RESPONSE OF ZINC AND BORON SPRAYS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.)cv. RED LADY

S.LOKESH
B.Sc. (Hons.) Horticulture

MASTER OF SCIENCE IN HORTICULTURE
(FRUIT SCIENCE)

DEPARTMENT OF FRUIT SCIENCE
HORTICULTURAL COLLEGE AND RESEARCH INSTITUTE,
ANANTHARAJUPET- 516 105, Y.S.R DISTRICT, ANDHRA PRADESH
Dr. Y.S.R. HORTICULTURAL UNIVERSITY

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BY

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THESIS SUBMITTED TO Dr. Y.S.R. HORTICULTURAL UNIVERSITY

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July, 2014

DECLARATION

I, Mr. S. LOKESH, hereby declare that the thesis entitled **"RESPONSE OF ZINC AND BORON SPRAYS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY"** submitted to Dr. Y.S.R. Horticultural University, Venkataramannagudem, for the degree of Master of Science in Horticulture (Fruit Science) is the result of original research work done by me. I declare that no material contained in the thesis has been published earlier in any manner.

Place: Anantharajupet

Name: S. LOKESH

Date: 30-08-2014.

I.D.No: AHM/12- 10

CERTIFICATE

This is to certify that the thesis entitled **"RESPONSE OF ZINC AND BORON SPRAYS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY"** submitted in partial fulfillment of the requirements for the degree of Master of Science in Horticulture (Fruit Science) of Dr.Y.S.R. Horticultural University, Venkataramannagudem, is a record of the bonafide research work carried out by **Mr. S. LOKESH** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigation have been duly acknowledged by the author of the thesis.

Thesis approved by the Student Advisory Committee

Chairman: **Dr. C. MADHUMATHI** ______________________

Senior Scientist (Horticulture) & Head,
Horticultural Research Station,
Dr.Y.S.R. Horticultural University,
Anantharajupet.

Member: **Dr. K. SWARAJYA LAKSHMI** ______________________

Associate Professor,
Department of Horticulture,
Horticultural College and Research Institute,
Dr.Y.S.R. Horticultural University,
Anantharajupet.

Member: **Sri. M. BALAKRISHNA** ______________________

Assistant Professor,
Department of Soil Science,
Horticultural College and Research Institute,
Anantharajupet

Date of final viva-voce: 25-08-2014.

CERTIFICATE

Mr. S. LOKESH has satisfactorily prosecuted the course of research and that the thesis entitled **"RESPONSE OF ZINC AND BORON SPRAYS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I certify that neither the thesis nor its part there of has been previously submitted by him for a degree of any University.

Place: ANANTHARAJUPET **(Dr. C. MADHUMATHI)**

Date: 30-08-2014. **Chairman**

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
/	:	Per
@	:	at the rate of
&	:	And
°C	:	degree Celsius
µg	:	Micro gram
µl	:	Micro litre
µm	:	Micrometre
μgml^{-1}	:	Micro gram per milli litre
°Brix	:	degrees brix
ASTA	:	American Spice Trade Association
B:C	:	Benefit Cost Ratio
B	:	Boron
CD	:	Critical difference
Cc	:	Cubic centimetre
cm	:	centimetre
Cu	:	Copper

$CuSO_4$	:	Copper sulphate
Cv	:	Cultivar
DAP	:	Days After Planting
EC	:	Emulcifiable concentration
etc.	:	and so on
et al.	:	et alia
Fe	:	Iron
$FeSO_4$	:	Ferrous sulphate
Fig.	:	Figure
FYM	:	Farm yard manure
Ft	:	Feet
G	:	Gram
g l^{-1}	:	gram per litre
g m^{-2}	:	gram per metre square
ha	:	Hectare
H_3BO_3	:	Borax
IAA	:	Indole, 3 Acetic Acid
i.e.,	:	that is
K	:	Potassium
kg	:	Kilogram

kg $plant^{-1}$	:	Kilogram per plant
kg ha^{-1}	:	Kilogram per hectare
kg m^{-2}	:	Kilogram per metre square
m	:	metre
m^{-2}	:	Per metre square
max.	:	Maximum
min	:	Minute
Min.	:	Minimum
mm	:	milli metre
Mn	:	Manganese
$MnSO_4$	:	Manganese sulphate
MT	:	Metric tonnes
m^2	:	meter-square
mg 100 g^{-1}	:	Milligram per hundred gram
Mg	:	Milligram
ml l^{-1}	:	milliliter per litre
N	:	Nitrogen
NHB	:	National Horticulture Board
NAA	:	Naphthalene Acetic Acid
No.	:	Number

Nm	:	Nanometer
P	:	Phosphorous
$Plant^{-1}$	:	Per plant
PRSV	:	Papaya ring spot virus
Pp	:	page number
q	:	quintal
$q\ 250^{-2}$	:	quintal per 250 square metre
$q\ ha^{-1}$	:	quintal per hectare
RBD	:	Randomised Block Design
RH	:	Relative humidity
RSS	:	Reducing Sugars
S.Em ±	:	Standard error mean ±
SG	:	Soluble granules
t	:	Tonne
$t\ acre^{-1}$	:	Tonne per acre
$t\ ha^{-1}$	:	Tonne per hectare
TSS	:	Total soluble solids
UV	:	Ultra Violet
Var	:	Variety
viz.,	:	Namely

Vit	:	Vitamin
Wt.	:	Weight
Zn	:	Zinc
$ZnSO_4$	:	Zinc sulphate

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ABSTRACT

A field experiment was carried out at Horticultural Research Station, Dr. YSRHU, Anantharajupet, Y.S.R. district, Andhra Pradesh, during 2013-2014 to find out the response of zinc and boron sprays on growth, yield and quality of papaya (*Carica papaya* L.) cv. Red Lady. The experiment consisted of nine treatments *viz.*, T_1-Borax at 0.25%, T_2-Borax at 0.50%, T_3-$ZnSO_4$ at 0.25%, T_4- $ZnSO_4$ at 0.50%, T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%, T_6- Borax at 0.25% + $ZnSO_4$ at 0.50%, T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%, T_8- Borax at 0.50% + $ZnSO_4$ at 0.50% and T_9-Control. The experiment was laid out in a Randomized Block Design with three replications.

The results indicated that significantly higher growth parameters such as plant height (243.33 cm), plant girth (46.20 cm) and number of leaves plant^{-1} (50.07) at 270 DAP and higher yield components like number of fruits plant^{-1} (63.53), yield plant^{-1} (106.73 kg), yield per hectare (240.1 t) were recorded with foliar application of Borax at 0.50% + $ZnSO_4$ at 0.25%. All the levels of zinc and boron did not influence the days to first fruit formation and disease incidence (PRSV), however

less number of days were taken to harvest in plants sprayed with Borax at 0.50%. The fruit characters like fruit weight (1.68 kg), fruit length (23.53 cm), fruit girth (44.84 cm), fruit volume (2675.00 cc), weight of fruit pulp (1460.01 g), pulp thickness (3.53 cm), cavity length (20.93 cm), cavity girth (10.93 cm) and cavity index (23.99 %) were found to be higher in the same treatment.

Significantly the highest TSS, total sugars and the lowest titrable acidity (0.123 %) was observed in papaya fruits when the plants were treated with Borax at 0.50% + $ZnSO_4$ at 0.50% as foliar spray. Higher shelf life was observed in papaya fruits when the plants were treated with Borax at 0.50% + $ZnSO_4$ at 0.25% as foliar spray. This treatment combination (Borax at 0.50% + $ZnSO_4$ at 0.25%) was superior in terms of maximum gross returns (4, 80,286.8), net returns (3, 43,716.6) and benefit-cost ratio (2.50).

Chapter-I

Introduction

Chapter-1

INTRODUCTION

Papaya (*Carica papaya L.*) is an important fruit of tropical and subtropical regions of the world belonging to the genus *Carica* of the family Caricaceae, with 48 species. It is the most cultivated species and commonly called as papaw or paw paw (Australia), mamao (Brazil) and tree melon (China). It is native of Tropical America and was introduced in to India in the 16th century via Malacca (Kumar and Abraham, 1942).

Papaya which remained as a backyard crop hitherto has become an important commercial fruit crop over the years for its nutritional and pharmaceutical values, besides its quick and continuous yielding habit generating early income to the growers. The ripe fruit of papaya is eaten as such throughout the tropics. Ripe fruits also find its extensive uses for several preparations like jam, soft drinks, ice-cream flavoring and crystallized fruit, while green fruits are often used in salads and pickled or cooked as a vegetable. Papain, a proteolitic enzyme present in the milk latex of green fruits, the dried latex powder is having great demand in the international market particularly in UK and U.S.A. The papain has various uses in the beverages, food and pharmaceutical industries, *viz.*, meat tendering, manufacturer of chewing gum and cosmetics, as a drug for digestive aliments, in the tanning industry for bating hides, for de-gumming materials in silk and to give shrink resistance to wool (Chan and Tang, 1978). Papaya leaves have medicinal value. Stem and bark is used for making ropes. Roots are used to cure the yaws and piles and act as a generative toxin. The other uses include extraction of oil, as a source of protein and medicine to quench thirst and as a vermifuge. Hence papaya has been called as “Common man’s fruit”.

Papaya fruit has occupied a place of pride in human diet because of its striking nutritional and medicinal values. It is a nutritive fruit containing carbohydrates, protein and minerals mainly iron, calcium and phosphorus. It is rich source of Vitamin ‘A’ having 2020 I.U./100g of fruit and a fair source of Vitamin-C. It’s delicious fruits are not only palatable, nutritive and digestive but also act as a mild laxative. National Commission on Agriculture has emphasized that in the present Indian dietary context, there is an urgent need for massive production of **“**Short duration, less expensive but nutritive fruits**”** (National Commission on Agriculture Report. 1976). Papaya exactly fits in this requirement and become an important fruit crop.

In India it is grown in an area of 0.132 Mha and annual production of 5.38 MMT with a productivity of 38.6MT/ ha, whereas in Andhra Pradesh it occupies an area of 0.0206 Mha with annual production 1.65 MMT (Indian stat Database 2012-2013). Its cultivation in India has spread over large areas stretching from the southern tropical to northern subtropical regions. The important papaya growing states in our country are Orissa, Kerala, Assam, West Bengal, Andhra Pradesh, Karnataka and Gujarat, while it is grown to some extent in parts of Tamil Nadu, Madhya Pradesh and Uttar Pradesh.

Micronutrients can tremendously boost crop yield and improve quality and post-harvest life of produce. They play an important role in disease resistance, since they function as enzyme activators and also play a role in lignin biosynthesis (Edward Raja, 2009). The decline in availability of organic manures due to greater use of inorganic fertilizer has made micronutrient supply precarious. Hence replacing micronutrients that have been removed or increasing organic matter to make native nutrients available, has not received sufficient attention.

Foliar application of micronutrients has gained importance in recent years, because the nutrients are sprayed directly to leaves, and can be made available to the plants at proper time when needed. Zinc and Boron occupies an important place due to its ability to positively influence plant growth and development and imparts resistance to biotic and abiotic stresses (Cakmak, 2008).

Zinc is the important constituent of several enzymes which regulate various metabolic reactions in the plant and also essential for auxin and protein synthesis. Boron is a constituent of cell membrane and essential for cell division. It acts as a regulator of potassium/calcium ratio in the plant and helps in nitrogen absorption and translocation of sugars in plant (Trivedi *et al.,* 2012).

Successful commercial cultivation of improved high yielding varieties of papaya crop depends on critical nutrient management due to its continuous growth, flowering and fruiting habit. Papaya requires high amounts of nutrients for growth and fruit production, and it was estimated that papaya removes about 989 mg B, 300 mg Cu, 3364 mg Fe, 1847 mg Mn, 8 mg Mo and 1385 mg Zn per tonne of fruit (Cunha and Haag, 1981). During last decade, papaya seedlings of cv. Red lady are being planted at an increasing rate in Rayalaseema region of Andhra Pradesh. A new papaya cultivar, Red lady introduced from Thailand has replaced the traditional varieties like Co-Selections, Coorg Honey Dew and Pusa Selections, because of its gynodioecious nature, high productivity, red colour flesh, good shelf life and good firmness of the fruit which made it suitable for long distance transport. Micronutrient requirement of papaya is not well documented especially for southern zone of Andhra Pradesh.

Hence the present investigation "Response of Zinc and Boron sprays on Growth, Yield and Quality of Papaya *(Carica papaya L.*) cv. Red Lady" was undertaken to find out the influence of micronutrient spray on growth, yield, and quality of papaya cv. Red lady, with the following objectives.

1. To study the influence of foliar application of Zinc and Boron on growth of papaya.
2. To determine the effect of Zinc and Boron on yield and quality of papaya.

Chapter-II

Review of Literature

CHAPTER - II

REVIEW OF LITERATURE

Micronutrients assume significance in horticultural crop production because of their ability to improve quality, input use efficiency, post harvest shelf life, disease resistance and their by increase in marketable yield. Crop-specific foliar formulation of micronutrients is a novel approach, wherein application of essential micronutrients in very dilute form has been found to regulate and accelerate various growth processes in plants. The literature available on foliar application of micronutrients *viz.*, zinc and boron either alone or in combination on growth, yield and quality of papaya as well as other fruit crops have been reviewed in this chapter.

2.1 EFFECT OF ZINC ON PLANT GROWTH PARAMETERS

Banik and Sen (1997) studied the effect foliar application of $ZnSO_4$ twice during July and October at different concentrations 0.1 per cent, 0.2 per cent and 0.4 per cent on six years old mango cv. Fazli and reported that all the $ZnSO_4$ treatments recorded significant increase in vegetative growth as indicated by plant height, plant spread and trunk girth over control.

Pant and Lavania (1998) observed that foliar spray of $ZnSO_4$ (0.15 per cent) + $FeSO_4$ (0.15 per cent) significantly increased the percentage of female plants in papaya.

Bahadur *et al.* (1998) concluded that foliar application of 0.25 per cent and 1.0 per cent $ZnSO_4$ increased flowering in mango cv. Dashehari.

Helail and Atawia (1990) studied the effect of pre-sowing treatment of pawpaw seeds by 1000 and 2000 ppm of zinc sulphate and reported that both the treatments enhanced germination percentage, plant height, thickness and produced higher number of leaves per plant over control.

Singh and Ahlawat (1995) stated that plant growth in terms of plant height, spread and shoot length were increased with foliar application of 2.0 per cent urea + 1.0 per cent $ZnSO_4$ on ber cv. Umran.

Rathore and Chandra (2002) observed increased plant height (34.45 per cent) and stem girth (18.63 per cent) with soil application of nitrogen 500 g +foliar spray of urea 0.15 per cent + $ZnSO_4$ 0.5 per cent on ber.

Alila *et al.* (2004) found an improvement of plant height, basal diameter and number of leaves per plant in pawpaw cv. Ranchi with the foliar application of $ZnSO_4$ @ 0.2 per cent at 2^{nd} and 4^{th} month after transplanting.

Singh *et al.* (2005) opined that the foliar application of $ZnSO_4$ 0.25 per cent and 0.5 per cent in papaya at two month after transplanting significantly increased the plant growth, number of leaves per plant and length of petiole (5^{th} leaf).

Sarolia *et al.* (2007) stated that foliar application of $ZnSO_4$ and $FeSO_4$ @ 0.3, 0.4 and 0.5 per cent concentrations improved the vegetative growth of guava trees in terms of terminal shoot length, shoot diameter and number of leaves per shoot.

An experiment conducted by Pathak *et al*. (2011) revealed that combined application of $FeSO_4$ 0.5 per cent + $ZnSO_4$ 0.5 per cent in banana enhanced the plant growth in terms of plant height, pseudo stem girth, number of leaves produced per plant and minimum duration between emergences of two successive leaves.

2.2 EFFECT OF BORON ON PLANT GROWTH PARAMETERS

Shanmugavelu *et al.* (1973) observed reduction in staminate flowers per axis as well as increase in hermaphrodite flowers per axis in papaya with the foliar application of boron @ 2 ppm when compared to control.

Singh and Rajput (1977) indicated that foliar application of boric acid at 0.2, 0.4, 0.6 and 0.8 per cent significantly increased the number of leaves per plant in mango.

Chattopadhyay and Gogoi (1992) obtained significantly higher petiole length (55.63cm), number of leaves (72.07) and spread of the plant (180.27cm) with the foliar application of borax @ 40 ppm in papaya.

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

Haggag *et al.* (1995) conducted an experiment to study the influence of foliar application of boric acid at a series of concentrations from 50 to 1250 ppm at late bud-swelling stage in mango. The results showed that boric acid @ 750 ppm has increased the percentage of hermaphrodite flowers.

Banik and Sen (1997) concluded that foliar application of boron 0.4 per cent + urea 0.1 per cent in mango promoted vegetative growth as indicated by plant height, stem girth and plant spread.

Morales and William (2003) reported that in papaya application of boron @ 0.07 mg $plant^{-1}$ at 35 days after emergence was found to be the best, in terms of shoot height, stem diameter, leaf number, leaf area and shoot dry matter.

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

Yadav *et al.* (2010) revealed that the foliar application of $CuSO_4$ 0.25 per cent + $MnSO_4$ 0.25 per cent + borax 0.1 per cent increased plant growth in papaya cv. Washington.

2.3 EFFECT OF ZINC ON YIELD ATTRIBUTING PARAMETERS

In a study conducted by Bambal *et al.* (1991) on effect of foliar application of micronutrients in pomegranate cv. Ganesh observed that foliar application of $FeSO_4$ 0.4 per cent + $ZnSO_4$ 0.3 per cent resulted in the highest number of fruits $plant^{-1}$ (103.83) over control.

Kamble *et al.* (1994) recorded an improvement in fruit weight and yield in ber with foliar application of $ZnSO_4$ 0.4 per cent + $FeSO_4$ 0.4 per cent + $MnSO_4$ 0.2 per cent.

Hassan (1995) revealed that foliar application of 75 ppm $ZnSO_4$ twice a year (Mid April and mid June) increased fruit yield in Washington Navel Orange over control.

Singh and Rethy (1996) recommended foliar application of $ZnSO_4$ (0.5 per cent) + NAA (20 ppm) to obtain the highest fruit yield in Kagzi lime.

Banik *et al.* (1997) reported that the foliar application of 0.45 per cent $ZnSO_4$ + 1 per cent urea on young mango plants produced the highest number of fruits and yield compared to control.

Devi *et al.* (1998) observed that soil application of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ (each of 50 g plant^{-1}) together with foliar spray of each at 0.5 per cent gave significant increase in fruit yield of Sathgudi sweet orange.

Pant and Lavania (1998) recorded significant increase in the fruit yield of papaya cv. Pant papaya-1 with foliar application of $ZnSO_4$ 0.15 per cent + $FeSO_4$ 0.15 per cent.

Ebeed *et al.* (2001) found that the foliar spray of some micronutrients (Fe + Zn + Mn, Fe + Mn) at flowering stage recorded the highest yield in mango.

Singh and Maurya (2004) noticed that foliar application of $ZnSO_4$ 0.4 per cent in mango increased the fruit yield over control.

Meena Kumari *et al.* (2009) opined that foliar application of $FeSo_4$ 0.50 per cent + $ZnSo_4$ 0.50 per cent + $CuSo_4$ 0.25 per cent twice at an interval of one month increased the fruit yield (30.54 kg tree^{-1}) in Kinnow mandarin over control.

In a study conducted by Patel *et al.* (2010) on the effect of micronutrients on yield and fruit quality of banana cv. Basrai under paired row planting method, observed that foliar application of $ZnSo_4$ 0.5 per cent + $FeSo_4$ 0.5 per cent recorded maximum bunch weight (23.85kg), bunch length (93.50cm), bunch girth (114cm), number of hands bunch^{-1}(11.70) and fruit yield (149.078 t ha^{-1}).

Pathak *et al.* (2011) conducted a study to determine the effect of micronutrients on growth, yield and quality of banana and recorded maximum bunch weight (16.30 kg), hands bunch^{-1} (9.2), fingers bunch^{-1} (129.2), yield (40.75 t.ha^{-1}), finger length (14.80 cm), finger breadth (13.10 cm), days to ripening (8.1 days) and highest B: C (3.61) with foliar application of $FeSo_4$ 0.5 per cent + $ZnSo_4$ 0.5 per cent.

Mirzapour and Khoshgoftarmanesh (2013) reported that in pomegranate foliar application of $FeSO_4$ 0.2 per cent + $ZnSO_4$ 0.2 per cent recorded the highest fruit yield (18078 kg ha^{-1}) over control.

