EFFECT OF ZINC AND BORON ON GROWTH, YIELD AND QUALITY OF PAPAYA [*Carica papaya .L.*] Cv. CO.5.

Thesis submitted in part fulfillment of the requirements for the award of degree of

MASTER OF SCIENCE (HORTICULTURE)

to the TamilNadu Agricultural University, Coimbatore.

By

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2000.

Certificate

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF ZINC AND BORON ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya.* L.) VAR. CO.5"** submitted in part fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN (Horticulture)** in Pomology, to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Miss. M. Kavitha** under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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(M. Kavitha)

Abstract

ABSTRACT

EFFECT OF ZINC AND BORON ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) CV. CO.5

By

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A field experiment was conducted during 1998-2000 on papaya cv. Co.5 at the orchard of the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore to study the effect of zinc and boron on growth, yield and quality of papaya. The study revealed that the growth parmeters were the highest in the treatment with foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting. The same treatment enhanced the yield by favourably increasing the number of fruits per tree, weight, length, volume, circumference of fruit and latex yield.

Fruit quality constituents *viz*., TSS, total sugars, reducing sugars, non-reducing sugars and ascorbic acid were maximum with foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting.

The biochemical parameters as determined by leaf total chlorophyll, chlorophyll à, chlorophyll b content, were recorded highest with foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting. Proteolytic enzyme activity and soluble protein were also significantly high with foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting.

Foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting has influenced the leaf and petiole Zn and B content while N, P, K content remained unaffected. Soil application of 1g Zn and 5 g Boron at 4^{th} and 12^{th} month after planting increased available Zn and B content of the soil while available N, P, K of the soil remained unaffected.

Based on the overall yield per hectare, it may be aptly concluded that the treatment involving foliar application of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting followed by the treatment, T_6 i.e foliar spray of 0.5% Zn + 0.1% B at 4^{th} and 12^{th} month after planting are highly beneficial to get maximum yield with higher return in comparison to the control (T_1) namely no application of either Zn or B.

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Introduction

INTRODUCTION

Papaya, an enigma among fruit crops, acknowledged as an important fruit crop hitherto has now attained the status of industrial crop yielding nutritious fruits round the year. Infact, there was a dramatic increase in the cultivation of papaya in view of increasing demand for its fruits in domestic markets and for the papain in the export trade.

Presently, papaya growers are confronted with motley of problems that hinder the complete expression of growth and productivity. The discernable and the most frequent constraints are found to be related with nutrients owing to its unique physiological plasticity. The nutritional needs of papaya differs from other fruit crops because of its continuous and simultaneous growth of vegetative and reproductive structures. Owing to its shallow rooted nature, it is not normally capable of sustaining itself by drawing up the nutrient reserves of deeper soil layers. Thus, proper comprehension of its nutrient need is irrefutably necessary for sustaining the yield of fruits and latex.

Among the nutrients, micronutrients though required in small quantities, are as important and indispensable as any other essential nutrient from plant nutrition point of view. Micronutrient disorders have become widespread in fruit crops with diminishing use of organic manures, adoption of high density planting, use of root stocks for dwarfing, disease and salt resistance, unbalanced N, P, K fertilizer application and extension of horticulture to marginal lands. Edward Raja and Anjaneyulu (1999) lamented that deficiencies of Zn, Mn and B are common in fruit crops including papaya in India.

Although sporadic efforts have been made to study the effect of micronutrients in papaya, no attempt however seems to have been made to study the effect of micronutrients in papaya cv Co.5. Therefore, the present investigation was conducted to study the effect of application of Zn and B on growth and development of papaya with special emphasis on yield of fruits and latex with the objectives as accentuated below:

1. To study the effect of Zn and B on growth and development of papaya.

2. To study the effect of Zn and B on yield and quality of fruit and latex in papaya.

Review of Literature

CHAPTER - I

REVIEW OF LITERATURE

Micronutrients like Zn, B, Mn, Cu, etc., are accredited to have favourable effect on the growth, yield and quality characters of crop plants. Works of many scientists stand as paradigms to espouse the same.

Among the micronutrients, zinc was unequivocally a cynosure since the early 1960's. About 50% of the 10,000 soils analysed under the ICAR scheme had been found to be zinc deficient (Takkar,1999). The proportion of zinc deficient soils fluctuate from state to state with 60-80%, of soils assessed to be deficient in Haryana, Madhya pradesh, Uttar pradesh, and 30-60%, in Bihar, Kerala, Punjab and TamilNadu. (Tandon, 1989). Zinc as an essential plant element was conceded by investigators in 1930's when little leaf of peaches and mottle leaf of citrus was corrected through zinc application (Chapman, 1937).

Similarly, Boron has been known to be a constituent of plants since 1857, However, this fact remained ignored till the dawn of the twentieth century. Agulhon (1910) unveiled the essentiality of B for plant life. This discovery was later corroborated by Katheriene Warington at Rothamsted experimental station, thus ascertaining the essentiality of B for plants. Paradoxically, this micronutrient has not been found to be essential for micro organisms or animals (Epstein, 1972).

In this chapter, literature available on the effect of micronutrients more particularly Zn and B on growth, yield and quality of important tropical fruit crops like banana, papaya, citrus, grapes, guava are reviewed, as very limited literature is available in papaya.

2.1. Growth attributes of the plant

2.1.1. Plant height

Application of micronutrients especially Zn and B have been reported to have profound effect in enhancing the plant height. Armstrong and Furr (1956), Armstrong (1956) and Khader *et al*, (1965) induced striking improvement in the growth of trifoliate orange seedlings through soil application of iron and zinc. On the contrary, Butler (1960) couldnot find any beneficial effect by the application of Fe, Mn, Zn, B on Grosmichael banana grown on fertile alluvial soil. These results are in consonance with Sahota and Arora (1981) who observed that the tree height and spread of Hamlin Sweet orange were not affected by 0.6% Zn spray. However, increase in plant height in papaya was obtained by Perz Lopez and Reyes (1983) applying B 2.3 kg/ha and 0.15% Fe spray (Veenapant and Lavania, 1989). Similarly, combined spray of B+Zn+Cu+Mn in cv. Chenichampa of banana (Das and Mohan,, 1993) and application of $ZnSo_4$ 25kg/ha in Red banana (Subramanian and Anchanam Alagia Pillai, 1997) registered significantly higher plant height.

2.1.2. Stem girth

Increased stem girth due to micronutrient application has been reported in different fruit crops. Foliar spray of 0.05 ppm B in papaya variety

Blue Solo (Parez Lopez and Norman F. Childers, 1980), 0.5% Zn spray in Hamilin Sweet orange (Sahota and Arora, 1981), application of 2.3 kg/ha of B in papaya cv. PR-7-95 (Parez Lopez and Ruben, 1983), combined spray of 0.5% Zn + 0.5% Mg + 0.5% Mn or 0.25% Cu in Coorg mandarin (Nanaya *et al*., 1985), 0.5% Zn spray in Pant papaya-1 (Veenapant and Lavania, 1989), Mn spray in banana cv. Chenichampa (Das and Mohan, 1993) and application of $ZnSo_4$ 25kg/ha in Red banana (Subramanian and Anchanam Alagia Pillai, 1997) recorded increased stem girth.

2.1.3. Leaf Number

Increased number of leaves due to micronutrient application has been corroborated by spraying with 0.05 to 0.10 per cent Fe in Thompson Seedless grapes (Rana and Sharma, 1979), 0.05 ppm B in papaya variety Blue Solo (Parez Lopez and Childers, 1980). These findings are in accordance with the reports of Das and Mohan (1993) in banana with Zn and B spray and Battacharya (1994) with non-chelated Zn in guava cv. Allahabad safeda and Banarasi.

2.1.4. Leaf area

Application of micronutrients, particularly B and Zn sprays helped to increase the leaf area in different fruit crops. Foliar spray of Mo 4 ppm (Srivastava, 1964) and Zn 0.5% spray in banana, (Das and Patro,1984) in banana, Fe 0.6% spray in Sweet orange, Zn in Washington Navel orange (Khader *et al*., 1978), 0.2% and 0.4% Fe spray in guava (Arora and Singh, 1980), combined spray of B, Zn, Cu and Mn in banana cv. Chenichampa (Das and Mohan, 1993) recorded significantly higher leaf area.

2.2. FRUIT CHARACTERS AND YIELD

2.2.1 Fruit characters

Micronutrients are acclaimed to have desirable effect on fruit characters of various fruit crops. In guava, application of Zn and B had resulted in increased fruit size in cv. Allahabad safeda, (Rajput and Chanda, 1976). In grapes cv. Thompson seedless, B spray 0.025% resulted in increased weight of clusters, weight of berry and volume of berry (Rana and Sharma, 1979), 0.4% Fe and 0.15% B improved fruit size (Khera and Dhawan, 1979). Such an increase in fruit size also finds support from the works of Sahota and Arora (1981) in Hamlin Sweet orange and Singh *et al*, (1983) in guava cv. Lucknow-49. Research on similar lines revealed that fruit weight increased linearly as B levels were raised from 2.3-6.8 kg/ha (Agripinoperez-Lopez and Ruben, 1983). Spraying of Romanian product Tisola at 1g/lt and trace elements like Fe, Zn, Mn, B and Mo at 0.1% increased the berry weight and number of bunches in grapes (Tesu *et al.*, 1988), 0.15% Fe spray enhanced fruit weight and fruit diameter in papaya (Veena pant and Lavania, 1989). Spray of 0.3% B + 0.5% Zn + 0.2% Cu resulted in largest size, volume and weight of fruits in Kagzi lime (Singh *et al.*, 1990), 0.2% and 0.4% Zn spray increased fruit weight in Allahabad safeda (Ali *et al.*, 1991), 0.6% Zn spray had increased fruit weight in Sardar guava (Sharma *et al.*, 1993). Application of 25 kg/ha of Zn increased bunch characters in Red banana (Subramaniam and Anchanam Alagia Pillai, 1997) and foliar spray of 0.4% Zn EDTA + 0.2% Cu EDTA increased fruit weight, fruit length, fruit girth and fruit volume in Seedless lemon (Sharma *et al.*, 1999).

Micronutrients, more particularly Zn and B were reported to have affected the yield favourably in many fruit crops as accentuated below.

Sl. No.	Name of the Crop	Micronutrients and its concentration	Per cent increase in yield	Authority
1.	Papaya cv. Pant Papaya-1	Zn 0.15 + B 0.15%	103.8%	Veena pant and Lavania (1989)
2.	Santra mandarin	$ZnSo_4$ 30kg/ha + $FeSo_4$ 15kg/ha	20.5%	Jadhav *et al.* (1979)
3.	Sweet Orange cv. Blood red	0.5% Zn	17.08%	Nanaya *et al.* (1985)
4.	Sweet Orange cv. Mosambi	0.5% chelated complex	11.07%	Desai *et al.* (1986)
5.	Kagzilime	0.5% Zn + 0.2 % Cu + 0.3% B	153.03%	Sing *et al.* (1990)
6.	Sweet Orange cv. Sathgudi	$ZnSo_4$ + (50g/tree) + $MnSo_4$ (50g/tree) + $FeSo_4$ (50g/tree) + 0.5% Zn + 0.5% Mn + 0.5% Fe	35.56%	Durga devi *et al.* (1997)
7.	Seedless lemon	0.4% Zn EDTA + 0.2% Cu EDTA	146.23%	Sharma *et al.* (1999)
8.	Grape cv. Thompson Seedless	0.2% B	41.30%	Satish Kumar and Satya Bhushan (1976).
9.	Grape cv. Thompson Seedless	0.025 % B	59.48%	Rana and sharma (1979)
10.	Guava cv. Lucknow - 49	Mn, Zn, B and Mg	37.36%	Ghosh (1986)

11.	Guava cv. Allahabad Safeda	0.2% B	15.78%	Wahid Ali, (1991)
12.	Guava cv. Sardar guava	0.6% Zn	35.82%	Sharma *et al.* (1993)
13.	Guava cv. Allahabad Safeda	0.5% Fe	14.46%	Ahmad *et al.* (1998)
14.	Red banana	25 kg/ha $ZnSo_4$	32%	Subramanian and Anchanam Alagia Pillai (1997)
15.	Pomegranate cv. Ganesh	0.3% $Mnso_4$	107.86%	Bambal *et al.* (1991)
16.	Pomegranate cv. Ganesh	0.25% Zn + 0.25% Fe + 0.25% Mn + 0.15% B	42.54%	Balakrishnan *et al.* (1996).

2.3. Biochemical and Quality characters

2.3.1. Leaf total chlorophyll

Increase in leaf chlorophyll content due to the application of Zn and B has been well documented in many fruit crops. Foliar spray of 0.5% Zn + 0.3% Mn + 0.5% Fe in Thompson seedless grapes (Kabeel *et al.*, 1981), 0.3% and 0.6% Zn (Haribabu and Rajput, 1984) and 0.1 to 0.5 per cent Zn spray (Patel and Patel, 1985) in acid lime, B sprays in Kagzilime, (Singh *et al.*, 1990), 0.5% Zn spray in Mosambi Sweet orange (Desai *et al.*, 1991) recorded marked influence on the chlorophyll content of leaves.

2.3.2. Fruit quality

Micronutrients, more particularly Zn and B were reported to have influenced the fruit quality parameters favourably in many fruit crops as accentuated below.

Sl. No.	Fruit	Micronutrients and its concentration	Fruits traits affected	Authority
1.	Papaya cv Blue solo	1.55 ppm B	Ratio of total soluble solids to titrable acidity increased	Parez Lopez and Norman F. Childers (1980)
2.	Papaya cv Pant papaya	0.15%, Fe + 0.15%, Zn + 0.15% B	TSS increased and acidity decreased	Veenapant and Lavania (1989)
3.	Grapes cv Thompson seedless	0.4% Zn + 0.2% B + 0.2% Mn	TSS and Juice percentage increased	Satish kumar and satya Bhushan (1976)
4.	Grapes cv Thompson seedless	0.15% B + 0.2% Fe	TSS, TSS to acid ratio increased acidity decreased	Khera and Dhawan (1979).
5.	Grapes cv Thompson seedless	0.025% B	TSS, total sugar, reducing sugar, non-reducing sugar, and sugar acid ratio increased	Rana and Sharma (1979).
6.	Sweet orange cv. Mosambi	Chelated Zn complex 0.5%	Juice, TSS, and ascorbic acid increased	Desai *et al.* (1986).
7.	Mandarin orange	0.6% B	Sugars, TSS acidity and sugar acid ratio increased	Rai *et al.* (1988).

