STUDIES ON INTEGRATED NUTRIENT MANAGEMENT, POST HARVEST TREATMENTS AND PACKAGING MATERIALS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY UNDER SOUTHERN TELANGANA.

SRINU BANOTHU

M.Sc. (Hort.)

DOCTOR OF PHILOSOPHY IN HORTICULTURE

(FRUIT SCIENCE)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE, RAJENDRANAGAR, HYDERABAD – 500 030

SRI KONDA. LAXMAN.T.S. HORTICULTURAL UNIVERSITY

JUNE - 2017

STUDIES ON INTEGRATED NUTRIENT MANAGEMENT, POST HARVEST TREATMENTS AND PACKAGING MATERIALS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY UNDER SOUTHERN TELANGANA.

BY

SRINU BANOTHU

M.Sc. (Hort.)

THESIS SUBMITTED TO SRI. K. L. T. S. HORTICULTURALUNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN HORTICULTURE
(FRUIT SCIENCE)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF HORTICULTURE, RAJENDRANAGAR, HYDERABAD – 500 030

SRI KONDA. LAXMAN.T.S. HORTICULTURAL UNIVERSITY

JUNE - 2017

CERTIFICATE

Mr. SRINU BANOTHU has satisfactorily prosecuted the course of research and that the thesis entitled **"STUDIES ON INTEGRATED NUTRIENT MANAGEMENT, POST HARVEST TREATMENTS AND PACKAGING MATERIALS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY UNDER SOUTHERN TELANGANA"** 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: Rajendranagar,
Hyderabad.

(Dr. A. MANOHAR RAO)
Chairman

Date:

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON INTEGRATED NUTRIENT MANAGEMENT, POST HARVEST TREATMENTS AND PACKAGING MATERIALS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY UNDER SOUTHERN TELANGANA"** submitted in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)** of Sri. K. L. T. S. Horticultural University, Rajendranagar, is a record of the bonafide research work carried out by **Mr. SRINU BANOTHU** 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 investigations have been duly acknowledged by the author of the thesis.

(Dr. A. MANOHAR RAO)
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairman: Dr. A. MANOHAR RAO
Professor & University (Head)
Dept. of Horticulture,
College of Agriculture, P.J.T.S.A.U.
Rajendranagar, Hyderabad - 500 030. ____________________

Member: Dr. VEENA JOSHI
Assistant Professor
Dept. of Fruit Science
College of Horticulture
S.K.L.T.S.Horticultural University
Rajendranagar, Hyderabad - 500 030. ____________________

Member: Dr. S. NARENDER REDDY
Professor (Crop Physiology),
College of Agriculture, P.J.T.S.A.U.
Rajendranagar, Hyderabad - 500030. ____________________

Member: Dr. S. HARISH KUMAR SHARMA
Assistant Professor (Soil Science)
College of Agriculture, P.J.T.S.A.U.
Rajendranagar, Hyderabad- 500030 ____________________

Date of final viva-voce:

DECLARATION

I, **Mr. SRINU BANOTHU** hereby declare that the thesis entitled **"STUDIES ON INTEGRATED NUTRIENT MANAGEMENT, POST HARVEST TREATMENTS AND PACKAGING MATERIALS ON GROWTH, YIELD AND QUALITY OF PAPAYA (*Carica papaya* L.) cv. RED LADY UNDER SOUTHERN TELANGANA"** Submitted to S.K.L.T.S. Horticultural University for the Degree of **DOCTOR OF PHILOSOPHY IN HORTICULTURE (FRUIT SCIENCE)** is a result of original research work done by me. It is further declared that the thesis or any part of this has not been published earlier in any manner.

Date: **(SRINU BANOTHU)**

Place: Hyderabad

ACKNOWLEDGEMENT

I feel great pleasure in expressing my deep sense of gratitude to **Dr. A. MANOHAR RAO,** Professor & University Head, Department of Horticulture, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. Telangana for readily accepting me as a Ph. D. student and also for providing valuable guidance and constant encouragement during the course of this investigation.

I also thank **Dr. K. VANAJALATHA**, Head of Department Fruit Science, Sri Konda Laxman Horticultural University Rajendranagar for their cordial co-operation in various way.

I wish extend my cordial thanks to **Dr. S, NARENDER REDDY** Professor, Department of Crop physiology, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. Telangana for providing necessary guidance during the course work. I also thankful to **Dr. VENNA JOSHI**, Assistant Professor, Department of Horticulture, Sri Konda Laxman Horticultural University Rajendranagar for helping in various guidance in my research work.