2.4 EFFECT OF BORON ON YIELD ATTRIBUTING PARAMETERS

Bambal *et al.* (1991) stated that the foliar application of boric acid 0.2 per cent was found responsible for increasing fruit yield in pomegranate.

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

In an experiment conducted by Ahmed *et al.* (1992) on the influence of boron on yield attributes in papaya reported that boron at 5 and 10g per plant significantly increased the production of uniform and healthy papaya fruits, maximum number of fruits (47.2 plant^{-1}) and higher fruit yield hectare^{-1}.

Chattopadhyay and Gogoi (1992) from their studies on influence of micronutrients in papaya cv. Ranchi observed that foliar application of boron @ 40 ppm in papaya produced maximum fruit weight (1000 g) and fruit yield (42.81 kg plant^{-1}) over control.

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

Lokhande and Moghe (1998) concluded that the plants receiving 200 g N + 100 g P via soil + a foliar spray of 1 per cent urea + 0.2 per cent boron + 50 ppm IAA at 90 days interval recorded maximum fruit weight (1.828 kg $fruit^{-1}$), fruit shape (0.996 shape index) and fruit yield (32.843 kg $plant^{-1}$) in papaya cv. Honeydew.

Yadav (1998) reported that the foliar application of urea (3 per cent) + borax (0.15 per cent) + NAA (10 ppm) on Guava produced higher yield and good quality fruits.

Saleh and Monem (2003) observed that the foliar spray of 0.3 per cent Potassium + 0.5 per cent boric acid on mango resulted significant increase in number of fruits per plant, fruit set, fruit yield, fruit weight, fruit size and pulp weight.

Singh and Maurya (2004) obtained significantly higher fruit yield with foliar application of H_3BO_3 (0.2 per cent) in mango then control.

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

Mollah *et al.* (2006) from their studies on response of papaya varieties to basal and foliar application of boron observed the highest fruit yield (49.01 t ha^{-1}) with foliar application of boron @ 1.0 kg ha^{-1} in cv. Shahi.

Khayyat *et al.* (2007) reported the highest yield (15.55 g), pulp weight, pulp/seed ratio, fruit length and diameter of fruit with the foliar application of H_3BO_3 (1500 ppm) when compared to control in date palm cv. Shahanv.

Edward Raja (2008) reported that application of boron in the form of colemanite (a slow release boron fertilizer) @ 2 kg ha^{-1} resulted in high fruit yield (26 kg $plant^{-1}$) with large and smooth skinned fruits followed by application of borax @ 1 kg ha^{-1} and 0.05 per cent foliar spray once in four months.

Application of borax 0.4 per cent as foliar spray resulted in maximum fruit set (42.50 per cent), fruit retention (22.60 per cent), fruit size (3.72 cm x 2.90 cm), number of fruit tree^{-1} (5422), weight of individual fruit (20.91 gm) and fruit yield tree^{-1} (111.05 Kg) in litchi (Manoj Kumar *et al.*, 2009).

Banyal and Rangra (2011) obtained significantly the highest fruit set (59.00) per panicle and fruit yield (18.08 kg tree^{-1}) with the foliar application borax @ 0.2 per cent in mid February and 1st week of May on litchi cv. Dehradun.

Bhowmick *et al.* (2012) reported that foliar application of borax 0.25 per cent on mango cv. Amrapali resulted in maximum number of fruits plant^{-1} (170), yield tree-^{1} (36.00 kg), fruit length (10.33 cm) and breadth (6.33 cm).

Bhatt *et al.* (2012) found that foliar application of borax (0.5 per cent) produced maximum fruit yield (28.52 kg tree^{-1}), fruit weight (167.29 g) and fruit volume (164.52 ml) in mango.

Singh *et al.* (2013) recorded maximum fruit yield (48.51 kg tree-^{1}) and fruit weight (165.6 g) in mango cv. Dashehari with the foliar application of 0.02 per cent boric acid.

2.5 EFFECT OF ZINC ON QUALITY PARAMETERS

Bahadur *et al.* (1998) revealed that the foliar application of $ZnSO_4$ @ 0.25 per cent and 0.1 per cent increased total soluble solids, reducing sugar and non-reducing sugar in mango.

Monga and Josan (2000) observed that the foliar application of $ZnSO_4$ (0.3 per cent) on Kinnow mandarin resulted in maximum juice content, total soluble solids and decreased acidity.

Meena Kumari *et al.* (2009) reported that foliar application of $FeSO_4$ 0.5 per cent + $ZnSO_4$ 0.5 per cent + $CuSO_4$ 0.25 per cent twice at an interval of one month increased the TSS (13.25^{0} Brix), total sugars (7.24 %) and acidity (0.70 %) in Kinnow mandarin.

Patel *et al.* (2010) noticed that foliar application of $ZnSO_4$ 0.5 per cent + $FeSO_4$ 0.5 per cent at 3rd, 5th and 7th month after planting in banana cv. Basrai increased the ascorbic acid content (25 mg/100 g) and TSS (22.03^0 Brix) which was significantly superior over control.

Anees *et al.* (2011) reported that foliar application of 0.4 per cent $FeSO_4$ +0.8 per cent H_3BO_3 +0.8 per cent $ZnSO_4$ in mango cv. Dashehari increased the quality of fruit like total soluble solids (27.9^0 Brix), ascorbic acid (150.3 mg/100 ml), non-reducing sugars (8.83 %) and less stone weight (28.13 g) and low acidity (0.178 %) compared to all other treatments and control.

Pathak *et al*. (2011) concluded that combined application of Fe (0.5 per cent) and Zn (0.5 per cent) at 3rd, 5th and 7th month after planting of banana suckers in combination showed maximum sugar/acid ratio (47.69), non-reducing sugar (10.04 %), total soluble solids (25.53^0 Brix) and total sugar (17.241 %) content of pulp.

Bhowmick *et al.* (2012) observed positive response in fruit quality in terms of TSS (20.75^o Brix), total sugars (17.08 %) and decreased acidity (0.18 %) with the foliar application of 1.0 per cent $ZnSO_4$ in mango cv. Amrapali.

2.6 EFFECT OF BORON ON QUALITY PARAMETERS

Shanmugavelu (1973) noticed that foliar application of boron @ 2 ppm in papaya cv. Honeydew decreased the production of staminate flowers to the extent of 34.26 per cent, induced cluster fruit bearing, with elongated fruit stalks with slender band smooth fruit surface and improved fruit quality in terms of brix/acid ratio, total and reducing sugars.

Foliar application of special commercial papaya fertilizer mix (14N-14P-14K + 0.30 per cent B) which contain 1 lb of elemental boron per 350 lb fertilizer mixture, reduced the flow of milky exudates from young fruits, which caused fruit surface browning and also reduced the symptoms of distorted skin and bumpy surface on the old fruits (Nishina, 1987).

Ratananukul *et al.* (1988) conducted field experiments on response of papaya grown in sandy soil to different rates of boron fertilizer and reported that addition of borax at a rate of 10 – 40 g $plant^{-1}$ improved fruit quality.

Chattopadhyay and Gogoi (1992) recorded the highest total soluble solids, total sugar and the lowest ascorbic acid content with foliar application of boron (40 ppm) in papaya.

Haggag *et al.* (1995) reported that foliar application of boric acid at 500 – 1250 ppm at bud swelling stage on mango significantly increased the total soluble solids, Sugars : acid, total sugar content and acidity in mango fruit while, ascorbic acid content was significantly reduced as compared to control.

Banik *et al.* (1997) recorded significant increase in fruit quality of mango cv. Fazli in terms of total soluble solids (20.4^{o} Brix) and total sugar (14.92 %) with the foliar spray of boron at 0.4 per cent + 1.0 per cent urea.

Pant and Lavania (1998) observed maximum level of total soluble solids and significantly higher sugar and sugar acid ratio with foliar spray of boron (0.15 per cent) in papaya.

Mrinalini and Tiwari (1998) observed that pre-harvest spray of borax (0.6 – 1.0 per cent) on eighteen year old guava cv. Sardar twice in October improved the quality of fruits in terms of size, weight, total soluble solids and ascorbic acid. They also reported that application of 0.2 per cent and 0.4 per cent borax also improved the shelf-life of guava fruits.

Sheng-Bin Ho (2000) reported that soil application of borax @ 2.5 – 5 g per plant, or 5 – 10 kg of borax per hectare or foliar application of 0.5 per cent of borax was found to be effective in reducing boron deficiency symptoms *viz.,* white latex exudates from cracks of the trunk, flower shedding, incomplete fertilization and deformed, lumpy and rugged surface fruits in papaya.

Tyagi and Datt (2004) showed that borax @ 5.0 kg per hectare was very effective in reducing bumpiness to a minimum level improving the quality of papaya fruits.

Bhatt *et al*. (2012) reported that foliar application of borax (0.5 per cent) improved TSS (17.8^0 Brix) and Sugars content of mango pulp.

Singh *et al.* (2013) observed that foliar sprays of boric acid (0.02 per cent) in mango cv. Dashehari resulted in improved TSS (18.59^o Brix) and total sugars (14.92 %) compared to control.

2.7 COMBINATION EFFECT OF ZINC AND BORON

2.7.1 Combination of zinc and boron on plant growth parameters

Kamble *et al.* (1994) reported that the foliar spray of $ZnSO_4$ 0.4 per cent + $FeSO_4$ 0.4 per cent + boric acid 0.2 per cent increased flowering in ber.

Banik and Sen (1997) studied the effect of foliar application of $ZnSO_4$ 0.1 per cent, $FeSO_4$ 0.2 per cent and borax 0.4 per cent twice on mango cv. Fazli in July and October and observed that both Zn and B promoted vegetative growth in terms of plant height, trunk girth and plant spread.

Balakrishnan (2000) revealed that the foliar spray of 0.25 per cent $ZnSO_4$ + 0.25 per cent $FeSO_4$ + 0.25 per cent $MgSO_4$ + 0.1 per cent borax on guava cv. Lucknow-49 resulted in the highest number of shoots per twig (5.97), length of shoot (16.6 cm), number of leaves (13.15) and chlorophyll content (3.03 mg/g).

Jeyakumar *et al.* (2001) noticed an improvement in stem girth and number of leaves plant^{-1} with the combined foliar application of $ZnSO_4$ 0.5 per cent and H_3BO_3 0.1 per cent on papaya at 4th and 8th month after transplanting.

Foliar application of micronutrients $FeSO_4$ (0.2 per cent) and boric acid (0.1 per cent) on pawpaw cv. Ranchi at 2nd and 4th month after transplanting resulted in increase of all growth parameters *viz.*, plant height, basal diameter and number of leaves per plant (Alila *et al.*, 2004).

Saraswathy *et al.* (2004) observed that foliar and soil application of $ZnSO_4$ (0.5 per cent and 50 or 100 g plant^{-1}) and borax (0.3 per cent and 25 or 50 g plant^{-1}) alone or in combination markedly improved the growth, yield and quality of sapota cv. PKM-1 compared to control.

Singh and Maurya (2004) stated that there was good response in improvement of flowering with foliar application of $ZnSO_4$ (0.4 per cent), $FeSO_4$ (0.4 per cent), $MnSO_4$ (0.2 per cent) and H_3BO_3 (0.2 per cent) alone or in combination on mango.

Singh *et al.,* (2010) opined that foliar application of borax @ 0.50 per cent + zinc sulphate @ 0.25 per cent at two months interval from transplanting resulted in maximum plant height (171.62 cm), plant girth (39.74 cm) and number of leaves plant^{-1}(31.17) in papaya cv. Ranchi.

Yadav *et al.* (2010) reported that in papaya cv. Washington foliar application of copper sulphate 0.25 per cent + manganese sulphate 0.25 per cent + borax 0.1 per cent recorded maximum plant height (2.21 m) and plant girth (29.77 cm), where as minimum plant height and girth (1.86 m and 23.5 cm) were recorded in control.

2.7.2 Combination of Zinc and Boron on yield attributing parameters

Bambal *et al.* (1991) reported that the foliar application of 0.4 per cent $FeSO_4$, 0.2 per cent boric acid, 0.3 per cent $MnSO_4$ and 0.3 per cent $ZnSO_4$ alone or in combination was found effective in increasing fruit yield in pomegranate.

Foliar application of 0.3 per cent Zn + 0.1 per cent Cu + 0.2 per cent B at 3 and 5 months after planting recorded highest fruit yield (196.25 q ha^{-1}), individual fruit weight, fruit size and pulp: peel in banana cv. Giant Governor (Ghanta and Dwivedi, 1993).

Balakrishnan *et al.* (1996) noticed increase in yield from 18.5 kg plant^{-1} in control to 26.37 kg plant^{-1} with foliar application of 0.25 per cent each of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ combined with 0.15 per cent boric acid showed increase in pomegranate cv. Ganesh.

Pant and Lavania (1998) observed the highest fruit yield in Pant Papaya-1 when boron was sprayed alone or in combination with zinc sulphate.

Kundu and Mitra (1999) reported that foliar spraying of Cu + B + Zn was most effective in increasing the yield and fruit weight in guava.

Kavitha *et al.* (2000) reported increase in the yield parameters of papaya cv. CO.5 during the fourth, eighth, twelfth and sixteenth month after planting with the 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}.

Jeyakumar *et al.* (2001) undertook a field experiment to determine the effect of zinc and boron on the fruit yield of papaya cv. Co 5. In their study, they revealed that foliar application of zinc sulphate @ 0.5 per cent in combination with borax @ 0.1 per cent recorded the highest fruit yield.

Jitendra (2003) reported that foliar application of zinc sulphate (0.4 per cent), ferrous sulphate (0.4 per cent), manganese sulphate (0.2 per cent) and boric acid (0.2 per cent), singly or in combination resulted in increased fruit weight and fruit yield in mango cv. Mallika.

Singh and Maurya (2004) observed that foliar application of micronutrients *i.e.*, $ZnSO_4$ (0.4 per cent), $FeSO_4$ (0.4 per cent), $MnSO_4$ (0.2 per cent) and H_3BO_3 (0.2 per cent) in combination were found to increase the fruit yield in mango.

Singh *et al.* (2005) reported that the combined application of 0.5 per cent borax and 0.25 per cent $ZnSO_4$ produced maximum fruit yield (93 t/ha) in papaya as compared to control (61.56 t/ha).

Singh *et al.* (2005) applied borax @ 0.50 per cent + zinc sulphate @ 0.25 per cent as foliar spray at two months interval from transplanting and record maximum fruit yield (37.20 kg per plant) in papaya cv. Ranchi.

Ray (2009) revealed that foliar application of $ZnSO_4$ 0.5 per cent and borax 0.1 per cent either alone or in combination resulted in better fruit yield in papaya.

Ghosh (2009) reported that foliar application of borax at 0.25 and 0.5 per cent and zinc sulphate at 0.50 and 1.0 per cent twice, once at pea and again at marble stage (15 days after first spray) recorded highest fruit weight (22.96 g) and yield (4,110.50 fruits plant^{-1}) in litchi cv. Bombai**.**

Thangaselvabai *et al.* (2009) applied 0.5 per cent $ZnSo_4$, 0.2 per cent $FeSo_4$, 0.2 per cent $CuSo_4$ and borax 0.1 per cent (at 3rd, 5th and 7th month after planting) as a foliar spray and obtained increased fruit yield in banana.

Yadav *et al.* (2010) reported that in papaya cv. Washington foliar application of copper sulphate 0.25 per cent + manganese sulphate 0.25 per cent + borax 0.1 per cent recorded significantly the highest number of fruits plant^{-1}(30.67), fruit weight (1.30 kg), yield (40.4 kg plant^{-1} and 993.29 q ha^{-1}), fruit length (25.0 cm) and fruit width (13.17 cm).

Kumawat *et al.* (2012) found that foliar application of $ZnSo_4$ (0.5 per cent) + borax (0.2 per cent) + $MnSo_4$ (0.1 per cent) twice during August and October months resulted significantly the highest fruit yield (12.63 kg plant $^{-1}$) in guava.

Bhalerao and Patel (2012) observed that foliar application of calcium nitrate 1000 ppm + borax 30 ppm + zinc sulphate 200 ppm + ferrous sulphate 200 ppm at 60, 90 and 120 days after planting on papaya cv. Taiwan Red Lady recorded the highest fruit yield (80.76 t ha^{-1}).

2.7.3 Combination of Zinc and Boron on quality parameters

Singh *et al.* (1989) stated that when ber plants treated with boron (0.03 per cent) + $ZnSO_4$ (0.5 per cent) + NAA (50 ppm) in foliar form recorded the highest total sugar, total soluble solids and ascorbic acid content and the lowest acidity in fruits.

Chattopadhyay and Gogoi (1992) noticed the highest TSS content (11.26 %) in papaya fruits harvested from plants treated with boron @ 40 ppm. They further reported that these fruits showed marked reduction in acidity when treated with 40 ppm borax, $CuSo_4$ or $ZnSo_4$.

Ghanta and Dwivedi (1993) observed that maximum fruit quality (in terms of TSS, total sugar, reducing sugar, sugar: acid and ascorbic acid content) was obtained with foliar application of 0.3 per cent $ZnSo_4$ + 0.1 per cent $CuSo_4$ + 0.2 per cent borax on banana cv. Giant Governor.

Kamble and Desai (1996) found that foliar applications of $FeSO_4$ 0.2 per cent and 0.4 per cent, $ZnSO_4$ 0.2 per cent and 0.4 per cent, $MnSO_4$ 0.2 per cent and 0.4 per cent and Boric acid 0.1 per cent or 0.2 per cent increased fruit weight, total soluble solids, total sugars and Vitamin C content in ber cv. Karaka.

Balakrishnan *et al.* (1996) concluded that foliar application of 0.25 per cent each of $ZnSO_4$, $FeSO_4$ and $MnSO_4$ combined with 0.15 per cent boric acid significantly increased juice content from 65.6 to 74.8 per cent whereas the highest total soluble solids (17.35^{o} B) was recorded with $ZnSO_4$ 0.4 per cent and Boric acid 0.2 per cent spray in pomegranate cv. Ganesh.

Chaitany *et al.* (1997) showed that foliar application of $ZnSO_4$ and borax both at 0.3 per cent improved the fruit quality in guava.

Pant and Lavania (1998) from their studies on effect of foliar sprays of iron, zinc and boron on papaya cv. Pant papaya -1 observed that maximum sugars (12.5 per cent) and sugars: acid (49.2) with foliar application of borax @ 0.15 per cent.

Kundu and Mitra (1999) noticed increase in TSS, total sugar and sugar/acid ratio in guava fruits and decline in fruit acidity with the foliar application of $ZnSO_4$ followed by borax.

Jeyakumar *et al.* (2001) observed that the foliar application of $ZnSO_4$ 0.5 per cent in combination with borax 0.1 per cent at 4th and 8th month after planting recorded maximum TSS in papaya.

Alila *et al.* (2005) observed that significantly higher ascorbic acid content was observed in fruits of papaya plants received foliar application of borax (0.1 per cent) + $FeSO_4$ (0.1 per cent) and $ZnSO_4$ (0.2 per cent), however maximum non-reducing sugars were recorded in fruits when treated with borax + $ZnSO_4$.

Singh *et al.* (2005) revealed that the combined application of 0.5 per cent borax and 0.25 per cent $ZnSO_4$ gave positive response in increasing the total soluble solids (6.81^{o}Brix), total sugar (6.88 %), reducing sugar (6.35 %), non-reducing sugar (0.53 %), ascorbic acid (57.11 mg/100 g pulp), β-carotene (3324.14 µg/100 g pulp) and total soluble solids: acid (58.41) content in papaya fruit.

Zinc sulphate (0.4 per cent), ferrous sulphate (0.4 per cent) and boric acid (0.2 per cent) singly or in combination as foliar spray resulted in increased total soluble solids, acidity and ascorbic acid content in mango cv. Mallika (Singh *et al.*,2009)**.**

Ghosh (2009) reported that foliar application of borax at 0.25 and 0.50 per cent and zinc sulphate at 0.50 and 1.0 per cent twice at pea and marble stage (15 days after first spray) observed the highest TSS (20.88 ^{0} Brix), total sugars (16.09 %), reducing sugars (14.77 %) with excellent colour due to high anthocyanin content (65.89 mg/100 g peel) and the lowest acidity (0.456 %) was noticed with foliar spray of borax at 0.50 per cent in litchi cv. Bombai.