8. Kagzi lime	0.5% Zn + 0.3% cu + 0.3% B	TSS and ascorbic acid increased	Sing *et al.* (1990).
9. Sweet orange cv. Jaffa	0.4% Zn + 0.4% B	Acidity increased	HarminderKaur (1990).
10. Sweet orange	0.5% Zn	Ascorbic acid, TSS, TSS acid ratio increased, acidity decreased.	Desai *et al.* (1986).
11. Assam lemon	0.4 % chelated Zn	TSS, total sugars, reducing sugars and TSS /acid ratio increased	Langsthasa and Bhattacharya (1991).
12. Sweet orange cv Sathgudi	50g/pt Zn + 50g/pt Fe + 50g/pt Mn 0.5% Zn + 0.5% Fe + 0.5 % Mn	TSS, total sugar, juice thickness, and acidity increased	Durga devi *et al.* (1989).
13. Guava cv Lucknow - 49	B + Mg + Zn	TSS and total sugars increased	Ghosh *et al.* (1986).
14. Guava cv Allahabad	1% K_2So_4 + 0.2% B	TSS and total sugars increased acidity decreased	Ali *et al.* (1991).
15. Guava	0.3% Zn + 0.3% Mg + 0.3% B	TSS, total sugars, reducing sugars, non-reducing sugars and ascorbic acid increased	Bagali (1992).
16. Guava cv Allahabad Safeda	0.5% Fe	TSS, ascorbic acid, pectin and acidity increased	Ahmed *et al.* (1998).

2.4 Nutrient uptake by plants

Foliar spray of Zn 0.4% and Fe 0.4% increased Zn and Fe composition of leaves in Sweet orange (Sandhu *et al.*, 1968) Parez and Childers (1980) observed higher P, Mg and B contents of fruits in trees receiving 1.5 ppm of B. Increasing B levels in the nutrient medium increased the Mn contents in blade and petiole. In grapes, Zn spray increased the leaf Zn content from 53.3 to 286.9 ppm (Gill *et al.*, 1980) and foliar sprays of Zn, Mn and Fe showed increased Zn, Mn and Fe contents in leaves (Kabeel *et al.*, 1981). In Hamlin sweet orange, Zn spray increased the leaf N content (Sahota and Arora, 1981). However B supply did not change the Fe, Cu contents either in blades (or) petioles significantly (Parez and Childers, 1982). Mann and Sindhu (1983) also observed that 0.5% Zn and 0.25% Cu spray alone and their combination in Kinnow tree did not influence the concentration of P and K in leaf. These results are in consonance with Kotur(1985) who observed that Zn and Cu spray failed to produce any marked change in P, K, Ca, Mg content. Investigation of Patel and Patel (1985) revealed that the highest Fe content in leaves of acid lime was due to 0.5% Fe spray. Nanaya *et al.* (1985) experimented with treatmental combinations involving 0.5% Zn, 0.5% Mn, 0.5% Mg and 0.25% Cu in Coorg mandarin and observed that Zn and its combinations increased the concentration of Zn in leaves significantly. Mg played a positive role in increasing the Zn concentration in the leaves. Mn and its combinations and Cu and its combinations increased the concentration of Mn and Cu in the leaves respectively. Mann and Takkar (1987) revealed that 0.15 and 0.30 per cent of acidic solution are more efficient than alkaline solution of 0.45 and 0.60 per cent $ZnSo_4$ in enhancing the Zn concentration in the leaves. They also observed that 0.15% acidic solutions are better than one or two sprays of 0.45 per cent acidic solution. In guava cv. Allahabad safeda maximum amount of leaf N and P was recorded with 0.4% non-chelated Zn while maximum leaf potassium was observed in 0.4% chelated Zn (Sharma and Bhattacharya, 1989). In Seedless lemon, foliar spray of 0.4% Zn EDTA and combination with 0.2% Cu EDTA was found to be the best treatment in influencing the leaf nutrient status (Sharma *et al.*, 1999).

2.5. Role of Micro Nutrients in the Physiology of Fruit Crops

Zinc is a nutrient element essential to plants and animals. The significance of Zn to stimulate growth in lower plants was emphasised as early as 1860's. The research of Tsui (1948) indicated that zinc is involved in the synthesis of tryptophan, a precursor of auxin. Investigations of Seatz and Jurinak (1957), suggested indirect role of Zn in regulating water relations in plants. Zn is also reported to catalyse the oxidation process in the cell, transform carbohydrates, regulate sugar consumption, increase the source of energy for chlorophyll production, aid in auxin formation, absorption of water and is itself involved in the elaboration of IAA hormone (Wear and Hagler, 1968). Zn is an essential component of proteinases and peptidases enzyme systems (Price, 1972). Investigations of Devlin (1972) suggest its role in protein synthesis Graham (1983) suggested that Zn deficiency inhibit protein synthesis and produces high concentration of non-protein amino acids.

There is perhaps less precise information available on the role of B in plants than for any other essential micronutrient. The function of B in plants remained almost obscure prior to the mid 1950's. Role of B is as yet not well understood and unlike other generally recognised micronutrients, it has not been shown to be a part of an enzyme system (Jackson and Chapman, 1975).

The research of Sisler *et al.* (1956) indicated that B enhances uptake and translocation of sugars and is implicated in carbohydrate metabolism. They proposed a micronutrient union with sugars, giving an ionizable sugar-borate complex that moves more readily through cellular membranes than does sugar alone. Russel (1957) established the role of B in N metabolism, hormone movement and action and cell division. Subsequent studies by Dugger and Humphreys (1960) implied a direct involvement of B in the enzymatic reaction of sucrose and starch synthesis. Weiser *et al.* (1967) reported that B does not enhance sugar translocation in plants, but it does enhance the foliar uptake of sucrose applied to the leaves, they concluded that this phenomenon of enhanced foliar uptake of sucrose has given rise in the past to the erroneous conclusion that B enhances sugar translocation. Slack and Whitlington (1964) postulated that B is involved in the synthesis of cell wall components. Lee and Aronoff (1967) suggested that B combines with 6-Phospho gluconic acid to form an enzyme-inhibitor complex, which regulates phenol synthesis, thereby preventing the typical necrosis and ultimate death of B deficient plants. Brown *et al.* (1972).

Effect of soil application of micronutrients vs foliar spray in fruit crops

Micronutrients are applied both as foliar spray and soil application. Perhaps, very limited research was conducted to compare the efficacy of soil application Vs foliar spray. Manchanda *et al.* (1972) compared the effect of soil versus foliar application of zinc in Sweet orange cv. Blood red and observed that soil or foliar application of Fe and Mn alone or in combination with Zn did not effect the yield and quality. However, Zn + Cu application followed by Cu spray enhanced the fruit quality. These results are in accord with Durgadevi *et al.* (1987) who observed that foliar spray of Zn, Mn and Fe resulted in better yield and quality compared to soil application. The study also revealed that the soil application of 50 g/plant each of $ZnSo_4$, $FeSo_4$ and $MnSo_4$ combined with foliar sprays of 0.5% of Zn, Fe and Mn increased the fruit yield and improved the fruit quality. This is further corroborated by Sharma *et al.* (1999) who concluded that foliar spray of chelated zinc and copper was more effective in influencing the yield, yield attributes and leaf nutrient status of seedless lemon trees as compared to soil application.

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

The present investigation was carried out at the Department of Pomology, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 1998-2000.

3.1 Experimental design and layout

The field investigation was started during December 1998 in an area of 0.20 ha. The experiment was laid out in randomised block design with eight treatments replicated thrice, each with a plot measuring 80 m^2 having 16 plants. The details of the treatments were as follows:

3.1.1 Treatment details

T_1 : Control

T_2 : Zn 0.5% foliar spray at 4^{th} and 12^{th} month after planting

T_3 : Zn 0.5% foliar spray at 4^{th}, 8^{th} and 16^{th} month after planting

T_4 : B 0.1% foliar spray at 4^{th} and 12^{th} month after planting

T_5 : B 0.1% foliar spray at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting

T_6 : Zn 0.5% + B 0.1% foliar spray at 4^{th} and 12^{th} month after planting

T_7 : Zn 0.5% + B 0.1% foliar spray at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting

T_8 : Soil application of 10g Zn + 5 g Boron at 4^{th} and 12^{th} month after planting

3.2 FIELD AND CULTURAL OPERATIONS

3.2.1 Nursery operations

Papaya seeds of cv Co.5 were collected from the college orchard, HC & RI, Tamil Nadu Agricultural University, Coimbatore. Totally four to five seeds were sown in polythene bags of 20 x 20 cm. size, filled with a mixture of red soil, sand and farmyard manure in equal proportions. The bags were kept under partial shade and irrigated through rose can regularly. The seeds germinated within 10-15 days, thereafter soils were drenched with one per cent Bordeaux mixture at fortnightly intervals thrice to avoid damping off. Besides, 3g per bag carbofuran was applied a week before transplanting to avoid nematode problems.

3.3 Main field preparation

The pits of 45x45x45 cm were dug at a spacing of 1.8x1.8m and filled with 2.5 Kg FYM. 45 days old seedlings of about 45cm height were transplanted on December 19, 1998.

3.4 Cultural operations

Once flower bud formation was noticed, thinning was done to ensure atleast one female plant in each pit. One male tree for every ten female plants were allowed for effective pollination. Regular cultural operations were followed as per TamilNadu Agricultural University recommendations (Anon, 1999).

3.5 Observation

In each experimental unit, five plants were selected at random and the following observations were recorded at three stages.

(i) Eighth month after planting

(ii) Twelth month after planting

(iii) Sixteenth month after planting

3.5.1 PLANT GROWTH ATTRIBUTES

Data on plant height, stem girth, leaf area, petiole length, number of leaves and petiole girth were recorded at three stages *viz.,* 8^{th}, 12^{th} and 16^{th} month after planting.

3.5.1.1 Plant height

The height of the plant was measured from a fixed point of 15 cm above the ground level to the growing tip of the plant and was expressed in cm.

3.5.1.2 Stem girth

The stem girth was also measured at 15 cm above the ground level and was expressed in cm.

3.5.1.3 Number of leaves

The fully developed, opened leaves were counted from the tip to the base of the tree.

3.5.1.4 Leaf area

Leaf area was calculated adopting the method of Karikari (1973).

$$y = 106x\text{-}2028$$

Where x represents the length of the median midrib in centimetre.

3.5.1.5 Petiole length

Length of the petiole was measured in ten fully matured leaves and their average was arrived and expressed in cm.

3.5.2 FRUIT CHARACTERS

Following fruit characters were recorded at three stages 8th, 12th and 16th month after planting

3.5.2.1 Weight of the fruit

The whole weight of 20 fruits was taken and their mean weight expressed in kilogram.

3.5.2.2 Fruit length

It was measured from the stylar end to the pedicel end of the fruit along the curve and expressed in centimetre.

3.5.2.3 Fruit circumference

It was measured at the broadest portion of the fruit and expressed in centimetre.

3.5.2.4 Volume of the fruit

If was calculated by water displacement method and expressed in millilitre.

3.5.2.5 Cavity volume

The amount of water held by the two cavities of the fruit after removing the seeds was measured and totalled as cavity volume in millilitre.

3.5.2.6 Cavity index

It was calculated by using the formula given below

$$\text{Cavity index} = \frac{\text{Cavity volume (ml)}}{\text{Fruit volume (ml)}} \times 100$$

3.5.2.7 Pulp thickness

After cutting the fruit into two halves, the pulp thickness was measured and expressed in centimetre.

3.5.3 YIELD CHARACTERS

3.5.3.1 Number of fruits per tree

Number of fruits including fruitlets borne on the tree at all the three stages were counted by making a red mark at the stem at each stage and were added to arrive at number of fruits per tree.

3.5.3.2 Yield of fruits per tree

The mean weight of fruit was multiplied with total number of fruits per tree and expressed in kilogram.

3.5.4 BIOCHEMICAL ANALYSIS

FRUITS

3.5.4.1 Total soluble solids

The total soluble solids content in the pulp was determined using a zeiss hand refractometer. The readings were recorded as brix.

3.5.4.2 Titrable acidity

The acidity was estimated as per the A.O.A.C method (1960) and expressed in percentage.

3.5.4.3 Ascorbic acid

The ascorbic acid content of the fruit was estimated as per the method of A.O.A.C. (1975) and expressed in milligram per 100 gram.

3.5.4.4 Total sugars

It was estimated by the method of A.O.A.C. (1960) and expressed in percentage.

3.5.4.5 Reducing sugars

It was estimated by the method of A.O.A.C. (1960) and expressed in percentage.

3.5.4.6 Non-Reducing sugars

The difference between total and reducing sugars was computed as non - reducing sugars and expressed in percentage.

3.5.4.8 Chlorophyll content

Total chlorophyll, chlorophyll a, chlorophyll b were estimated in a fully expanded leaf as per the procedure outlined by Yhoshida *et al.* (1971) and expressed in milligram per 100 gram.

3.5.4.9 IAA oxidase activity

The enzyme IAA oxidase activity in the leaf sample was determined as per the method of Parthasarathi *et al.* (1970) calorimetrically at 540 nm. The OD values were referred to a standard curve using auxin (IAA 10 to 100 $\mu g\ l^{-1}$) and expressed in $\mu g\ g^{-1}\ h^{-1}$ of fresh sample.

3.5.4. 10 Soluble protein

Soluble protein was estimated by spectrophotometry method only with T_1 and T_7 samples as per the procedure outlined by Lowry *et al.* (1951)

3.6 Latex extraction

Latex was tapped from 75 days old green fruits by lancing to a depth of 2mm using a stainless steel blade. Four longitudinal incissions were given per fruit and each fruit was lanced four times at four days interval. The latex was collected in aluminium trays. The total wet weight of latex was taken and expressed in gram per fruit.

In the present study, the yield of latex per fruit was calculated at three stages *viz.*, eighth, twelth and sixteenth month after planting.

Drying

The latex collected in a day was oven dried at 55°C for two hours and the dry weight of the latex was recorded. Before drying, KMS 50 mg/100g of latex was added as a preservative. The crude papain was powdered and packed in polythene bags.

3.7 Assay of papain activity

The proteolytic enzyme activity was estimated thrice. At 12^{th} and 16^{th} month after planting it was estimated only for T_1 and T_7 treatments. The method adopted was "Tyrosine release assay" of Moore (1984) and the enzyme activity was expressed in Tyrosine units Tu per milligram of papain.