I sincerely extend my profound gratitude and appreciation to the member of my Advisory Committee, **Dr. S. HARISH KUMAR SHARMA** Associate Professor, College of Agriculture, Rajendranagar for his valuable help.

It gives me great pleasure to express my deep sense of gratitude to **Dr. K. VANAJALATHA**, Associate Dean and Head, College of Horticulture, Rajendranagar for his cooperation and kindness during my study.

I sincerely extend my profound gratitude and appreciation to **Dr. K. Ravindar Reddy (Registrar),** Dr. Vijaya (Directorate of Research), Dr. Ravi Chandrasekhar (COE), Dr. M. Padma (Dean of Horticulture), Dr. Saidaiah, Dr. Raja Goud, Dr. A. Bhagwan and Dr. Kiran Kumar College of Horticulture, Rajendranagar, Hyderabad.

I allocate my highest respect and heartful regards from my inner core of heart to my ever loved parents, **Sri. SETYA BANOTH** and **Smt. SATHAYALI BANOTH** who have given me life and taught the concepts of life and their dedicated efforts to educate me to this level, With boundless affection, I owe an encompassing dept to most beloved sister & brotherin - law **Bhauv Singh & Jayothi** and **Sandhya, Akaash and Sravani** for constant encouragement throughout my career they have been a fountain of inspiration throughout my life without whose help in every walk of life, this work would not have been possible.

It is a pleasure to acknowledge the affection and inspiration rendered by my Seniors Dr. Hanuman Naik (Scientist), Chena Naik (Scientist), Bhaskar Rao (SMS), my classmates, friends Rammohan, Narsimha Reddy, Somu, Anil Kumar Vishnu, Mrs, Jyothi, Kuna Ravi, Phani, Kishor, Naidu, Rupa, Anitha, Sudha and my juniors R. Thirupathi, Venkatram, Rambabu, Chaitu, Ramesh Naik, Praveenreddy, Raju, Harsha, Shaik, R. Vijay, Sudheer, V. K, and Sathish Rathod, Kranthi Kumar, Kamal whose cheerful company I have never felt my work as burden.

I express my heartfelt gratitude and thanks to my Divisional senior’s Dr. Ramana (Assistant professor), Jagan for their valuable guidance and encouragement.

I express my immense and whole hearted thanks to all non-teaching staff members at collage of horticulture and Agriculture Rajendranagar for their cooperation, help during the course of my research work.

I humbly thank to authorities of Sri Konda Laxman Telangana Horticultural University and Government of India (UGC) for the financial help in the form of stipend during my study and Research period.

(SRINU BANOTHU)

CONTENTS

List of Tables

List of Figures

18	Effect of integrated nutrient management on Titrable acidity (%) of papaya	
19	Effect of post harvest treatments and growth regulators on PLW (%) of papaya	
20	Effect of post harvest treatments and growth regulators on Firmness (Kg cm^{-2}) of papaya	
21	Effect of post harvest treatments and growth regulators on Spoilage (%) of papaya	
22	Effect of post harvest treatments and growth regulators on TSS (^{O}Brix) of papaya	
23	Effect of post harvest treatments and growth regulators on Titrable acidity (%) of papaya	
24	Effect of post harvest treatments and growth regulators on Reducing sugars (%) of papaya	
25	Effect of post harvest treatments and growth regulators on Non reducing sugars (%) of papaya	
26	Effect of post harvest treatments and growth regulators on Total sugars (%) of papaya	
27	Effect of post harvest treatments and growth regulators on Shelf life (Days) of papaya	
28	Effect of post harvest treatments and growth regulators on Ascorbic acid (mg/100 g of pulp) of papaya	
29	Effect of packaging materials Physiological loss in weight of papaya cv. Red Lady	
30	Effect of packaging materials Firmness (Kg.cm^{-2}) of papaya cv. Red Lady	
31	Effect of packaging materials Spoilage (%) of papaya cv. Red Lady	
32	Effect of packaging materials TSS (^{O}Brix) of papaya cv. Red Lady	
33	Effect of packaging materials on Ascorbic acid (mg/100 g of pulp) of papaya cv. Red Lady	
34	Effect of packaging materials on Titrable acidity (%) of papaya cv. Red Lady	
35	Effect of packaging materials on Total sugar of papaya cv. Red Lady	
36	Effect of packaging materials on Shelf life (Days) of papaya cv. Red Lady	