Thangaselvabai *et al.* (2009) applied foliar sprays of 0.5 per cent $ZnSO_4$, 0.2 per cent $FeSO_4$, 0.2 per cent $CuSO_4$ and borax 0.1 per cent at 3rd, 5th and 7th month after planting showed higher fruit quality in banana.

Yadav *et al.* (2010) reported that copper sulphate 0.25 per cent + manganese sulphate 0.25 per cent + borax 0.1 per cent when applied as foliar spray on papaya cv. Washington recorded TSS (9.60 %), total sugars (9.72 %) and acidity (0.053 %) which was found to be superior over control.

Kumawat *et al.* (2012) opined that foliar sprays of $ZnSO_4$ (0.5 per cent) + borax (0.2 per cent) + $MnSO_4$ (0.1 per cent) twice in the months of August and

October on rejuvenated guava plants recorded increased fruit yield (12.63 kg plant^{-1}), fruit quality (TSS 13.20 %, total sugars 6.98 % and Vitamin – C content 239 mg/100 g pulp).

2.8 Effect of boron other micronutrients on incidence of PRSV

Wang and Ko (1975) reported that mosaic affected papaya plants developed deficiency of boron resulting in deformation of fruits which could be rectified by foliar application of 0.25 per cent borax.

Lokhande and Moghe (1990) concluded that application of 200 g N + 100 g P through soil + a foliar spray of 1 per cent urea + 0.2 per cent boron + 50 ppm IAA at 90 days interval starting from 15 DAP to the PRSV inoculated plants showed positive response in improvement of stem height (220.01 cm), diameter (28.30 cm) and productivity of PRSV inoculated plants (32.84 kg plant^{-1}) compared to PRSV inoculated control plants (3.7 kg plant^{-1}) and also non inoculated control plants (4.7 kg plant^{-1}) in papaya cv. Honeydew.

A study conducted by Lokhande and Moghe (1998) on correlation between yield and different fruit quality traits on PRSV inoculated field grown papaya cv. Honeydew showed highly significant result with inhibited disease severity and improved fruit quality and yield with soil application of 200 g N + 100 g P per plant in four equal splits followed by foliar spray of each test chemical applied at 90 days interval starting from 15 days after transplanting.

Verghese *et al*., (2001) stated that use of insecticides and micronutrients was one of the strategies for managing the papaya crop to PRSV.

Jahir Basha (2002) reported that foliar application of boron @ 0.2 per cent delayed the symptom expression of PRSV by 3 and 5 days with 70 and 60 per cent disease incidence, when applied before and after inoculation of virus respectively. Under glass house and field condition the same treatment when applied at 15 days intervals showed promising effect with increased petiole length and reduced blister number, distortion of leaves, vein clearing of leaf, shoe string leaf and mild mosaic symptoms in the seedlings of papaya cv. Solo.

Balanced mixture of nutrients (organic and inorganic sources) around 10 kg FYM, 2kg neem cake, 1 kg sterameal, 200 g each of nitrogen, phosphorus and potassium in 6 split doses (once in 2 months), 0.5 per cent Zn ($ZnSO_4$) and 0.1 per cent boron (H_3BO_3) applied through foliar spray twice first at flowering (3-5 weeks) and second at 4 weeks after flowering can delay or avoid the disease incidence of PRSV in papaya (Sharma *et al.,* 2005).

Kudada and Prasad (2006) reported that interaction of winter season and higher manuring levels, despite higher disease incidence significantly recorded higher number of fruits per plant and fruit weight.

Delay in symptom expression (293 – 301.20 days of planting) with fruit yield of 9.12 – 8.90 kg plant^{-1} was observed when boron (19 per cent B 1.5g/l) was applied as foliar spray along with soil application of phorate (10 per cent G @ 5g/ pit) followed by boron alone wherein disease incidence was observed 292.25 – 297.40 days after planting with a fruit yield of 8.92 – 8.25 kg plant^{-1} in papaya cv. Surya (Kunkalikar *et al.,* 2006).

Chapter- III

Materials and Methods

CHAPTER - III

MATERIALS AND METHODS

The present investigation on "Response of Zinc and Boron sprays on growth, yield and quality of papaya (*Carica papaya* L.) cv. Red Lady" was conducted during 2013-2014 at Horticultural Research Station, Dr.Y.S.R. Horticultural University, Anantharajupet, YSR District, Andhra Pradesh. The details of materials used and the methods adopted in the experiments are described here under.

3.1 THE EXPERIMENTAL FIELD

3.1.1 Geographical location of the experimental site

The experiment was carried at HRS, Anantharajupet that in located in Rayalaseema region of the Andhra Pradesh and is situated at an altitude of 215 meters (531 feet) above mean sea level and located at 13.98^0 North latitude and 79.40^0 East longitudes.

3.1.2 Climate

The meteorological data pertaining to rainfall, mean minimum and maximum temperatures, humidity during the experimental period (February 2013 to January 2014) was recorded and presented in Appendix –1.

During the crop period, the total rainfall received was 807.0 mm. The weekly mean maximum and minimum temperatures during the crop growth period ranged from 39.3^0C to 31.0^0C and 18.8^0C to 28.0^0C respectively. The relative humidity during the period of crop growth ranged between from 77.0 to 87.0 %.

3.1.3 Soil type

The soil type of experimental site is sandy loam with good drainage. The soil pH is varying from 7.3 to 8.0 and EC 0.23 dSm^{-1}.

3.1.4 Soil analysis

Soil samples were taken before planting of Papaya seedlings and after the harvest of the crop and samples were analyzed for the following Physico-chemical properties and methods employed for each of them are presented below.

Table 3.1Physicochemical properties of experiment site

A. Chemical composition

Properties	**Characterization**	**Method of analysis**
Soil pH	7.58	Glass electrode pH meter model 335 (Jackson, 1973)
Electrical conductivity (dSm^{-1})	0.232	Conductivity Bridge ELICO Model EM 88 (Jackson,1973)
Available Nitrogen (kg ha^{-1})	204.30	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available Phosphorus (P_2O_5) (kg ha^{-1})	18.84	Olsen's method (Olsen , 1954)
Available Potassium (K_2O) (kg ha^{-1})	395.0	Neutral normal Ammonium Acetate method using Flame Photometer (Muhr, 1965).
Available Zinc (ppm)	0.963	DTPA method using Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978)
Available Boron (Ppm)	0.716	Hot water method (Berger and Trough, 1939)

B. Physical composition

Properties	Characterization	Method of analysis
Sand (%)	70	International pipette method (Piper, 1966)
Silt (%)	10	
Clay (%)	20	
Textural class	Sandy loam	

3.2 Experimental details

Crop : Papaya

Variety : Red Lady

Spacing : 2.0 X 2.0m

Date of planting : 11-02-2013

Plot size : 8.0 x8.0 m

No. of Treatments : 9

Design : RBD

Replication : 3

Location : Horticultural Research Station, Anantharajupet.

3.2.1 Treatments

T_1. Borax at 0.25%

T_2. Borax at 0.50%

T_3. $ZnSO_4$ at 0.25%

T_4. $ZnSO_4$ at 0.50%

T_5. Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6. Borax at 0.25% +$ZnSO_4$ at 0.50%

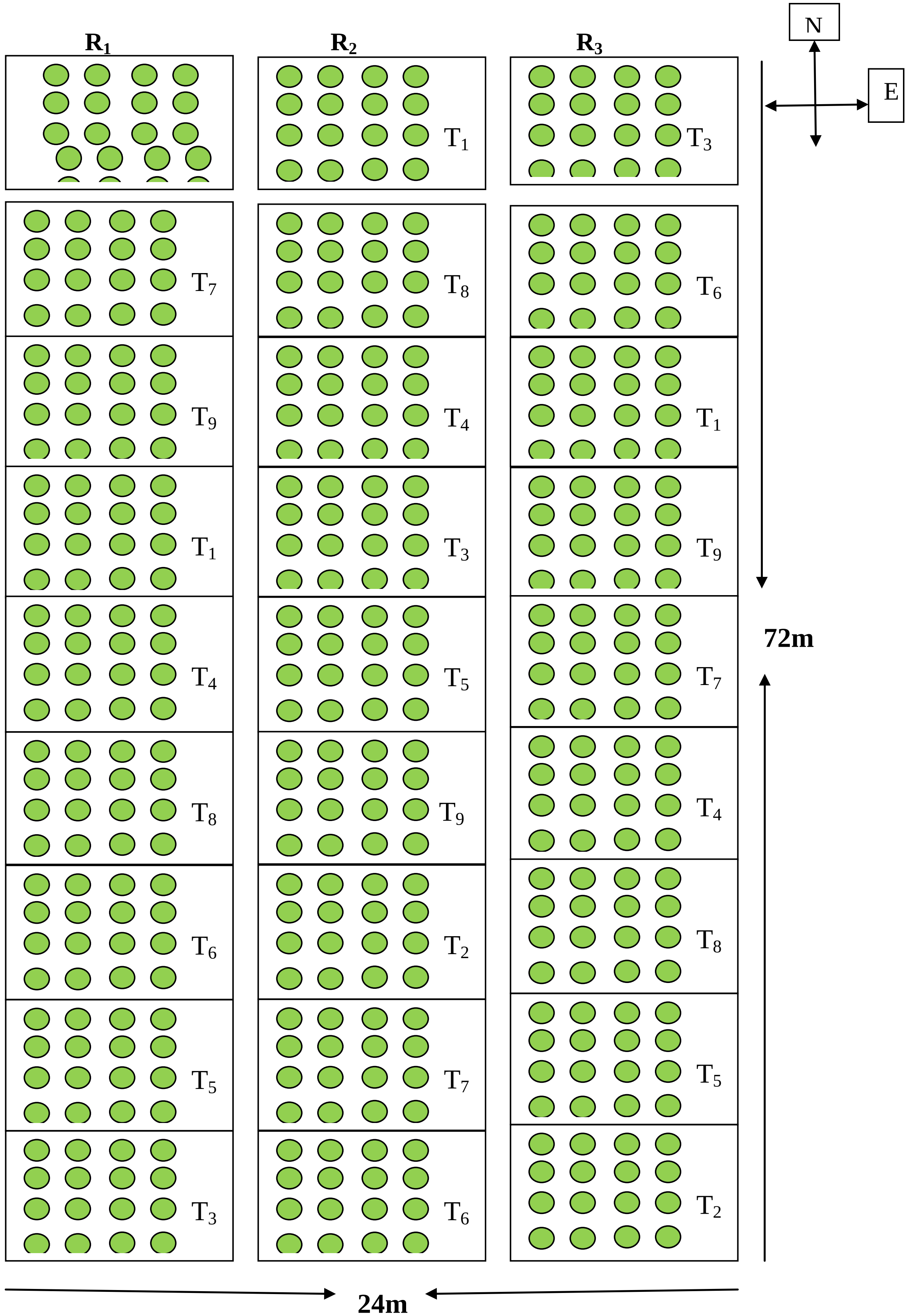
T_7. Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8. Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9. Control (water spray).

3.2.2 Experimental designs and Lay out

The design for the experiment was Randomized Block Design (RBD) having 3 replications and 9 treatments. Treatments were allocated randomly to each replication. Each treatment consisted of 16 plants, one replication had 144 plants. Total 3 replications had 432 plants. The total area under this experiment was 1510.72 m^2.



Layout plan of experiment

3.3 CULTIVATION DETAILS

3.3.1 Preparatory cultivation

The experimental field was thoroughly ploughed with tractor drawn mould board plough to a depth of 30 cm and harrowed twice to a fine tilth. The field was levelled and divided into plots as per the layout of the experiment.

3.3.2 Digging of pits

Pits of 45 × 45 × 45 cm size were dug at a spacing of 2.0 × 2.0 m and allowed to expose to sunlight for one week before planting of seedlings.

3.3.3 Planting material

Healthy, disease free and uniform Papaya cv. Red Lady seedlings were procured from local nursery, Rly. Kodur and were planted in the experimental site on 11-02-2013.

3.3.4 Quantities of inorganic fertilizers

Recommended dose of major nutrients for papaya @ 250: 250: 500g NPK $plant^{-1}year^{-1}$ were applied in six split doses with two months interval. Foliar application of micronutrients like Zinc and Boron were applied in six split doses with two months interval.

3.3.5 Inoculation of biofertilizers

For this study, biofertilizers viz., *Azospirillum lipoferum* (strain ICM 1001) and Phosphate Solubilizing Bacteria (PSB) were procured from Agricultural Research Station (Acharya N G Ranga Agricultural University), Amaravathi, Andhra Pradesh. *Azospirillum* and PSB @ 20 g each $plant^{-1}$ applied in the pits at the time of planting of seedlings.

3.3.6 Planting of seedlings

Papaya seedlings were planted in the pits during the month of February along with the manures like farmyard manure and biofertilizers according to the treatments. The seedlings were provided with irrigation immediately after planting.

3.3.7 Cultural operations

The experimental field was kept weed free by regular inter cultivation in between rows and by hand weeding in the tree basins. Irrigation is given at regular intervals once in 10-15 days intervals based on environmental conditions.

3.4 OBSERVATIONS RECORDED

Five plants from each treatment plot were selected at random and tagged for recording the observations on the following growth, yield and quality parameters. The data were averaged and expressed per plant.

3.4.1. Growth parameters

Plant growth parameters like plant height, plant girth and number of leaves per plant were recorded at 90 days intervals.

3.4.1.1. Plant height (cm)

Height of the plant was recorded in centimeters from the coller region to the base of the last fully opened leaf on the main stem using a measuring scale, at 90 days interval. The mean plant height was calculated by averaging the values of five random plants.

3.4.1.2. Plant girth (cm)

Plant stem girth was measured by using a flexible measuring tape at a marked point fifteen centimeters above the soil at 90 days interval. The mean plant girth was calculated and expressed in centimeters.

3.4.1.3. Number of leaves per plant

The number of leaves produced per plant in each treatment was counted and recorded at 90 days intervals and the average was worked out.

3.4.1.4. Days to first fruit formation

The number of days taken from transplanting to first fruit formation on the plant in each treatment was recorded by visual observations.

3.4.2. Yield parameters

3.4.2.1. Days to harvest

Number of days taken from date of planting to mature fruits from the sample plants in each treatment was recorded; average was worked out and presented as days taken for harvesting.

3.4.2.2. Number of fruits per plant

Harvesting of fruits was done at 15 days interval and number of fruits harvested per plant on each tagged plant was recorded from each treatment up to the end of the final harvest and the mean number of fruits per plant was worked out.

3.4.2.3. Yield per plant (kg)

Yield of the total fruits harvested in different intervals from the sample plants in each treatment was recorded and expressed in kilogram per plant.

3.4.2.4. Yield per hectare (tonnes)

Total weight of fruits harvested from all the plants in the treatment was used for calculation of yield and expressed in tonnes per hectare.

3.4.2.5. Fruit weight (kg)

The weight of ten randomly selected fruits was measured with the help of electronic weighing balance individually and mean fruit weight was calculated.

3.4.2.6. Fruit length (cm)

Fruits were longitudinally cut and fruit length was measured with the help of a measuring scale from stock end to the floral end of the fruit and expressed in centimeters.

3.4.2.7. Fruit girth (cm)

The middle portion of the fruit was measured using a thread then thread was placed on measuring scale and observation was recorded as fruit girth and expressed in centimeters.

3.4.2.8. Fruit volume (cc)

A container filled with water was taken and placed inside another container. Then the fruits were taken individually and submerged without forcing. The amount of water displaced was measured with the help of measuring cylinder to record the fruit volume.

3.4.2.9. Cavity length (cm)

Fruits were cut opened longitudinally and the cavity length of papaya fruit was measured with the help of a scale and expressed in centimeters.

3.4.2.10. Cavity girth (cm)

The cavity girth of the randomly selected fruits of papaya was measured in centimeters and mean girth was calculated.

3.4.2.11. Cavity index (%)

The volume of water filled in both the cavities of the fruit was measured. This was divided by the whole fruit volume. The fruit cavity index was calculated using the following formula.

$$\boldsymbol{Fruit\ cavity\ index}\ (\%) = \frac{\boldsymbol{volume\ of\ the\ fruit\ cavity}}{\boldsymbol{volume\ of\ the\ fruit}} \times \mathbf{100}$$

3.4.2.12. Fruit pulp weight (g)

The weight of fruit pulp was measured after removing the peal and seeds with electronic weighing balance and expressed in grams.

3.4.2.13. Fruit pulp thickness (cm)

The randomly selected fruits were cut open longitudinally to measure the pulp thickness with the help of Vernier calipers and the mean was computed and recorded in centimeters.

3.4.3. Fruit quality parameters

From the harvested lot, ten fruits were randomly selected from each treatment to record the fruit quality parameters.

3.4.3.1. Total soluble sugars (^{o} Brix)

Fully ripe fruits were peeled and pulp was crushed for juice extraction. The juice was used for determining the total soluble solids by using hand refractometer of 0-32 range (Erma make, Japan). The values were corrected at 20^{0} C and expressed as degree brix.

3.4.3.2. Titrable acidity (%)

Titrable acidity of the fruit pulp was estimated by titration method and expressed as per cent citric acid using the factor that 1ml of 0.1 NaOH neutralizes 0.0064g of citric acid (A.O.A.C., 1980). A known quantity of the fruit pulp was taken after macerating with distilled water by through mixing and titrated against standard 0.1 N sodium hydroxide solution using phenolphthalein as indicator and acidity was calculated by using the following formula.

$$\boldsymbol{Titrable\ acidity}\ (\%) = \frac{\mathbf{1XEq.wt.of\ acidXNormality\ of\ NaOHXTitre\ value}}{\mathbf{10\ X\ wt.of\ sample}} \times \mathbf{100}$$

3.4.3.3. Total Sugars (%)

The percentage of total sugars was estimated by A. O. A. C. method (1980). Twenty ml of juice was taken into 100 ml conical flask and 20 ml of distilled water was added and to this 5 ml of 6 N HCl was added to conical flask and kept in a hot water bath at 70^0 C for exactly 8 minutes. After that, the flask was removed from water bath and cooled to room temperature. The excess acidity was neutralized by adding 40 per cent Sodium Hydroxide to the conical flask using phenolphthalein as indicator. This was indicated by the formation of pink colour. Then the solution was made up to the mark in a 100ml volumetric flask by adding distilled water.

This solution was taken into a burette and was titrated against 10 ml of Fehlings solution (A & B) in hot condition, using methylene blue as indicator till the brick red colour precipitate is formed. The percentage of total sugars was estimated by using the factor 10 ml of Fehling solution = 0.05g glucose.

$$Total\ Sugars = \frac{0.05 \times 100 \times 100}{Titre\ value \times 20}$$

3.4.3.4. Shelf life (days)

Shelf life was treated as a period (in days) between harvest of the fruit and end of edible life of the fruit at room temperature. End of shelf life was counted at a stage when 50 per cent of the stored fruits become unfit for consumption.

3.4.4. Disease incidence (Papaya ring spot virus)

The incidence of papaya ring spot virus disease was recorded in each treatment. The percent incidence of disease, days taken for appearance and number of plants infected were recorded through visual observation from the date of transplanting. Percentage of disease incidence was calculated as per the following formula.

$$Percent\ disease\ incidence\ (\%) = \frac{number\ of\ infected\ plant}{Total\ number\ of\ observed\ plant} \times 100$$

3.4.5. Economics

Benefit cost ratio was calculated for all the treatments separately. Details of cost of cultivation are furnished in the appendix II.

3.4.6. Statistical analysis

The experimental data were statistically analyzed following the standard procedures (Panse and Sukhatme, 1985). The statistical significant difference was tested with the help of 'F' test at 0.05 level of probability.

Chapter-IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present field investigation entitled "Response of zinc and boron sprays on growth, yield and quality of papaya (*Carica papaya* L.) cv. Red Lady" was carried out at Horticultural Research Station, Anantharajupet, Y.S.R. district Dr.YSRHU**,** A.P., during 2013-14. The data were recorded at various stages of crop growth with regard to growth, yield and quality parameters. The data were statistically analyzed and the results are presented here under.

