit set percent	Time for harvest (days)
T_1	1.78	75.53	243.00
T_2	2.11	74.07	248.67
T_3	1.78	74.93	244.67
T_4	2.56	79.73	231.33
T_5	2.33	78.07	237.00
T_6	2.56	79.07	233.27
T_7	2.90	85.07	220.67
T_8	1.44	69.07	253.67
T_9	1.22	63.40	253.80
SEm(±)	0.23	0.43	0.63
CD (0.05)	0.68	1.30	1.89

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

micronutrients and calcium on time for harvest.

The least number of days required for the harvest was found in T_7 (220.67) which differed significantly from other treatments and highest number of days required for harvest was recorded for T_9 (253.80) which was statistically on par with T_8 (253.67).

Foliar application of Borax, Zinc sulphate and Calcium nitrate @ 0.5% decreased the time for harvest in papaya.

4.2 YIELD CHARACTERS

4.2.1 Fruit weight

The data on the fruit weight as influenced by the foliar application of micronutrients and calcium in papaya are presented in the Table 8.

A significant difference in fruit weight was observed due to the influence of micronutrients and calcium. The highest value for fruit weight was observed for T_7 (722.00g) which had significant difference over others treatments. This was followed by T_4 (690.97g) which also differed significantly from other treatments. The lowest value was identified for T_9 (384.27g) which had significant difference over other treatments.

4.2.2 Fruit length

A perusal of data depicted in the Table 9. revealed the effects of foliar application of micronutrients and calcium on the fruit length of papaya.

Fruit length recorded from different treatments showed significant variation where highest value was found for T_7 (21.03cm) which differed significantly from other treatments. This was followed by T_4 (19.20 cm) which also differed significantly from other treatments. The lowest fruit length was noticed with T_9 (14.5cm) which had significant difference over other treatments.

4.2.3 Fruit girth

The influence of foliar application of micronutrients and calcium on fruit girth was recorded and tabulated in Table 9.

The data recorded for fruit girth indicated that foliar application of micronutrients and calcium had a great influence on the fruit girth where maximum was found for T_7 (39.80cm) which had a significant difference from other treatments and followed by T_4 (36.73cm) which was on par with T_6 (36.27cm). The lowest fruit

Table 8. Effect of foliar application of micronutrients and calcium on fruit weight and fruit volume of papaya

Treatments	Fruit weight (g)	Fruit volume (cc)
T_1	592.33	503.67
T_2	567.33	492.00
T_3	605.00	519.00
T_4	690.97	593.67
T_5	644.33	571.67
T_6	665.73	583.33
T_7	722.00	709.33
T_8	433.97	340.00
T_9	384.27	309.00
SEm(±)	4.81	1.30
CD (0.05)	14.42	3.91

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

girth was found for T_9 (26.80cm) which differed significantly from other treatments.

4.2.4 Fruit volume

The data on fruit volume as influenced by the foliar application of micronutrients and calcium are presented in Table 8.

Highest value for fruit volume was observed for T_7 (709.93cc) which differed significantly over other treatments and was followed by T_4 (593.67 cc) which also differed significantly from other treatments. The least value for fruit volume was found with T_9 (309.00cc) which differed significantly from other treatments.

Increasing volume of fruit was found as result of foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%).

4.2.5 Pulp percentage

The effect of foliar application of micronutrients and calcium on pulp percentage are inscribed in Table 10.

The data on the pulp percentage of fruits showed that highest value was obtained for T_7 (82.10%) which differed significantly from other treatments. This was followed by T_4 (78.73%) which also differed significantly from other treatments. The lowest value for pulp percentage was reported from T_9 (61.30%) which differed significantly from other treatments.

4.2.6 Flesh thickness

Flesh thickness was significantly influenced by foliar application of micronutrients and calcium (Table 10.)

The highest value of flesh thickness was noticed with T_7 (3.27cm) which had significant difference from other treatments. This was followed by T_4 (3.13cm) which was on par with T_6 (3.07 cm) and differed significantly from other treatments. The lowest flesh thickness was observed for T_9 (1.87cm) which was on par with T_8 (1.97cm) and differed significantly from other treatments.

4.2.7 Number of fruits plant^{-1}

The result regarding number of fruits per plant as influenced by the foliar application of micronutrients and calcium are presented in the Table 11.

Number of fruits per plant among the different treatments showed significant variation, where T_7 (50.55) recorded highest value which differed significantly from other treatments. This was followed by T_4 (47.56) which was on par with T_6 (46.67)

Table 9. Effect of foliar application of micronutrients and calcium on fruit length and fruit girth of papaya

Treatments	Fruit length (cm)	Fruit girth (cm)
T_1	17.67	33.33
T_2	17.43	32.70
T_3	17.87	34.07
T_4	19.20	36.73
T_5	18.40	36.07
T_6	18.60	36.27
T_7	21.03	39.80
T_8	16.00	29.33
T_9	14.50	26.80
SEm(±)	0.18	0.21
CD (0.05)	0.54	0.62

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 10. Effect of foliar application of micronutrients and calcium on pulp percent and flesh thickness in papaya

Treatments	Pulp percent	Flesh thickness (cm)
T_1	72.07	2.53
T_2	71.27	2.47
T_3	72.50	2.63
T_4	78.73	3.13
T_5	75.63	2.90
T_6	76.60	3.07
T_7	82.10	3.27
T_8	63.63	1.97
T_9	61.30	1.87
SEm(±)	0.24	0.04
CD (0.05)	0.72	0.13

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

and differed significantly from other treatments. The lowest number of fruits was identified for T_8 (35.22) which was on par with T_9 (35.55) and differed significantly from other treatments.

Foliar application of borax, zinc sulphate and calcium nitrates resulted in the production of highest number of fruits per plant in papaya.

4.2.8 Number of seeds fruit^{-1}

The data described in the Table 11. clearly indicate the effects of foliar application of micronutrients and calcium on number of seeds per fruit.

Statistical data on number of seeds per fruit revealed that T_7 (355.00) had less number of seeds per fruits compared to other treatments and differed significantly from other treatments. This was followed by T_6 (386.00) which also differed significantly from other treatments. The highest number of seeds was observed for T_9 (835.11) which had significant difference over other treatments.

Micronutrient and calcium combination decreased the number of seeds in fruit in papaya

4.2.9 Total yield per plant

The data on the influence of foliar application of micronutrients and calcium on total yield per plant are presented in Table 12.

Information on total yield per plant from different treatments indicated that foliar application of micronutrients and calcium had a great role in increasing the yield per plant where highest value for yield was obtained for T_7 (36.5kg) which differed significantly from other treatments and was followed by T_4 (32.85 kg) which also differed significantly from other treatments. The lowest yield per plant was found for T_9 (13.67kg) which differed significantly from other treatments.

4.2.10 Days taken for maturity

Effects of foliar application of micronutrients and calcium on days taken for fruit maturity are given in the Table 12.

Days taken for maturity of fruits among the different treatments revealed that T_7 (118.00 days) recorded the lowest value which showed significant difference from other treatments. This was followed by T_4 (120.33 days) which also differed significantly from other treatments and the highest value for fruit maturity was shown by T_9 (131.67 days) which was on par with T_8 (130.77 days) and had significant

Table 11. Effect of foliar application of micronutrients and calcium on number of fruits plant^{-1} and number of seeds fruit^{-1} in papaya

Treatments	No. of fruits plant^{-1}	No. of seeds fruit^{-1}
T_1	41.67	735.33
T_2	41.55	768.11
T_3	42.56	685.33
T_4	47.56	649.44
T_5	45.89	665.55
T_6	46.67	386.00
T_7	50.55	355.00
T_8	35.22	780.67
T_9	35.55	835.11
SEm(±)	0.45	2.11
CD (0.05)	1.35	6.31

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 12. Effect of foliar application of micronutrients and calcium on total yield plant^{-1} and days taken for maturity of fruits

Treatments	Total yield plant^{-1} (kg)	Days taken for maturity
T_1	24.68	127.00
T_2	23.57	127.22
T_3	25.75	127.00
T_4	32.85	120.33
T_5	29.56	124.44
T_6	31.07	122.33
T_7	36.50	118.00
T_8	15.29	130.77
T_9	13.67	131.67
SEm(±)	0.33	0.46
CD (0.05)	0.98	1.38

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

a) Treatment 9

- Control plants
- No micronutrients (boron and zinc) And calcium foliar spray

b) Treatment 7

Foliar spray of borax (0.5%) + zinc sulphate (0.5%)+ calcium nitrate (0.5%)

Plate 6. Size of papaya fruits from control and best treatment

Treatment 7

- Foliar spray of Borax (0.5%)
  + zinc sulphate (0.5%)
  + calcium nitrate (0.5%)

Treatment 9

Control plants
No micronutrients and
calcium foliar spray

Plate 7. Papaya plants of control and best treatment

difference over other treatments.

It was found that foliar application of micronutrients and calcium had a great influence on decreasing the days for fruit maturity in papaya.

4.3 QUALITY CHARACTERS

4.3.1 TSS

The data regarding the TSS value as influenced by the foliar application of micronutrients and calcium are depicted in the Table 13.

The highest value of TSS was reported from T_7 (14.5ºbrix) which was significantly different from other treatments. This was followed by T_6(14.00ºbrix) which was on par with T_4 (13.87 ºbrix) and differed significantly from other treatments. The lowest value was noted for T_9 (11.17ºbrix) which had significant difference over other treatments.

Foliar application of micronutrients (boron and zinc) and calcium @ 0.5% resulted in an increment in the TSS content of papaya.

4.3.2 Acidity

The influence of foliar application of micronutrients and calcium on the acidity of fruits are inscribed in the Table 13.

Acidity of papaya pulp was found to be lowest for T_7 (0.115%) which was on par with T_6 (0.127%) and differed significantly from other treatments. and highest value was recorded by T_9 (0.239%) which had significant difference over other treatments.

Acidity was found to be lowest when plants were sprayed with Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%).

4.3.3 Total carotenoids

The results about the total carotenoids presented in Table 13. It clearly indicated the effects of foliar application of micronutrients and calcium on total carotenoids content in papaya fruit.

The carotene content in the papaya was found to be highest for T_7 (2.27 mg $100g^{-1}$) which was differed significantly from other treatments followed by T_4 (2.14 $mg100g^{-1}$) which also differed significantly from other treatments. The lowest carotene content was recorded for T_9 (1.40 mg $100g^{-1}$).

Plants provided with Borax, zinc sulphate and calcium nitrate @ 0.5% foliar

Table 13. Effect of foliar application of micronutrients and calcium on TSS, acidity, total carotenoids and ascorbic acid content of papaya

Treatments	TSS (º brix)	Acidity (%)	Carotenoids (mg 100 g^{-1})	Ascorbic acid (mg 100 g^{-1})
T_1	13.13	0.16	1.80	57.27
T_2	13.13	0.17	1.78	56.90
T_3	13.27	0.16	1.83	57.53
T_4	13.87	0.14	2.14	61.73
T_5	13.73	0.14	1.98	59.03
T_6	14.00	0.13	2.04	60.73
T_7	14.50	0.12	2.27	65.30
T_8	11.93	0.22	1.47	45.43
T_9	11.17	0.24	1.40	43.20
SEm(±)	0.08	0.01	0.01	0.21
CD (0.05)	0.25	0.01	0.04	0.62

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

spray had influence on increasing the total carotenoid content of papaya fruits.

4.3.4 Ascorbic acid content

It is quite apparent from Table 13. that there is significant difference in the amount of ascorbic acid as influenced by the foliar application of micronutrients and calcium.

The different treatments of micronutrients and calcium given to papaya plants revealed that ascorbic acid content was significantly higher in T_7 (65.30mg $100g^{-1}$) which differed significantly from other treatments. This was followed by T_4 (61.73mg$100g^{-1}$) which also differed significantly from other treatments. The lowest value for ascorbic acid content was noticed with T_9 (43.20mg $100g^{-1}$) which had significant difference over other treatments.