List Plates

LIST OF APPENDIX

LIST OF ABBREVIATION AND SYMBOLS USED

% :	Per cent
@ :	At the rate of
^{0}C :	Degree Celcius
BA:	Benzyl adenine
BF :	bio-fertilizers
CaCl2 :	Calcium chloride
CBR :	Cost-Benefit Ratio
CD :	Critical Difference
cm :	Centimeter
CRD :	Completely randomized design
cv. :	Cultivar
DAP :	Days after planting
et al. :	Et alia (and others)
etc. :	Etcetera
Fig.	Figure
FYM :	Farmyard Manure
g :	Gram
g m^{-2} :	Gram per metre square
g $plant^{-1}$:	Gram per plant
GA_3	Gibberellic acid
ha^{-1} :	Per hectare
i.e., :	That is
Kg :	Kilogram
kg^{-1} :	Per kilogram
m :	metre
m ha :	Million hectare
m^{-1} :	Per metre
m^2 :	Square metre
mg kg^{-1} :	Milligram per kilogram
mg lit^{-1}	Milligrams per litre
mM	milli molar
mm :	Millimetre
MOP :	Muriate of Potash
N	Normality
NC :	Neem cake
NPK :	Nitrogen, Phosphorus and Potassium
NS :	Non-significant

$plant^{-1}$ **:**	Per plant
PLW	Physiological loss in weight
ppm **:**	Parts per million
PSB **:**	Phosphorus solubilizing bacteria
RDF **:**	Recommended Dose of Fertilizers
RDN **:**	Recommended Dose of Nitrogen
$Rs.ha^{-1}$ **:**	Rupees per hectare
S Em± **:**	Standard error of mean
SSP **:**	Single super phosphate
t ha^{-1} **:**	tonnes per hectare
$tree^{-1}$ **:**	Per tree
TSS	Total soluble solids
TSS **:**	Total soluble solids
Var.	Variety
VC **:**	Vermicompost
viz. **:**	Namely
º B **:**	Brix
HDPE **:**	High-density polyethylene
LDPE **:**	Low-density polyethylene

Chapter - I

INTRODUCTION

Papaya (*Carica papaya* L.) is evergreen herbaceous commercial fruit crop of tropical and subtropical region. It belongs to family Caricaceaeis an important fruit crop among fruit crops and attained unprecedented popularity in recent years, due to largely its ease of cultivation quick returns, and adoptability to diverse soil and climate conditions. Moreover, papaya fruit is attractive, delicious and also rich in vitamins and minerals.

Papaya is indigenous to South Mexico and Costa Rica. It was introduced to India from Malacca. It is cultivated throughout the tropics both for fresh fruits and papain. In India it is grown area of 133 lakh ha, with a production of 5699 M.T (NHB, 2015-16). Its cultivation in India has spread over large areas stretching from the southern tropical to northern sub - tropical region. The important papaya growing states are Orissa, Kerala, Assam, West Bengal, Andhra Pradesh, Telangana, Karnataka, Maharashtra and Gujarat, while, it is grown to some extent in part of Tamil Nadu, Madhya Pradesh and Uttar Pradesh. It performs better in South India than in North India because of frost injury to the plants in the Northern Plains.

Papaya fruit has occupied a place of pride in human diet because of its striking nutritional and medicinal values. It is one of the richest source of carotene (pro - vitamin) and a fair source of vitamin C, besides being high in sugars and pectin. It’s delicious fruit are not only palatable, nutritive, digestive and 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 becomes an important fruit crop.

The yield and quality of papaya are known to be influenced by different factors such as nutrition, cultural practice etc. Among these, nutrition plays an important role which has great influence on vegetative growth as well as yield (Srivastava, 2008). To maintain and sustain higher levels of soil fertility and crop productivity, organic manures are very important in the present day system of crop production. The conjunctive use of organic manures will not only improve the soil health but will helps to increase yield and quality of papaya. Chemical fertilizers constitute the major component of inputs. Expenditure on this component is ever increasing and making the cultivation economically not viable. Besides, the continuous use of chemical fertilizers is posing new problems because of depletion of soil health. Microorganisms capable of making nutrients available to the plants offer great scope in alleviating this situation. Therefore, use of bio fertilizers in conjunction with organic manures becomes a priority (Solaippan and Ramiah, 1990).