4.1 Growth characters

4.1.1 Plant height (cm)

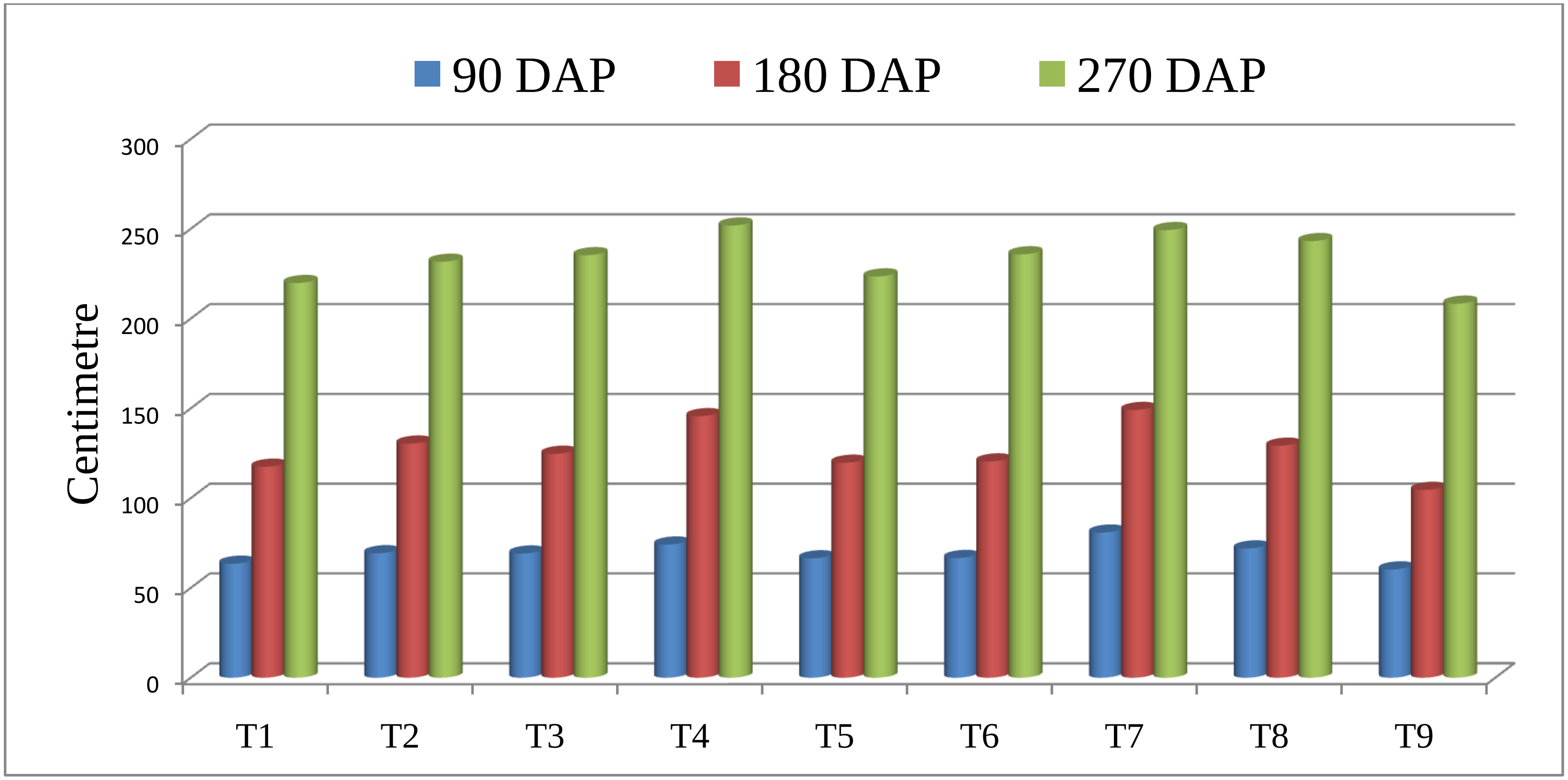
Significant differences were observed with respect to plant height at 90 DAP (Days After Planting) and 180 DAP (Table 4.1. and Fig 1.). Application of borax at 0.50% + $ZnSO_4$ at 0.25% has recorded significantly maximum plant height (80.83 cm) at 90 DAP and it was on par with application of $ZnSO_4$ at 0.50% (74.17 cm). At 180 DAP, the plants sprayed with borax at 0.50% + $ZnSO_4$ at 0.25% have shown significantly the highest plant height (149.13 cm) and it was on par with application of $ZnSO_4$ at 0.50% (145.67 cm). At 90 DAP and 180 DAP, the treatment control has registered significantly lesser plant height (60.33 cm and 104.60 cm) respectively. No significant differences in plant height was observed at 270 DAP due to different treatments.

The increase in plant height might be due to improved photosynthetic activity and respiration of plants as influenced by zinc and boron. Zinc play important role in metabolism of nitrogen and synthesis of auxin in the plant and it was also involved in cell division and cell enlargement as well as enhance the plant growth and development (Modi *et al.,* 2012). In case of boron, it increased the phenolic compounds which regulated to polar auxin transport (Brawn and Amber, 1973). Perez-Lopez and Reyes (1984) and Singh *et al.* (2010) have also reported an appreciable increase in plant height with the spray of micronutrients (Boron and Zinc) in combination or alone in papaya cv. Ranchi. Jeyakumar *et al.* (2001) observed increased plant growth with staggered application of Zinc Sulphate (0.5%) in combination with borax (0.1%) at 4^{th} and 8^{th} months after planting in papaya.

Table 4.1. Influence of foliar application of zinc and boron on plant height of papaya cv. Red Lady.

Treatments	**Plant height (cm)**		
	90 DAP	180 DAP	270 DAP
T_1- Borax at 0.25%	63.50	117.50	219.83
T_2- Borax at 0.50%	69.33	130.40	231.67
T_3- $ZnSO_4$ at 0.25%	69.17	124.73	235.33
T_4- $ZnSO_4$ at 0.50%	74.17	145.67	251.83
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	66.50	119.73	223.50
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	66.67	120.47	235.83
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	80.83	149.13	249.33
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	72.00	129.20	243.17
T_9- Control	60.33	104.60	208.33
S.Em (±)	2.22	5.09	8.40
CD (P=0.05)	6.65	15.27	N.S

Fig.1. Influence of foliar application of zinc and boron on plant height of papaya cv. Red Lady at different growth stages



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.1.2 Plant girth (cm)

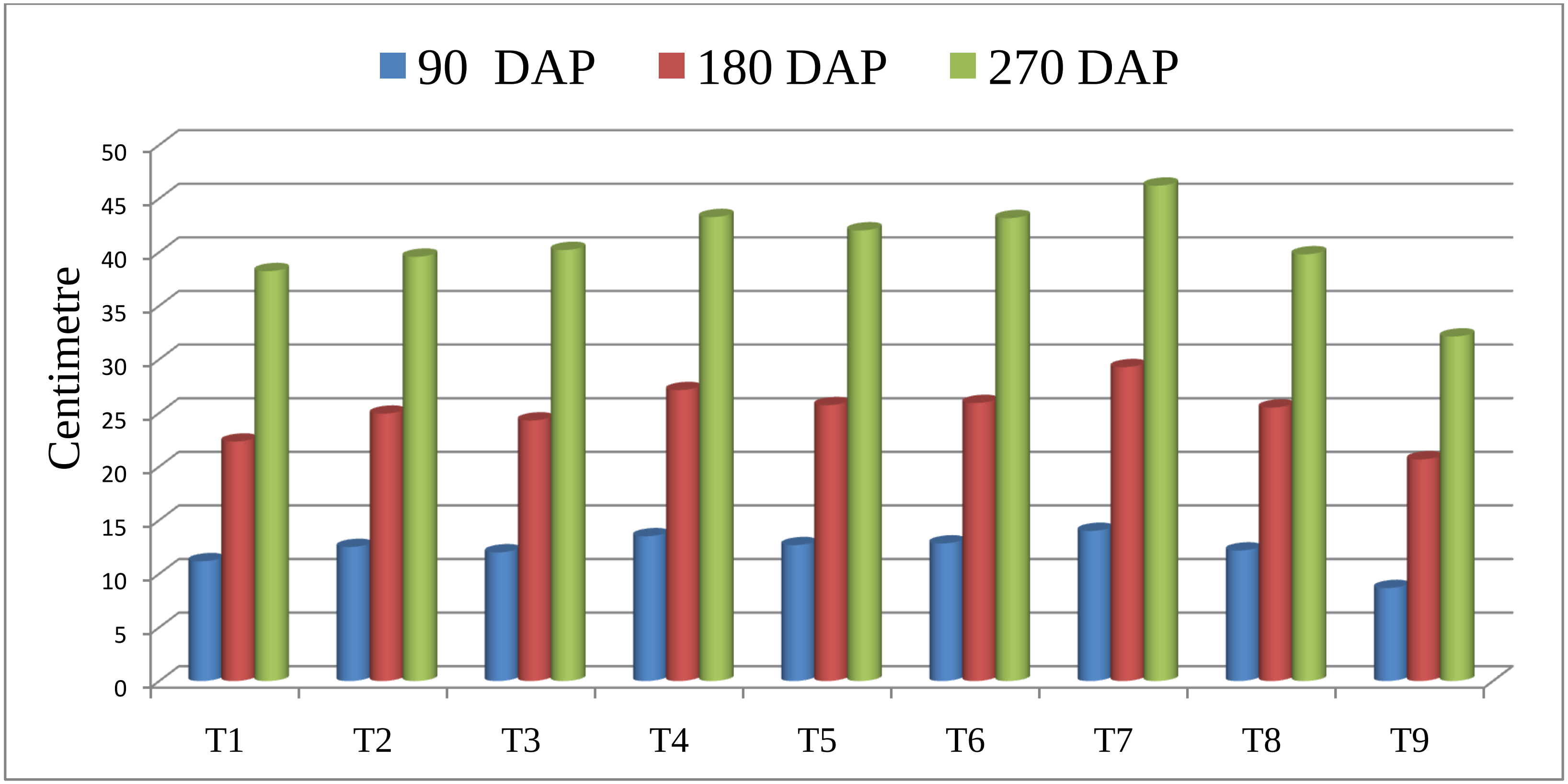
The data presented in Table 4.2. and Fig 2. revealed that significant differences were observed with respect to plant girth at 90 DAP and 180 DAP. Maximum plant girth (14.00 cm) was observed with the foliar application of borax at 0.50% + $ZnSO_4$ at 0.25% which was found statistically significant at 90 DAP and it was on par with application of $ZnSO_4$ at 0.50% (13.50 cm), borax at 0.25% + $ZnSO_4$ at 0.50% (12.83 cm), borax at 0.25% + $ZnSO_4$ at 0.25% (12.67 cm) and borax at 0.50% (12.50 cm). At 180 DAP, the plants applied with borax at 0.50% + $ZnSO_4$ at 0.25% have shown significantly the highest plant girth (29.27 cm) and it was at par with application of $ZnSO_4$ at 0.50% (27.13 cm). At 90 DAP and 180 DAP, the treatment control has registered significantly minimum plant girth (8.67 cm and 20.67 cm respectively). Significant differences were not observed in plant girth due to different treatments at 270 DAP.

The increase in plant girth at 90 DAP and 180 DAP could be attributed to the beneficial effect of zinc and boron in increased metabolic activities which lead to increase in plant metabolites responsible for cell division, cell elongation and ultimate plant growth. Similar increase in plant girth was observed with the foliar application of micronutrients (zinc and boron) when applied alone or in combination in papaya cv. Honey dew by Lokhande and Moghe (1991) and in cv. Ranchi by Singh *et al.* (2010).

Table 4.2. Influence of foliar application of zinc and boron on plant girth of Papaya cv. Red Lady.

Treatments	Plant girth (cm)		
	90 DAP	180 DAP	270 DAP
T_1- Borax at 0.25%	11.17	22.33	38.23
T_2- Borax at 0.50%	12.50	24.93	39.57
T_3- $ZnSO_4$ at 0.25%	12.00	24.30	40.20
T_4- $ZnSO_4$ at 0.50%	13.50	27.13	43.27
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	12.67	25.73	42.03
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	12.83	25.93	43.17
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	14.00	29.27	46.20
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	12.17	25.50	39.80
T_9- Control	8.67	20.67	32.13
S.Em (±)	0.55	1.08	2.44
CD (P=0.05)	1.64	3.25	N.S

Fig.2. Influence of foliar application of zinc and boron on plant girth of Papaya cv. Red Lady at different growth stages.



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.1.3 Number of leaves plant^{-1}

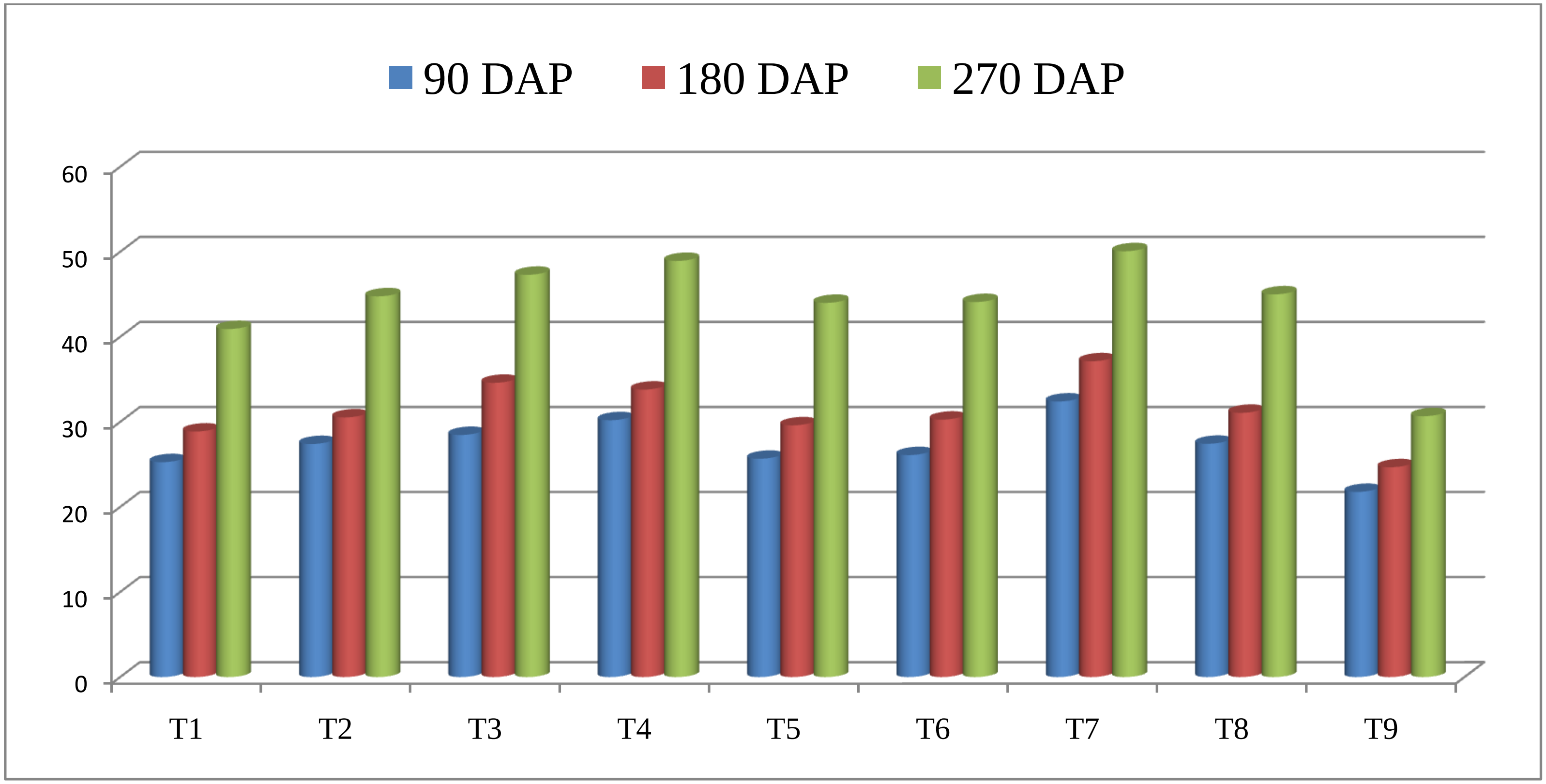
Total number of leaves plant^{-1} was significantly influenced at each crop stage by different treatments at 90 DAP, 180 DAP and 270 DAP (Table 4.3. and Fig 3.). At 90 DAP plants supplied with borax at 0.50% + $ZnSO_4$ at 0.25% have put forth significantly maximum leaves plant^{-1} (32.40) and it was on par with application of $ZnSO_4$ at 0.50% (30.20) and $ZnSO_4$ at 0.25% (28.47). At 180 DAP, application of borax at 0.50% + $ZnSO_4$ at 0.25% have shown significantly maximum number of leaves plant^{-1} (37.13) and it was on par with application of $ZnSO_4$ at 0.25% (34.60) and $ZnSO_4$ at 0.50% (33.80). At 270 DAP, the plants applied with borax at 0.50% + $ZnSO_4$ at 0.25% have shown significantly maximum number of leaves plant^{-1} (50.07) and it was on par with application of $ZnSO_4$ at 0.50% (48.93) and $ZnSO_4$ at 0.25% (47.30), borax at 0.50% + $ZnSO_4$ at 0.50% (45.00), borax at 0.50% (44.77), borax at 0.25% + $ZnSO_4$ at 0.50% (44.10) and borax at 0.25% + $ZnSO_4$ at 0.25% (44.00). At 90 DAP, 180 DAP and 270 DAP, the treatment control has produced significantly lesser number of leaves plant^{-1} (21.77, 24.67 and 30.67 respectively).

A definite increase in number of leaves per plant with all concentrations of zinc and boron alone or in combination as compared to control might be due to increase in photosynthetic compounds and leaf chlorophyll which ultimately involved in leaf bud formation, cell division, cell enlargement and cell wall development of plant and leaf tissue which increased number of leaves, delayed the process of leaf senescence and also gave strength for their persistency (Sajid *et al.* 2010). These results were in conformity with Singh *et al.* (2002) in papaya who observed that the application of zinc and boron as foliar spray not only increased the number of leaves but also reduced leaf drop in papaya cv. Ranchi.

Table 4.3. Number of leaves plant^{-1} in papaya cv. Red Lady as influenced by zinc and boron practices.

Treatments	**No. of Leaves Plant^{-1}**		
	90 DAP	180 DAP	270 DAP
T_1- Borax at 0.25%	25.27	28.87	40.93
T_2- Borax at 0.50%	27.40	30.53	44.77
T_3- $ZnSO_4$ at 0.25%	28.47	34.60	47.30
T_4- $ZnSO_4$ at 0.50%	30.20	33.80	48.93
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	25.67	29.60	44.00
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	26.10	30.27	44.10
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	32.40	37.13	50.07
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	27.43	31.07	45.00
T_9- Control	21.77	24.67	30.67
S.Em (±)	1.59	1.40	2.77
CD (P=0.05)	4.76	4.21	8.31

Fig.3. Number of leaves plant^{-1} in papaya cv. Red Lady as influenced by zinc and boron practices at different growth stages.



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.1.4 Days to first fruit formation

In the plant crop, non significant differences were observed in the days to first fruit formation due to different treatments (Table 4.4). However, less number of days was taken to first fruit formation with foliar application of boron at 0.50% whereas more number of days was recorded in control.

4.2 Yield parameters

4.2.1 Days to harvest

Significant variation was observed among the treatments with respect to days to harvest (Table 4.5. and Fig 4.). Foliar application of borax at 0.50% has taken significantly less number of days to fruit harvest (216.40 days) and it was at par with $ZnSO_4$ at 0.50% (217.53 days) and borax at 0.25% + $ZnSO_4$ at 0.50% (219.53 days) treatments. Maximum number of days to harvest (284.40 days) was recorded in control.

It is apparent from the results that less number of days to harvest was taken by the plants received high concentration of zinc, boron and a combination of low concentration of boron and high concentration of zinc as compared to untreated plants in control. This may be due to significant effect of boron and zinc in higher synthesis of metabolites. Furthermore, the supply of B needed for reproductive growth in many crops is more than that needed for vegetative growth (Mengel and Kirkby, 1982, Marschner, 1986; Hanson, 1991), and the same may be true in papaya. Boron plays vital role in early flower initiation, flower bud formation and production of indigenous and florigenic substances. Besides stimulation of pollen germination, growth of pollen tube, fertilization process, it also involved in glucose metabolism, hydrocarbons and their transport. Similar findings were in conformity with the findings of Modi *et al.* (2012) in papaya cv. Madhu Bindu and Singh *et al.* (2005) in cv. Ranchi.