Solutions required

a). Casein substrate : 10g of Hammarsten quality casein was suspended in 500 ml of phosphate cysteine EDTA buffer to obtain casein substrate.

b). Phosphate - Cysteine EDTA Buffer : 3.55 g of anhydrous disodium hydrogen phosphate was transfered into a 500 ml volumetric flask, 70 g of EDTA and 3.05 g of cysteine hydrochloride was added and mixed. The pH was adjusted to 6 with 1N Hydrochloride in 1N Sodium hydroxide and diluted to 500 ml with water.

3. TCA Solution

It was prepared by dissolving 300 g of TCA in water and diluted to one litre.

4. Papain Solution

It was prepared by dissolving an accurately weighed sample (100 mg) in phosphate cysteine EDTA buffer solution. Solution so prepared was diluted to 100 ml with phosphate cysteine EDTA buffer solution. 2 ml of this solution was diluted to 50 ml with the same buffer solution. And the solution was used within 30 minutes of prepartion.

5. Tyrosine solution

It was prepared by adding 100 mg of tyrosine in 100 ml of 0.1 M Hcl. From that solution 1ml was taken and made upto 20 ml ie., 50 μg/ml.

Procedure

For 'each papain sample prepared, four test-tubes containing 5 ml casein substrate and 1 ml phosphate cysteine EDTA buffer was prepared and marked T_1, T_2, B_1, B_2 and placed in a water bath for 10 minutes to reach the bath temperature. 1 ml of papain solution was added to T_1 and T_2 and was mixed immediately. After exactly 60 minutes, 3 ml of trichloro acetic acid solution was added to the tubes T_1, T_2, B_1, B_1 and mixed again. All tubes were replaced in water bath for 30 to 40 minutes and precipitated protein was allowed to coagulate completely followed by filtering through whatman No.1 filter paper, and reading the absorbance of each filtrate and the tyrosine standards at 250 nm.

Let OD of tyrosine standard (50 μg/ml) = s

Let OD of T-B (T - Average of T_1 and T_2)

(B = Average of B_1 and B_2) = D

Let concentration of papain (μg) per ml = x_1, then

$$\text{tyrosine units} = \frac{Dx50}{5} \times \frac{10x1000}{5} \times \frac{1}{60} \text{ per mg papain sample.}$$

3.8 PLANT NUTRIENT ANALYSIS

The youngest fully matured leaf was used for analysis. The leaves were collected at three stages *viz.*, 8th month (I stage), 12th month (II stage), and 16^{th} month (III stage). Leaves were washed with 0.1N Hcl and again with double distilled water, dried, powdered and analysed for the following elements.

3.8.1 Nitrogen

Total' nitrogen content in the leaf blade and petiole was estimated by Microkjeldahl method (Humphries, 1956) and expressed in percentage.

3.8.2 Phosphorous

The phosphorus in the triple acid extract of the given leaf blade and petiole sample was estimated by Colorimetric method (Jackson, 1967) and expressed in percentage.

3.8.3 Potassium

The potassium in the triple acid extract of the leaf blade and petiole sample was estimated by emission spectroscopy method (Jackson, 1967) and expressed in percentage.

3.8.4 Zinc

Total zn content of leaf blade and petiole were estimated from the triple acid extract, using atomic absorption spectrophotometer (Jackson, 1967) and expressed in ppm.

3.8.5 Boron

Total B content of leaf blade and petiole were estimated in leaf blade and peitole by caramine method (Hatchar and Wilcox, 1950) and expressed in ppm to determine the B.

3.9 NUTRIENT AVAILABILITY IN SOIL

Initial soil sample was collected to assess the initial nutrient status. It was done before transplanting. Thereafter, soil samples were collected at three stages *viz.*, 8th month after planting, 12th month after planting and 16th month after planting and analysed for the available nutrients.

3.9.1 Nitrogen

This was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed as kilogram per hectare.

3.9.2. Available Phosphorus

This was estimated colorimetrically by Olsen's method (Olsen *et al.*, 1954) and expressed as kilogram per hectare.

3.9.3 Available Potassium

This was estimated following the method of Stanford and English (1949) and expressed as kilogram per hectare.

3.9.4 Available Zinc

The DTPA extract was fed into atomic absorption spectrophotometer at the wave length of 2138.6 A to estimate the available Zinc (Lindsay and Norwell, 1978) and expressed in ppm.

3.9.5 Available Boron

The available B (Hot-water soluble B) in the soil was estimated by carmine method (Hatcher and Wilcox, 1950) and expressed in ppm.

3.10 Statistical analysis

The data collected in respect of growth attributes of plant, biometrics of fruit and yield, biochemical characters, nutrient uptake by the plant and nutrient availability in the soil were subjected to statistical analysis following the method of Panse and Sukhatme (1969).

Experimental Results

CHAPTER III

EXPERIMENTAL RESULTS

The results emanated from the investigation to determine the effect of zinc and boron on growth, yield and quality of papaya cv. Co.5 are encompassed in this chapter.

4.1 Plant growth attributes

Plant growth attributes *viz.*, plant height, stem girth, leaf area, petiole length and number of leaves were recorded at 8th, 12th and 16th month after planting and designated as stage I, II and III respectively.

4.1.1. Plant height

The perusal of the data indicated significant difference in plant height at stage I and II, while it was not significantly affected at stage III (Table 1). At stage I, maximum plant height was associated with T_7 (319.86 cm) followed by T_6. While at stage II, the maximum plant height with T_7 (373.80 cm) remained on par with T_6 and T_8. T_7 continued to register the maximum plant height at stage III also.

4.1.2. Stem girth

The stem girth did differ significantly at all stages of observation. Maximum stem girth of 49.53, 66.04 and 74.38 cm was observed with T_7 at stage II and III respectively (Table 1). At stage I, T_7 was followed by T_6. At stage II T_7 remained on par with T_6, T_8 and T_5 while at stage III T_7 was on par with T_6 alone.

Table 1. Effect of Zinc and Boron on plant height (cm), stem girth (cm) and leaf area (cm^2)

Treatments	Plant height			Stem girth			Leaf area		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	288.49	342.32	394.74	42.23	56.24	66.15	2550.81	2606.99	2572.80
T_2	295.07	345.76	396.57	42.98	57.49	68.23	2644.61	2651.54	2653.41
T_3	297.07	349.63	399.25	43.37	58.32	69.59	2716.84	2735.36	2740.25
T_4	300.98	353.48	402.40	44.06	59.97	70.23	2724.12	2784.30	2798.09
T_5	302.95	360.46	403.33	44.91	61.57	70.97	2881.03	2898.33	2911.99
T_6	307.50	365.97	407.56	47.38	64.21	72.81	2960.53	2989.60	3008.15
T_7	319.86	373.80	410.71	49.53	66.04	74.38	3072.86	3098.43	3110.37
T_8	304.49	364.29	406.07	45.96	62.83	71.22	2910.70	2933.07	2954.61
SEd	4.7008	4.9729	13.06	0.5852	2.1535	2.0305	111.2269	66.6096	69.7554
CD at 5%	10.0834	10.6670	NS	1.2553	4.6192	4.3555	238.583	142.8790	149.6267

4.1.3 Leaf area

Significant difference was observed among treatments for leaf area at all stages. Maximum leaf area (3072.86, 3098.43, 3110.37 cm ^{2}) was recorded with T_7 at stage I, II and III respectively (Table 1). At stage I, T_7 was on par with T_6, T_8 and T_5. At stage II, T_7 remained on par with T_6 and at stage III, T_7 was on par with T_6 and T_8.

4.1.4 Petiole length

Petiole length exhibited significant difference at stage I and II alone. The highest petiole length (98.33, 109.88 and 119.45 cm) was registered with T_7 followed by T_6 at stage I, II and III respectively (Table 2).

4.1.5 Number of leaves

Number of leaves differed significantly at stage I alone. T_7 registered the maximum number of leaves at all the three stages followed by T_6 and T_8 in the descending order (Table 2).

4.2 FRUIT CHARACTERS

4.2.1. Fruit weight

Fruit weight was significantly affected at all the stages. T_7 recorded the maximum fruit weight of 2220.73 g at stage I and it was on par with T_6, T_8 and T_5. A similar trend becomes obvious at stage II and III as well (Table 3, Fig.1).

Table 2. Effect of Zinc and Boron on petiole length (cm) and number of leaves.

Treatments	Petiole length			Number of leaves		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	92.19	103.64	108.22	35.16	33.66	27.01
T_2	93.15	104.05	110.31	35.57	34.40	27.24
T_3	93.65	104.82	111.25	36.63	34.83	27.51
T_4	94.23	104.94	112.51	36.83	35.50	27.92
T_5	94.85	105.53	114.32	36.98	35.54	28.24
T_6	97.55	108.77	116.06	37.57	36.03	28.35
T_7	98.33	109.88	119.45	38.22	36.41	29.25
T_8	95.90	106.03	115.76	37.25	35.80	28.33
SEd	0.7153	0.9906	3.0570	0.7418	1.7237	1.0837
CD at 5%	1.5344	2.1249	NS	1.5911	NS	NS

4.2.2 Fruit length

Significant variation in fruit length was noticed at stage I and II only (Table 3). T_7 recorded the maximum fruit length (30.56 and 26.45 cm) at stage I and II respectively. At both stages, T_7 was on par with T_6 and T_8. T_7 continued to record the maximum fruit length at stage III also.

4. 2.3. Fruit circumference

Fruit circumference was found to differ significantly among treatments at stage I and II only (Table 3). At stage I and II the maximum fruit circumference (53.84 and 48.80 cm) was obtained with T_7 which was on par with T_6 and T_8. T_7 continued to record the maximum circumference at stage III as well.

4.2.4. Fruit volume

Significant difference existed for fruit volume at stage I and II only. At stage I, T_7 recorded the maximum volume (3189.29 ml) which was on par with T_6 and T_8. Similarly, at stage II, T_7 registered the maximum volume (2873.15 ml) which remained on par with T_6, T_8, T_5 and T_4. And at stage III also T_7 continued to be effective in registering the higher fruit volume (Table 3).

4.2.5. Cavity volume

The cavity volume exhibited significant differences among treatments at stage I and II, while it failed to attain the level of significance at stage III (Table 4). At both stage I and II, the highest cavity volume of 822.98 ml and 704.36 ml was associated with T_7 which was on par with T_6.

Table 3. Effect of Zinc and Boron on fruit weight (g), fruit length (cm), fruit circumference (cm) and fruit volume (ml).

Treatments	Fruit weight			Fruit length			Fruit circumference			Fruit volume		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	1780.63	1610.61	1221.39	23.20	22.20	17.11	42.84	41.17	31.59	2520.65	2422.29	1858.67
T_2	1832.76	1655.53	1253.71	23.78	22.61	17.54	43.90	41.73	32.39	2582.88	2457.42	1905.32
T_3	1895.40	1700.82	1305.92	25.06	22.96	18.24	46.25	42.39	33.66	2722.29	2494.23	1980.49
T_4	1943.70	1738.60	1333.64	25.47	23.89	18.60	47.01	44.12	34.34	2766.01	2595.52	2020.38
T_5	2012.60	1793.30	1369.43	26.62	24.90	19.08	49.14	45.97	35.22	2891.29	2704.63	2071.92
T_6	2150.63	1898.68	1439.21	29.39	25.95	20.00	51.96	47.85	36.93	3101.19	2815.16	2172.41
T_7	2220.73	1946.4	1469.70	30.56	26.45	20.41	53.84	48.80	37.67	3187.29	2873.15	2216.36
T_8	2095.63	1849.7	1405.8	28.83	25.49	19.56	51.32	47.04	36.11	3019.09	2767.16	2124.35
SEd	52.5851	106.7043	108.0914	0.8084	1.3682	1.2996	1.4057	2.5090	1.9456	83.2818	147.5231	155.7773
CD 5%	112.7961	228.8829	231.8582	1.7341	2.9348	NS	3.0153	5.3818	NS	178.6412	316.4399	NS

4.2.6. Cavity index

The cavity index varied significantly among different treatments at all the three stages. The highest cavity index of 26.76, 25.73, and 24.36 per cent was associated with T_7 followed by T_6 at stage I, II and III respectively (Table 4).

4.2.7. Pulp thickness

Different treatments failed to exhibit significant difference for pulpthickness at any stage of observation (Table 4).

4.3 Fruit and latex yield

4.3.1. Number of fruits per tree

Number of fruits increased significantly with different treatments .The maximum number of fruits were obtained with T_7 (166.75) followed by T_6 (161.56) and T_8 (160.80) in order (Table 5, Fig. 2).

4.3.2. Yield of fruits per tree

Significant difference was also obtained for fruit yield per tree among different treatments. The higher fruit yield was obtained with T_7 (330. 68 kg/ tree) closely followed by T_6 and T_8 in order (Table 5, Fig. 3).

4.3.3. Latex yield

Latex yield did differ significantly among the various treatment at all stages (Table 5, Fig.4). The highest latex yield was observed with T_7 at all stages. However many other treatments particularly T_6 and T_8 remained on par with T_7.

Table 4. Effect of Zinc and Boron on Cavity volume (ml), Cavity index (%) and Pulp thickness (cm)

Treatments	Cavity volume			Cavity index			Pulp thickness		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	659.82	585.20	444.94	25.09	24.27	23.16	3.01	3.01	2.98
T_2	679.21	593.08	458.55	25.43	24.45	23.58	3.20	3.01	3.01
T_3	702.59	603.41	477.64	25.49	24.52	23.88	3.15	2.92	2.95
T_4	720.31	627.18	487.77	25.67	24.76	23.97	2.95	3.05	3.10
T_5	745.85	646.35	498.89	25.81	24.95	24.09	2.98	3.02	3.02
T_6	797.00	689.33	524.37	26.59	25.44	24.16	3.03	3.05	3.03
T_7	822.98	704.36	537.54	26.76	25.73	24.36	3.02	3.03	3.11
T_8	776.62	658.10	512.16	26.13	25.19	24.11	3.04	3.01	3.05
SEd	19.4899	32.3036	39.4176	0.1600	0.0911	0.1573	0.0601	0.0462	0.0674
CD at 5%	41.8062	69.2917	NS	0.3432	0.1953	0.3374	NS	NS	NS

Table 5. Effect of Zinc and Boron on fruit yield (number and weight of fruits (kg) per tree and latex yield (g/fruit)

Treatments	Number of fruits	Yield of fruits	Latex yield		
			Stage I	Stage II	Stage III
T_1	136.98	230.17	18.53	12.54	4.53
T_2	144.36	240.84	19.27	12.98	4.64
T_3	148.18	255.41	19.61	13.21	5.18
T_4	155.34	273.15	20.14	13.66	5.43
T_5	156.08	284.55	21.03	14.15	5.61
T_6	161.56	311.96	21.68	15.06	6.18
T_7	166.75	330.68	22.76	15.23	6.54
T_8	160.80	301.17	21.65	14.72	5.97
SEd	1.1561	3.8295	0.6344	0.629	0.2755
CD at 5%	2.4812	8.2144	1.3608	1.350	0.5908

4.4. Biochemical and quality characters

4.4.1. Leaf total chlorophyll

Total leaf chlorophyll content declined from stage I to III. The variations were statistically significant among treatments at all the stages (Table 6). Among the treatments, the highest total chlorophyll content was recorded with T_7 (137.52, 133.81, 129.82 mg/100g) at stage I to III respectively. However, T_7 remained on par with T_6 and T_8.