The integrated nourishment paves the way to overcome the problems, which involves conjugative use of chemical fertilizers organic manures to sustain crop production and maintenance of soil health (Nambiar and Abrol, 1989). Papaya is an important fruit crop with good export value and the information on the effect of various organics sources of nutrients and integrated nutrient management practices is lacking under agro climatic condition of Telangana. In Telangana, papaya is grown in marginal lands under irrigated conditions and hence, there is a need to reduce its cost of cultivation by using nutrients in integrated manner by adding organic and inorganic manures.

A papaya cultivar, Red Lady introduced from Thailand has replaced the traditional varieties like Coimbatore - selections, Coorg

Honey Dew and Pusa selections because of its high productivity, red colour flesh and gynodioecious nature.

Papaya is highly perishable fruit and can be stored only for four days at room temperature. Ripening in fleshy fruits is preceded by a shift in metabolism which leads to characteristic changes in their composition, texture and colour. The compositional changes include an increase in reducing sugars and aroma compounds and decline in acidity, astringency and chlorophylls (Selvaraj *et al.,* 1982). Post-harvest loss of papaya fruit up to 75 and 90 percent have been reported in India and Costarica (Cerbez and Seenz, 1993). The principal causes for post - harvest losses, include harvesting fruits at full ripened stage, inadequate packing and poor post-harvest handling. Further, the shelf life of fruit is also directly related to the rate of respiration (Srivastava *et al.,* 1961). Bio - chemically and physiologically post-harvest technology is mainly concerned with slowing down the rate of respiration of the produce.

Papaya is a climacteric fruit and shows a drop in respiration to a pre - climacteric minimum prior to ripening. At the onset of ripening, respiration increase and rises to a maximum called the climacteric peak and subsequently declines slowly. Respiration is accompanied by various biochemical changes which brings about characteristic taste, aroma and palatability of fruits, while senescence brings about the degradative process which makes the fruits unfit for consumption. By adopting proper post-harvest handling practices and proper understanding of the biochemical changes during fruit ripening and senescence, the post - harvest losses can be minimized to a greater extent.

Storage of papaya fruit at low temperature is limited as are susceptible to chilling injury and controlled atmospheric storage is limited due to high capital cost, but the experimental evidences had revealed that, post - harvest treatment of fruits with various ripening retardants like wax emulsion, gibberellins, calcium chloride, benzyl adenine and spermine improved the shelf life and quality of fruits and vegetables (Mehta *et al.,* 1986; Padhmanbhan *et al.*, 1994 and Bhagwan *et al.*, 2000).

The shelf life of papaya fruit is relatively shorter than other tropical fruits as a direct consequence of weak cell wall integrity. It was reported that the calcium chloride treatment of fruits protected them against postharvest detioration by binding with hydrolysis such as galacturonase and promote the shelf - life. Further, calcium has been shown to inhibit ethylene production and thus delay ripening (Al-Ani and Richardson, 1985). It was observed that the fruit that are rich in calcium are more resistant to mechanical injury and post harvest losses. Treatment with calcium prevented the post harvest losses in ber and pear (Siddiqui and Gupta 1989). In addition to this, there is few growth regulators believed to promote shelf life of papaya fruit. Mehta *et al.* (1986) suggested that GA_3@100ppm significantly suppresses the succinate activities of malate dehydrogenase during post-harvest ripening of papaya and thus retards ripening.

Within the same species, different varieties respond differently to post - harvest chemical treatments in extending the shelf life and in hastening the ripening process. In Telangana, the cv. Red Lady has emerged as a leading commercial variety. Hence increasing the shelf life of fruits by using various technologies like post harvest treatments with different chemicals and packaging materials are important. Keeping this view it is proposed to studies on integrated nutrient management on growth, yield, quality and effect of Post harvest treatments, Packaging materials on shelf life and quality of papaya (*Carica papaya* L.) *cv*. Red lady under southern Telangana with the following objectives:

Objectives:

1. To study the effect of INM on growth and yield of Papaya.
2. To study the effect of different INM treatments on quality aspects of Papaya.
3. To study the effect of different post harvest treatments on quality and Shelf life of Papaya.
4. To study the effect of different packaging material on shelf life and quality of Papaya.