4.3.5 Total sugars

The data regarding the influence of foliar application of micronutrients and calcium on total sugar content is presented in the Table 14.

Statistical data from table revealed that total sugar content was highest in T_7 (9.83%) which had significant difference over other treatments. This was followed by T_6 (9.40%) and T_4 (9.33) which were on par and lowest value was observed for T_9 (6.60%) which also differed significantly from other treatments.

Plants supplied with borax, zinc sulphate and calcium nitrate @ 0.5% showed an increment in total sugar content in papaya.

4.3.6 Reducing sugar

The results on the reducing sugar as influenced by the foliar application of micronutrients and calcium are illustrated in the Table 14.

Reducing sugar content was noticed higher in T_7 (8.60%) which was significantly different from other treatments. This was followed by T_6 (8.17%) which also differed significantly from other treatments and the lowest reducing sugar content was noticed with T_9 (5.17%) which had significant difference over other treatments.

4.3.7 Non-reducing sugar

Effects of foliar application of micronutrients and calcium on the content of non-reducing sugar are presented in the Table 14.

The lowest value for non-reducing sugar was found for the treatment, T_2 (0.733%) which differed significantly from other treatments. This was followed by T_5

Table 14. Effect of foliar application of micronutrients and calcium on Total sugar, reducing sugar and non-reducing sugar of papaya

Treatments	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
T_1	8.53	7.23	1.30
T_2	8.27	7.53	0.74
T_3	8.63	7.23	1.40
T_4	9.33	8.00	1.33
T_5	9.07	7.93	1.14
T_6	9.40	8.17	1.23
T_7	9.83	8.60	1.23
T_8	7.03	5.67	1.36
T_9	6.60	5.17	1.43
SEm(±)	0.04	0.04	0.06
CD (0.05)	0.12	0.11	0.17

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

(1.13%) which was on par with T_6 (1.23%), T_7 (1.23%) and T_1 (1.30%) and highest value for non-reducing sugar content was noticed with T_9(1.43%) which was on par with T_3 (1.40%), T_8 (1.37%), T_4 (1.33%) and T_1(1.30%).

4.3.8 Colour of pulp and peel

Color of pulp and peel of papaya fruit at edible ripe stage as influenced by the foliar application of micronutrients and calcium are presented in the Table 15.

Color of pulp and peel varies according to the treatment combination and color of peel was found to be Brilliant Greenish yellow (3B) for T_8 and Brilliant Greenish yellow (1A) for T_9, Brilliant Yellow (9C) for T_1, Brilliant Yellow (8A) for T_2 and Brilliant Yellow (9C) for T_3. Vivid Yellow (9B) was observed for T_4, Vivid Yellow (9B) for T_5, Vivid Yellow (9A) for T_6 and Vivid Yellow (12A) for T_7.

Pulp color was Vivid Yellowish Pink (30C) for T_4, Vivid Yellowish Pink (28A) for T_5, Vivid Yellowish Pink (30C) for T_6 and Vivid Yellowish Pink (30 B) for T_7. Vivid Orange (28 B) color of pulp was noted for T_1, Light Orange (28 C) for T_2 and Vivid Orange (28 B) for T_3. Treatment T_8 showed Light Yellowish Pink (26D) and T_9 showed Light Yellowish Pink (27A).

4.3.9 Firmness of pulp

Data on Firmness of pulp as influenced by the foliar application of micronutrients and calcium are presented in the Table 15.

Data on firmness of pulp of papaya revealed that treatment T_7 had highest firm flesh (91.74 N) and on par with T_4 (91.11 N) and T_6 (90.98 N) and lowest value was identified for control treatment (77.86 N) and it was on par with T_9 (77.92 N).

4.3.10 Organoleptic evaluation of fruits

The mean score for organoleptic qualities of fruits as influenced by the foliar application of micronutrients and calcium are depicted in the Table 16.

The mean score of all characters such as appearance, color, texture, taste, flavour and overall acceptability varied significantly among treatments. T_7 recorded highest mean score for appearance (8.63), color (8.61), Flavour (8.67), taste (8.90), texture (8.74) and overall acceptability (8.74). The lowest mean score for appearance was observed in T_8(6.39) and T_9 reported lowest score for color (6.37), flavour (6.20) ,texture (6.02), taste (6.16) and overall acceptability (6.04) .

Table 15. Effect of foliar application of micronutrients and calcium on color of pulp, color of peel and firmness of pulp of papaya

Treatments	Color of peel	Color of pulp	Firmness of pulp (N)
T_1	Brilliant Yellow (9C)	Vivid Orange (28B)	82.84
T_2	Brilliant Yellow (8A)	Light Orange (28C)	82.64
T_3	Brilliant Yellow (9C)	Vivid Orange(28B)	88.24
T_4	Vivid Yellow (9B)	Vivid Yellowish Pink (30C)	91.11
T_5	Vivid Yellow (9B)	Vivid Yellowish Pink(28A)	85.33
T_6	Vivid Yellow (9A)	Vivid Yellowish Pink (30C)	90.98
T_7	Vivid Yellow (12A)	Vivid Reddish Orange (30B)	91.74
T_8	Brilliant Greenish Yellow (3B)	Light Yellowish Pink (26D)	77.92
T_9	Brilliant Greenish yellow(1A)	Light Yellowish Pink (27A)	77.86

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

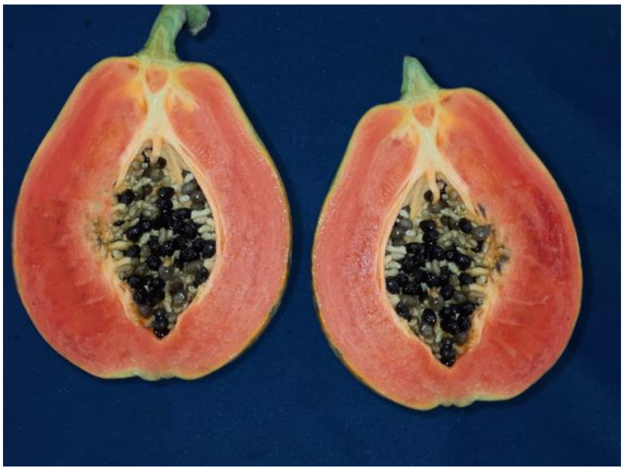
Treatment 7

- Foliar spray of Borax (0.5%) + zinc sulphate (0.5%) + calcium nitrate (0.5%)

Treatment 9

Control plants
No micronutrients (boron and zinc) and calcium foliar spray

Plate 8. Peel colour of papaya fruits from control and best treatment



Treatment 9

- Control plants
- No micronutrients(boron and zinc) and calcium foliar spray

b) Treatment 7

Foliar spray of Borax (0.5%) +
zinc sulphate (0.5%) +
calcium nitrate (0.5%)

Plate 9. Pulp colour of papaya from control and best treatment

Table 16. Effect of foliar application of micronutrients and calcium on organoleptic scoring of papaya fruit

Treatments	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
T_1	7.65 (57.20)	7.54 (51.06)	7.52 (51.25)	7.55 (53.69)	7.58 (53.69)	7.58 (55.43)
T_2	7.47 (49.00)	7.63 (58.23)	7.4 (49.50)	7.33 (48.03)	7.46 (51.07)	7.24 (52.63)
T_3	7.57 (53.40)	7.45 (49.77)	7.61 (58.30)	7.52 (57.37)	7.60 (58.07)	7.42 (55.37)
T_4	8.38 (102.50)	8.40 (106.97)	(8.40 (105.00)	8.46 (107.90)	8.50 (105.57)	8.22 (105.44)
T_5	8.27 (94.23)	8.24 (94.80)	8.24 (93.60)	8.18 (89.70)	8.31 (94.63)	8.06 (95.30)
T_6	8.43 (106.17)	8.35 (103.23)	8.38 (103.60)	8.38 (102.70)	8.47 (104.20)	8.17 (101.73)
T_7	8.63 (118.50)	8.61 (120.60)	8.67 (122.93)	8.74 (125.10)	8.90 (124.40)	8.74 (129.70)
T_8	6.39 (14.40)	6.43 (17.50)	6.32 (18.43)	6.23 (18.40)	6.27 (19.53)	6.14 (18.73)
T_9	6.46 (16.60)	6.37 (15.50)	6.20 (14.57)	6.02 (14.60)	6.16 (14.62)	6.04 (13.43)
K W value	122.13	123.06	123.47	124.19	121.97	127.94
χ^2 -15.51(8,0.05)						

⸎The value in the parenthesis is the mean rank

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

4.4 SHELF LIFE OF FRUITS AT AMBIENT CONDITIONS

The data related to the effect of foliar application of micronutrients and calcium on shelf life of papaya fruit at ambient condition are presented in the Table 17.

Highest shelf life of papaya fruit was obtained from T_7 (7.00 days) which differed significantly from other treatments. This was followed by T_6 (6.22 days) which was on par with T_4 (6.11 days) and T_5 (6 days) and lowest shelf life was identified for T_9 (4.2 days) which was on par with T_8 (4.42 days).

4.5 SOIL ANALYSIS AFTER THE EXPERIMENT

4.5.1 pH, EC and Organic carbon

Perusal data on soil analysis after experimentation in Table 18. It clearly indicates that foliar application of micronutrients and calcium did not have any significant effect on soil pH, EC and organic carbon content.

4.5.2 Soil NPK, B, Zn and Ca content

There was no significant difference noticed in the NPK content, boron, zinc and calcium content of soil as result of foliar application of different combination of micronutrients (B and Zn) and calcium are illustrated in the Table 19.

4.6 PLANT ANALYSIS

4.6.1 Plant NPK content

A reference to data presented in the Table 20. revealed the effects of micronutrients (Boron and Zinc) and calcium on index leaf NPK content.

The highest nitrogen content in index leaf petiole was estimated for T_7 (2.76%) and it was significantly different from other treatments. This was followed by T_6 (2.52%) which also differed significantly from other treatments. Lowest nitrogen content was found for T_8 (1.57%) which had significant difference over other treatments.

Index leaf analysis for leaf phosphorous content was found to be highest for T_7 (0.36%) which had significant difference over other treatments and was followed by T_4 (0.31%) which was on par with T_6 (0.30%) and T_5 (0.29%) which differed significantly over other treatments and T_9 (0.12%) recorded lowest percent of phosphorous and significantly different from other treatments.

The treatment T_5 (3.15%) registered highest percent of potassium content

Table 17. Effect of foliar application of micronutrients and calcium on shelf life of papaya

Treatments	Shelf life of fruit (Days)
T_1	5.20
T_2	5.30
T_3	5.66
T_4	6.11
T_5	6.00
T_6	6.22
T_7	7.00
T_8	4.42
T_9	4.20
SEm(±)	0.12
CD (0.05)	0.32

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 18. Effect of foliar application of micronutrients and calcium on Soil P^{H}, EC and Organic carbon after the experiment

Treatments	After experiment		
	Soil pH	EC (dSm^{-1})	Organic Carbon (%)
T_1	4.43	0.17	0.57
T_2	4.50	0.16	0.57
T_3	4.47	0.16	0.57
T_4	4.43	0.17	0.56
T_5	4.50	0.17	0.56
T_6	4.43	0.17	0.56
T_7	4.37	0.16	0.56
T_8	4.43	0.16	0.57
T_9	4.47	0.17	0.56
SEm(±)	0.05	0.01	0.00
CD (0.05)	NS	NS	NS

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 19. Effect of foliar application of micronutrients and calcium on nitrogen, phosphorous, potassium, boron, zinc and calcium content in soil after the experiment

Treatments	After experiment					
	Nitrogen (Kg ha^{-1})	Phosphorous (Kg ha^{-1})	Potassium (Kg ha^{-1})	Boron (ppm)	Zinc (ppm)	Calcium (ppm)
T1	154.03	29.87	95.44	1.12	2.13	118.13
T2	154.04	29.85	95.45	1.13	2.12	118.10
T3	154.04	29.86	95.45	1.14	2.14	118.13
T4	154.05	29.86	95.46	1.13	2.12	118.20
T5	154.04	29.84	95.45	1.13	2.12	118.06
T6	154.05	29.88	95.43	1.13	2.13	118.06
T7	154.06	29.87	95.43	1.12	2.12	118.10
T8	154.04	29.88	95.44	1.14	2.13	118.13
T9	154.07	29.84	95.44	1.14	2.14	118.37
SEm(±)	0.07	0.01	0.03	0.01	0.01	0.04
CD (0.05)	NS	NS	NS	NS	NS	NS

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

in leaf petiole which was significantly different from other treatments and was followed by T_7 (3.07%) which also had significant difference over other treatments. T_9 (1.21%) recorded least value which differed significantly from other treatments.