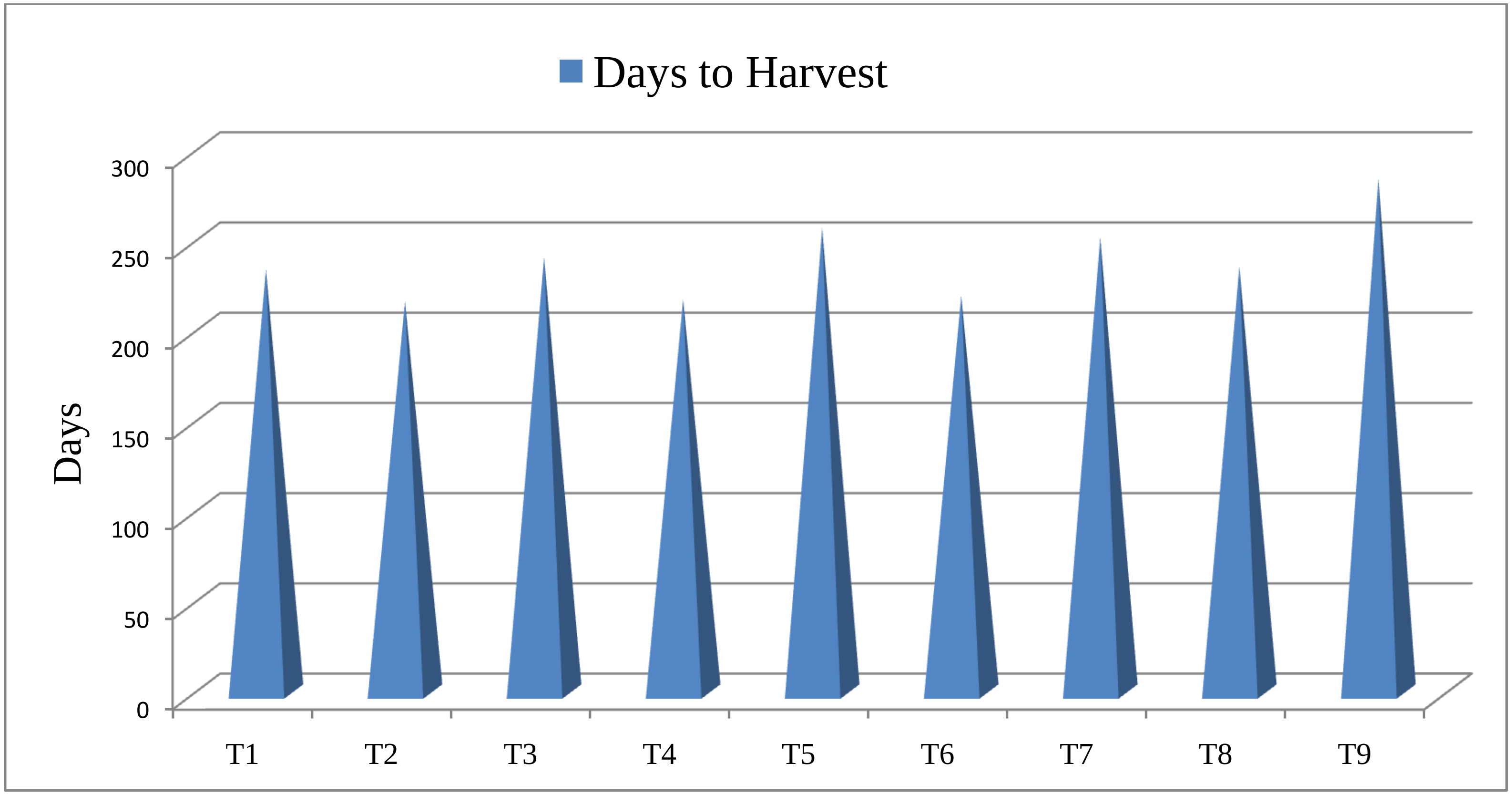
Table 4.4. Influence of foliar application of zinc and boron on Days to first fruit formation in papaya cv. Red Lady.

Treatments	Days to first fruit formation
T_1- Borax at 0.25%	176.27
T_2- Borax at 0.50%	161.00
T_3- $ZnSO_4$ at 0.25%	179.60
T_4- $ZnSO_4$ at 0.50%	164.13
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	182.00
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	170.07
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	180.47
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	173.27
T_9- Control	186.60
S.Em (±)	7.44
CD (P=0.05)	N.S

Table 4.5. Influence of foliar application of zinc and boron on Days to harvest in papaya cv. Red Lady.

Treatments	Days to harvest
T_1- Borax at 0.25%	234.13
T_2- Borax at 0.50%	216.40
T_3- $ZnSO_4$ at 0.25%	240.87
T_4- $ZnSO_4$ at 0.50%	217.53
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	257.00
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	219.53
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	251.80
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	235.60
T_9- Control	284.40
S.Em (±)	4.82
CD (P=0.05)	14.45

Fig.4. Influence of foliar application of zinc and boron on Days to harvest in papaya cv. Red Lady.



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.2.2 Number of fruits plant^{-1}

Number of fruits per plant differed significantly due to different treatments (Table 4.6. and Fig 5.). Significantly the highest number of fruits plant^{-1} (63.53) was obtained with foliar spray of borax at 0.50% + $ZnSO_4$ at 0.25% and it was on par with application of $ZnSO_4$ at 0.50% (60.40), borax at 0.50% (59.33), borax at 0.50% + $ZnSO_4$ at 0.50% (55.87), borax at 0.25% + $ZnSO_4$ at 0.50% (55.60) and borax at 0.25% + $ZnSO_4$ at 0.25% (53.93). The least number of fruits plant^{-1} (42.07) was observed in control.

All the concentrations of zinc, boron and their combinations increased number of fruits per plant significantly over control. The beneficial effect of zinc and boron directly or indirectly, involved in fruit setting, retention and their activity improved number of fruits per plant. These chemicals are also associated with photosynthesis, hormone metabolism which promotes synthesis of auxin, necessary for fruit set and fruit growth (Rajkumar *et al.* 2014). The increase in number of fruits probably due to influence of boron which increases pollen grain germination and pollen tube elongation, consequently leads to higher fruit set and finally more number of fruits per plant (Allah, 2006). This finding was also in agreement with the findings of Kudada and Prasad (2002) in papaya cv. Rajdoot. Singh *et al.* (2010) have also reported an appreciable increase in number of fruits per plant with the spray of micronutrients *viz.*, borax and zinc sulphate, when they were applied in combination or alone in papaya cv. Ranchi.

4.2.3 Yield plant^{-1} (kg)

A perusal of data (Table 4.6. and Fig 6.) showed that foliar sprays of zinc and boron had significant effect on yield per plant of papaya for different treatments. Significantly superior plant yield was obtained with the application of borax at 0.50% + $ZnSO_4$ at 0.25% (106.73 kg) and it was on par with $ZnSO_4$ at 0.50% (100.26 kg) and borax at 0.50% (97.30 kg). Whereas lowest fruit yield plant^{-1} (43.75 kg) was observed in control.

This increase in yield per plant was obviously due to increase in number of fruits per plant, more fruit weight and larger size of fruit with the application of zinc and boron. The significant increase in yield by boron application might be accredited to the positive effect of boron on increasing the rates of carbohydrates and RNA metabolism (Parr and Loughman, 1983). Zinc application increased the rate of photosynthesis and activity of carbonic anhydrase in leaves. These results were in conformity with the findings of Ghanta, (1992) in papaya and Ali (1991) in guava. Improvement of plant yield due to zinc and boron is in conformity with the work of Kundu *et al.* (1989), Singh *et al.* (2010), Yadav and Singh (2010) and Modi *et al.* (2012) in papaya.

4.2.4 Yield (t ha^{-1})

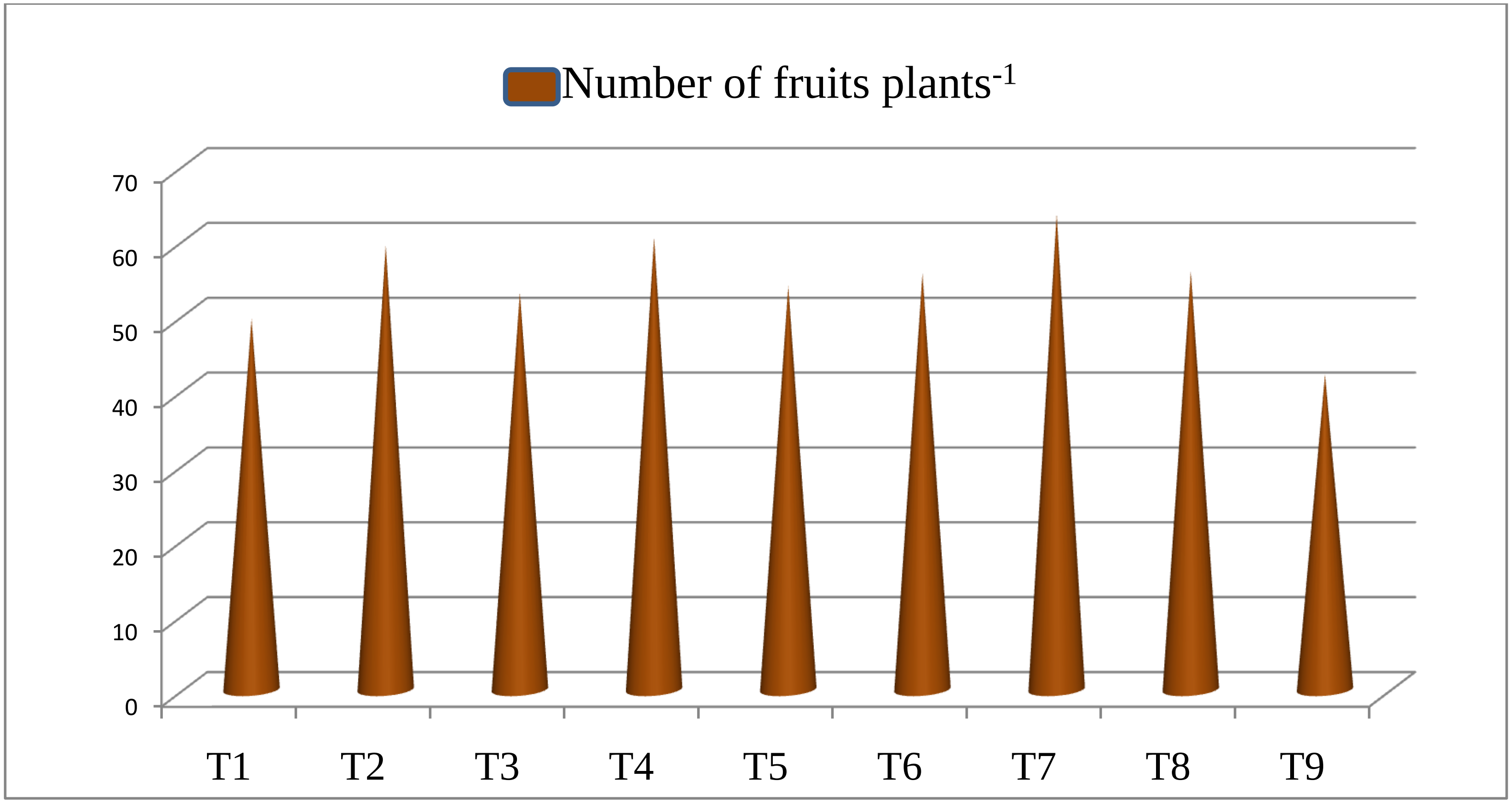
The data presented in Table 4.6 and Fig 6. indicates significant effect of foliar application of zinc and boron alone or in combination on fruit yield per hectare in papaya. Significantly maximum fruit yield was obtained with the application of borax at 0.50% + $ZnSO_4$ at 0.25% (240.1 t ha^{-1}) and it was on par with application of $ZnSO_4$ at 0.50% (225.5 t ha^{-1}) and borax at 0.50% (218.9 t ha^{-1}). The treatment control has registered significantly the lowest yield (98.4 t ha^{-1}).

This increment was due to higher yield of fruits per plant. The results are in agreement with the finding of Pant and Lavania (1998), Kavitha *et al*. (2000), Modi *et al*. (2012) and Singh *et al.* (2010) in papaya and Banik *et al*. (1997), Singh and Maurya (2004) in mango.

Table 4.6.Influence of foliar application of zinc and boron on the number of fruits plant^{-1}, yield plant^{-1} and yield ha^{-1} in papaya cv. Red Lady

Treatments	**Number of fruits plant^{-1}**	**Yield plant^{-1} (kg)**	**Yield ha^{-1} (t)**
T_1- Borax at 0.25%	49.53	61.41	137.2
T_2- Borax at 0.50%	59.33	97.30	218.9
T_3- $ZnSO_4$ at 0.25%	53.07	70.58	158.8
T_4- $ZnSO_4$ at 0.50%	60.40	100.26	225.5
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	53.93	74.42	167.4
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	55.60	80.62	181.3
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	63.53	106.73	240.1
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	55.87	90.50	203.6
T_9- Control	42.07	43.75	98.4
S.Em (±)	3.31	5.15	7.55
CD (P=0.05)	9.93	15.44	22.63

Fig.5. Influence of foliar application of zinc and boron on the No. of fruits plant^{-1} in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

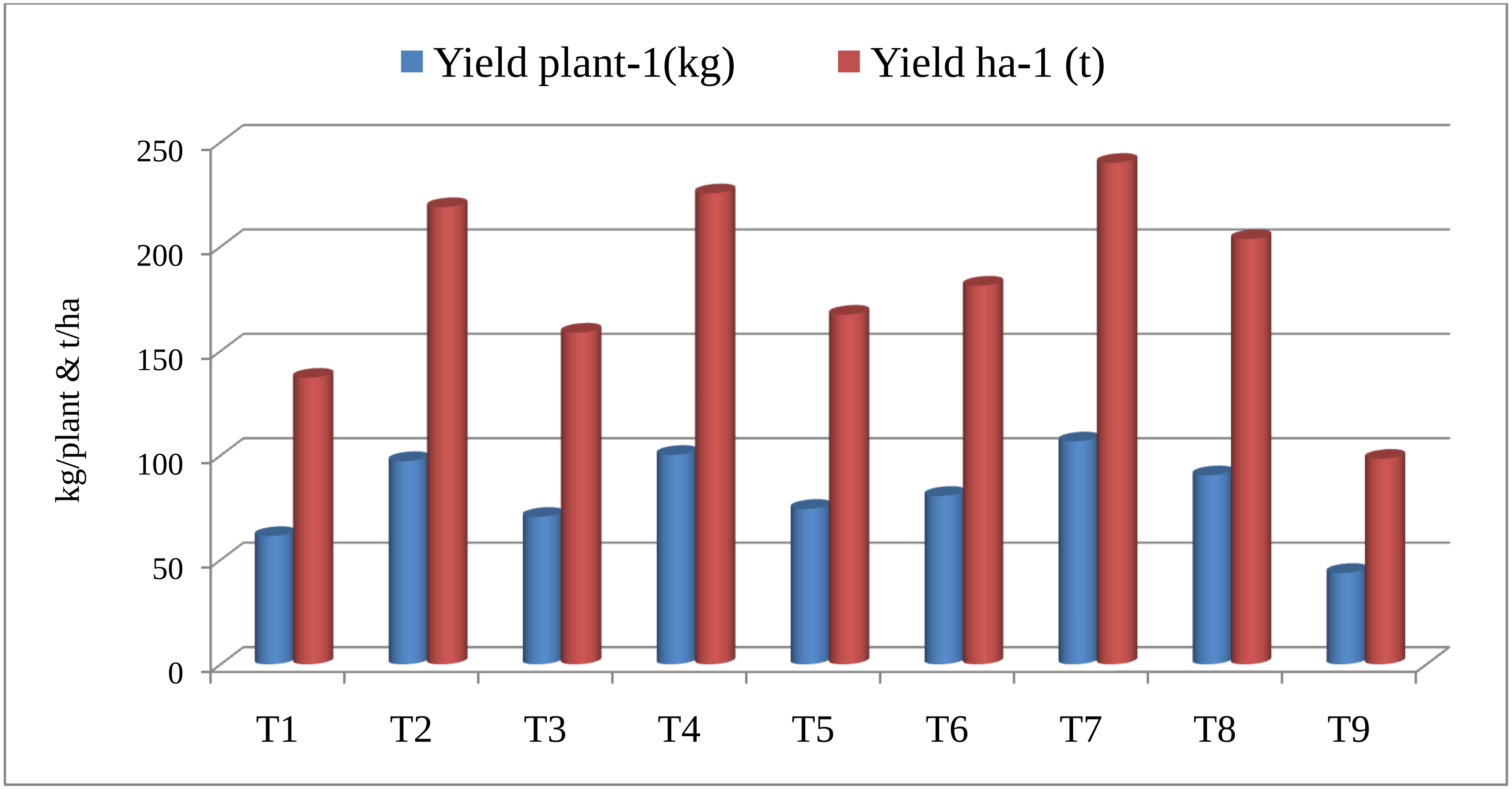
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

Fig.6. Influence of foliar application of zinc and boron on the yield plant^{-1} and yield ha^{-1} in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.2.5 Fruit weight (kg)

Fruit weight was significantly influenced by different treatments. The data presented in Table 4.7 and Fig 7. revealed that significantly higher fruit weight was observed with the treatment of borax at 0.50% + $ZnSO_4$ at 0.25% (1.68 kg) and it was on par with application of $ZnSO_4$ at 0.50% (1.66 kg), borax at 0.50% (1.64 kg), borax at 0.50% + $ZnSO_4$ at 0.50% (1.62 kg), borax at 0.25% + $ZnSO_4$ at 0.50% (1.45 kg) and borax at 0.25% + $ZnSO_4$ at 0.25% (1.38 kg). The plants in the treatment control produced fruits with less weight (1.04 kg) which was observed to be statistically at par with the treatment of borax at 0.25% (1.24 kg).

The appreciable improvement in fruit weight by boron and zinc application has been also reported by Pant and Lavania (2000), Ghanta (1992), Yadav *et al.* (2010) and Singh *et al*. (2010) in papaya. The increase in fruit weight with the sprays of borax and $ZnSO_4$ might be due to the involvement of these chemicals in hormonal metabolism, increase in cell division and expansion of cell wall. Boron is also known to stimulate rapid mobilization of water and sugar in the fruit which intern increased in accumulation of dry matter within the fruit (Bhatt *et al.* 2012). Application of zinc also improved the other physical characteristics of papaya fruits. It was probably due to the effect of zinc in regulating the semi permeability of cell walls, thus mobilizing more water into fruits resulting increase in fruit weight (Singh *et al.* 2010).

4.2.6 Fruit size

4.2.6.1 Fruit length (cm)

Significant differences were reported with regards to fruit length among different treatments (Table 4.7 and Fig 8.). Application of borax at 0.50% + $ZnSO_4$ at 0.25% has registered significantly higher fruit length (23.53cm) and it was on par with $ZnSO_4$ at 0.50% (22.80 cm), borax at 0.25% + $ZnSO_4$ at 0.25% (22.33 cm), borax at 0.50% (22.20 cm), borax at 0.50% + $ZnSO_4$ at 0.50% (22.00 cm) and $ZnSO_4$ at 0.25% (21.93 cm) treatments.

The fruit length recorded was significantly shorter (19.67cm) in plants from treatment control and it was on par with treatment of borax at 0.25% (20.73 cm).