Chapter - II

REVIEW OF LITERATURE

The nutritional requirement of papaya is quite typical in view of its continuous growth behavior like vegetative, flowering and fruiting habit. Papaya requires continuous nutrients in large amount and use of large quantity of chemically formulated fertilizers alone is not only feasible but also costly to the farmers, as majority of them are small and marginal farmers. Apart from this, heavy use of fertilizers causes environmental hazards and deleterious effect on soil structure, micro flora, and quality of water and also productivity on long term basis (Anon., 2005). The literature pertaining to use of organic manures and combination of organic and inorganic source of nutrients on growth, yield, quality and post harvest aspects of papaya and other fruits is very meager, hence the related literature in different fruit crops have been reviewed and presented in this chapter with following heads.

2.1 Effect of integrated nutrient management on growth and yield of papaya

2.2 Effect of integrated nutrient management on quality of papaya

2.3 Effect of post harvest treatment of chemicals and growth regulators on quality and shelf life of papaya.

2.4 Effect of different packaging materials on shelf life and quality of papaya.

2.1 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH AND YIELD OF PAPAYA

The yield and quality of papaya are known to be influenced by different factors such as nutrition, cultural practice etc. Among these, nutrition plays an important role which has great influence on vegetative growth as well as yield (Srivastava, 2008). To maintain and sustain higher levels of soil fertility and crop productivity, organic manures are very important in the present day system of crop production. The conjunctive use of organic manures will not only improve the soil health but also helps to increase yield and quality of Papaya. The integrated nourishment paves the way to overcome the problems, which involves conjugative use of chemical fertilizers organic manures to sustain crop production and maintenance of soil health (Nambiar and Abrol, 1989).

Study conducted by Barve (1992) reported better growth of grape vines with sole application of vermicompost.

Gubbuk *et al.* (1993) obtained the highest plant height by applying 225 Kg FYM per mat in Dwarf Cavendish banana and 150 Kg per mat for Basrai banana.

Venkatesh (1995) observed increased yield in Thompson Seedless grapes by application of vermicompost @5.0 tonnes per hectare.

Walling and Sanyal (1995) obtained marked variation in yield and fruit quality of guava cv. Allahabad Safeda by following different levels of N and K application. Significant responses were noted in number of fruit, fruit size and fruit weight per plant with the levels of N applied, but no significant variations were observed to different levels of K application and N-K combinations.

The highest yield was obtained by supplying the plantation (Robusta Banana) with 18 tonnes of poultry manure per hectare with or without standard inorganic N P K (Hemeng *et al.*, 1995).

Ray and Yadav (1996) studied the effect of combine application of organic manure and chemical fertilizers on growth and productivity of banana cv. Basarai and found that the combination of 25% FYM + 75% inorganic fertilizers (recommended RDF 200 g N, 50 g P_2O_5 and 200 g K_2O per plant) not only produced taller plant but also shortened the time required for emergence of bunch.

Aneesa Rani and Sathiamoorthy (1997) studied combined effect of organic, inorganic and bio fertilizers on total biomass and growth enhancement of papaya cv. Co - 6 plant dry matter, root: shoot ratio, root length, total biomass and percentage growth enhancement were noted higher in the treatment receiving 25 percent each of FYM and neem cake and inorganic N source and 50 or 75 percent sterameal and 50 or 25 percent inorganic P source alone with bio fertilizer like *Azospirillum*, *phosphobacteria* and VAM each at 20 g/plant.

Agrawal *et al.* (1997) reported that splitting of N, P and K helps in accumulation of photo - assimilates and also helps in better availability of nutrients during crop period and thus favours the yield and quality improvement in banana.

Ray *et al.* (1999) reported that the application of FYM 10 kg + neem cake 2 kg + cake-o-meal 1 Kg with 200g N, 200g P_2O_5 and 200g K_2O per plant showed highest stem circumference (33.4 cm) and minimum days to fruit setting (154.8 days), but addition of Zn 0.5% + B 0.1% spray resulted minimum fruit initiation height (100.3 cm) and maximum fruit length (74.5 cm) in papaya.

Ram *et al.*(1999) reported that the application of 600 g neem-coated urea per tree produced the highest fruit yield, total soluble solids, reducing sugars and ascorbic acid content in guava cv. Sardar.

El - Naby (2000) reported that plant treated with banana compost with 50 or 25 percent chemical fertilizers (NPK) + sulphur has recorded higher plant height in Maghrabi banana.