4.6.2 Plant micronutrient (Boron and Zinc) and calcium content

A significant difference among treatments for micronutrient content in leaf petiole of papaya is illustrated in Table 21.

The treatment T_7 (38.12ppm) resulted in highest leaf boron content which was significantly different from other treatments and was followed by T_4 (36.32ppm) which also had significant difference over other treatments. Whereas T_9 (18.24ppm) recorded lowest value and was on par with T_8 (18.98ppm) which had significant difference over other treatments.

The data on leaf Zinc content revealed a significantly highest value for T_7 (68.37ppm) followed by T_5 (63.43ppm) and both of them differed significantly from other treatments. The least value for zinc content in petiole was recorded for T_9 (9.17ppm) which also had significant difference over other treatments.

The estimation of leaf analysis for Calcium content was significantly high for T_7 (8547.23ppm) which was followed by T_6 (5521.13 ppm) and both of them were significantly different from other treatments. T_9 (1210.30ppm) observed to be lowest value for leaf petiole calcium content which had significant difference over other treatments.

4.7 FRUIT ANALYSIS

4.7.1 Fruit NPK content

The data on the fruit NPK content as influenced by foliar application of micronutrients and calcium inscribed in the Table 22.

The fruit analysis revealed the highest nitrogen content in T_7 (4.64ppm) which showed significant difference from others and was followed by T_6 (4.14 ppm) which also differed significantly from other treatments. The lowest nitrogen content in the fruit was noted for T_9 (1.97 ppm) which was on par with T_8 (2.03 ppm).

The highest fruit phosphorous content was obtained in the treatment T_7 (90.40ppm) which was significantly different from other treatments and was followed by T_4 (77ppm) which also significantly difference from other treatments. T_9 (31.17 ppm) showed lowest value for fruit phosphorous content which had significant

Table 20. Effect of foliar application of micronutrients and calcium on Nitrogen, Phosphorous and Potassium content in leaf petiole of papaya

Treatments	Nutrients		
	Nitrogen (%)	Phosphorous (%)	Potassium (%)
T_1	2.03	0.20	2.42
T_2	2.10	0.19	2.16
T_3	2.16	0.22	2.02
T_4	2.42	0.31	2.80
T_5	2.32	0.29	3.15
T_6	2.52	0.30	2.74
T_7	2.76	0.36	3.07
T_8	1.57	0.15	1.37
T_9	1.72	0.12	1.21
SEm(±)	0.02	0.01	0.01
CD (0.05)	0.05	0.02	0.03

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 21. Effect of foliar application of micronutrients and calcium on Boron , Zinc and Calcium content in leaf petiole of papaya

Treatments	Micronutrients and Calcium		
	Boron (ppm)	Zinc (ppm)	Calcium (ppm)
T_1	33.56	34.17	2236.11
T_2	24.48	59.77	2436.17
T_3	25.14	36.57	4641.20
T_4	36.32	43.70	5205.03
T_5	35.24	63.43	4941.30
T_6	25.10	60.37	5521.13
T_7	38.12	68.37	8547.23
T_8	18.98	10.20	1260.70
T_9	18.24	9.17	1210.30
SEm(±)	0.28	0.08	0.18
CD (0.05)	0.85	0.24	0.53

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

difference over other treatments.

The data on fruit potassium content noted the highest for T_5 (3254.33ppm) followed by T_7 (3172 ppm) and both of them were significantly different from other treatments. The least fruit potassium content was identified for T_9 (1112.33ppm) which had significant difference over other treatments.

4.7.2 Fruit micronutrient (Boron and Zinc) and calcium content

The data regarding fruit micronutrient (B and Zn) and calcium content as influenced by foliar spray of micronutrient and calcium are illustrated in Table 23.

The treatment T_7(1.45 ppm) recorded highest values for fruit boron content and this was followed by T_5(1.37 ppm) and both of them were significantly different from other treatments. The lowest boron content was identified for T_9(0.947 ppm), which also had significant difference over other treatments.

The chemical analysis for fruit Zinc content resulted in highest value for T_7 (0.41 ppm), which was significantly different from other treatments. This was followed by T_6 (3.93 ppm) which also had significant difference over other treatments. T_9(0.20 ppm) and T_8 (0.20 ppm) the lowest value and differed significantly from other treatments.

The treatment T_7 (721.33ppm) reported significantly the highest value for fruit calcium content and this was followed by T_6 (682 ppm) and both of them were significantly different from other treatments. T_9 (321.67 ppm) resulted in least fruit calcium content which had significant difference over other treatments.

4.8 PEST AND DISEASE INCIDENCE

There was no severe incidence of pest and disease in the field and the incidence was less than 1% for observed disease such as foot rot and leaf spot of papaya.

4.9 ECONOMIC ANALYSIS

The data regarding the net income and B:C ratio of papaya cultivation as influenced by the foliar application of micronutrients and calcium are depicted in the Table 24.

4.9.1 Net income

The foliar application of micronutrients and calcium on papaya has shown a significant influence on net income and the highest net income was noted for T_7

Table 22. Effect of foliar application of micronutrients and calcium on Nitrogen, Phosphorous and Potassium content in papaya fruit

Treatments	Nutrients		
	Nitrogen (ppm)	Phosphorous (ppm)	Potassium (ppm)
T_1	3.34	50.33	2572.00
T_2	3.33	47.23	2261.67
T_3	3.47	55.50	2122.33
T_4	4.03	77.00	2903.67
T_5	3.81	73.00	3254.33
T_6	4.14	74.50	2842.00
T_7	4.64	90.40	3172.00
T_8	2.03	37.60	1475.67
T_9	1.97	3.17	1112.33
SEm(±)	0.03	0.25	2.08
CD (0.05)	0.08	0.745	6.25

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 23. Effect of foliar application micronutrients and calcium on Boron , Zinc and Calcium content in papaya fruit

Treatments	Micronutrients and Calcium		
	Boron (ppm)	Zinc (ppm)	Calcium (ppm)
T_1	1.32	0.25	527.00
T_2	1.14	0.38	501.33
T_3	1.18	0.23	582.00
T_4	1.32	0.25	591.67
T_5	1.37	0.26	542.67
T_6	1.28	0.39	682.00
T_7	1.45	0.41	721.33
T_8	0.98	0.20	342.00
T_9	0.95	0.20	321.67
SEm(±)	0.00	0.00	0.43
CD (0.05)	0.01	0.00	1.30

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

Table 24. Net income and B:C Ratio of papaya grown under foliar spray of micronutrients and calcium

Treatments	Net income (Rs ha^{-1})	B:C Ratio
T_1	159240	1.56
T_2	139260	1.49
T_3	178500	1.63
T_4	271735	1.93
T_5	215476	1.74
T_6	241297	1.83
T_7	301300	2.04
T_8	66636	1.32
T_9	46060	1.23
SEm(±)	49.61	0.01
CD (0.05)	75.56	0.04

1) T1 - Borax (0.5%)

2) T2 - Zinc sulphate (0.5%)

3) T3 - Calcium nitrate (0.5%)

4) T4 - Borax (0.5%) + Calcium nitrate (0.5%)

5) T5 - Borax (0.5%) + Zinc sulphate (0.5%)

6) T6 - Zinc sulphate (0.5%) + Calcium nitrate (0.5%)

7) T7 – Borax (0.5%) + Calcium nitrate (0.5%) + Zinc sulphate (0.5%)

8) T8 - Water spray

9) T9 - Control (KAU, POP-2016)

(Rs.301300). This was followed by T_4 (Rs.271735) and both of them were significantly different from other treatments. The least net income was observed for T_9 (Rs.46060) which also showed significant difference from other treatments.

4.9.2 B: C ratio

The highest B:C ratio was recorded for T_7 (2.04) which differed significantly from other treatments. This was followed by T_4 (1.93) which also had significant difference over other treatments. The lowest B:C ratio noted for T_9 (1.23) which was significantly different from other treatments.

Discussion

5. DISCUSSION

Papaya (*Carica papaya* L.) is an important fruit crop of Kerala having high nutritive value and good yield potential. Application of micronutrients and secondary nutrients along with the application of macronutrients play a key role in the growth and development of papaya, thereby improving the crop yield, post-harvest life and value of the produce. In the current investigation, papaya plants were supplied with micronutrients (B and Zn) and calcium as foliar spray in order to find out its effect on growth, yield and quality. The experimental results regarding the growth, yield, quality, nutrient status of soil, plant and fruit, pest and disease incidence and economics are analysed and discussed below.

2.1 BIOMETRIC CHARACTERS

2.1.1 Height and girth of plants and number of leaves

The present study indicated that foliar application of Borax (0.5%) and Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) resulted in highest plant height, plant girth and number of leaves in papaya (Fig.2). Foliar application of micronutrients (B and Zn) and calcium had a significant influence in increasing the plant height and leaf number of papaya plant at all stages of growth except 2 MAP and 4 MAP. But it had significant influence in increasing the stem girth of papaya at all stages of growth.

The findings of the present study are supported by the results of Ahmed *et al*. (1992), Veena and Lavania (1998), Singh *et al.* (2000), Modi *et al*. (2012), Madani *et al*. (2013) and Manjunatha *et al*. (2014) in papaya. Jeykumar (2001) reported that foliar application of $ZnSO_4$ (0.5%) along with H_3BO_3 (0.1%) resulted in highest stem girth and number of leaves in papaya cv.CO-5. This result is in agreement with the findings of the present study also. Bhalerao and Patel (2015) noticed the highest plant height, stem girth and leaf area of papaya var. Taiwan Red Lady was seen under foliar application of calcium nitrate 1000 mg L^{-1}, borax 30 mg L^{-1} along with zinc sulphate 200 mg L^{-1}. Results of the present experiment also showed an increase in plant height, girth and leaf number due to the foliar application of boron, zinc along with calcium.

This might be due to the increase in vegetative characters regulated by zinc, boron and calcium. Zinc acts as an essential constituent of tryptophan, the precursor of auxin which helps to enhance vegetative growth and reduce abscission (Bhalerao and Patel, 2015) and zinc will also improve the photosynthetic rate and chlorophyll content, finally leading to increased canopy area (Khan *et al*., 2009 and Gurung *et al*., 2016).