4.4.2. Chlorophyll a

A gradual decrement in chlorophyll content was noticed from stage I to III. Statistically significant variation existed among the treatments at all the stages. The highest chlorophyll a content was observed with T_7 (103.94, 100.97, 97.36 mg/100g) at stage I, II and III respectively. T_7 remained on par with T_6, T_8 and T_5 at stage I and III, while at stage II it remained on par with T_6 alone (Table 6).

4.4.3. Chlorophyll b

Chlorophyll b content tends to decline gradually from stage I to III. Marked difference was observed among different treatments. Maximum chlorophyll b content of 36.05, 33.84 and 32.46 mg/100g was registered with T_7 at stage I, II and III respectively (Table 6). T_7 was on par with T_8, T_4, T_5 and T_6 at stage I, while it was on par with T_6 and T_8 at stage II and III respectively.

Table 6. Effect of Zinc and Boron on leaf total chlorophyll, chlorophyll a and chlorphyll b content (mg/100g) IAA oxidase activity (mg/g/hr) and soluble protein content (mg/g)

Treat-ments	Total chlorophyll			Chlorophyll a			Chlorophyll b			IAA oxidase activity
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	
T_1	131.41	126.42	121.21	98.55	94.80	90.90	32.86	31.46	30.30	677.64
T_2	132.46	128.19	122.55	99.31	96.15	91.91	33.11	32.05	30.64	677.28
T_3	133.87	128.92	123.71	101.39	96.68	92.78	33.70	32.56	30.93	676.41
T_4	135.27	131.27	124.37	101.65	98.45	93.27	34.28	32.81	31.11	676.22
T_5	136.26	131.83	126.59	102.27	98.87	94.97	34.51	32.96	31.66	675.91
T_6	137.21	133.23	129.16	103.11	99.91	96.86	34.65	33.31	32.29	675.08
T_7	137.52	133.81	129.82	103.94	100.97	97.36	36.05	33.84	32.46	673.08
T_8	136.82	132.14	128.32	102.48	99.10	96.17	34.16	33.03	32.03	675.57
SEd	1.3094	0.8591	1.3835	0.7133	0.5680	1.0420	0.3029	0.2863	0.3438	1.2798
CD at 5%	2.8086	1.8427	2.9697	1.5300	1.2184	2.2352	0.6497	0.6141	0.7374	2.7451

4.4.4 IAA Oxidase activity

The influence exerted by different treatments attained the statistical significance for IAA oxidase activity (Table 6). The minimum IAA oxidase activity (673.08 µg/g/hr) was associated with T_7 which was however on par with T_6 and T_8.

4.4.5 Titrable acidity

Titrable acidity failed to reach the level of significance at any stage of observation (Table 7).

4.4.6. Total, reducing and non-reducing sugar

Total and reducing sugars differed significantly at all stages, while non-reducing sugars did not differ significantly only at stage III (Table 7). The highest total sugars and reducing sugar were obtained with T_7 (8.505 and 7.039 per cent respectively) at stage I, (7.830 and 6.585 per cent respectively) at stage II, (6.57 and 5.56 per cent respectively) at stage III. While, the highest non-reducing sugars (1.528 and 1.452 per cent respectively) were recorded with T_7 at stage I and II. T_7 continued to be effective at stage III as well.

4.4.7. Ascorbic acid

Among the treatments, significantly higher ascorbic acid content (47.02, 47.14, 47.07 mg/100g) was observed with T_7 at stage I, II and III respectively, while the lowest was recorded with control (Table 8).

Table 7. Effect of Zinc and Boron on titrable acidity (%), total sugars (%), reducing sugars (%), and non-reducing sugars(%) of fruits.

Treatments	Titrable acidity Stage I	Titrable acidity Stage II	Titrable acidity Stage III	Total sugars Stage I	Total sugars Stage II	Total sugars Stage III	Reducing sugars Stage I	Reducing sugars Stage II	Reducing sugars Stage III	Non-reducing sugars Stage I	Non-reducing sugars Stage II	Non-reducing sugars Stage III
T_1	0.240	0.250	0.242	7.764	6.856	5.867	6.570	5.824	4.967	1.189	1.023	0.901
T_2	0.261	0.260	0.261	7.818	6.946	5.946	6.598	5.860	5.034	1.192	1.036	0.912
T_3	0.263	0.263	0.260	7.943	7.062	6.072	6.645	5.905	5.141	1.209	1.157	0.935
T_4	0.274	0.277	0.261	7.972	7.254	6.120	6.719	6.102	5.181	1.311	1.285	0.939
T_5	0.272	0.277	0.282	8.123	7.434	6.186	6.795	6.244	5.304	1.317	1.322	0.948
T_6	0.286	0.290	0.290	8.314	7.746	6.412	6.948	6.438	5.429	1.404	1.359	0.983
T_7	0.281	0.293	0.291	8.505	7.830	6.575	7.039	6.585	5.566	1.528	1.452	1.004
T_8	0.270	0.283	0.283	8.164	7.606	6.312	6.810	6.302	5.343	1.330	1.337	0.967
SEd	0.0119	0.0148	0.0156	0.0370	0.0468	0.0996	0.0668	0.0539	0.0782	0.0813	0.0885	0.0319
CD 5%	NS	NS	NS	0.0794	0.1003	0.2136	0.1433	0.1157	0.1678	0.1745	0.1898	NS

4.4.8. TSS

The TSS content of fruits declined from stage I to III. The highest TSS (14.80, 13.86 and 12.94°B) with T_7 remained on par with T_6 and T_8 at stage I, II and III respectively (Table 8).

4.4.9. Sugar-acid ratio

Different treatments failed to exhibit significant differences for sugar acid ratio at any stage of observation (Table 8).

4.4.10. Proteolytic enzyme activity of latex

The enzyme activity of latex was higher with T_7 than control (Table 8).

4.5. Leaf nutrient concentration

Leaf blade nutrient concentration

4.5.1. Nitrogen

The leaf blade nitrogen content failed to attain level of significance at any stage of observation (Table 9).

4.5.2. Phosphorus

The leaf blade phosphorus content did not differ significantly among the treatments at any stage of observation (Table 9).

4.5.3. Potassium

The influence exerted by different treatments failed to alter the potassium content of leaf blade significantly at all stages of observation (Table 9).

Table 8. Effect of Zinc and Boron on ascorbic acid content (mg/100g), TSS (°brix), sugar-acid ratio, and proteolytic enzyme acitivity of latex (Tu/mg).

Treatments	Ascorbic acid			TSS			Sugar acid ratio			Proteolytic enzyme activity
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I
T_1	45.11	45.42	44.01	12.30	11.46	10.80	32.38	27.55	23.47	204.32
T_2	45.87	45.63	44.29	12.40	11.80	11.70	30.90	26.73	23.16	204.34
T_3	45.93	45.97	44.36	12.90	12.36	11.83	29.82	26.65	23.09	204.35
T_4	46.09	46.11	44.56	13.23	12.76	12.13	29.55	26.02	22.41	204.36
T_5	46.47	46.52	45.75	13.53	13.03	12.34	30.10	26.87	22.66	204.49
T_6	46.97	46.87	46.98	14.63	13.56	12.75	29.75	26.69	22.26	205.21
T_7	47.02	47.14	47.07	14.80	13.86	12.94	30.61	26.71	22.30	205.90
T_8	46.86	46.65	45.86	14.30	13.31	12.62	30.34	26.43	22.87	205.11
SEd	0.1439	0.1759	0.5538	0.2021	0.2309	0.3467	1.1427	0.8487	1.2924	0.4820
CD 5%	0.3087	0.3774	1.1879	0.4335	0.4952	0.7437	NS	NS	NS	NS

Table 9. Effect of Zinc and Boron on leaf blade nitrogen content(%), Phosphorus content (%) and potasium content (%)

Treatments	Nitrogen			Phosphorus			Potassium		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	3.46	3.31	2.82	0.331	0.318	0.266	3.83	3.73	3.94
T_2	3.59	3.44	3.27	0.335	0.319	0.263	3.91	3.81	4.02
T_3	3.48	3.47	3.00	0.331	0.318	0.268	3.89	3.78	4.00
T_4	3.62	3.38	2.96	0.332	0.320	0.267	3.98	3.95	4.01
T_5	3.69	3.56	2.98	0.332	0.322	0.268	3.96	3.97	3.95
T_6	3.63	3.52	3.10	0.334	0.324	0.270	4.01	4.02	4.00
T_7	3.72	3.58	3.17	0.335	0.327	0.271	4.09	4.13	4.05
T_8	3.61	3.51	3.00	0.333	0.324	0.269	3.90	4.05	3.75
SEd	0.1669	0.5701	0.6890	0.0118	0.0038	0.0192	0.0736	0.0787	0.0813
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.5.4. Zinc

Zn content of leaf blade gradually declined from stage I to III. It differed significantly among treatments at all the three stages, (Table 10). The highest Zn content was observed with T_7 (63.44, 59.04 and 53.59 ppm) followed by T_6 which was on par with T_8 at stage I, II and III respectively.

4.5.5. Boron

A decrement in leaf blade B content was obvious from stage I to III. Significant difference existed among treatments with reference to B content (Table 10). The highest B content was registered with T_7 (39.89, 36.94, and 32.31 ppm) which was on par with T_6 at stage I, II and III respectively.

Petiole nutrient content

4.5.6. Nitrogen

Different treatments failed to exhibit significant differences for petiole nitrogen at all stages of the observation (Table 11).

4.5.7. Phosphorus

The influence exerted by different treatments failed to alter the phosphorus content of the petiole significantly at any stage of observation (Table 11).

4.5.8. Potassium

Different treatments failed to reach the level of significance for petiole potassium content at any stage of observation (Table 11).

Table 10. Effect of Zinc and Boron on leaf blade Zinc content (ppm) and Boron content (ppm).

Treatments	Zinc			Boron		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	44.42	42.20	40.37	33.35	29.02	27.21
T_2	56.01	51.35	46.44	34.29	29.65	28.70
T_3	59.55	53.25	46.54	35.56	31.13	29.04
T_4	48.63	43.07	39.39	36.83	32.24	30.24
T_5	49.51	44.05	40.37	37.24	34.48	30.27
T_6	62.18	58.08	53.36	39.60	36.00	31.33
T_7	63.44	59.04	53.59	39.89	36.94	32.31
T_8	62.15	57.64	53.44	39.48	35.57	31.09
SEd	0.5740	0.6661	1.4650	0.5489	1.6234	0.3838
CD at 5%	1.2313	1.4287	3.1425	1.1775	3.4823	0.8233

Table 11. Effect of Zinc and Boron on petiole nitrogen content (%), phosphorus content (%) and potassium content (%)

Treatments	Nitrogen			Phosphorus			Potassium		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	2.21	1.97	1.89	0.327	0.282	0.216	4.92	4.13	3.94
T_2	2.21	1.99	1.90	0.328	0.283	0.216	4.93	4.15	3.97
T_3	2.23	1.95	1.91	0.330	0.285	0.219	4.99	4.16	3.98
T_4	2.24	1.95	1.88	0.330	0.284	0.218	5.01	4.20	4.00
T_5	2.22	1.94	1.87	0.329	0.285	0.218	5.04	4.22	4.00
T_6	2.24	1.98	1.90	0.330	0.287	0.219	5.05	4.27	4.01
T_7	2.25	1.97	1.87	0.331	0.286	0.219	5.06	4.26	4.02
T_8	2.25	1.96	1.84	0.331	0.285	0.217	5.03	4.24	4.01
SEd	0.0722	0.0540	0.0202	0.0017	0.0053	0.0049	0.0489	0.0649	0.0123
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.5.9. Zinc

Significant differences existed among treatments at all stages (Table 12). The highest Zn content was observed with T_7 (36.30, 34.27 and 29.93 ppm) followed by T_8 which was on par with T_6 at stage I, II and III respectively.

4.5.10 Boron

Treatments differed significantly for B content at all the stages (Table 12). The highest B content was observed with T_7 (39.24, 37.54, and 34.29 ppm) followed by T_6 which was on par with T_8 at stage I, II and III respectively.

4.6. Nutrient availability in the soil

4.6.1. Nitrogen

Different treatments failed to reach the level of significance for soil available N at any stage of the observation (Table 13).

4.6.2. Phosphorus

Differences among treatments failed to reach the level of significance for soil available P at any stage of observation (Table 13).

4.6.3. Potassium

The influence exerted by different treatments did not attain statistical significance for soil available K content (Table 13).

Table 12. Effect of Zinc and Boron on petiole Zinc content (ppm) and Boron content (ppm)

Treatments	Zinc			Boron		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	27.63	25.17	22.06	30.93	29.43	29.22
T_2	32.76	29.60	27.37	32.17	31.82	28.98
T_3	33.42	30.02	27.83	33.59	31.95	30.05
T_4	27.83	28.44	25.02	33.80	32.06	30.94
T_5	29.92	28.63	26.43	34.24	33.62	32.11
T_6	35.24	34.05	28.71	37.74	35.05	34.05
T_7	36.30	34.27	29.93	39.24	37.54	34.29
T_8	35.13	33.55	28.56	36.91	34.59	33.98
SEd	0.1673	0.1568	0.1481	0.3651	0.3518	0.4377
CD at 5%	0.3590	0.3364	0.3176	0.7831	0.7547	0.9389

Table 13. Effect of Zinc and Boron on soil nitrogen content (kg/ha), phosphorus content (kg/ha) and potassium content (kg/ha).