4.2.6.2 Fruit girth (cm)

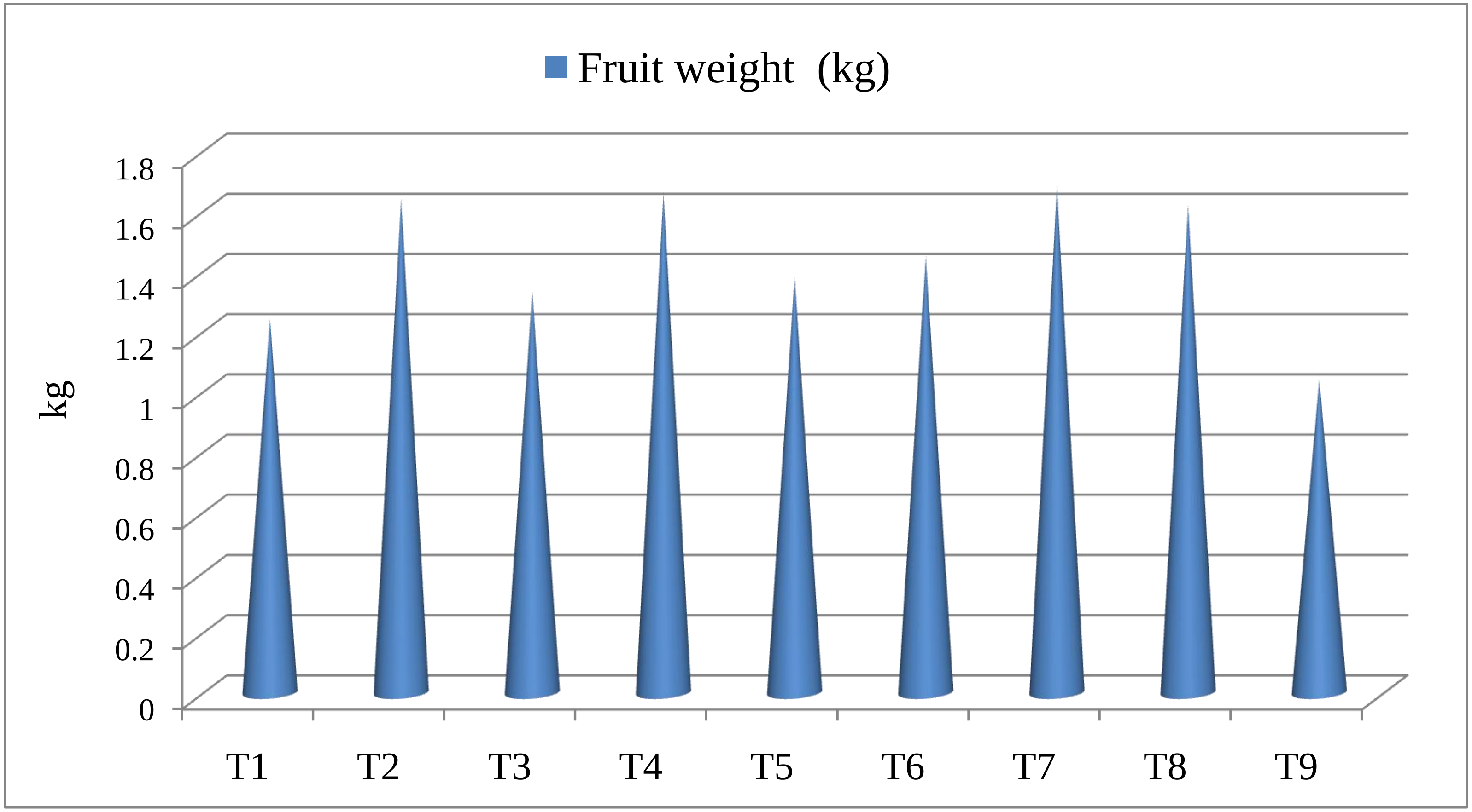
A perusal of data (Table 4.7 and Fig 8.) showed that foliar sprays of zinc and boron have significant effect on fruit girth of papaya fruits for different treatments. The treatment borax at 0.50% + $ZnSO_4$ at 0.25% has recorded significantly higher fruit girth (44.84 cm) and it was on par with application of $ZnSO_4$ at 0.50% (41.93 cm), borax at 0.25% + $ZnSO_4$ at 0.50% (41.20 cm), borax at 0.50% (41.04 cm) and borax at 0.50% + $ZnSO_4$ at 0.50% (40.67 cm). Whereas, significantly less fruit girth (33.97 cm) was observed in control

Larger size of fruits (fruit length and girth) with the application of boron and zinc might be due to their involvement in cell division, cell expansion and increased volume of intercellular spaces in the mesocarpic cells. It could also be due to higher mobilization of photosynthates from other parts of the plant towards the developing fruits that are extremely active metabolic sink (Singh *et al.,* 2001). The beneficial effect of zinc sulphate was well documented by Chadda and Singh (1971) and has been attributed to the activity of endogenous auxins and that of other growth stimulatory compounds. Zinc helps in regulating the cell wall permeability, thereby allowing more mobilization of water in fruits that contributed to the greater fruit length and girth (Wali *et al.,* 2005). These results were in close conformity with the findings of Chaitanya (1997) and Rajkumar *et al.* (2014) in guava, Singh *et al.* (2010) and Yadav *et al.* (2010) in papaya have reported an appreciable increase in fruit size (length and diameter) with the foliar application of zinc and boron.

Table 4.7. Influence of foliar application of zinc and boron on fruit weight, fruit length and fruit girth in papaya cv. Red Lady

Treatments	**Fruit weight (kg)**	**Fruit length (cm)**	**Fruit girth (cm)**
$\mathbf{T_1}$- Borax at 0.25%	1.24	20.73	38.57
$\mathbf{T_2}$- Borax at 0.50%	1.64	22.20	41.04
$\mathbf{T_3}$- $ZnSO_4$ at 0.25%	1.33	21.93	40.37
$\mathbf{T_4}$- $ZnSO_4$ at 0.50%	1.66	22.80	41.93
$\mathbf{T_5}$- Borax at 0.25% + $ZnSO_4$ at 0.25%	1.38	22.33	40.13
$\mathbf{T_6}$- Borax at 0.25% +$ZnSO_4$ at 0.50%	1.45	21.40	41.20
$\mathbf{T_7}$- Borax at 0.50% + $ZnSO_4$ at 0.25%	1.68	23.53	44.84
$\mathbf{T_8}$- Borax at 0.50% +$ZnSO_4$ at 0.50%	1.62	22.00	40.67
$\mathbf{T_9}$- Control	1.04	19.67	33.97
S.Em (±)	012	0.57	1.39
CD (P=0.05)	0.35	1.71	4.18

Fig.7. Influence of foliar application of zinc and boron on fruit weight in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

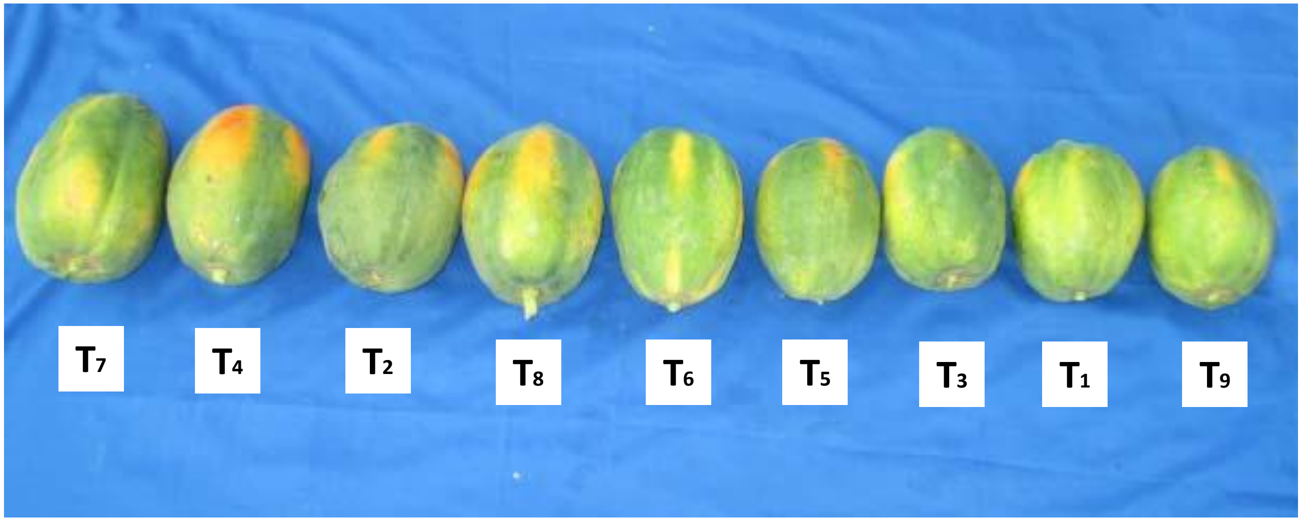
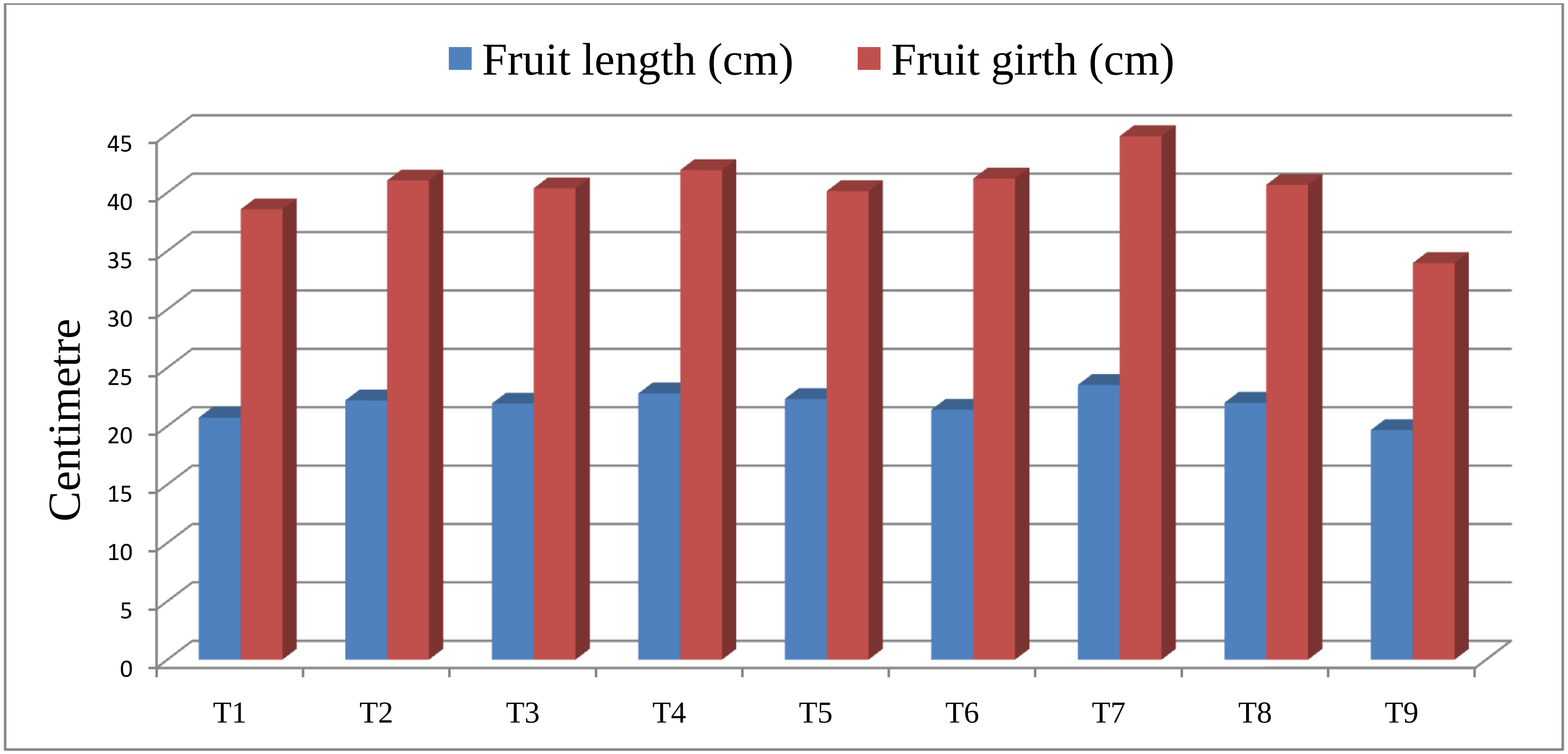


Plate 1. Fruit size of papaya as influenced by foliar application of zinc and boron at different combinations.

Fig.8. Influence of foliar application of zinc and boron on the fruit length and fruit girth in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

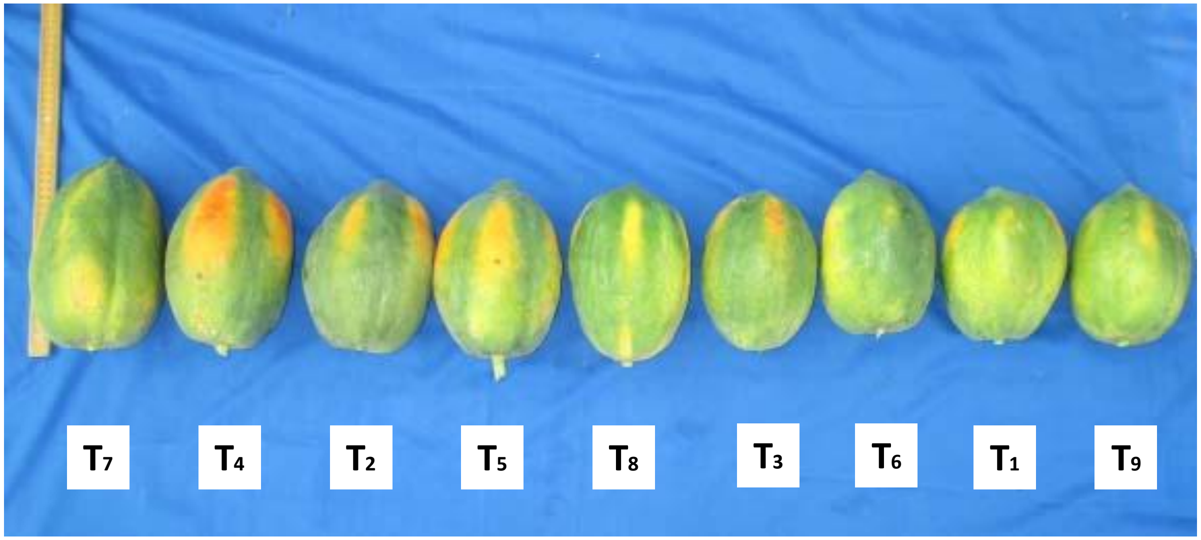


Plate 2. Fruit length of papaya as influenced by foliar application of zinc and boron at different combinations.

4.2.7 Fruit volume (cc)

The data on fruit volume showed highly significant differences among the treatments (Table 4.8 and Fig 9.). The mean values varied from 1009.33 cc to 2675.00 cc.

The highest fruit volume was recorded significantly with the application of borax at 0.50% + $ZnSO_4$ at 0.25% (2675.00 cc) and it was on par with application of $ZnSO_4$ at 0.50% (2390.00 cc). The treatment control has registered significantly the lowest fruit volume (1009.33 cc) and it was on par with application of Borax at 0.50% + $ZnSO_4$ at 0.50% (1174.00 cc) and $ZnSO_4$ at 0.25% (1291.67 cc).

Improvement in fruit volume could be attributed to the beneficial effect of zinc and boron as its application was known to increase the fruit volume in guava (Rajkumar *et al.,* 2014) and in mango (Sankar *et al.,* 2013).

4.2.8 Cavity length (cm)

Significant differences were reported with regards to fruit cavity length among different treatments (Table 4.9 and Fig 10.). Application of borax at 0.50% + $ZnSO_4$ at 0.25% has registered significantly maximum fruit cavity length (20.90 cm) and it was on par with borax at 0.50% (19.37 cm). The minimum fruit cavity length was (14.57cm) observed in the treatment control and it was on par with borax at 0.25% (16.20 cm).

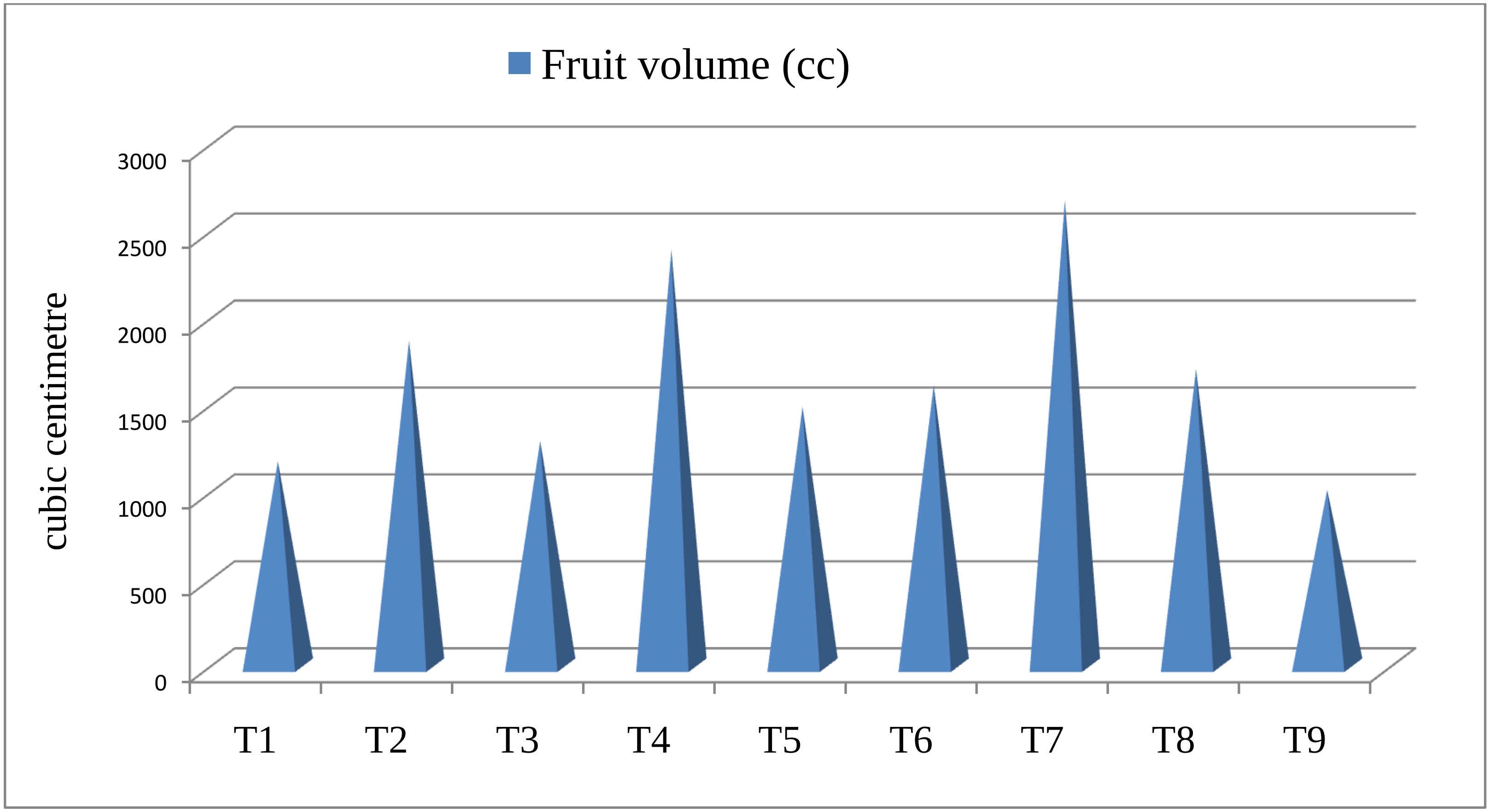
4.2.9 Cavity girth (cm)

Significant differences were observed among the treatments regarding fruit cavity girth (Table 4.9 and Fig 10.). The treatment borax at 0.50% + $ZnSO_4$ at 0.25% has recorded significantly higher fruit cavity girth (10.93 cm), whereas lesser cavity girth was recorded in the control (5.77 cm) and it was on par with borax at 0.25% (6.27 cm) and borax at 0.25% + $ZnSO_4$ at 0.50% (6.53 cm).

Table 4.8. Influence of foliar application of zinc and boron on fruit volume in papaya cv. Red Lady

Treatments	Fruit volume (cc)
T_1- Borax at 0.25%	1174.00
T_2- Borax at 0.50%	1866.67
T_3- $ZnSO_4$ at 0.25%	1291.67
T_4- $ZnSO_4$ at 0.50%	2390.00
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	1486.67
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	1610.00
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	2675.00
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	1703.33
T_9- Control	1009.33
S.Em (±)	126.24
CD (P=0.05)	378.42

Fig.9. Influence of foliar application of zinc and boron on fruit volume in Papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

The increase in cavity length and girth was associated with corresponding increase in fruit length and girth.

4.2.10 Cavity index (%)

The data presented in the Table 4.9 and Fig 10. Show highly significant variation among treatments with respect to fruit cavity index. Fruit cavity index values ranged from 23.99 (%) to 31.34 (%).