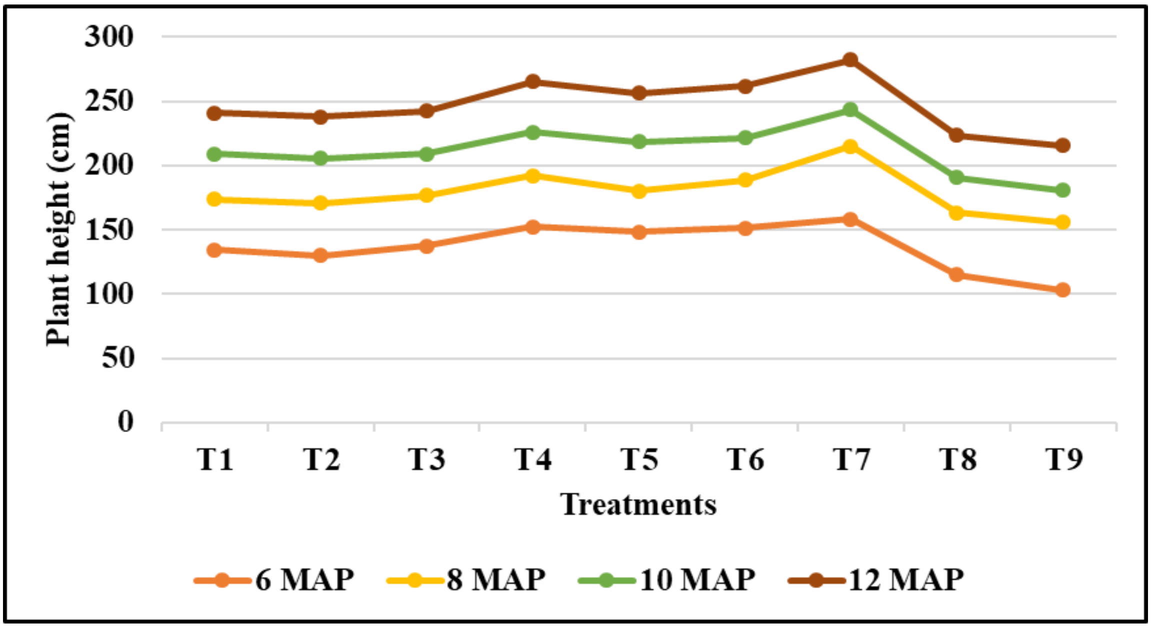
A higher concentration of boron will increase the amount of phenolic compounds regulating the polar auxin transport and enhance the vegetative growth in plants (Brawn and Amber, 1973). Boron and Zinc help in nitrogen metabolism which resulted in more nitrogen uptake (Meena, 2013). Increment in the amount of plant metabolites in cells responsible for cell division, cell elongation and plant growth due to the increased metabolic activities regulated by the combined effects of boron and zinc (Bhalerao and Patel, 2015).

Insufficient level of Calcium will lead to reduced meristematic growth and malformation of newly emerged leaves (Mengel and Kirkby, 2001) and $Ca(NO_3)_2$ has the potential to enhance more vigorous shoot growth (Elmore *et al*., 2007). Calcium is required for cell division and elongation, and it increases plant height by enhancing the mitotic activity in plant shoot meristems (Dodd *et al*., 2012). Similar findings were noted by Rab and Haq (2012). Easter wood (2005) noticed that calcium deficiency will lead to the death of growing points, abnormally dark green foliage and weakened stems in plants.

2.1.2 Height at first flowering, days to flowering and time for harvest

The current experiment recorded a significant reduction in height at first flowering, days to flowering and time for the harvest of fruit for the plants treated with foliar application of borax, zinc sulphate along with calcium nitrate @ 0.5% each as foliar spray (Fig 3.). The result was in harmony with the reports of Reddy (2010) who noted that foliar application of boron 0.2 per cent resulted in lowest plant flowering height and minimum days to flowering in papaya cv. Sunrise Solo. An experiment carried out by Meena (2013) in papaya cv. Red Lady revealed that plants received 50g Zinc Sulphate and 20g Borax bears flowering at a lower node and a minimum number

Fig. 2. Effect of foliar application of micronutrients and calcium on plant height of papaya



of days required for fruit setting to harvest. The results are in conformity with Modi *et al.* (2012) who noticed a significant reduction in days to flower bud initiation and minimum days taken for fruit setting to the first harvest in papaya cv. Madhu Bindu as influenced by higher levels of borax. The experimental results also correlated with the findings of Alila *et al*. (2004), Shekhar *et al*. (2010) Singh *et al*. (2010), Bhalerao and Patel (2015) and Yadav and Solanki (2015).

Due to increased metabolic activities such as translocation of carbohydrates, nitrogen metabolism, respiration, cell wall development and RNA synthesis by boron and zinc will finally lead to a lower height at first flowering, earliness in flowering and early fruit maturity (Ding *et al*., 1991). The activity of boron on indigenous florigenic substances and stimulation on flower initiation behaviour (Reddy, 2010) or completion of vegetative growth in the early stage may reduce the days taken to first flowering in papaya (Shekher *et al*., 2010).

2.1.3 Sex expression and sex ratio of plants

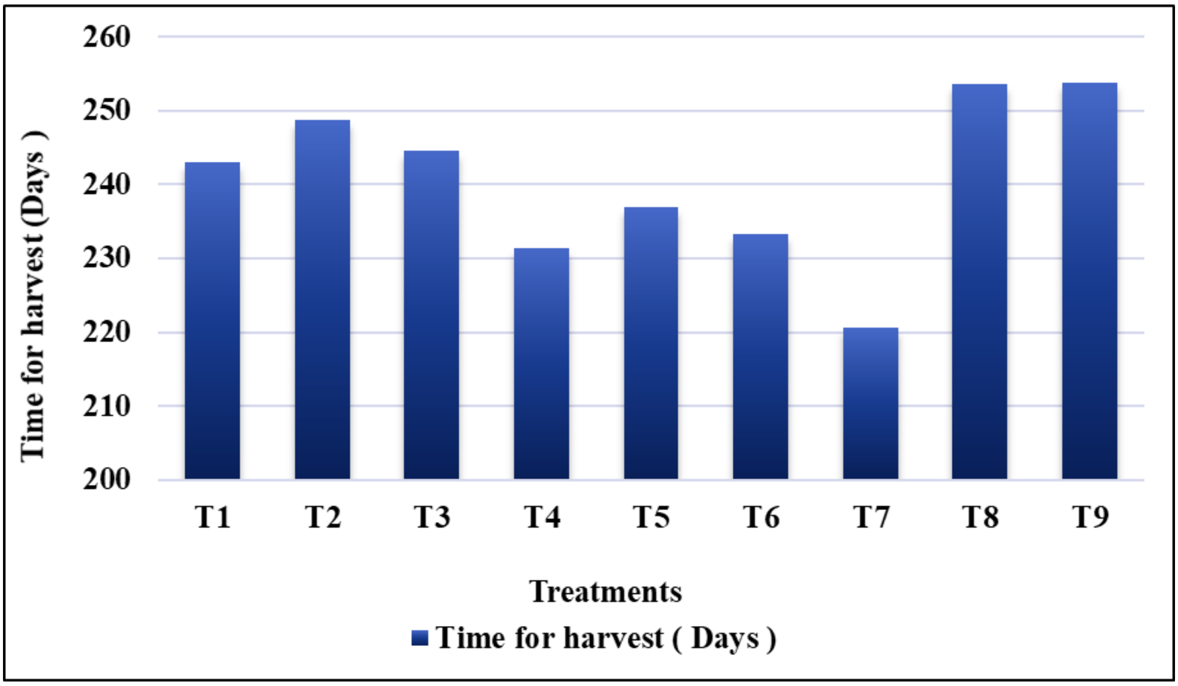
In the present investigation, foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) significantly increased the number of female plants compared to bisexual plants in papaya but did not have a significant effect on sex ratio of papaya. This may be due to the effect of boron in enhancing the level of indole acetic acid which helps to increase femaleness (Puzzina, 2004).

The results were compared with the reports of Veena and Lavania (1998) who observed a significant increase in female plants in Pant papaya-1 when treated with a foliar spray of $ZnSO_4$ (0.15 per cent) along with $FeSO_4$ (0.15 per cent). Ghanta *et al*. (1994) and Shanmugavelu *et al*. (1973) agreed with similar results in papaya and Farid *et al*. (2007) in jack fruit.

2.1.4 Number of flowers per cluster and Fruit set

Results of the present study revealed that foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) increased the number of flowers per cluster and fruit set per cent in papaya.

Fig. 3. Effect of foliar application of micronutrients and calcium on time taken for harvest of papaya fruits



Meena (2013) agreed with similar results in papaya cv. Red Lady where the application of 0.25% $ZnSO_4$ and 0.1% borax recorded more number of flowers and higher fruit set. Similarly, foliar application of boron (0.05%) resulted in the production of the highest number of flowers and highest fruit set in papaya cv. Sunrise Solo (Reddy, 2010). Similar findings were reported by Mansour and El-Sied (1981) in guava, Dutta *et al*. (2000) in litchi and Manjunatha *et al.* (2014) in papaya.

Increase in number of flowers may be due to the role of micronutrient on enhancing the flowering through auxin biosynthesis (Veena and Lavania, 1989) or reduction in premature shedding of blossoms and buds as stimulated by calcium (Easterwood, 2005)

Increase in fruit set percentage might be due to the effect of boron on stimulating more production of pollen, increase pollen viability (Madani *et al*., 2012) better pollen germination, pollen tube growth and fertilization process (Peres-Lopez and Reyes-Jurado, 1983 and Youzhi and John, 1995) or reducing the abscission of flower buds and flowers by micronutrients (Veena and Lavania, 1989). Increase in auxin content due to the action of Zinc also helps in fruit set and growth (Bhalerao and Patel, 2015).

2.2 YIELD CHARACTERS

2.2.1 Weight, length, girth and volume of fruit

From the study, it was noted that yield parameters of papaya like fruit weight, length, girth and volume of fruits were increased significantly with foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%).

The results of the present experiment were confirmed with earlier reports of Reddy (2010) who noticed that foliar application of boron 0.2 per cent per papaya cv. Sunrise Solo led to the highest fruit weight, length, girth and volume. Similarly, Manjunatha *et al*. (2014) noticed that highest fruit length weight, girth and volume in papaya cv. Red Lady treated with $ZnSO_4$, Borax and $FeSO_4$ at 0.25%, 0.1% and 0.5% respectively. These results were also correlated with the findings of

Chattopadhyay and Gogoi (1988), Lokhande and Moghe (1998), Veena and Lavania (1998), Meena (2013) and Bhalerao and Patel (2015) in papaya.

Enhancement in fruit weight, length, girth and volume may be due to the accumulation of more dry matter in the fruit by the translocation of carbohydrates from the leaf to fruit and rapid synthesis of protein in the developing fruits regulated by zinc and boron (Singh *et al*., 2000 and Singh *et al*., 2010) or movement of more water into fruits through semi permeable cell membrane regulated by zinc thus resulting increase in fruit size (Bhalerao and Patel, 2015).

2.2.2 Pulp percentage and Flesh thickness

Highest value for pulp percentage and flesh thickness was observed with the application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) as foliar spray.

The results are in line with the reports of Reddy (2010) in papaya cv. Sunrise Solo who recorded that foliar application of boron 0.2 per cent per plants resulted in highest pulp percentage and flesh thickness. Similarly, maximum pulp thickness and pulp content in papaya cv. Ranchi was observed by Singh *et al*. (2010) in the plants treated with borax at 0.50% and $ZnSO_4$ at 0.25%. Similar findings were noted by Dutta *et al*. (2000), Singh *et al*. (2007), Meena (2013) in papaya, Haq *et al*. (2013) in Litchi and Waskela *et al*. (2013) in guava.

Accumulation of more photosynthates in the fruits due to the action of boron and zinc will lead to more pulp percentage and flesh thickness (Singh *et al*., 2000 and Singh *et al*., 2010).

2.2.3 Number of fruits per plant, number of seeds per fruit and total yield per plant

In the current study, foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) significantly increased the number of fruits per plant and total yield per plant and reduced the number of seeds per fruit (Fig 5.).

The results given by Ahmed *et al*. (1992) also was in corroboration with findings of present study where the application of 5 to 10 g boron per plant in papaya cv.P-011 significantly increased the number of fruits plant-^{1} and yield. Kavitha *et al*. (2000b) reported that foliar sprays of Zn @ 0.5% and B @ 0.1% at 4th, 8th, 12th and 16th month after planting improved the total number of fruits per tree and yield in papaya cv.CO-5. Raja (2010) found that boron treated fruits showed more healthy seeds in two papaya cultivars, Surya and Red Lady compared to control. Similar results were found by Rawat *et al*. (2010) in guava cv. Luknow-49. Results of the present experiment were also correlated with the findings of Reddy (2010), Modi *et al*. (2012), Meena (2013), Bhalerao and Patel (2015) and Vasanthu *et al.* (2015).