Treatments	Nitrogen			Phosphorus			Potassium		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	239.37	230.37	223.21	21.90	19.14	19.50	803.46	814.16	813.05
T_2	240.25	231.50	224.48	23.34	20.03	19.95	804.60	813.59	812.21
T_3	240.44	231.53	224.03	23.30	19.59	18.76	805.55	815.54	811.34
T_4	240.60	231.18	224.52	21.26	20.48	18.13	805.72	814.73	812.60
T_5	241.25	232.22	225.34	22.42	21.38	18.27	806.49	814.60	813.29
T_6	243.26	234.53	226.69	24.36	22.26	19.57	807.50	816.44	814.51
T_7	241.63	235.03	224.81	23.43	22.71	19.78	808.81	819.33	815.01
T_8	242.49	234.05	225.51	25.30	21.82	19.41	806.97	816.42	813.98
SEd	12.0601	11.0302	0.9405	14.4862	13.1267	11.8214	110.6230	109.2341	106.2640
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.6.4. Zinc

The effect of different treatments revealed significant difference for available soil Zn content at all the stages. The highest soil available Zn (1.338, 1.325 and 1.319 ppm) was registered with T_8 which was on par with T_7 at stage I, II and III respectively (Table 14).

4.6.5. Boron

Significant difference existed among the treatments with reference to available soil B at all stages. The highest soil available B (0.354, 0.312 and 0.276 ppm) was recorded with T_8 at all the stages. However T_8 remained on par with T_7 and T_6 (Table 14).

Table 14. Effect of Zinc and Boron on soil zinc content (ppm) and Boron content (ppm).

Treatments	Zinc			Boron		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
T_1	1.11	1.109	1.020	0.294	0.288	0.258
T_2	1.197	1.186	1.170	0.296	0.289	0.267
T_3	1.210	1.191	1.189	0.296	0.290	0.271
T_4	1.117	1.113	1.108	0.298	0.293	0.272
T_5	1.128	1.118	1.111	0.310	0.296	0.274
T_6	1.230	1.227	1.226	0.311	0.299	0.275
T_7	1.258	1.252	1.249	0.334	0.305	0.275
T_8	1.338	1.325	1.319	0.354	0.312	0.276
SEd	0.0867	0.0667	0.0923	0.0007	0.0061	0.0080
CD at 5%	0.1861	0.1782	0.1924	0.0015	0.0132	0.0018

Discussion

CHAPTER - IV

DISCUSSION

Maximising productivity in papaya depends upon the adoption of improved crop management practices such as optimum plant population, applying required fertilizers etc., Papaya has tremendous yield potential due to precocious bearing and indeterminate growth habit with simultaneous vegetative growth, flowering and fruiting. Hence, the extent of various nutrients removed from the soil by whole papaya plant at different stages namely vegetative, preflowering, flowering, fruit development, harvest etc., by Veeranah and Selvaraj (1984) revealed that K, N, Ca, Mg and P were the important chemicals in order for papaya. Recently,micronutrients such as Zn, B, Fe, Mn etc., are reported to increase the fruit yield and also the quality in many fruit crops but their role in a exhaustive crop like papaya is very rare. Earlier studies with micronutrients particularly with Boron recorded 162% increase in yield (Veenapant and Lavania, 1989) and the increase was 107% with multiplex, multinutrient mixture formulation (Medicinal and Aromatic plants improvement project, 1985). In the present investigation the effect of Zn and B through foliar application either in single or combination was assessed on the growth, yield, quality of yield, including the latex yield in cv. Co.5. The results of the present experiment are discussed under the following head lines.

Plant growth attributes

In papaya production, plant height assumes pragmatic significance as it is directly related to productivity. The plant height or girth at flowering can be used as an index of plant vigour to reflect yield potential in papaya (Purohit, 1993). In the present investigation, T_7 ie. foiar spray of Zn 0.5% + and B 0.1% at 4th, 8th, 12th and 16th month after planting registered increased plant height, indicating the superiority of first order interactions when applied as foliar spray at every four month interval corroborating the findings of Veenapant and Lavania (1989) in papaya, Srivastava (1966) and Das and Mohan (1993) in banana. Stem girth decides the healthy stature of the plant rather than the plant height. In the present study the girth was maximum with T_7 ie. foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting, once again highlighting the supremacy of first order interaction when applied as foliar spray at every four months interval. These observations are in congruence with those of Veenapant and Lavania (1989) in papaya, Das and Mohan (1993) in banana.

In papaya, petiole length is a deciding factor for proper positioning of leaves to harness the solar radiation and to enhance the photosynthetic rate. The treatment with foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting in the present study emerged as the best treatment registering the maximum petiole length. Longer petioles are considered more desirable than the shorter ones as they facilitate better exposure of fruits in the central axis for better fruit growth and enhanced quality.

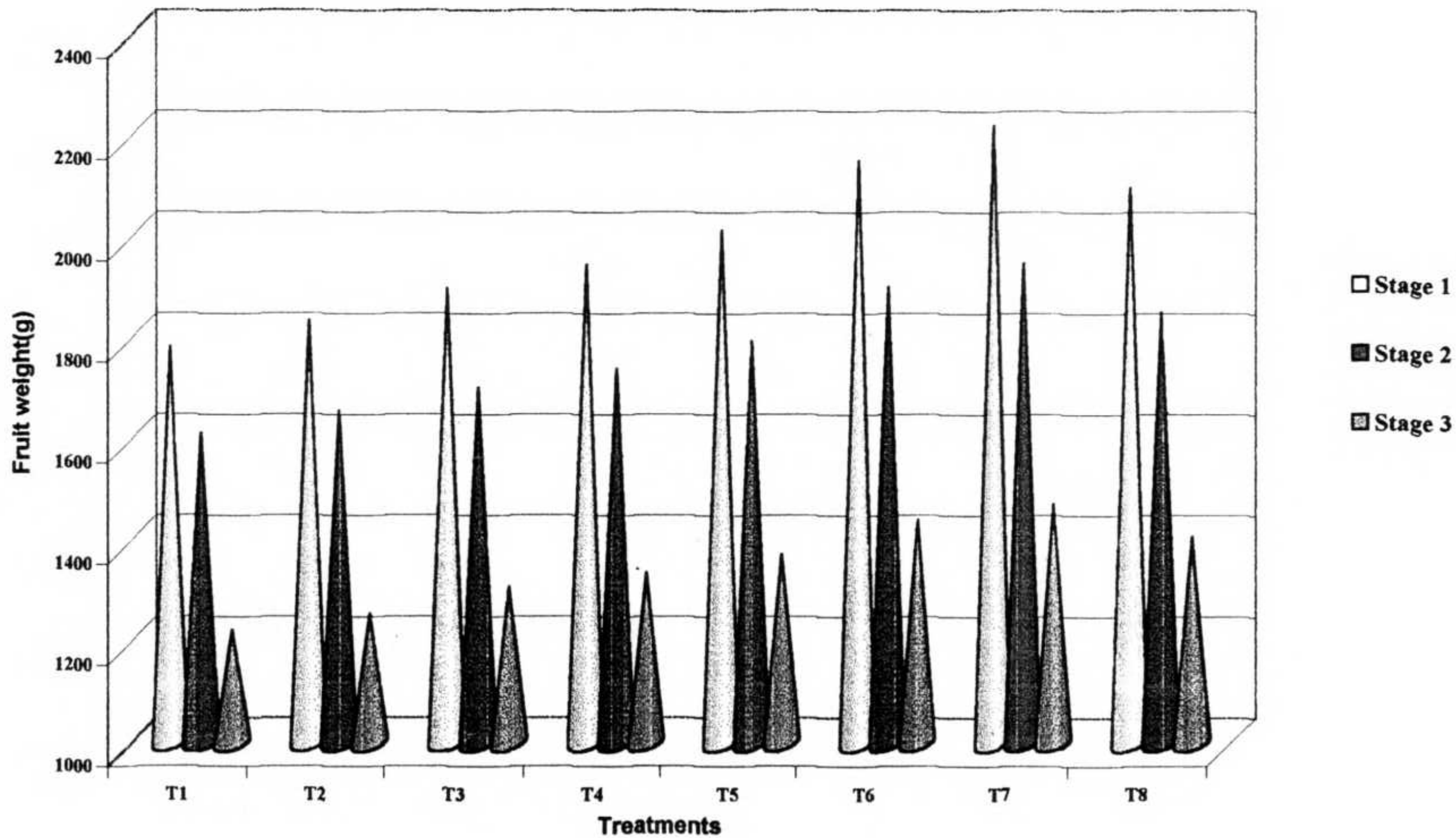
Leaf area and leaf number are irrefutable factors contributing towards increment in yield through enhanced photosynthesis. In the present study the increased number of leaves and leaf area was greater with T_7 ie. foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting, indicating the role of Zn and B for higher leaf production. These results are in accord with the observations of Das and Mohan (1993) and Subramanian and Pillai (1997) in banana.

Thus the increment in growth attributes with the best treatment can be ascribed to the interaction effect of Zn and B. The contribution of Zn in increasing the growth can be ascribed to its role in growth promoting activities. Zn aids in the formation of auxins, the growth promoting compound and is necessary for the formation of the amino acid tryptophane, itself involved in the elaboration of IAA hormone (Wear and Haggler, 1968). It is also involved in water relationships ie. it promotes the absorption of water and in so doing prevents stunting (Seatz and Jurniak, 1957). Futhermore, Zn being a constituent of many glycolytic, respiratory and several NAD and FAD dependent enzymes is very crucial for plant growth. Though the exact physiological role of B is not completely certain, it has been suggested that B is primarily needed to maintain the apical growing points and is directly concerned in the process of cell division (Whittington, 1956). It is also involved in the synthesis of pectin and cell wall components and in maintaining the correct water relations (Slack and Whittington, 1964).

Fruit characters

In the present investigation, Zn or B when applied alone or in their combination had resulted in increased fruit characters when compared to untreated ones. Fruit weight rather has a profound effect in enhancing the fruit yield in terms of weight than any other trait. In the present study, maximum accretion of fruit weight was observed with foliar spray of Zn 0.5%

Fig. 1. Effect of zinc and boron on fruit weight



+ B 0.1% at 4th, 8th, 12th and 16th month after planting corroborating the findings of Veenapant and Lavania (1989) in papaya, Ghosh (1986), Bagali (1992) in guava, Rath *et al.* (1980), Banik *et al.* (1999) in mango, Balakrishnan *et al.* (1996), and Satishkumar and Satya Bushan (1976) in grapes.

Fruit volume, a product of length x circumference of the fruit, determines the external size of the fruit. In the present study, the favouritism of foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting in increasing the volume of the fruit is apparent. This emphasises the favourable interaction effect of Zn and B when applied at four month interval in enhancing the yield. This lends buttress from the works of Veenapant and Lavania (1989), Rath *et al.* (1980), Banik *et al.* (1999) in mango, Subramanian and Pillai (1997) in banana, Satish kumar and Satyabushan (1976) in grapes, Bagali *et al.* (1992) in guava.

Perhaps, the possible reason for enhancement in physical characters is due to the role of Zn in regulating the semipermiability of cell walls thus mobilising more water into fruits thereby increasing the size of the fruit. The favourable effect was also attributed to the fact that Zn is essential in nitrogen metabolism (Asana *et al.*, 1971) and it also increases the synthesis of auxin which promotes the cell size (Agarwala and Sharma, 1978). Furthemore Zn acts as a catalyst in the oxidation and reduction process and is also of great importance in the sugar metabolism (Wear and Hagler, 1968) which might have improved physical characters of papaya. The improvement in physical characters due to B application may be attributed to its involvement in cell division and cell expansion (Russel, 1957).

Maximum cavity volume and cavity index were also observed with foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting. This is perhaps due to the interaction between Zn and B in the over all development of the fruit, which resulted in the increased cavity volume and cavity index of the fruits. Enticingly, longer cavity volume favours proper development of seeds which are the sources of certain hormones.

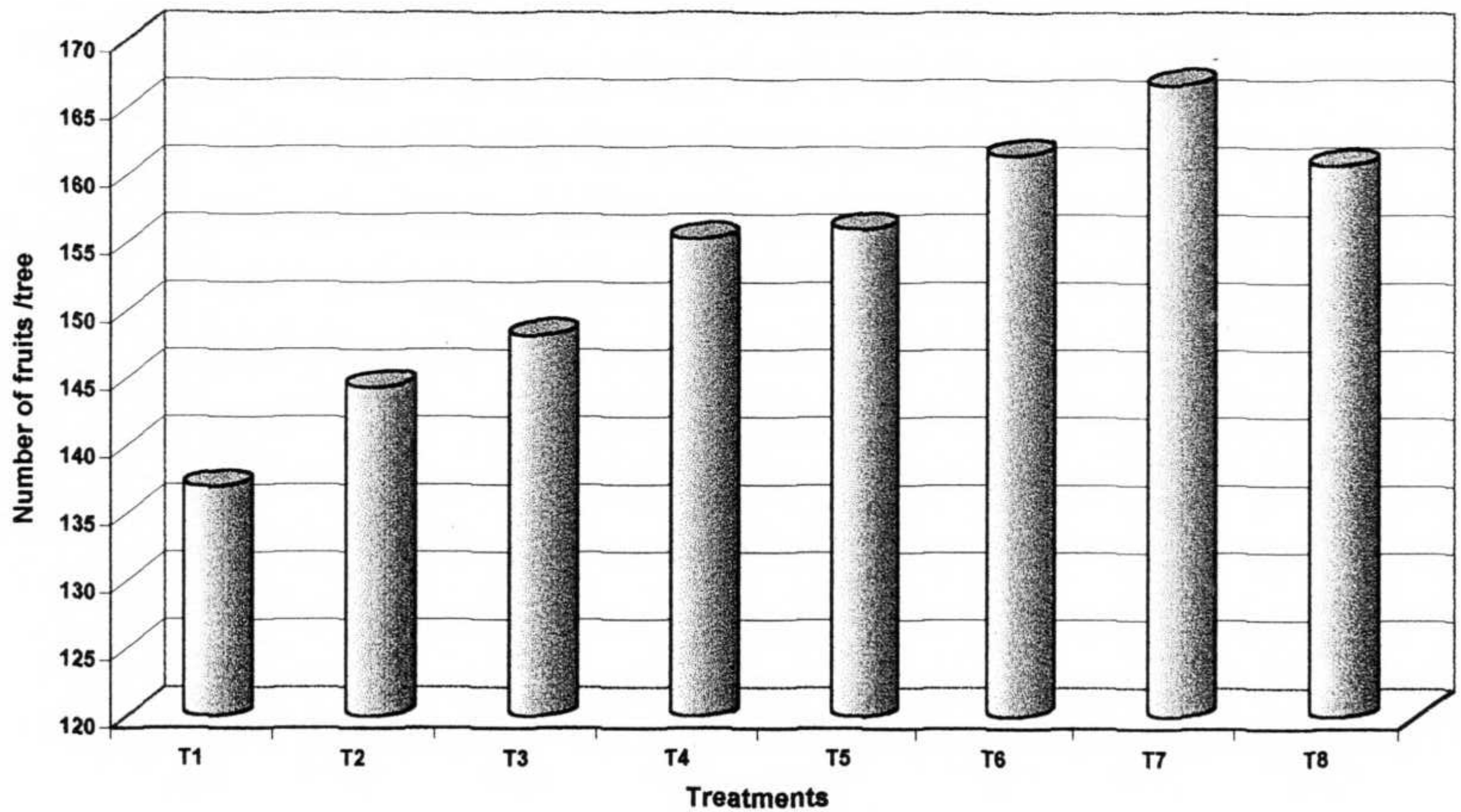
Pulp thickness, another important fruit character remained inconsequential, thus accentuating the unalterable genetic character of the variety.