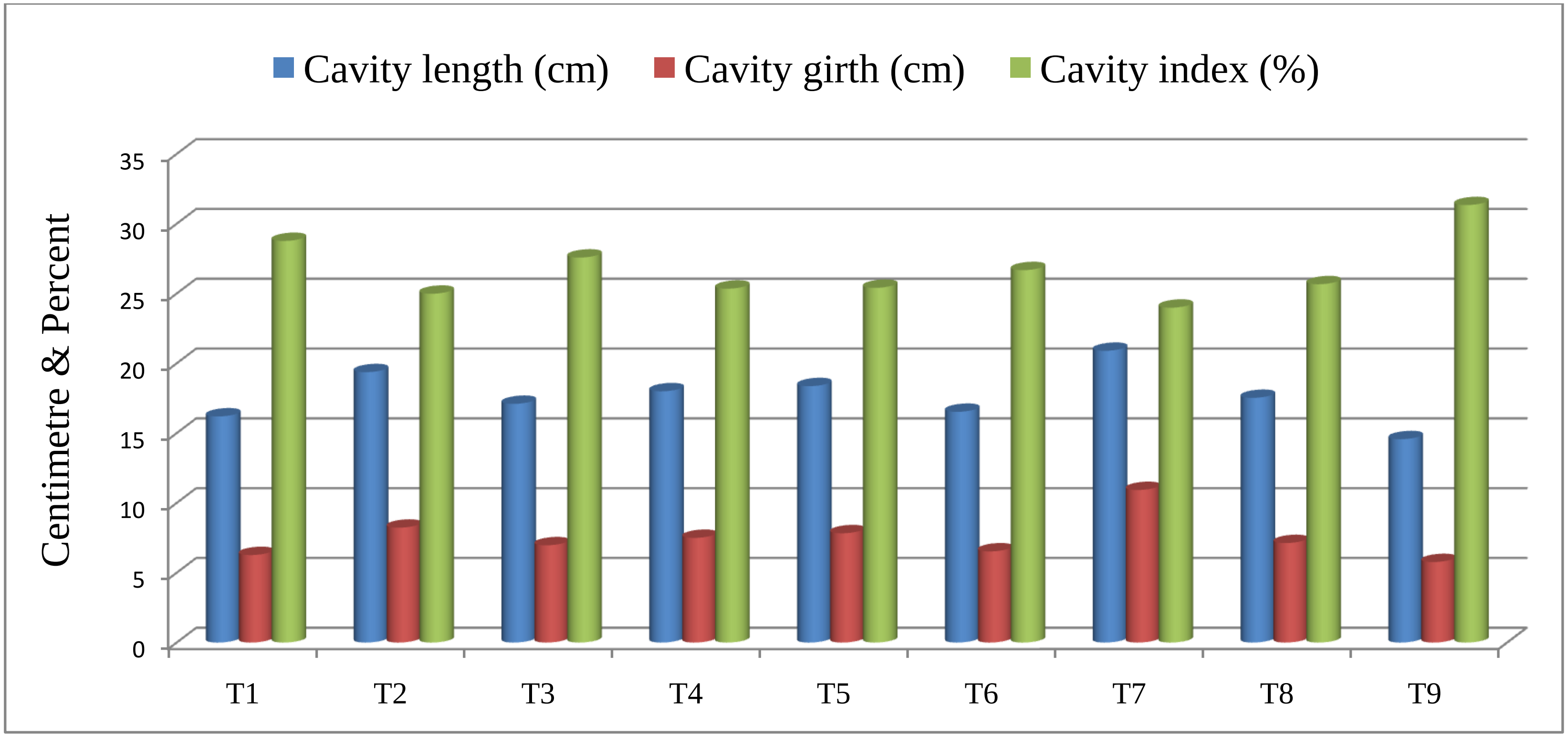
The lowest fruit cavity index was recorded in borax at 0.50% + $ZnSO_4$ at 0.25% (23.99 %) and it was on par with borax at 0.50% (24.99 %), $ZnSO_4$ at 0.50% (25.35 %), borax at 0.50% + $ZnSO_4$ at 0.25% (25.41 %) and borax at 0.50% + $ZnSO_4$ at 0.50% treatments. Significantly maximum fruit cavity index was noticed in fruits from control (31.34 %).

Minimum fruit cavity index observed due to foliar application of boron and zinc alone or in combination when compared to control might be ascribed to the increased fruit size and volume which could have subsequently reduced the cavity index.

Table 4.9.Influence of foliar application of zinc and boron on fruit cavity length, cavity girth and cavity index in papaya cv. Red Lady

Treatments	Cavity length (cm)	Cavity girth (cm)	Cavity index (%)
T_1- Borax at 0.25%	16.20	6.27	28.77
T_2- Borax at 0.50%	19.37	8.23	24.99
T_3- $ZnSO_4$ at 0.25%	17.10	6.97	27.58
T_4- $ZnSO_4$ at 0.50%	18.00	7.50	25.35
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	18.37	7.83	25.41
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	16.53	6.53	26.68
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	20.90	10.93	23.99
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	17.53	7.13	25.67
T_9- Control	14.57	5.77	31.34
S.Em (±)	0.58	0.35	0.69
CD (P=0.05)	1.74	1.04	2.06

Fig.10. Influence of foliar application of zinc and boron on fruit cavity length, cavity girth and cavity index in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.2.11 Fruit pulp weight (g)

Fruit pulp weight was significantly influenced by different treatments (Table: 4.10 and Fig 11.). Significantly the highest pulp weight was recorded with the application of borax at 0.50% + $ZnSO_4$ at 0.25% (1460.02 g) which was at par with the application of $ZnSO_4$ at 0.50% (1410.02 g), borax at 0.50% (1390.01 g), borax at 0.50% + $ZnSO_4$ at 0.50% (1280.01 g) and borax at 0.25% + $ZnSO_4$ at 0.50% (1200.04 g). Significantly less pulp weight was noticed from control (730.03 g) and it was on par with borax at 0.25% (990.01 g) treatments.

This increase in fruit pulp weight was due to minimum fruit cavity index, increased fruit length, width, fruit weight and more accumulation of photosynthates in the matured fruits by beneficial effect of boron and zinc. The favourable effects of boron and zinc sprays in increasing the pulp weight have also reported by Singh *et al.* (2010) in papaya cv. Ranchi.

4.2.12 Fruit pulp thickness (cm)

Highly significant differences among treatments were observed with respect to fruit pulp thickness (Table 4.10 and Fig 12.). Fruit pulp thickness ranged from 1.09 to 3.53 cm.

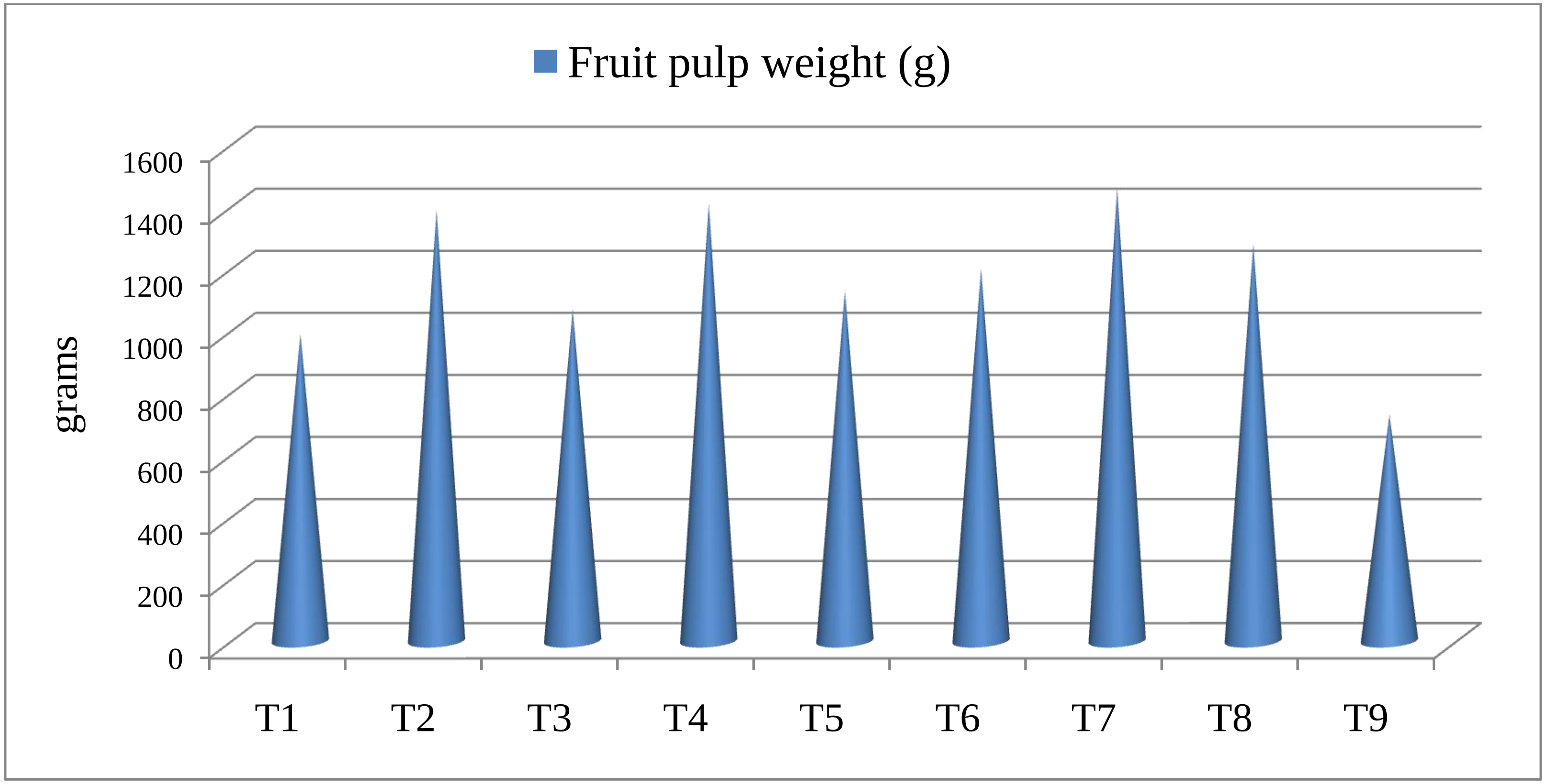
Maximum pulp thickness was recorded in fruits obtained with application of borax at 0.50% + $ZnSO_4$ at 0.25% (3.53 cm) followed by borax at 0.50% + $ZnSO_4$ at 0.50% (2.70 cm) treatments. The fruits obtained from control treatment recorded minimum pulp thickness (1.09 cm) and it was on par with borax at 0.25% (1.63 cm) and $ZnSO_4$ at 0.25% (1.80 cm) treatments.

The increased pulp thickness might be due to the reduced fruit cavity index and increased fruit size. The results are conformity with Singh *et al.* (2010) in papaya cv. Ranchi.

Table 4.10. Influence of foliar application of zinc and boron on fruit pulp weight and pulp thickness of papaya cv. Red Lady

Treatments	**Fruit pulp weight (g)**	**Fruit pulp thickness (cm)**
T_1- Borax at 0.25%	990	1.63
T_2- Borax at 0.50%	1390	2.20
T_3- $ZnSO_4$ at 0.25%	1070	1.80
T_4- $ZnSO_4$ at 0.50%	1410	2.50
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	1130	2.03
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	1200	2.53
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	1460	3.53
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	1280	2.70
T_9- Control	730	1.09
S.Em (±)	96.46	0.18
CD (P=0.05)	289.15	0.53

Fig .11. Influence of foliar application of zinc and boron on fruit pulp weight of papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

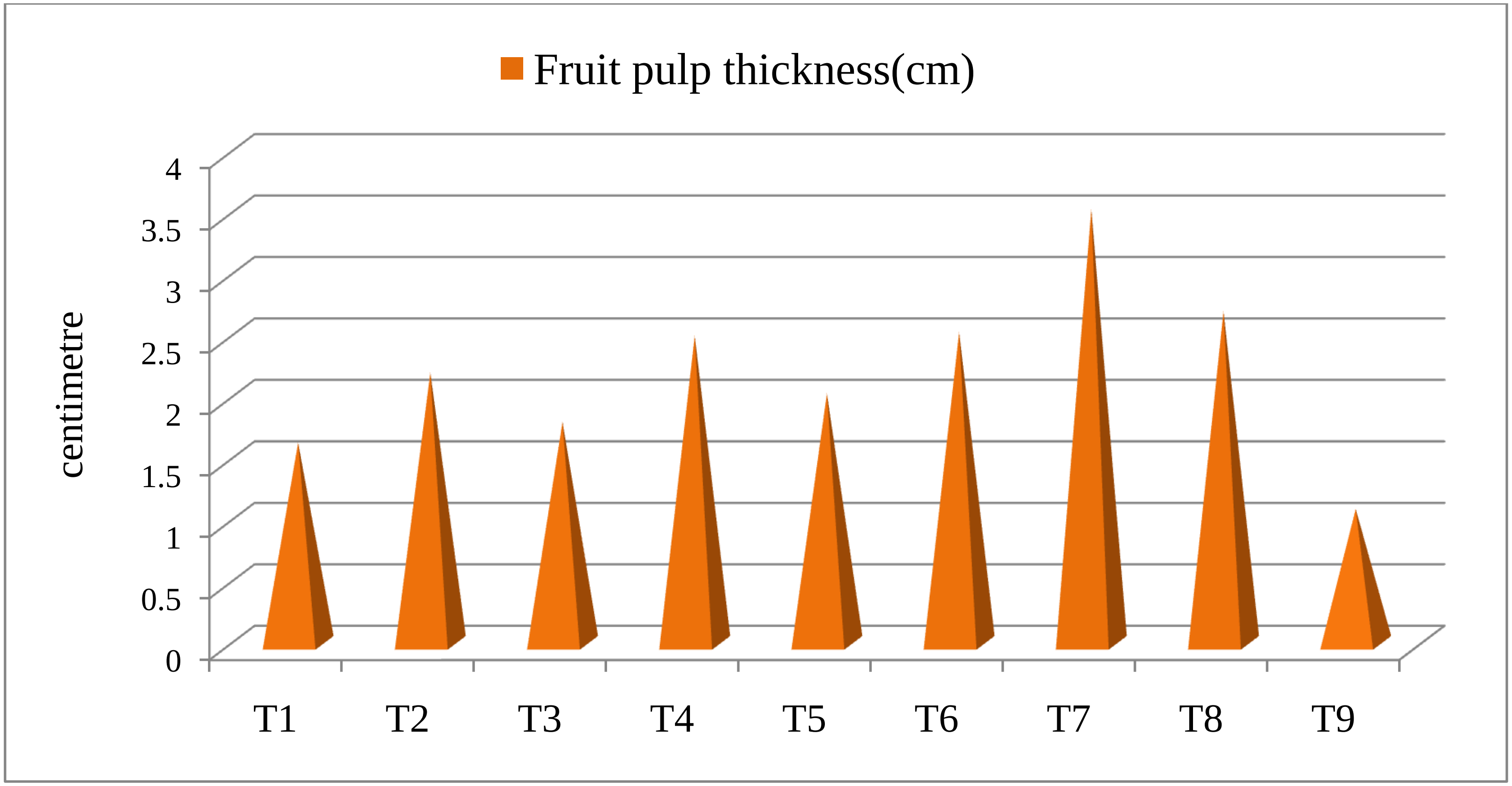
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

Fig .12. Influence of foliar application of zinc and boron on fruit pulp thickness of papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.3 Fruit quality parameters

4.3.1 Total Soluble Solids (%)

The foliar spray of both the nutrients (zinc and boron) alone and in combination showed significant effect on TSS content in papaya (Table 4.11 and Fig 12.). The maximum accumulation of total soluble solids content in papaya fruits was observed with the foliar application of borax at 0.50% + $ZnSO_4$ at 0.50% (16.13 ^{0}B) and it was on par with borax at 0.50% + $ZnSO_4$ at 0.25% (15.5 ^{0}B), $ZnSO_4$ at 0.50% (14.26 ^{0}B) and borax at 0.25% + $ZnSO_4$ at 0.50% (14.1 ^{0}B) treatments.

The TSS content was significantly less (10.86 ^{0}B) in fruits obtained from the plants in treatment control and it was at par with borax at 0.25% (11.13 ^{0}B), borax at 0.25% + $ZnSO_4$ at 0.25% (11.23 ^{0}B) and $ZnSO_4$ at 0.25% (11.96^0 B).

The increased accumulation of TSS could be due to catalytic action of micronutrients (zinc and boron) and their combined synergetic effect particularly at higher concentrations. The increase in TSS by boron might be due to more rapid translocation of sugars from leaves to developing fruits. The favourable effects of boron and zinc sprays in increasing the TSS content have also been reported by Kavitha *et al.* (2000) and Singh *et al.* (2010) in papaya and Rawat *et al.* (2010) in guava.

4.3.2 Total Sugars (%)

The data presented in Table 4.11 and Fig 13. showed that foliar application of zinc and boron had significant effect on total sugars for different treatments.

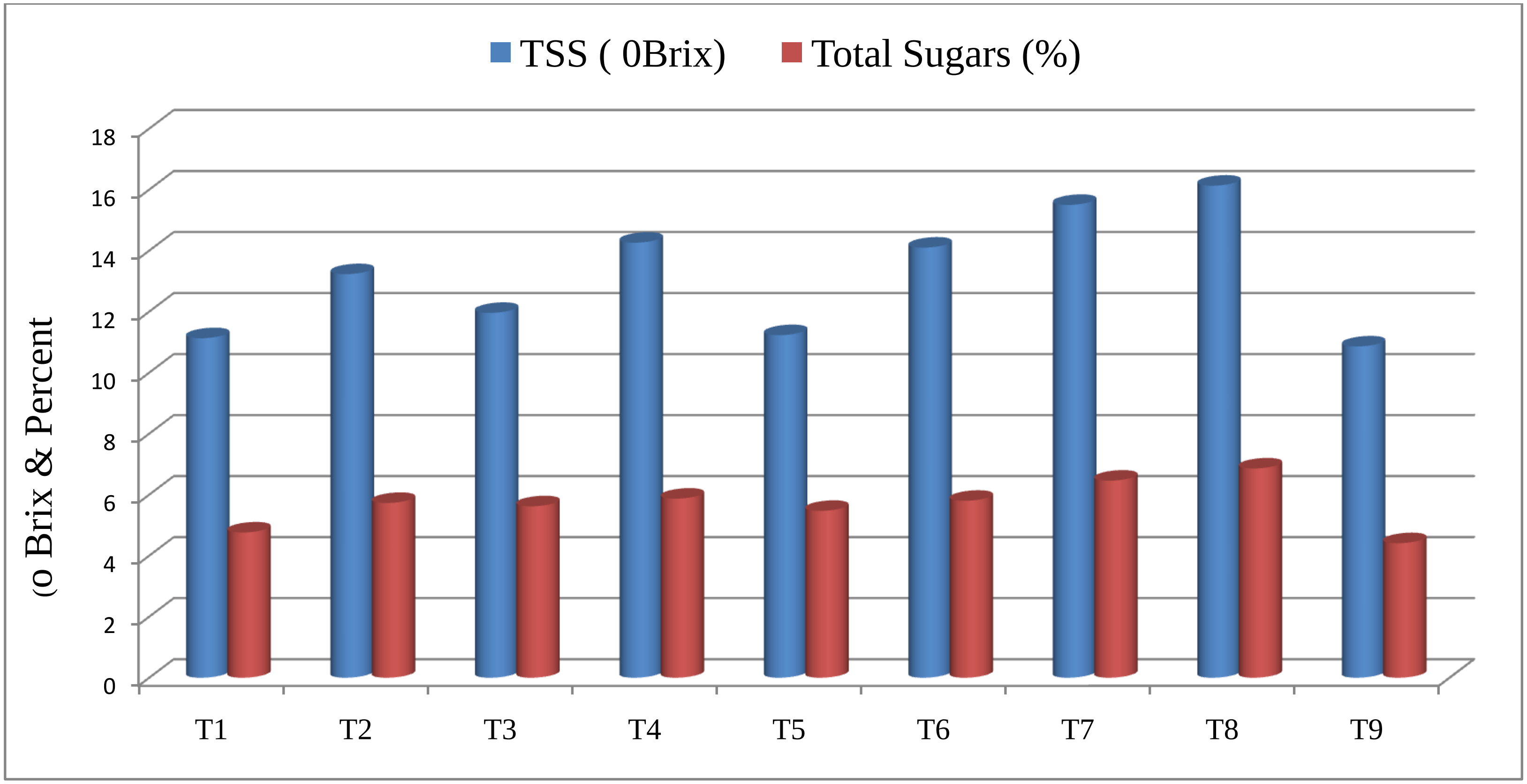
The data indicate the maximum total sugars in treatment with borax at 0.50% + $ZnSO_4$ at 0.50% (6.86 %) which was observed statistically at par with borax at 0.50% + $ZnSO_4$ at 0.25% (6.46 %), $ZnSO_4$ at 0.50% (5.87 %), borax at 0.25% + $ZnSO_4$ at 0.50% (5.80 %) and borax at 0.50% (5.73 %) treatments. Whereas it was observed to be minimum (4 .41 %) in control and it was on par with borax at 0.25% (4.76 %) and borax at 0.25% + $ZnSO_4$ at 0.25% (5.47 %).