More number of fruit production possibly due to the presence of more number of flowers and high fruit set. Synthesis of more protein and IAA as influenced by zinc (Jeykumar *et al*., 2001) or higher fruit setting, fruit retention, fruit growth and development (Shekher *et al*., 2010) also leads to more fruit number. Garcia *et al*. (1984) reported that fruit drop decreased as leaf Zn content increased. Supplemental foliar sprays of micronutrients during flowering have been shown to increase the number of fruit (Whiley *et al.*, 1996). Zinc stabilizes membrane permeability by increasing the mobility of Calcium to fruits. Calcium being a main constituent of cell wall in the form of calcium pectate which plays an important role in the strengthening of pedicel attached to the proximal end of fruit resulted in less fruit drop (Edward (2009) and Gupta *et al*. (1985).

Higher yield may be due to the increase in number of fruits and fruit weight, or reduction in fruit drop (Shekher *et al*., 2010) due to more fruit retention because of biosynthesis of IAA by boron and Zinc (Meena, 2013). According to Krishnamoorthy (1992), fruit drop is an abscission phenomenon controlled by the application of zinc

which ultimately reduces the fruit drop by encouraging the endogenous auxin production. Boron also reduces the activity of abscisic acid (Veena and Lavania, 1989) due to the indirect action in auxin synthesis that delayed the formation of abscission layer during early stages of fruit development (Guardiola and Garcia, 2000).

Fig. 4. Effect of foliar application of micronutrients and calcium on fruit weight of papaya

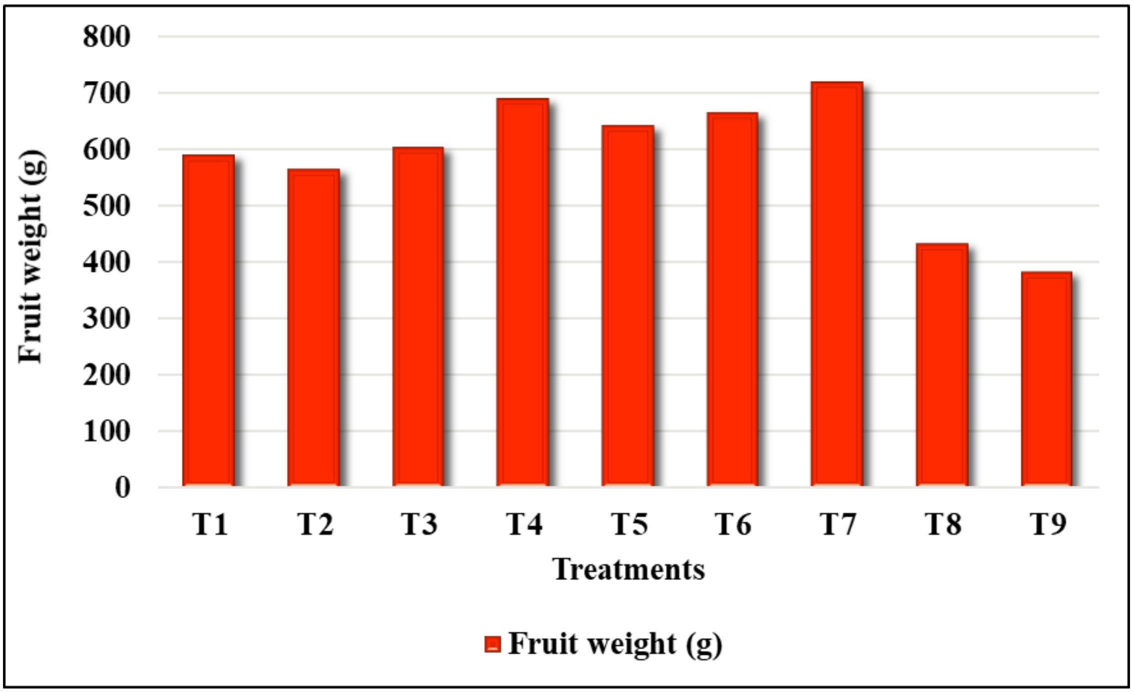
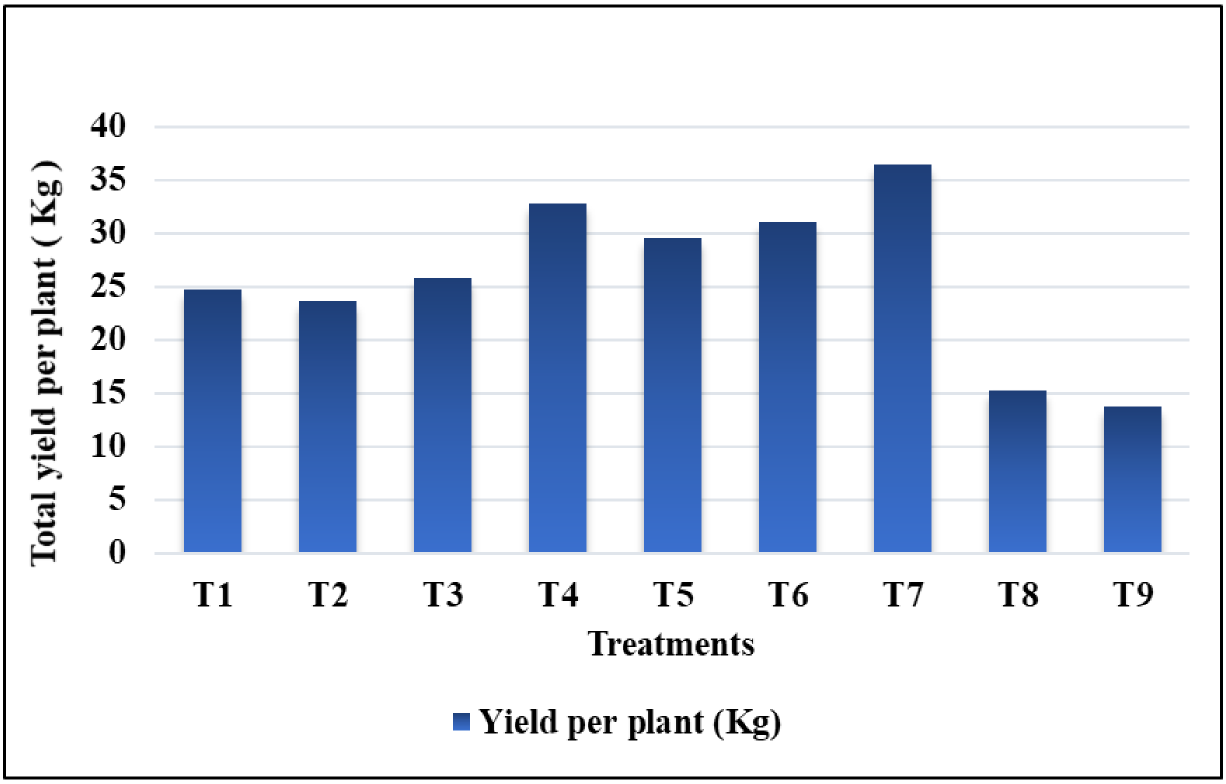


Fig. 5. Effect of foliar application of micronutrients and calcium on total yield plant^{-1} of papaya



2.2.4 Days taken for fruit maturity

Observation on days taken for the maturity of fruit as influenced by the foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) recorded the least value.

The present study was also correlated to the results of Reddy (2010) who noted that in papaya cv. Sunrise Solo, soil application of boron @ 0.2% resulted in minimum days taken for fruit maturity. Sachin *et al*. (2019) reported that foliar application of Zinc sulphate (1%) + Borax (1%) + Copper sulphate (1%) resulted in minimum days for fruit maturity in guava cv. Lalit. This may be due to increased metabolic activities such as translocation of carbohydrates, nitrogen metabolism, respiration, cell wall development and RNA synthesis by boron and zinc (Ding *et al*., 1991).

2.3 QUALITY CHARACTERS

2.3.1 TSS, Acidity, Total carotenoids and Ascorbic acid content

The present study revealed that highest TSS, total carotenoids, ascorbic acid content and lowest acidity was recorded for the treatment, foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) (Fig 6.).

The results of the present study is in conformity with the reports of Singh *et al*. (2000) who revealed that foliar application of borax at 0.50% and $ZnSO_4$ at 0.25% increased TSS, total carotenoids, ascorbic acid and decreased acidity in papaya cv. Ranchi. Reddy (2010) reported that highest TSS, total carotenoids, ascorbic acid and minimum acidity in papaya cv. Sunrise Solo as a result of foliar application of boron 0.2 per cent. Veena and Lavania (1989), Madani *et al*. (2012), Modi *et al*. (2012), Meena (2013) and Bhalerao and Patel (2015) also arrived at similar results in papaya.

The increased biosynthesis of metabolites, translocation of photosynthates and minerals into developing fruits promoted by Zinc and Boron might have resulted in higher total soluble solids in fruits (Jeykumar *et al*., 2001).

The decrease in titrable acidity might be due to conversion of acids into sugars and its derivatives by the action of boron and zinc during glycolytic pathway or respiration or both (Singh *et al*., 2010). Accumulation of total sugar (Meena, 2013) by the breakdown of starch to sugar, synthesis of protein, neutralization of physiologically important organic acid by boron also helps to reduce acidity (Reddy, 2010). Micronutrient application may enhance the carotene content of papaya fruit by improving the carotene synthesis.

The higher ascorbic acid content in papaya fruits might be due to the conversion of sugars into ascorbic acid influenced by boron and zinc (Kavitha *et al*., 2000a) or low oxygen permeability of tissues stimulated by calcium by inhibiting the action of oxidizing enzymes which delay oxidation reaction of vitamin C and reduce the vitamin C loss (Ayranci and Tunc, 2004 and Eryani-Raqeeb *et al*., 2009). Singh *et al*. (2005) and Madani *et al*. (2016) found similar results. Zinc application also increased the ascorbic acid content because of more accumulation of total soluble solids or availability of more metabolites for ascorbic acid synthesis (Kumar and Shukla, 2005).

2.3.2 Total sugars, Reducing sugar and Non reducing sugar

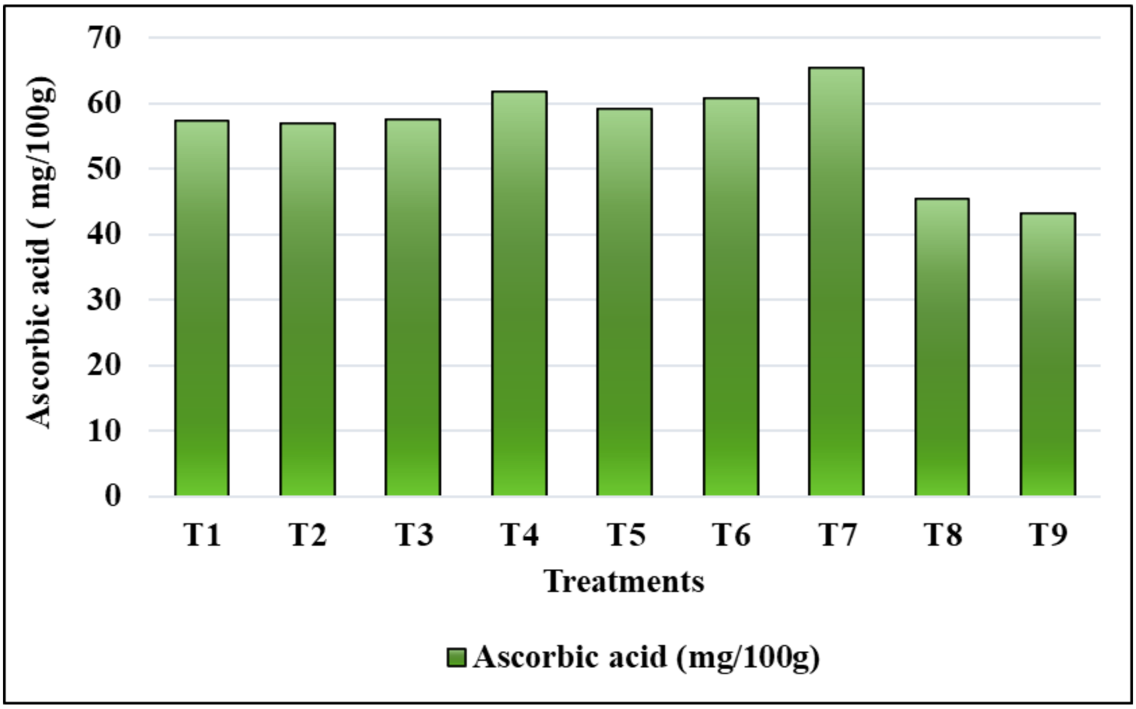
Higher values for total sugars and reducing sugar was obtained with the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) However, the highest value for non-reducing sugar was noted for control.