Fruit yield and latex yield

An increase in number of fruits without any depressing effect on fruit size can be claimed as increased yield/plant with certitude. In the present investigation, T_7 ie. foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting recorded the highest fruit number, perhaps due to the desirable effect of first order interaction of nutrients when applied at four month intervals ascertaining the earlier studies of Veenapant and Lavania (1989) in papaya, Banik *et al.* (1997) in mango, Subramanian and Pillai (1997) in banana, Bambal *et al.* (1991) in pomegranate, Pant and Pant (1969) in apple.

In the current investigation, when the effect of micronutrients like Zn and B was analysed, it was found that their application did increase the fruit number which could be explained due to increased fruitset and retention. Increased fruitset due to B was attributed to stimulation of pollen

Fig. 2. Effect of zinc and boron on number of fruits/tree



germination, growth of pollen tube, stimulation of fertilisation process and higher synthesis of metabolites (Prez lopez and Reyes, 1983) and it was also partly due to reduction in abscission of buds and flowers under the influence of chemicals (Veenapant and Lavania, 1989). Furthermore, maximum fruit retention with B was associated with hormonal metabolism, photosynthesis and water relations in plants.

The enhanced fruit production observed under Zn treatment was probably due to the synthesis of protein and IAA in plant in the presence of Zn which intum would influence the flower production vis a vis increased fruitset. Maximum fruit retention was due to enhanced synthesis of auxins in the plants (Tsui, 1948) leading to diminished drop rate. The highest fruit yield per tree was recorded with T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting thus emphasising the desirable impact of first order interaction of nutrients when applied at four month interval. This lends buttress from the earlier works of Veenapant and Lavania (1989) in papaya, Singh *et al.* (1990) in kagzilime, Rana and Sharma (1979) in grapes, Ghosh (1986) in guava, Bambal *et al.* (1991), Balakrishnan *et al.* (1996) in pomegranate. Thus, the increase in yield can be attributed to improvement in fruit set, i.e number of fruits per plant including size and weight of individual fruit.

Latex is an unique byproduct of papaya, foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting registered the highest latex yield, ascertaining the supremacy of this treatment, indicating the influence of interaction effect of micronutrients on the latex yield.

Fig.3.Effect of zinc and boron on fruit yield(kg/tree)

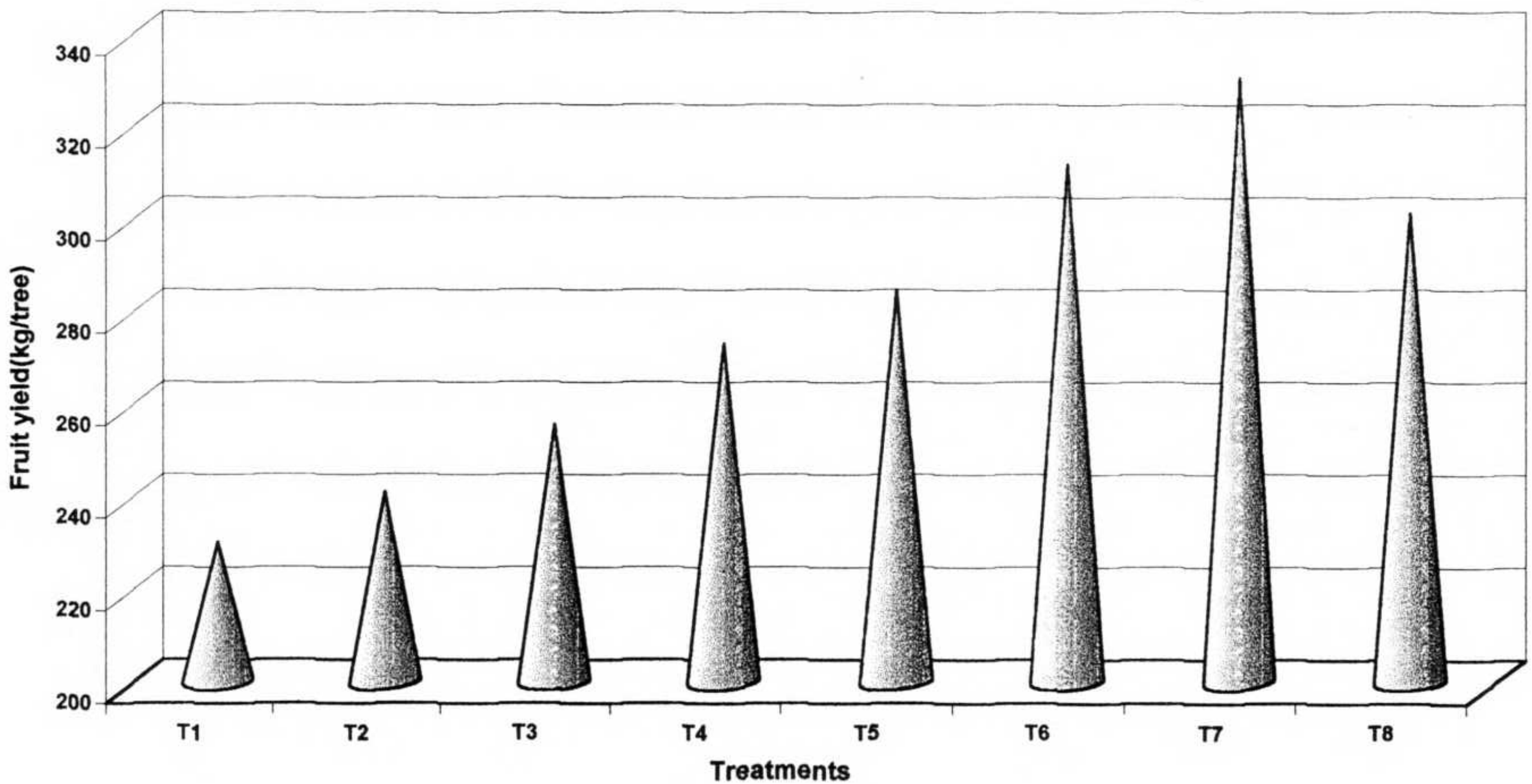
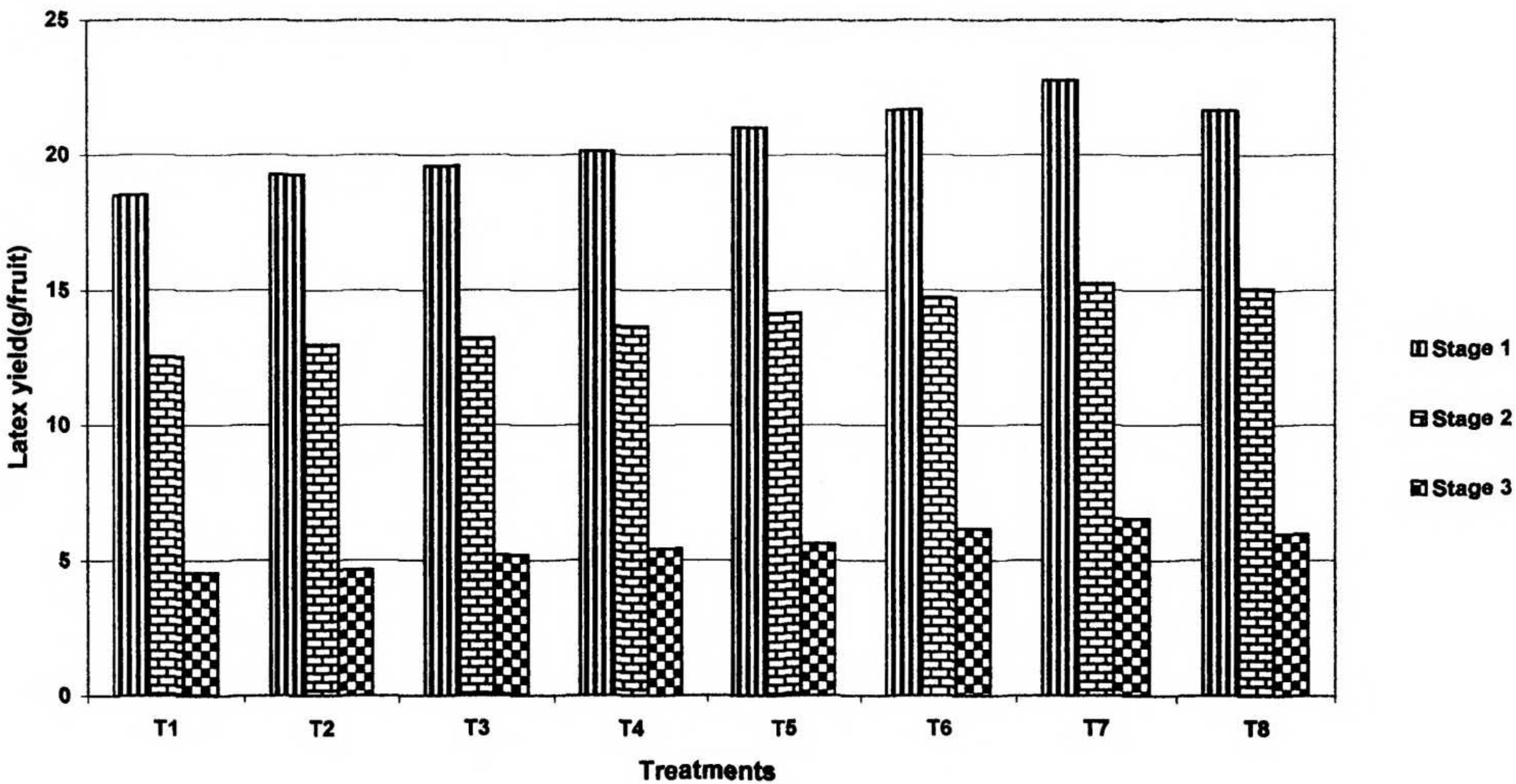


Fig.4.Effect of zinc and boron on latex yield(g/fruit)



Biochemical and quality characters

Maximum total chlorophyll, chlorophyll a and chlorophyll b was registered with T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting. There are ample evidences by Haribabu and Rajput (1984), Patel and Patel (1985) and Desai *et al.* (1991) in citrus, projecting the influence of zn in increasing the leaf chlorophyll content. Similarly, Singh *et al.* (1990) observed increased chlorophyll content in kagzilime with B sprays. The increment in chlorophyll production due to application of Zn was perhaps due to enhanced conversion of phylloxanthin to chlorophyllin.

The assessment of IAA activity aid in comprehending the status of unoxidised auxin. As the IAA oxidase activity has a negative correlation with auxin content, it follows that control which recorded the highest IAA oxidase activity had maximum suppression of auxin synthesis and thus minimum accumulation, while T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting recorded the lowest enzyme activity signifying accumulation of auxins.

The assessment of soluble protein helps in comprehending the activity of RUBISCO, which is related to the photosynthetic efficiency of the plant. In the present invesitgation soluble protein assessed only for the following two treatments :

Control (No micronutrients) = 16.29 mg/g.

T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting = 16.93 mg/g, Signified the role of Zn and B in enhancing photosynthetic efficiency.

Any element that is essential for the growth and development of plants must have a direct or indirect influence on N metabolism, including synthesis of proteins. Zn deficiency is reported to inhibit protein synthesis and produce high concentration of non protein nitrogen including amino acids (Graham, 1983). It is also observed that deficiency of Zn caused reduction of RNA synthesis and ribosome stability. Equally, B is also involved in protein synthesis (Slack and Whittington, 1964 and Lee and Aronoff, 1967).

Quality of latex as assessed by proteolytic enzyme activity remained inconsequential with different treatments. Thus no alteration in quality of latex was obvious in the present investigation. However T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting registered slightly higher papain activity over control. It was 205.90, 203.97 and 198.44 Tu/mg with T_7, while it was 204.32, 201.09 and 196.02 Tu/mg with control.

Fruit quality characters

An increase in fruit yield with concomitant increase in fruit quality is a desirable factor in any studies. In the present investigation the best quality fruits interms of TSS, total sugar, reducing sugar, non-reducing sugars and ascorbic acid content were observed with T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting. Similar increase in the quality of fruits was corroborated by Veenapant and Lavania (1989) in papaya, while it was in contradiction with the investigation of Parez and Childers (1982) who observed that only the ratio of total sugars to total acidity increased significantly with B spray, while other quality components such as soluble solids, total sugars, titrable acidity were unaffected by B supply.

The enhancement of fruit quality as a result of Zn spray in the present study can be explained on the basis of general role of zn in plant metabolism. The highest TSS was due to the increased total sugar content which might be due to the increased total sugar content owing to the efficient translocation of available phtosynthetates to fruit juice rather than to other parts. The contribution of B for different quality traits like TSS and different fraction of sugars might be due to hydrolysis of complex polysaccharides into simple sugars, synthesis of metabolites and rapid translocation of photosynthetic products and minerals from other parts of plant to developing fruits. Higher level of ascorbic acid formed in this treatment was due to higher sugar content as ascorbic acid is synthesised from sugar.

Plant and soil nutrient status

Foliar diagnosis to assess the nutrient requirement of a given crop is based on the assumption that within certain limits there is apositive relationship among dose of nutrients applied, leaf content of the element and fruit yield or quality of fruits (Bhargava and Chadha, 1988). This nutrient concentration in the tissue is influenced by many factors one such is the stage of the crop in question.

In the present investigation the effect of different treatments on N, P, K concentration of leaf blade and petiole did not show any significant influence on the N, P, K status of the leaves. However this finding is the contradiction of earlier findings of Parez and Norman F. Childers (1980) in papaya who observed that N and P in leaf blade were slightly and irregularly altered by different B levels while K in blades showed little response in papaya. However, higher leaf Zn and B concentration are recorded with T_7 i.e foliar spray of 0.5% Zn + 0.1% B at 4th, 8th, 12th and 16th month after planting in the present study are inaccordance with those of Parez and Norman F. Childers (1980) in papaya with B sprays. The increase in concentration of Zn and B over control due to foliar spray indicate that the trees were responding favourably to Zn and B application as their status in the soil was considered inadequate. In this study, soil analysis indicated that Zn and B are in deficient range.