Increased concentrations of boron and zinc alone or in combination showed a positive effect in increasing the total sugars percentage in papaya fruits might be due to breakdown of complex polymers into simple substances by hydrolytic enzymes. Gauch and Duggar (1953) provided evidences which were indicative of participation of boron in sugar translocation in higher plants. They reported that boron, by virtue of its ability to make "complex" (sugar-borate complex) with sugars facilitated the transport of sugars in plants. However, zinc acts as a catalyst in the oxidation and reduction processes and it has great importance in the sugar metabolism (Rath *et al.*, 1980). These findings were in accordance with the results of Kavitha *et al.* (2000). Singh *et al.* (2010) in papaya. Trivedi *et al.* (2012). Singh and Brahmachari (1999) in guava also observed higher total sugars with the foliar application of zinc and boron.

Table 4.11.Influence of foliar application of zinc and boron on TSS and total sugars of papaya cv. Red Lady

Treatments	**TSS(^{o} Brix)**	**Total Sugars (%)**
T_1- Borax at 0.25%	11.13	4.76
T_2- Borax at 0.50%	13.23	5.73
T_3- $ZnSO_4$ at 0.25%	11.96	5.62
T_4- $ZnSO_4$ at 0.50%	14.26	5.87
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	11.23	5.47
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	14.10	5.80
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	15.50	6.46
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	16.13	6.86
T_9- Control	10.86	4.41
S.Em (±)	0.69	0.39
CD (P=0.05)	2.07	1.18

Fig.13. Influence of foliar application of zinc and boron on TSS and Total sugars of papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.3.3 Titrable acidity (%)

Titrable acidity in the fruits was significantly affected by different treatments (Table 4.12 and Fig 14.). The data revealed that acid content in fruits reduced under the effect of all treatments in comparison to control. Among the treatments significantly minimum acidity per cent (0.123 %) was recorded by the application of borax at 0.50% + $ZnSO_4$ at 0.50% followed by borax at 0.50% + $ZnSO_4$ at 0.25% (0.128 %) treatments and the maximum under control (0.192 %).

The reduction of titrable acidity of papaya fruits due to application of different levels of boron, zinc and their different combinations might be due to positive influence of boron and zinc in rapid conversion of acids into sugars and their derivatives by the reaction involving the reversal of glycolic pathway or might have been used as substrate in the respiration or both (Pandey *et al*. 2008). The results were in close conformity with the findings of Singh *et al.* (2010) and Yadav *et al*. (2010) in papaya also reported reduction of acidity in fruits with foliar application of micronutrients (zinc and boron) alone or in combination with other nutrients.

4.3.4 Shelf life (Days)

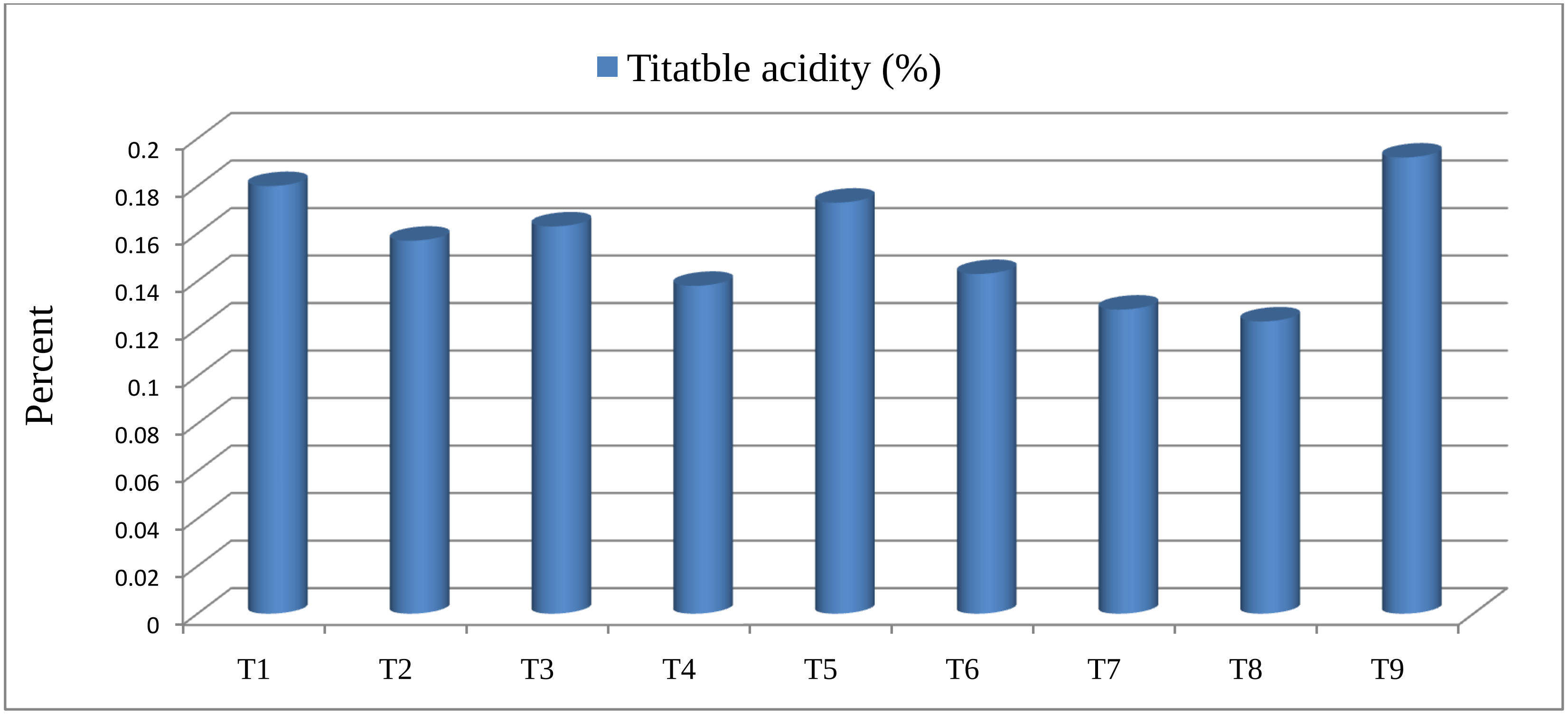
Shelf life of the fruits was significantly influenced by different treatments. Fruits obtained with the foliar application of borax at 0.50% + $ZnSO_4$ at 0.25% (13.67 days) have shown significantly higher shelf life and it was on par with $ZnSO_4$ at 0.50% (12.67 days) and borax at 0.50% + $ZnSO_4$ at 0.50% (12.33 days) treatment. Shorter shelf life (5.67 days) was noticed in fruits obtained in control and it was at par with borax at 0.25% (7.33 days). (Table 4.12 and Fig 15)

In general polyamines play a role in extension of shelf life of fruits by affecting the permeability of cell membranes along with their opposing effects on the action of ethylene (Bhaghavan *et al.,* 2000). In papaya extension of shelf life could be ascribed to the beneficial effect of zinc and boron on hormonal metabolism, photosynthesis and water relations in plants. Further, it may be due to slower conversion of starch to sugars and also less and delayed incidence of papaya ring spot virus, which deteriorates the fruit quality. Appreciable improvement in shelf life by Zinc and boron application has also been reported by Ratananukul *et al.* (1988), Kavitha *et al.* (2000), Singh *et al.* (2005) and Kudada and Prasad (2006) in papaya.

Table 4.12.Influence of foliar application of zinc and boron on the titrable acidity and shelf life in papaya cv. Red Lady

Treatments	**Titrable acidity(%)**	**Shelf life (Days)**
T_1- Borax at 0.25%	0.180	7.33
T_2- Borax at 0.50%	0.157	10.67
T_3- $ZnSO_4$ at 0.25%	0.163	8.33
T_4- $ZnSO_4$ at 0.50%	0.138	12.67
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	0.173	9.00
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	0.143	11.00
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	0.128	13.67
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	0.123	12.33
T_9- Control	0.192	5.67
S.Em (±)	0.003	0.77
CD (P=0.05)	0.01	2.30

Fig.14. Influence of foliar application of zinc and boron on the Titrable Acidity in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

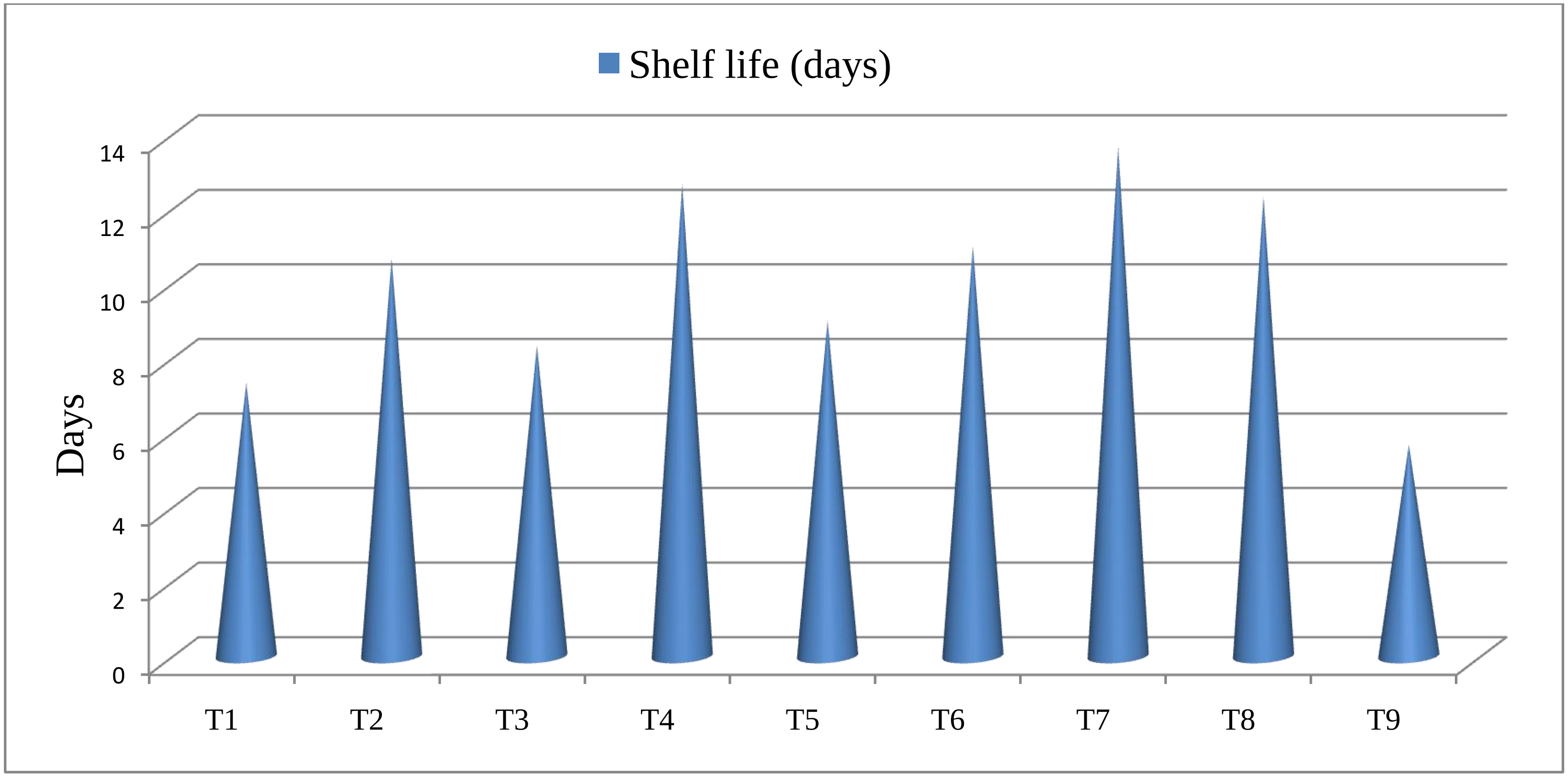
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

Fig.15. Influence of foliar application of zinc and boron on the Shelf life in papaya cv. Red Lady



T_1- Borax at 0.25%

T_2- Borax at 0.50%

T_3- $ZnSO_4$ at 0.25%

T_4- $ZnSO_4$ at 0.50%

T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%

T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%

T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%

T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%

T_9- Control

4.4 Disease incidence (%)

4.4.1. PRSV

There is no significant difference among the treatments on percent disease incidence of papaya ring spot virus (Table 4.13). However, less incidence of PRSV was observed in plants applied with borax at 0.50% + $ZnSO_4$ at 0.25% (26.50 %) followed by $ZnSO_4$ at 0.50% (28.00%), whereas, the maximum incidence was noticed in control (52.08%). Non significant results of per cent disease incidence might be due to the more cool hours coupled with heavy rains resulted in easy movement of vectors to inoculate the virus nonpersistently.

4.5 Economics

The economic analysis (Table 4.14) of foliar application of zinc and boron alone or in combination indicated that the foliar application of borax at 0.50% + $ZnSO_4$ at 0.25% gave maximum gross returns (480286.8) followed by $ZnSO_4$ at 0.50% (451188.0)

The treatment receiving foliar application of 0.50% borax + 0.25% $ZnSO_4$ at two months interval after planting along with recommended dose of fertilizers resulted in highest B: C of 2.50 followed by foliar application of $ZnSO_4$ at 0.50% (2.32) compared to all other treatments.

Table 4.13. Influence of foliar application of zinc and boron on PRSV incidence in papaya cv. Red Lady.

Treatments	**PRSV (%)**
T_1- Borax at 0.25%	39.58
T_2- Borax at 0.50%	29.17
T_3- $ZnSO_4$ at 0.25%	37.50
T_4- $ZnSO_4$ at 0.50%	28.00
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	35.83
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	35.42
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	26.50
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	31.25
T_9- Control	52.08
S.Em (±)	6.53
CD (P=0.05)	N.S

Table 4.14. Economics of papaya cv. Red lady cultivation per hectare as influenced by application of zinc and boron.

Treatments	**Total cost of cultivation ha^{-1}**	**Gross returns ha^{-1}**	**Net returns ha^{-1}**	**Benefit : Cost**
T_1- Borax at 0.25%	128782.5	274596.3	145813.8	1.13
T_2- Borax at 0.50%	131845.0	437855.4	306310.4	2.30
T_3- $ZnSO_4$ at 0.25%	131145.5	317624.0	186478.5	1.42
T_4- $ZnSO_4$ at 0.50%	135871.0	451188.0	315317.0	2.32
T_5- Borax at 0.25% + $ZnSO_4$ at 0.25%	133508.0	334905.3	201397.3	1.50
T_6- Borax at 0.25% +$ZnSO_4$ at 0.50%	138237.5	362790.0	224552.5	1.62
T_7- Borax at 0.50% + $ZnSO_4$ at 0.25%	136570.3	480286.8	343716.6	2.50
T_8- Borax at 0.50% +$ZnSO_4$ at 0.50%	141296.0	407292.3	265996.3	1.90
T_9- Control	126420.0	196887.6	70467.6	0.56

Chapter-V

Summary and Conclusions

CHAPTER - V

SUMMARY AND CONCLUSION

The present investigation entitled "Response of zinc and boron sprays on growth, yield and quality of papaya (*Carica papaya* L.) cv. Red Lady" was conducted at Horticultural Research Station, Anantharajupet, Y.S.R. district, Andhra Pradesh, during 2013-2014. The experiment was laid out in Randomized Block Design (RBD) with nine treatments and three replications involving foliar application of two levels each of Borax (0.25 and 0.50 percent) and $ZnSO_4$ (0.25 and 0.50 percent) individually or in combination at two months interval after planting. The salient features of findings are outlined below.

1. Vegetative characters like plant height, plant girth at 90 DAP and 180 DAP and number of leaves per plant at 90 DAP, 180 DAP and 270 DAP were significantly higher with the foliar application of borax at 0.50% + $ZnSO_4$ at 0.25%. All the levels of zinc and boron did not influence the days to first fruit formation; however less number of days were taken to harvest in plants sprayed with borax at 0.50%.
2. Observations on yield parameters like number of fruits per plant, yield per plant and yield per hectare revealed that foliar application of Borax at 0.50% + $ZnSO_4$ at 0.25% on plants proved to be the best treatment compared to all other treatments.
3. High values for fruit characters like fruit weight, fruit length, girth, fruit volume, weight of pulp, pulp thickness, cavity length, cavity girth and cavity index were recorded with the application of Borax at 0.50% + $ZnSO_4$ at 0.25%.
4. Quality parameters like TSS, total sugars were observed to be the highest and titrable acidity was lowest in the treatment with foliar application of Borax at 0.50% + $ZnSO_4$ at 0.50%. Maximum shelf life was recorded with the application of Borax at 0.50% + $ZnSO_4$ at 0.25% found to be the highest.

5. Economics of different treatments showed that foliar application of Borax at 0.50% + $ZnSO_4$ at 0.25% yielded better return in comparison to other treatments with highest B: C. Foliar application of $ZnSO_4$ at 0.50% found to be the next best treatment regarding B: C ratio.
6. Pertaining to disease incidence (PRSV), significant differences were not evident with all the levels of boron and $ZnSO_4$ alone or in combination. However, minimum percent disease incidence of PRSV was observed with the foliar application of borax at 0.50% + $ZnSO_4$ at 0.25%.

Conclusion

On the basis of the results obtained in the present investigation, it could be inferred that foliar application of borax at 0.50% + $ZnSO_4$ at 0.25% has showed a beneficial influence on vegetative characters at different stages, fruit yield, quality and its attributes along with higher benefit cost ratio.

Hence, foliar application of borax at 0.50% + ZnSO4 at 0.25% at two months interval after planting of papaya cv. Red Lady for reaping optimum fruit yield and higher net returns in Rayalaseema region of Andhra Pradesh.

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Appendices

Appendix - I

Monthly meteorological data during the period of study

(2013-14)

MONTH	RELATIVE HUMIDITY (%)		TEMPERATURE (^{O}C)		RAINFALL (mm)	RAINY DAYS
	Morning 8.00 hrs	Evening 14.00hrs	Max.	Min.		
February (2013)	83.3	36.1	28.9	19.3	40.0	1
March	84.1	36.8	31.2	23.0	34.2	1
April	85.4	39.9	38.8	27.8	NIL	NIL
May	85.8	38.4	39.9	29.0	5.0	1
June	86.1	37.8	35.9	25.8	14.4	2
July	85.4	36.0	32.5	24.7	62.2	5
August	86.1	35.6	31.2	23.3	55.8	6
September	87.6	37.0	31.5	23.3	90.2	8
October	86.7	36.4	30.8	22.4	182.1	9
November	86.6	36.1	28.9	22.1	54	3
December	86.8	36.8	26.3	17.9	8.00	1
January (2014)	87.1	38.9	25.8	18.6	NIL	NIL
February	86.1	36.5	28.8	19.0	NIL	NIL

Appendix – II

Cost of cultivation of Papaya cv. Red Lady per hectare

S.No.	Particulars	Cost ha^{-1} (Rs/-)
1	Land preparation (Deep ploughing and harrowing)	10,000.00
2	Preparation of channels	2,210.00
3	Digging pits	6,500.00
4	**Cost of fertilizers treatments wise per hectare**	
4.1	Borax at 0.25%.	2362.50
4.2	Borax at 0.50%.	5425.00
4.3	$ZnSO_4$ at 0.25%.	4725.50
4.4	$ZnSO_4$ at 0.50%.	9451.00
4.5	Borax at 0.25% + $ZnSO_4$ at 0.25%.	7088.00
4.6	Borax at 0.25% +$ZnSO_4$ at 0.50%	11813.50
4.7	Borax at 0.50% + $ZnSO_4$ at 0.25%.	10150.50
4.8	Borax at 0.50% +$ZnSO_4$ at 0.50%.	14876.00
4.9	Control (Water spray).	-
5	Irrigation	7,540.00
6	Weeding	13,200.00
7	Fertilizer application	53,520.00
8	Planting material	17,500.00
9	Planting	2,040.00
10	Labour cost for spraying of chemicals	10,950.00
11	Plant protection chemicals	3,000.00