Higher value for total sugar and reducing sugar for papaya var. Taiwan Red Lady was found with the foliar application of calcium nitrate 1000 mg L^{-1}, borax 30 mg L^{-1}, zinc sulphate 200 mg L^{-1} and ferrous sulphate 200 mg L^{-1} (Bhalerao and Patel, 2015). Similar findings were also noted by Kavitha *et al*. (2000a) and Modi *et al*. (2012) in papaya.

More accumulation of sugars might be due to carbohydrate transformation, hexokinase activity and breakdown of starch to sugar by the role of Zinc, which acts as a catalyst in oxidation-reduction processes in plants (Bhalerao and Patel, 2015).

2.3.3 Colour of pulp and peel and Firmness of pulp

Fig. 6. Effect of foliar application of micronutrients and calcium on ascorbic acid content in papaya



The current investigation clearly indicated that an improvement in colour of pulp and peel and firmness of pulp of fruit were noticed in the plants receiving foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%).

Findings of Bhalerao and Patel, 2015 is in accordance with current study where, higher firmness of fruit of papaya var. Taiwan Red Lady was found with the foliar application of calcium nitrate 1000 mg l^{-1}, borax 30 mg l^{-1}, zinc sulphate 200 mg l^{-1} and ferrous sulphate 200 mg l^{-1}. Manjunatha *et al*. (2014) concluded that in papaya cv. Red Lady, plants treated with $ZnSO_4$ (0.25%) and Borax (0.1%) six days after the harvest of fruits showed good colour development. The present study was in uniformity with the results of Ramakrishna *et al*. (2001), Reddy (2010) and Madani *et al*. (2013) in papaya.

Increase in the amount of carotenoids will improve the colour of pulp and peel and structural integrity provided by calcium will enhance the firmness of fruits.

2.3.4 Organoleptic evaluation of fruits

In the present study, foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) resulted in highest mean score for appearance, color, flavour, taste, texture and overall acceptability in papaya.

Similarly, findings of Madani *et al*. (2015) registered that texture and flavor of papaya fruits (Eksotika II) were improved with preharvest calcium application at the rate of 4000 or 5400 mg l^{-1}. Ratananukul *et al.* (1988) reported similar finding in colour and appearance of papaya.

Higher TSS, total sugars, ascorbic acid and low acidity may improve the taste and flavour of papaya fruits. Improved texture and appearance can be achieved through the application of boron which reduces the number of bumpy fruits in papaya with uneconomical distorted fruits (Nishina, 1991). Calcium application improves the structural integrity of cell wall (Madani *et al*., 2015) where calcium ions forming the cross links between free carboxyl groups of the pectin chains which is the constituent of cell wall (Garcia *et al*., 1996) or by controlling the water transmission from fruits due to the formation of calcium pectate as a result of interaction between calcium and pectic acid (Rolle and Chism, 1987).

2.4 SHELF LIFE OF FRUITS

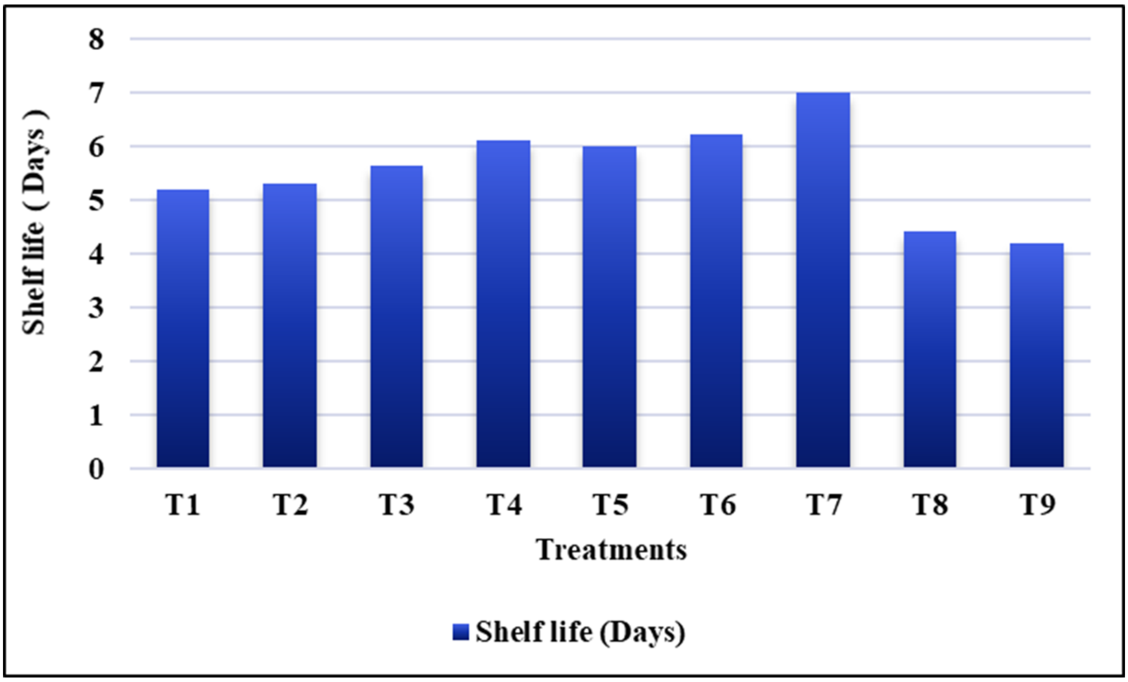
A significant increase in the shelf life of papaya fruits was obtained due to the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate(0.5%) (Fig 7.).

Increased shelf life of papaya var. Taiwan Red Lady was found with the foliar application of calcium nitrate 1000 mg L^{-1}, borax 30 mg L^{-1}, zinc sulphate 200 mg L^{-1} and ferrous sulphate 200 mg L^{-1} (Bhalerao and Patel, 2015). Similar results was previously reported by Kavitha *et al*. (2000a), Madani *et al.* (2014) and Manjunatha *et al*. (2014). Meena (2013) reported that application of $ZnSO_4$ (0.5%) and borax (0.2%) recorded 24.35% higher shelf life in papaya cv. Red Lady.

Longer shelf life may be due to increased stability and strength of cell walls due to enhanced calcium content in the tissue which provides resistance to harmful enzymes produced during microbial infestation and also delays the aging of fruits (Lara *et al*., 2004). Resistance may be due to the formation of cross-links between the free carboxyl group within the pectin-polysaccharide matrix as influenced by the calcium ions (Easterwood, 2005) or calcium may affect the osmotic balance in the microbial cells and thereby inhibiting the pectinolytic enzymes production (Arras *et al*., 1998) or calcium application may reduce the spore germination, sporulation and growth of pathogens, finally reduces the decay of fruits during storage (Conway *et al*., 1994 and Singh *et al*., 2005). Agusti *et al*. (2004) registered that low calcium concentration in fruits leads to inferior quality and short storage life.

Increased calcium concentration will decrease the level of ethylene (Madani *et al*., 2016) since, Calcium is able to trigger the biosynthetic pathway of ethylene production by inactivating enzymatic reaction (Njoroje *et al*., 1998) or a significant reduction in weight loss of papaya can be brought due to enhancement in cell wall

Fig. 7. Effect of foliar application of micronutrients and calcium on shelf life of papaya fruit



resistance to water permeability as a result of the addition of calcium (Han *et al*., 2004). Raja (2010) found that boron has an essential role in calcium mobility.

2.5 SOIL ANALYSIS

Data on soil analysis indicated that foliar spray of micronutrients (B and Zn) and calcium did not have any significant effect on soil pH, EC, available organic carbon, nitrogen, phosphorous, potassium, boron, zinc and calcium content.

2.6 PLANT ANALYSIS

The present experiment revealed that highest nitrogen, phosphorous, boron, zinc and calcium content in the leaf petiole was recorded for the treatment, foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%), where foliar spray of Zinc sulphate (0.5%) and Borax (0.5%) registered highest value for potassium content (Fig 9.).

Jeykumar *et al*. (2001) found that plants treated with 0.5% $ZnSO_4$ and 0.1% H_3BO_3 showed higher micronutrient concentration in the leaves of papaya. Foliar application of 0.03 % borax on papaya increased leaf boron status and in papaya cv. Red Lady (Vasanthu *et al*., 2015). A single spray of Boron in banana cv. Giant Governor showed the highest amount of N, P and K in leaf (Ghanta and Mitra, 1993).

Madani *et al*. (2013) suggested that spraying of higher levels of calcium may induce higher calcium and lower potassium in papaya leaves where calcium shows synergistic effect at lower concentration (Premaratne and Oertli, 1994) but at higher concentration antagonism between calcium and potassium resulted in less leaf potassium content (Zharare *et al*., 2009).

Higher leaf nitrogen in papaya might be due to the supply of nitrogen with calcium nitrate (Madani *et al*., 2013). Similar results were found by Abdel-Hafeez *et al*. (2010). Pandey and Sinha (2006) opined that boron has a stimulant effect on leaf nitrogen content or intensified nitrate absorption from the soil. Decreased activity of nitrate reductase enzyme by boron application was found by Kumar and Shukla (2005).

Madani *et al*., 2015 identified that phosphorous concentration in leaves of papaya was increased with increasing calcium concentration because of the synergistic effect between phosphorous and calcium. Hamzawi (2010) and Kadir (2005) concluded the same result in apple. Highest phosphorus content may be due to higher phosphorus uptake by leaves, high phosphorus metabolism and more translocation of phosphorous into the plant.

Foliar application of boron and soil application of phosphorous enhance the boron uptake from soil (Gunes and Alpaslan, 2000). Plant boron concentration increased with increasing boron application and was greater around pH 6 (Smith *et al*., 2013). Synergistic effect of boron and zinc enhances the boron concentration in plant tissue (Shaaban et al., 2004).

Foliar application of micronutrients and calcium at a higher level increase their concentration in leaf petiole because foliar spray enhance the absorption of nutrients and utilizing it for the physiological activity (Topcuoglu, 2002). Application of zinc improved the leaf nitrogen and Zinc content (Dutta and Dhua, 2002).

2.7 FRUIT ANALYSIS

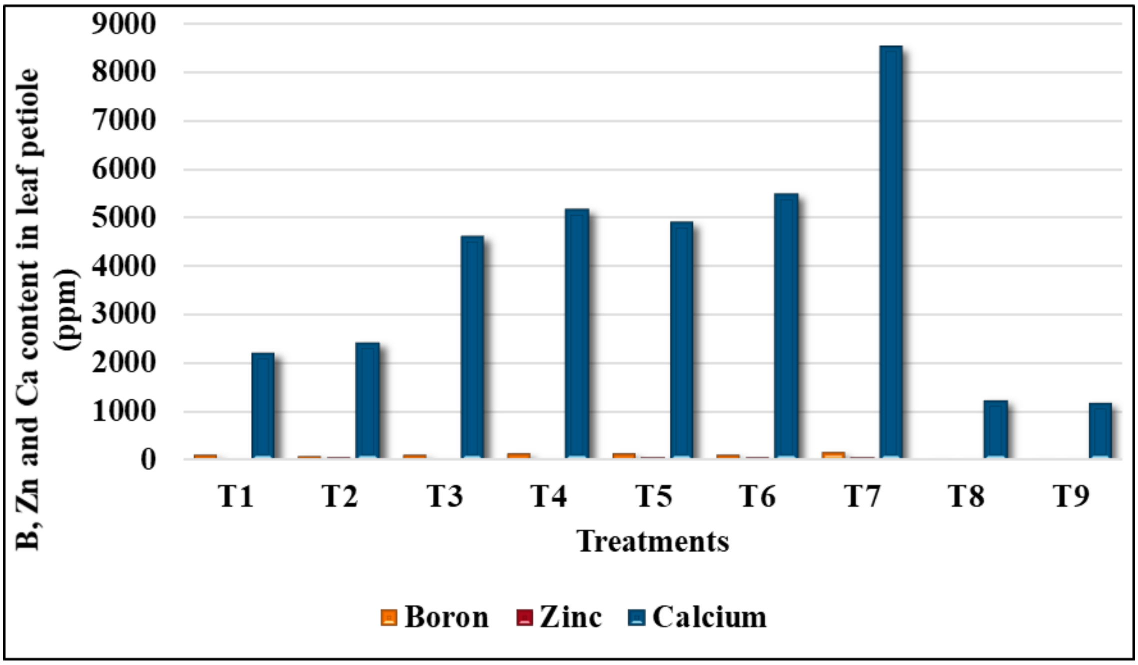
In the current study the foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) increased the fruit nitrogen, phosphorous, boron, zinc and calcium content, however, fruit potassium content was higher for Zinc sulphate (0.5%) and Borax (0.5%) spray.