The soil available N, P, K content estimated at any stage did not get statistically affected. This is normally expected as micronutrients did not necessarily influence the native N, P, K content of the soil on the other hand the available B and Zn content of the soil was much affected by the treatment T_8 *viz*., soil application of 10 g Zn + 5 g B at 4th and 12th month after planting.

Foliar vs soil application

The results of present study reveal the efficiency of foliar application over soil application as T_7 i.e foliar application of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting was always found to be better than T_8 ie. soil application of 10 g of Zn + 5 g of Boron at 4th and 12th month after planting, espousing the findings of Durgadevi *et al.* (1997) and Sharma *et al.* (1972) in citrus. However, Manchanda *et al.* (1972) did not observe any difference between soil and foliar application in citrus.

Thus it appears that foliar application is the most effective method of supplying micronutrients for obvious reasons. The quantity required is also small compared to the soil application. A great benefit of foliar nutrition accrues from the environment point of view, that it supplies to the optimum level,while larger amounts given to the soil for the same effectiveness leads to soil pollution. Furthermore, the foliar nutrition is rapid, timely and most effective when soil conditions are unfavourable for soil application.

From the foregoing discussion it is obvious that the best treatment ie. the foliar application of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting has helped to improve the growth attributes, fruit characters, fruit and latex yield (Fig.7) including qualtiy prarameters (Fig. 8). The spectacular increase in the yield due to the application Zn and B . could be expected as the soil analysis revealed that Zn and B status were below the critical limit. Hence, addition of these nutrients through foliar spray have favourably accelerated the physiological processes leading to better vigour, growth and yield.

In any crop management studies, any improved practice should be cost effective, such a comparitive analysis in the present study between the recommended practice and the best treatment was made and furnished in Annexure No.1 It may be seen from this, application of foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} month after planting was highly remunerative in generating additional income over present practice.

Fig.5.Comparitive efficiency of best treatment over control in influencing growth attributes

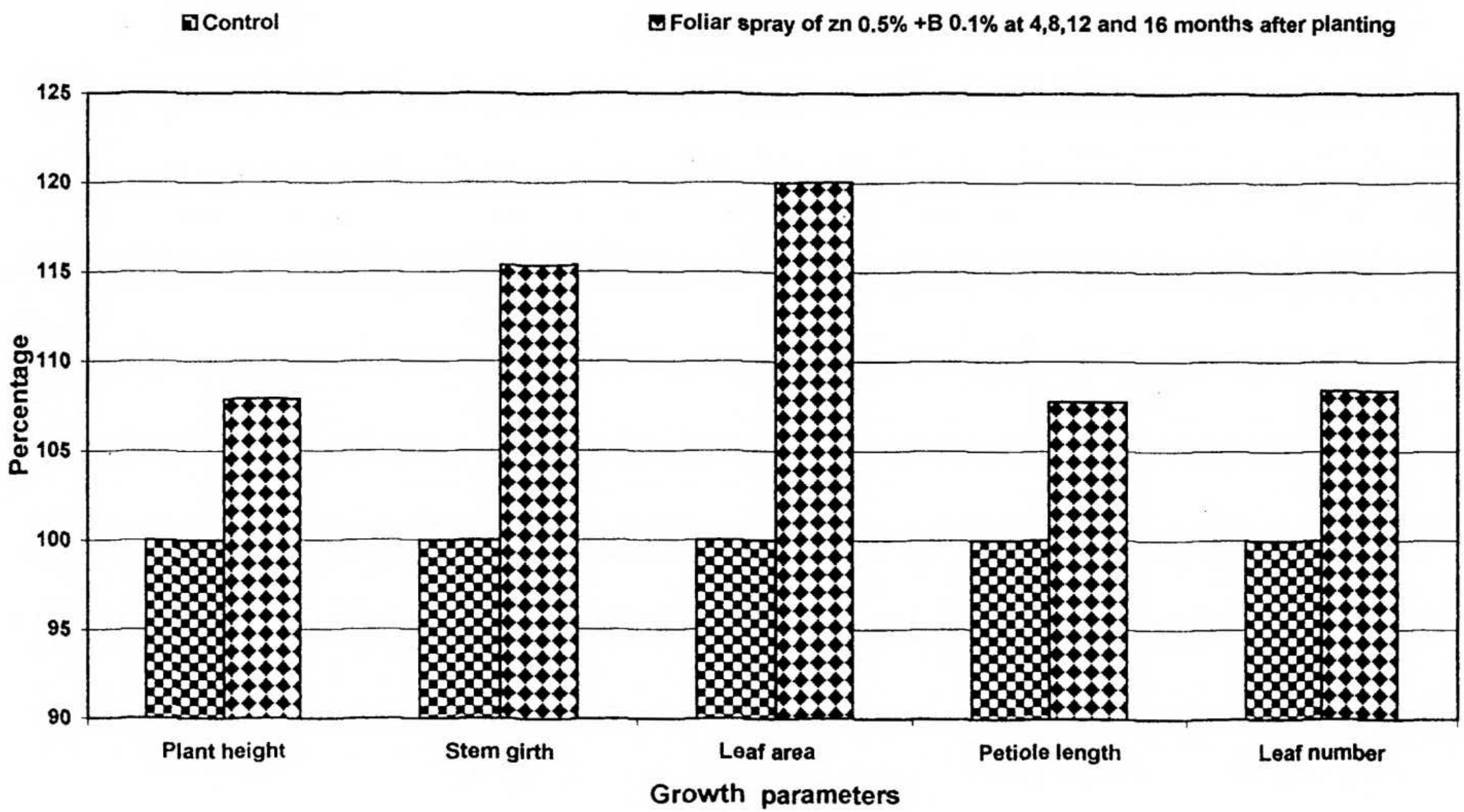


Fig. 6. Comparitive efficiency of best treatment over control in influencing fruit characters

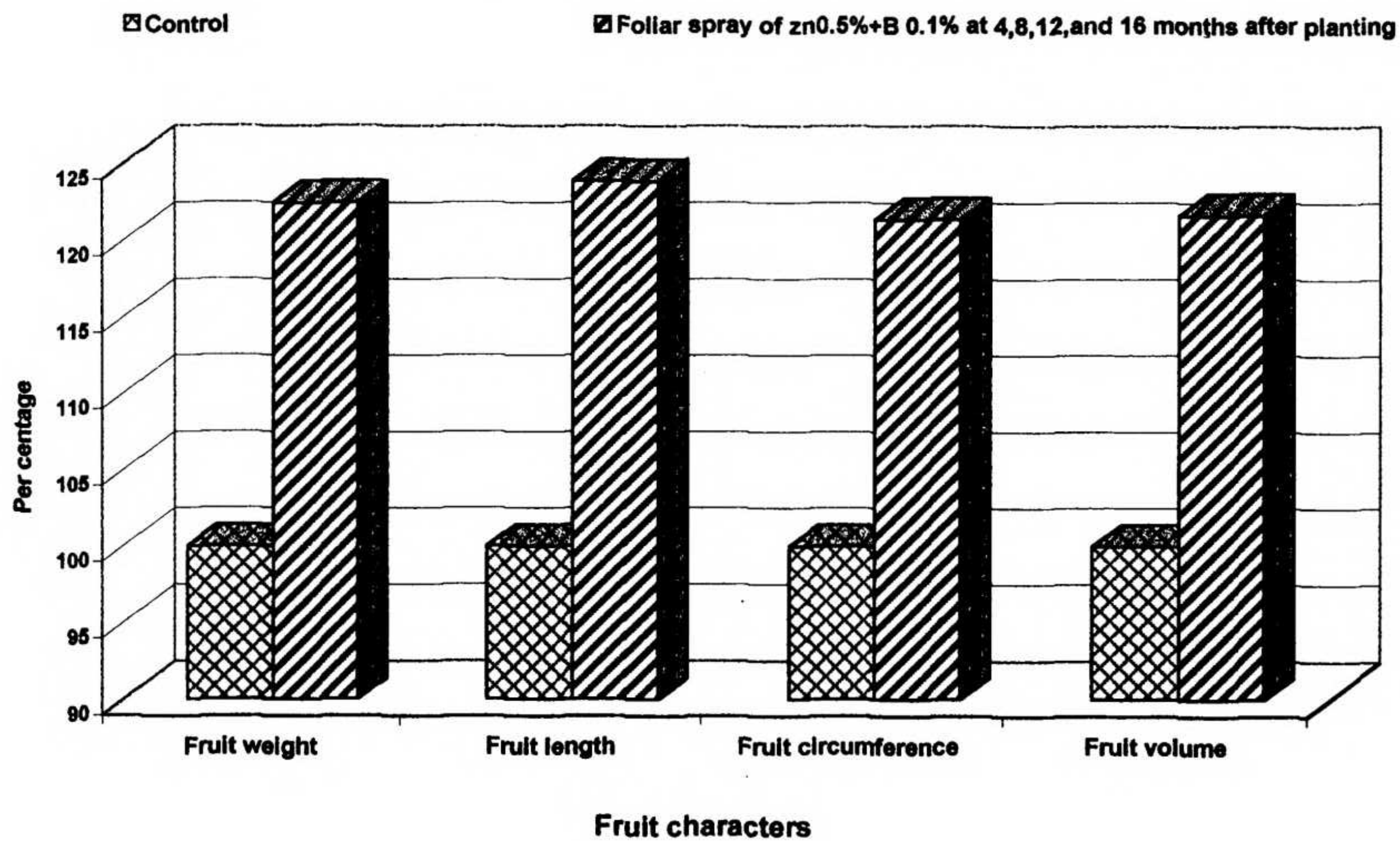


Fig. 7. Comparitive efficiency of best treatment over control in influencing yield attributes

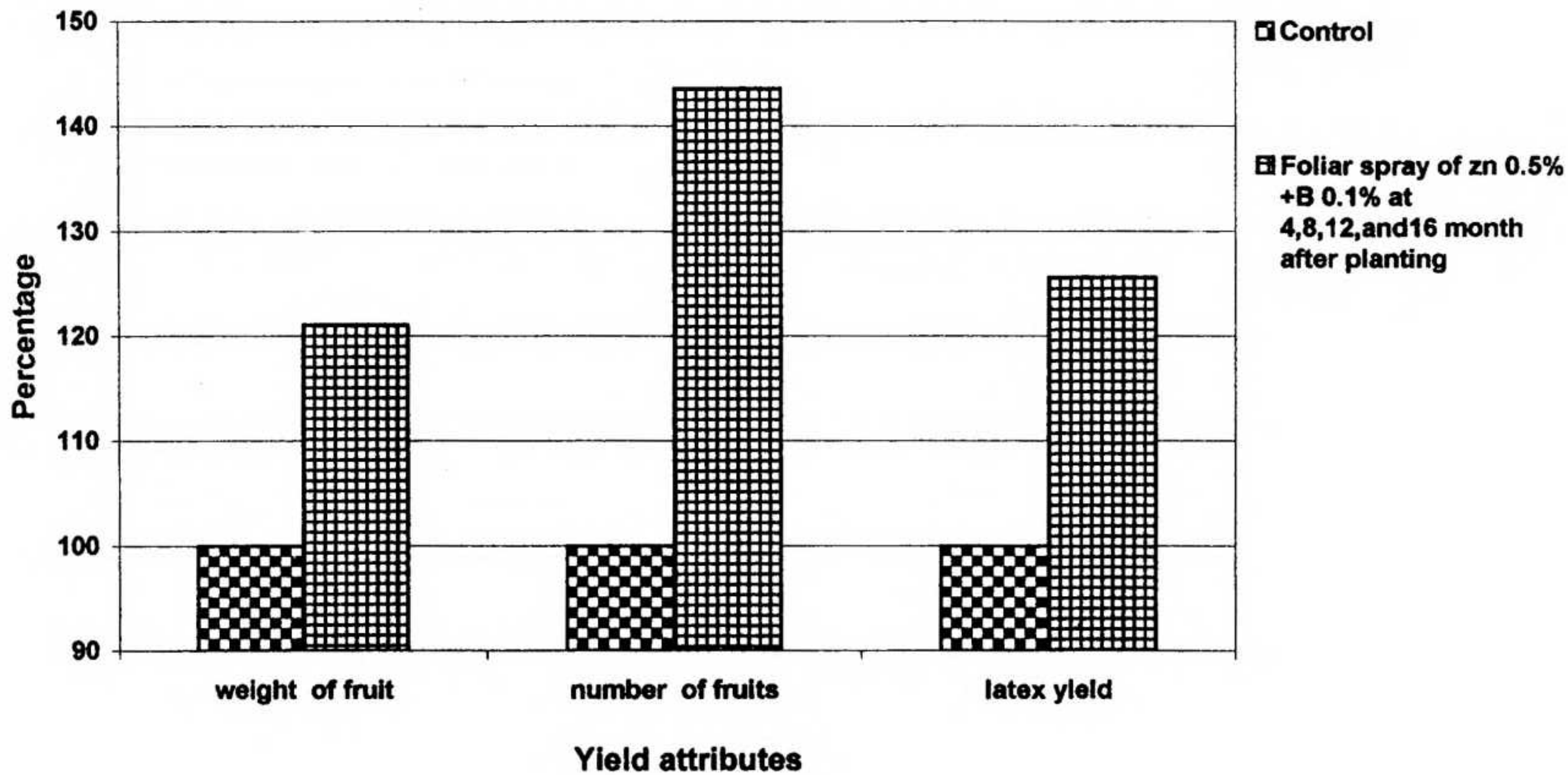
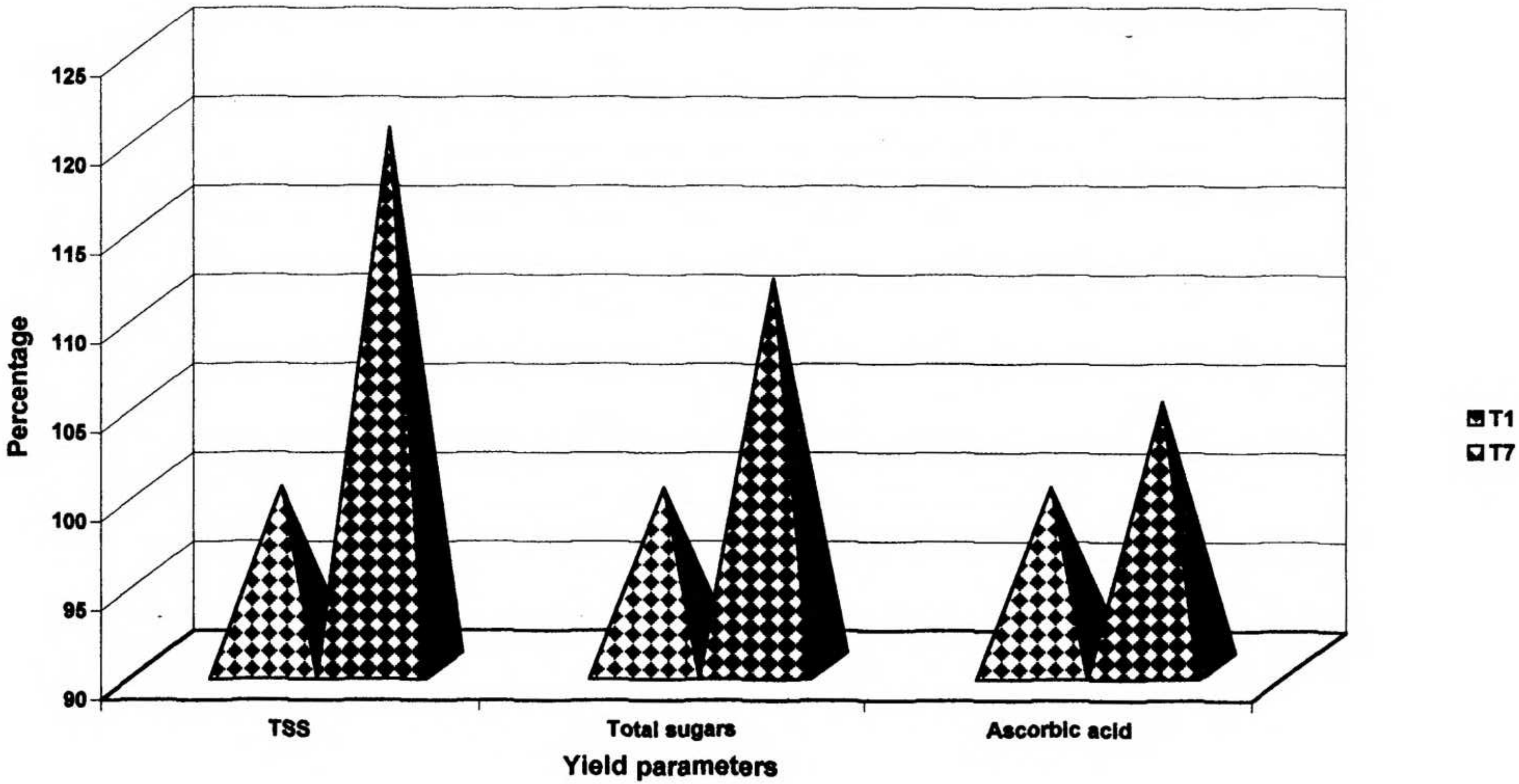