Calcium contents of flesh of papaya fruits increased with calcium treatment at 1.5 to 3.5% (Eryani Raqeeb *et al*., 2009). These findings are in conformity with results of Madani *et al*. (2015) in papaya, Garcia *et al*. (1996) in strawberry and Patel (2015) in mango. Higher leaf nutrient content will lead to higher fruit nutrients as a result of translocation.

2.8 PEST AND DISEASES INCIDENCE

No severe pest and disease incidence were noted in the field.

Fig. 8. Effect of foliar application of micronutrients and calcium on Boron, Zinc and Calcium content in leaf petiole of papaya



Reddy (2010) observed that foliar application of boron (0.2%) showed less papaya ringspot disease incidence and papaya mite incidence in papaya cv. Sunrise solo. Madani *et al*. (2014) found that six pre-harvest foliar calcium sprays (0.5%) in papaya cv. Eksotika-2 reduced anthracnose incidence during storage. Nishina (1987), Madani *et al*. (2015) and Harish (2018) also arrived similar conclusion.

Higher calcium content in cells reduces the disease incidence by lowering the activity of middle lamella dissolving enzymes such as polygalacturonase, pectolytic enzymes and pectate transaminase produced by fungus and bacteria during infection of plant tissue by maintaining the structural integrity (Easterwood, 2005) or high concentration of calcium in the cytosol become toxic to the fungus at conicidal stage in such a way that they cannot regulate intracellular calcium (Droby *et al*., 1997 and Miceli *et al*., 1999). Calcium may inhibit the fungal germination either by enhancing the fungal cell wall degrading enzymes (Wisniewski *et al*., 1995) or by providing cell wall integrity (Biggs, 1999). The activity of enzymes such as pectin methylesterase and polygalacturonase will increase due to the increased permeability of cell membrane due to calcium deficiency was identified by Deytieux-Belleau *et al*. (2008). Similar results were also reported by Ortiz *et al*. (2011), Poovaiah (1986) and Mignani *et al*. (1995).

2.9 ECONOMIC ANALYSIS

The investigation carried out revealed that foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) resulted in highest net income and highest B:C ratio.

The results of the present experiment were in conformity with the findings of Meena (2013) who concluded that highest net returns and maximum B:C ratio were obtained under the treatment of $ZnSO_4$ (0.5%) and borax (0.2%) in papaya cv. Red Lady. Similar results were also reported by Reddy (2010) and Manjunatha (2012) in papaya.

Higher net income and B:C ratio are due to the increase in fruit yield and increased marketability of papaya fruits as influenced by the foliar application of micronutrients and calcium (Singh *et al*., 1993).

Summary

6. SUMMARY

The research work on “Foliar nutrition with calcium and micronutrients for growth and yield enhancement in papaya (*Carica papaya* L.)” was conducted with the objective to study the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya using IIHR variety Surya. The investigation was carried out in Department of Fruit Science, College of Agriculture Vellayani, during 2019 April to 2020 April. The salient findings of this study are summarized as follows.

The field experiment was laid out in RBD with 9 treatments and 3 replications. Treatments were T1- Borax (0.5%), T2- Zinc sulphate (0.5%) and T3- Calcium nitrate (0.5%), T4 - T1+T3, T5 - T1+T2, T6 - T2+T3, T7 - T1+T2+T3, T8 -Water spray and T9 - control (KAU, POP). Organic manure (10 kg FYM plant^{-1}) and NPK (240: 240: 480 g plant^{-1} year^{-1}) were given uniformly to all treatments as soil application as per KAU POP. Treatments from T1 to T8 were applied at 4th and 7th months after planting as foliar spray.

In the current study growth parameters like plant height, plant girth and number of leaves were taken at bimonthly interval from 2 MAP to 12 MAP.

Treatment with foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) increased the plant height at 6 MAP, 8MAP,10MAP and 12 MAP.

Observation on plant girth showed a significant increase at all stages of crop growth due to the combined application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) as foliar spray.

The study revealed that application of micronutrients (Boron and Zinc) and calcium had a positive influence with respect to the number of leaves. The plants treated with Borax, Zinc sulphate and Calcium nitrate @ 0.5% resulted in the highest number of leaves at 6MAP, 8MAP, 10MAP and 12MAP.

From the present investigation, it was found that foliar application of Boron, Zinc and calcium had a positive effect in reducing the height at first flowering and days to flowering in papaya. A significant reduction in height at first flowering and days to flowering was found with the foliar spray of Borax (0.5%), Zinc sulphate

(0.5%) and Calcium nitrate (0.5%).

In general, combined application of Borax, Zinc sulphate and Calcium nitrate @ 0.5% as foliar spray increased the femaleness in papaya where the number of female plants were higher than that of bisexual plants. But there was no significant effect on sex ratio.

Plant treated with foliar spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) at 4th and 7th month after planting resulted in the highest fruit set per cent and number of flowers per cluster in papaya. However, it reduced the time for harvest of fruit.

Yield Characters such as fruit weight, fruit length, fruit girth, fruit volume, pulp percentage, flesh thickness, number of fruits per plant and total yield per plant were significantly higher for the plants provided with Borax, Zinc sulphate and Calcium nitrate @ 0.5% as foliar spray, where as it reduced the number of seeds per fruit and number of days taken for fruit maturity in papaya.

A positive response was seen in the qualitative characters like TSS, total carotenoids, ascorbic acid, total sugar, reducing sugar, color of pulp and peel and firmness of pulp with the combined spray of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) whereas reduced value for totable acidity was found with the same spray. Water spray recorded the highest value for non-reducing sugar content in papaya.

Organoleptic qualities of fruits varied significantly with the application of micronutrients (Boron and Zinc) and calcium. Mean score for organoleptic characters like appearance, color, texture, taste, flavour and overall acceptability were observed to be highest for the plants treated with Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) as foliar spray.

The foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) at 4th and 7th month after planting resulted in the longest shelf life of papaya fruit.

From this study it was observed that micronutrients (Boron and Zinc) and calcium foliar spray did not have any effect on soil pH, EC, soil available organic carbon, nitrogen, phosphorous, potassium, boron, zinc and calcium content.

Data obtained from the plant analysis for nitrogen, phosphorous, boron, zinc and calcium content showed an increment and the highest value was reported with the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%). Potassium content in the leaf petiole was the highest for plants treated with Borax (0.5%) and Zinc sulphate (0.5%) as foliar spray.

Foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) recorded highest fruit nitrogen, phosphorous, boron, zinc and calcium content. Fruit potassium content was highest with the foliar application of Borax and Zinc sulphate @ 0.5%.

Observed diseases in the papaya field such as foot rot and leaf spot were not severe and the incidence was less than 1%.

The foliar spray of micronutrients (Boron and Zinc) and calcium on papaya had shown a significant influence on net income and B:C ratio. The highest value for net income and B:C ratio was observed with the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) at 4^{th} and 7^{th} month after planting.

From the above findings it is concluded that foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) at 4^{th} and 7^{th} month after planting had a positive influence on biometric, yield, quality characters, shelf life, soil, plant, fruit nutrient content and economics of cultivation of papaya. This study points out the importance of foliar application of micronutrients and secondary nutrients for the farming community because of its essential role on vegetative, yield, quality characters and disease resistance there by making economically viable cultivation of papaya under Kerala conditions.

FUTURE LINE OF WORK

Dose of borax adopted for this experiment is 0.5% and more evaluation can be done to reduce the dose of boron if needed.

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FOLIAR NUTRITION WITH CALCIUM AND MICRONUTRIENTS FOR GROWTH AND YIELD ENHANCEMENT IN PAPAYA (*Carica papaya* L.)

by

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(2018-12-009)

THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE VELLAYANI,

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2020

ABSTRACT

FOLIAR NUTRITION WITH CALCIUM AND MICRONUTRIENTS FOR GROWTH AND YIELD ENHANCEMENT IN PAPAYA (*Carica papaya* L.)

The study entitled "Foliar nutrition with calcium and micronutrients for growth and yield enhancement in papaya (*Carica papaya* L.)" was conducted at Department of Fruit Science, College of Agriculture Vellayani, from 2019 April to 2020 April. Micronutrients and secondary nutrients like calcium play a major role in crop production due to their essentiality in plant metabolism and adverse effect that manifest due to their deficiency. The present work was undertaken to assess the effect of foliar application of micronutrients and calcium on growth, yield and quality of papaya.

The field experiment was laid out in Randomized Block Design (RBD) with 9 treatments and 3 replications. Surya, IIHR (Indian Institute of Horticultural Research) gynodioecious variety was used for the research purpose. Treatments were T_1- Borax (0.5%), T_2 - Zinc sulphate (0.5%) and T_3 - Calcium nitrate (0.5%), T_4 - T_1 + T_3, T_5 - T_1 + T_2, T_6 - T_2 + T_3, T_7 - T_1 + T_2 + T_3, T_8 - Water spray and T_9 – Control (KAU POP). Treatments from T_1 to T_8 were applied at 4th and 7th months after planting. Organic manure (10 kg FYM plant^{-1}) and NPK (240: 240: 480 g plant^{-1} year^{-1}) were given uniformly to all treatments as soil application as per KAU POP recommendation.

Treatment with foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) increased the biometric parameters like plant height and number of leaves at 6 MAP, 8 MAP,10 MAP and 12 MAP. A significant increase in plant girth at all stages of growth was observed for the same treatment.

From the present investigation, it was found that foliar application of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) reduced the height at first flowering, days to flowering, duration for harvest of papaya fruit and increased the number of female plants than that of bisexual plants, fruit set percent and number of flowers per cluster.

The results indicated that yield characters such as fruit weight, fruit length, fruit girth, fruit volume, pulp percentage, flesh thickness, number of fruits per plant

and total yield per plant were highest with the combined application of Borax, Zinc sulphate and Calcium nitrate @ 0.5% respectively as foliar spray, where, number of seeds per fruit and days taken for maturity of fruits reduced significantly for the same treatment.

With regard to qualitative attributes studied TSS, total carotenoids, ascorbic acid, total sugar, reducing sugar, colour of pulp and peel and firmness of pulp were shown positive response with the spray of Borax (0.5%), Zinc sulphate (0.5%) along with Calcium nitrate (0.5%) however, reduction in acidity was found with the same treatment. Water spray recorded the highest value for non-reducing sugar content in papaya.

The foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%) increased the organoleptic qualities like appearance, colour, texture, taste, flavour and overall acceptability. Shelf life of papaya fruits were longer with the same treatment.

From this study it was observed that soil parameters like soil pH, EC, organic carbon, available nitrogen, phosphorous, potassium, boron, zinc and calcium did not show any significant variation with the foliar application of micronutrients and calcium.

Data from the plant analysis and fruit analysis of papaya showed that nitrogen, phosphorous, boron, zinc and calcium content was highest with the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%). But Potassium content in both leaf petiole and fruit was highest for the plants treated with Borax (0.5%) and Zinc sulphate (0.5%) foliar spray.

Foot rot and leaf spot incidence were observed in the papaya field. Proper plant protection measures controlled the infestation which was less than 1 percent.

The highest net income and B:C ratio was observed with the foliar application of Borax (0.5%), Zinc sulphate (0.5%) and Calcium nitrate (0.5%).

From the above findings, it was concluded that foliar application of Borax (0.5%), Zinc sulphate (0.5%), Calcium nitrate (0.5%) at 4th and 7th months after planting along with the application of organic manure (10 kg FYM plant^{-1}) and NPK (240: 240: 480 g plant^{-1} year^{-1}) had increased the growth, yield and quality characteristics of papaya and it was economically viable too.

സംഗ്രഹം

"പപ്പായയുടെ (കാരിക്ക പപ്പായ എൽ.) വളർച്ചയും, വിളവും വർദ്ധിപ്പിക്കുന്നതിന് കാൽസ്യവും സൂക്ഷ്മ മൂലകങ്ങളും" എന്ന വിഷയത്തിൽ 2019 ഏപ്രിൽ മുതൽ 2020 ഏപ്രിൽ വരെ വെള്ളായണി കാർഷിക കോളേജിലെ ഫലശാസ്ത്ര വിഭാഗത്തിൽ ഒരു പഠനം നടത്തി. ചെടികളുടെ രാസവിനിമയത്തിൽ ബോറോൺ, സിങ്ക്, കാൽസ്യം എന്നിവയുടെ അനിവാര്യതയും അവയുടെ കുറവ് മൂലം പ്രകടമാകുന്ന പ്രതികൂല ഫലവും കാരണം സൂക്ഷ്മ മൂലകങ്ങളും, കാൽസ്യം പോലുള്ള ദ്വിതീയ പോഷകങ്ങളും വിള ഉൽപാദനത്തിൽ പ്രധാന പങ്ക് വഹിക്കുന്നു. പപ്പായയുടെ വളർച്ച, വിളവ്, ഗുണനിലവാരം എന്നിവയിൽ സൂക്ഷ്മ പോഷകങ്ങളുടെയും കാൽസ്യത്തിന്റെയും ലായനി പത്രപോഷണം വഴി നൽകുന്നതിൻറെ ഫലം വിലയിരുത്തുന്നതിനാണ് ഇപ്പോഴത്തെ പ്രവർത്തനം ഏറ്റെടുത്തത്.

റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈനിൽ (ആർബിഡി) 9 ട്രീട്മെന്റുകൾ, 3 തവണ ആവർത്തിച്ചുകൊണ്ടുള്ള ഫീൽഡ് പരീക്ഷണം നടത്തി. ഇന്ത്യൻ ഇൻസ്റ്റിറ്റ്യൂട്ട് ഓഫ് ഹോർട്ടികൾച്ചറൽ റിസർച്ച് ഇനമായ സൂര്യ ഗവേഷണ ആവശ്യത്തിനായി ഉപയോഗിച്ചു. T_1- ബോറാക്സ് (0.5%), T_2 - സിങ്ക് സൾഫേറ്റ് (0.5%), T_3 - കാൽസ്യം നൈട്രേറ്റ് (0.5%), T_4 - T_1 + T_3, T_5 - T_1 + T_2, T_6 – T_2 + T_3, T_7 - T_1 + T_2+ T_3, T_8 - വാട്ടർ സ്പ്രേയും, T_9 - നിയന്ത്രണം (കേരള കാർഷിക സർവകലാശാലയുടെ ശുപാർശ പ്രകാരം) എന്നിവയായിരുന്നു പ്രയോഗ രീതികൾ. നടീലിനു ശേഷം 4, 7 മാസങ്ങളിൽ T_1 മുതൽ T_8 വരെയുള്ള ട്രീട്മെന്റുകൾ പ്രയോഗിച്ചു. കേരള കാർഷിക സർവകലാശാലയുടെ ശുപാർശ പ്രകാരം 10 കിലോ കാലിവളം, നൈട്രജൻ: ഫോസ്ഫറസ്: പൊട്ടാഷ്യം (240: 240: 480 ഗ്രാം, ഒരു ചെടിക്ക് എന്ന തോതിൽ നൽകി.

ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവയുടെ പത്രപോഷണം വഴി (6, 8, 10, 12 മാസങ്ങളിൽ) സസ്യങ്ങളുടെ ഉയരവും, ഇലകളുടെ എണ്ണവും വർദ്ധിച്ചു. വളർച്ചയുടെ എല്ലാ ഘട്ടങ്ങളിലും സസ്യങ്ങളുടെ കനം കൂടുന്നതായി ഗവേഷണത്തിൽ കണ്ടെത്തി.

ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവയുടെ പത്രപോഷണം വഴി പപ്പായ ചെടി പൂവിടുന്നതിൻറെ ഉയരം, പൂവിടാൻ എടുക്കുന്ന ദിവസങ്ങൾ, പപ്പായ പഴത്തിന്റെ വിളവെടുപ്പ് കാലാവധി എന്നിവ കുറഞ്ഞതായി കണ്ടെത്തി. ദ്വലിംഗ സസ്യങ്ങളേക്കാൾ പെൺ സസ്യങ്ങളുടെ എണ്ണം, പഴങ്ങളുണ്ടാകുന്ന ശതമാനം, ഒരു പൂങ്കുലയിലെ പൂക്കളുടെ എണ്ണം എന്നിവ വർദ്ധിച്ചു.

ഫലങ്ങളുടെ ഭാരം, പഴത്തിന്റെ നീളം, പഴത്തിന്റെ ദൈർഘ്യം, പഴത്തിന്റെ അളവ്, പൾപ്പ് ശതമാനം, പഴത്തിൻറെ മാംസക്കനം, ഒരു ചെടിയിലെ പഴങ്ങളുടെ എണ്ണം, ഒരു ചെടിയിലെ ആകെ വിളവ് എന്നിവ ബോറാക്സ്, സിങ്ക് സൾഫേറ്റ്, കാൽസ്യം നൈട്രേറ്റ് എന്നിവയുടെ സംയോജിത പ്രയോഗത്തിലൂടെ ഉയർന്നതാണെന്ന് ഫലങ്ങൾ സൂചിപ്പിക്കുന്നു. യഥാക്രമം 0.5 ശതമാനത്തിലുള്ള പത്രപോഷണം ഇവിടെ, ഒരു പഴത്തിന് വിത്തുകളുടെ എണ്ണവും പഴങ്ങൾ പാകമാകാൻ എടുക്കുന്ന ദിവസങ്ങളും ഗണ്യമായി കുറച്ചു.

ടി.എസ്.എസ്., ആകെയുള്ള കരോട്ടിനോയിഡുകൾ, അസ്കോർബിക് ആസിഡ്, പഞ്ചസാര, പൾപ്പ്, തൊലി എന്നിവയുടെ നിറം, പൾപ്പിന്റെ ദൃഢത എന്നിവ ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവയുടെ ഉപയോഗത്താൽ നല്ല പ്രതികരണമാണ് കാണിച്ചത്. അതേ പ്രയോഗത്തിലൂടെ പഴത്തിൻറെ അസിഡിറ്റി കുറയുന്നതായി കണ്ടു.

ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവയുടെ പത്രപോഷണം പപ്പായ പഴത്തിൻറെ രൂപം, നിറം, ഘടന, രുചി, രസം, സ്വീകാര്യത തുടങ്ങിയ ഗുണങ്ങൾ വർദ്ധിപ്പിച്ചു. അതേ പ്രയോഗം പപ്പായ പഴങ്ങളുടെ സൂക്ഷിപ്പ് കാലാവധി ഉയർത്തി.

മണ്ണിന്റെ അമ്ലത്വം, വൈദ്യുതീവാഹകശക്തി, ഓർഗാനിക് കാർബൺ, ലഭ്യമായ നൈട്രജൻ, ഫോസ്ഫറസ്, പൊട്ടാസ്യം, ബോറോൺ, സിങ്ക്, കാൽസ്യം തുടങ്ങിയ മണ്ണിന്റെ സ്വഭാവ സവിശേഷതകൾ സൂക്ഷ്മ പോഷകങ്ങളുടെയും കാൽസ്യത്തിന്റെയും ഉപയോഗത്തിൽ കാര്യമായ വ്യത്യാസമൊന്നും കാണിക്കുന്നില്ലെന്ന് ഈ പഠനത്തിൽ നിന്ന് മനസ്സിലായി.

സസ്യ വിശകലനത്തിൽ നിന്നും പപ്പായയുടെ പഴ വിശകലനത്തിലൂടെയും ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവ വഴിയുള്ള പത്രപോഷണം നൈട്രജൻ, ഫോസ്ഫറസ്, ബോറോൺ, സിങ്ക്, കാൽസ്യം എന്നിവയുടെ അളവ് ഏറ്റവും ഉയർന്നതാണെന്ന് കാണിച്ചു. ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%) പത്രപോഷണത്തിലൂടെ സസ്യങ്ങളിൽ ഇല ഞെട്ടിലും പഴത്തിലും പൊട്ടാസ്യം കൂടുതലായി കണ്ടെത്തി.

ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%) എന്നിവയുടെ പത്രപോഷണം പപ്പായയിൽ വരുമാനം ഉയർത്തുന്നതായി കണ്ടെത്തി.

ഈ ഗവേഷണത്തിൽ നിന്ന് നടീലിനു ശേഷം 4, 7 മാസങ്ങളിൽ ബോറാക്സ് (0.5%), സിങ്ക് സൾഫേറ്റ് (0.5%), കാൽസ്യം നൈട്രേറ്റ് (0.5%), എന്നിവ

പത്രപോഷണത്തിലൂടെയും, കാലിവളം 10 കിലൊ, നൈട്രജൻ: ഫോസ്ഫറസ്: പൊട്ടാഷ്യം (240: 240: 480 ഗ്രാം) ഒരു ചെടിക്ക് വർഷമൊന്നിന് നൽകുന്നതിലൂടെ പപ്പായയുടെ വളർച്ച, വിളവ്,കായ്കളുടെ ഗുണനിലവാരം എന്നിവ ഉയരുന്നതായും, സാമ്പത്തികമായി മെച്ചമുണ്ടാക്കുന്നതായും കണ്ടെത്തി.

Appendices

APPENDIX-I

Weather data during the cropping period

Month	Temperature(°C)		Relative humidity (%)		Rainfall (mm)
	Max	Min	Max	Min	
June-19	31.91	25.37	90.40	77.96	10.66
July-19	30.89	24.90	91.41	79.8	5.89
August-19	30.75	24.24	92.03	77.9	10.70
September-19	30.99	24.43	91.3	78.03	9.32
October-19	30.76	24.13	92.83	77.09	13.06
November-19	31.9	24.54	91.50	77.93	3.04
December-19	31.91	23.83	92.22	77.13	6.48
January-20	32.31	22.92	92.48	63.62	1.77
February-20	33.04	23.25	90.31	60.75	0.00
March-20	33.60	24.75	87.55	59.98	2.10
April-20	34.24	25.76	84.85	62.29	2.65

APPENDIX II

COLLEGE OF AGRICULTURE VELLAYANI

Department of Fruit Science

Score card for assessing the organoleptic qualities of papaya cv. Surya.

Title: Foliar nutrition with calcium and micronutrients for growth and yield enhancement in papaya (*Carica papaya* L.)

Criteria		Samples								
	1	2	3	4	5	6	7	8	9	10
Appearance										
Colour										
Flavour										
Texture										
Taste										
Overall Acceptability										

<u>Score (9 point hedonic scale)</u>

Like extremely-9

Like very much-8

Like moderately-7

Like slightly-6

Neither like nor dislike-5

Dislike slightly-4

Dislike moderately-3

Dislike verymuch-2

Dislike extremely-1

Name

Date: Signature