Fig.8.Comparative efficiency of best treatment over control in influencing quality attributes



Summary

CHAPTER VI

SUMMARY

Studies on the effect of zinc and boron on growth, yield and quality of fruit and latex in papaya cv. Co.5 were conducted at the orchard of Tamil Nadu Agricultural University, Coimbatore. The salient findings are summarised below.

1. The maximum plant height, girth, leaf area, petiole length, number of leaves was registered with foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting at all stages.

2. Foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th month after planting recorded maximum accretion of fruit weight, fruit length, fruit circumference and fruit volume at all stages.

3. As regards cavity volume and cavity index T_7 i.e Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th after planting emerged as the best treatment at all stages.

4. No treatment exerted any effect on the pulp thickness of the fruit at any stage of observation.

5. With reference to biochemical parameters the highest leaf total chlorophyll, chlorophyll a and chlorophyll b were registered with foliar spray of Zn 0.5% + B 0.1% at 4th, 8th, 12th and 16th after planting.

6. The soluble protein recorded with T_7 i.e foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} after planting was significantly higher than control.

7. Higher fruit quality components viz., TSS, total sugars, reducing sugars, non-reducing sugars and ascorbic acid were registered with foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} after planting.

8. Titrable acidity and sugar acid ratio remained unaffected with all treatments at all stages.

9. No treatment had any effect on proteolytic enzyme activity of latex.

10. The N, P, K content of leaf blade and petioles remained unaltered with different treatments.

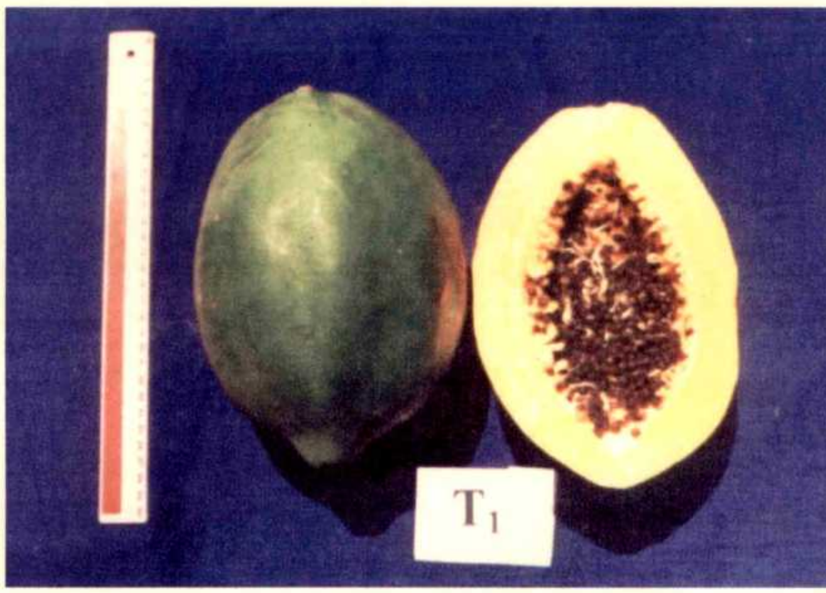
11. Foliar spray of Zn 0.5% + B 0.1% at 4^{th}, 8^{th}, 12^{th} and 16^{th} after planting registered the maximum content of Zn and B in leaf blade and petiole.

12 Different treatments exerted no efect on the soil available N, P, K content while soil application of 1 g Zn + 5 g B at 4^{th} and 12^{th} month after planting increased Zn and B content in the soil.

13. The cost benefit ratio worked out for the best treatment and the present practice showed the cost effectiveness of the present superior treatment.

Plates

Plate1. Effect of zinc and boran on fruit size under T_7 (foliar spray of Zn 0.5% + B 0.1% at 4 th, 8th, 12th and 16 th month after planting) at stage II



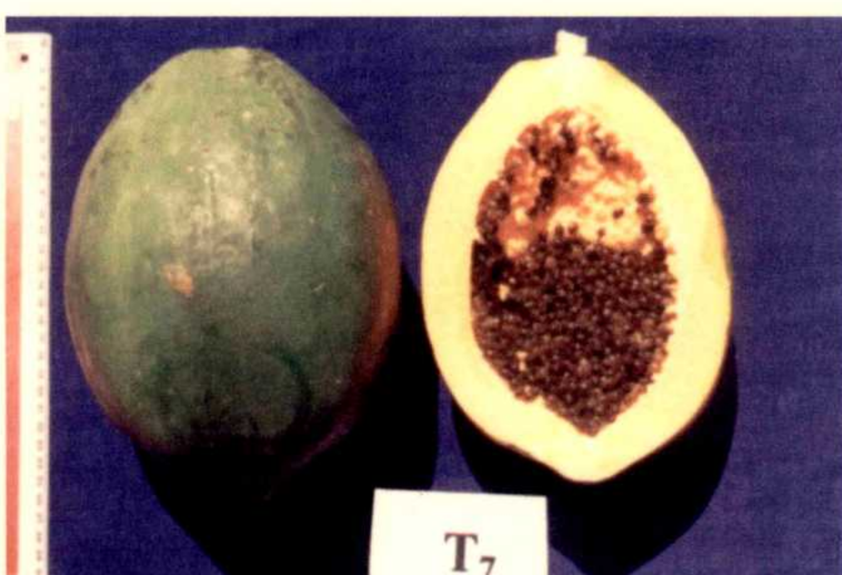
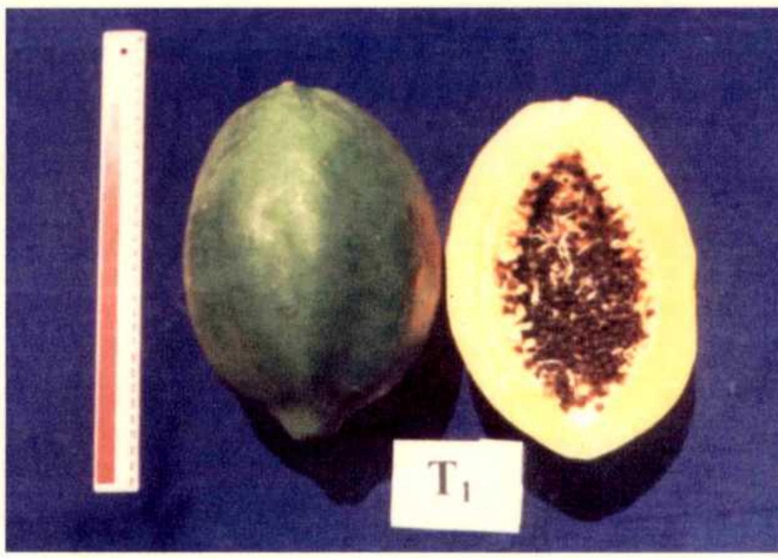


Plate2. Effect of zinc and boran on fruit size under T_6 (foliar spray of Zn 0.5% + B 0.1% at 4th and 12th month after planting) at stage II



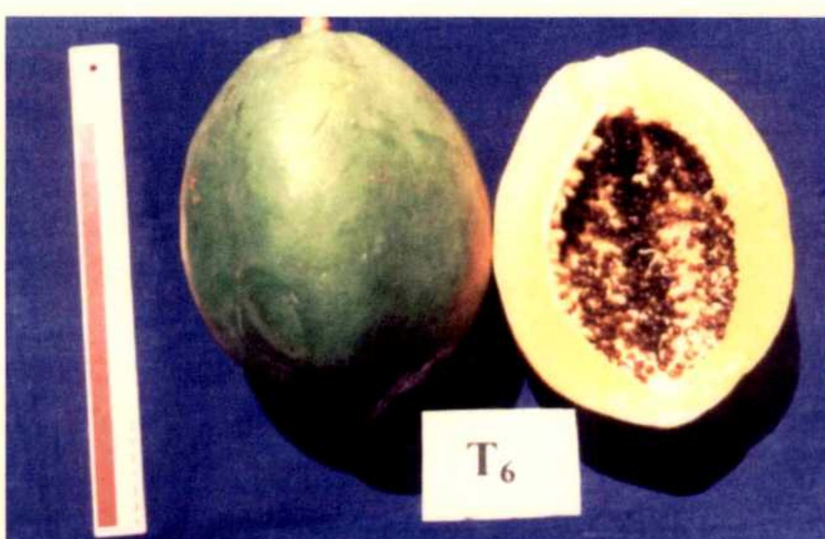
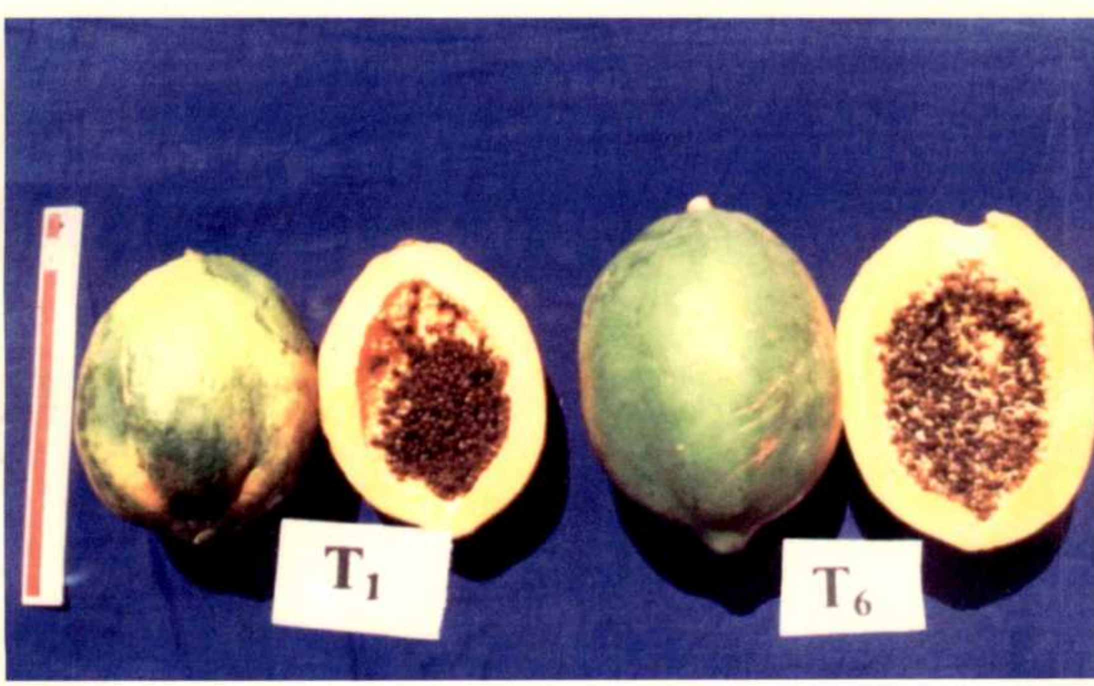


Plate3. Effect of zinc and boran on fruit size under T_7 (foliar spray of Zn 0.5% + B 0.1% at 4 th, 8th, 12th and 16 th month after planting) at stage III

Plate4. Effect of zinc and boran on fruit size under T_6 (foliar spray of Zn 0.5% + B 0.1% at 4 th and 12th month after planting) at stage III



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*** Originals not seen.**

Annexure

ANNEXURE - I

Additional Cost/Benefit analysis between recommended practice and the best treatment (Dec 1998 to May 2000).

S.No	Treatments	Fruit yield MT/ha	Additional yield over present practice (MT/ha)	Additional income over the present practice (Rs)	Additional cost involved over present practice (Rs)	Net additional income (Rs)
1.	Present treatment	380				
2.	Best treatment	463	83	49,800	5,048	44,752

* Only for fruityield was considered and latex yield was not taken into consideration.