Corrales *et al*. (2000) noticed that, when guava plants were supplemented with poultry manure (30 Kg) with 66 percent mineral fertilizer gave higher yield and improved nutrient content of plant.

Goramnagar *et al.* (2000) found that the maximum leaf area, plant height and plant spread in Nagpur orange plants which were fed with FYM (15 Kg) + N (360g) + P_2O_5 (180g) per plant.

Geetha and Nair (2000) studied that the combinations of 3 organic fertilizers (*Azospirillum*, cowpea as green manure and vermicompost using the earthworm species *Eudrilus euginiae*) and 4 N rates (0, 95, 143 and 190 g per plant). The application of cowpea as green manure and vermicompost resulted in the highest increases in bunch weight (13.15 and 12.19% over the control, respectively). The current recommended N rate (190g per plant) decreased banana yield, while 75% of this rate (143g per plant) increased banana yield.

Dubey and Yadav (2001) found that the application of pig manure along with nitrogen and phosphorus significantly influenced the yield of acid lime (80 kg pig manure + 750 g + 500 g P_2O_5) per tree.

Jeyabaskaran *et al.* (2001) studied that the application of 80 percent recommended NPK (200:50:400g NPK/plant) + 15 kg poultry manure per plant recorded maximum growth parameters *like*, plant height, pseudo stem girth, total number of leaves and total leaf area and followed by application of rice husk ash @ 15 kg/plant + 80 percent recommended NPK and pressmud 15 kg/plant + 80 percent recommended NPK in ratoon of Poovan banana.

Soorianathasundaram *et al*. (2001) reported that the usage of inorganic N fertilizer by partial substitution with organic sources and the effect of such substitution on growth and yield of banana *cv.* Nendran. Significant reduction of the pseudostem height was observed with the addition of organic N sources and corresponding decrease inorganic levels.

Conradle (2001) reported that when grapevine nourished with N 50 kg ha^{-1} in the form of poultry manure during bud break increased the shoot length.

Manjunath *et al.* (2001) reported that the application of VAM fungus (*Glomus fascicu*) was found to be effective in papaya in increasing the plant height, stem girth, petiole length and number of leaves.

Tirkey *et al.* (2002) studied the growth of plant treated with inorganic fertilizers (100:100:150 g NPK per plant) along with organic manure (10 kg poultry manure per plant) over the inorganic fertilizer alone (300:200:300 g NPK per plant) in banana cv. Dwarf Cavendish.

Ram and Nagar (2003) reported that higher yield (13.69 kg/plot) in Allahabad safeda of guava, when it was nourished with 200 kg FYM + 200g Azotobacter.

Mustaffa *et al.* (2003) reported that application of distillery sludge (25 kg) + vermicompost (1kg) + neem cake (1kg) + poultry manure (2.5 kg) significantly increased the bunch weight and enhanced the qualitative parameters of banana.

Bhavidoddi (2003) reported that 100% inorganic fertilizer alone recorded maximum plant height during initial period of growth up to 150 days in banana after planting whereas, at later period of growth, treatment comprising 25% N as FYM + 75% N as inorganic fertilizer has recorded maximum plant height and a similar trend with other vegetative growth parameters such as pseudostem girth, number of leaves and leaf area was recorded.

Shivaputra *et al.* (2004) studied the effect of *Vesicular Arbuscular Mycorrhiza* (VAM) on the yield and yield components of papaya *cv.* Sunset Solo. Their results revealed that *G. fasciculatum* inoculated plants showed the maximum number of fruits and fruit weight. The most effective treatment in term of higher yield and early reproductive phase was recorded *G. fasciculatum* + 75 percent RDF + vermicompost 2 t/ha.

Kanamadi *et al*. (2004) reported that the effect of bio fertilizers on growth and yield of Banana *cv*. Rajapuri. The application of *Vesicular Arbuscular Mycorrhiza* (250g/plant) + *phosphate solubilizing bacteria* (50g/plant) + *Azospirillum* (50g/plant) + *Tricodermaharzianum* (50g/plant) in combination with 100 and 75 percent RDF (180:108:225g NPK/plant) had registered the vigorous growth in term of pseudo stem height, girth and leaf area.

Nachegowda *et al*. (2004) studied the influence of organic manure *viz*., farmyard, sheep, poultry, sericulture manure and vermicompost along with inorganic fertilizers on growth, yield and quality of Banana *cv*. Robusta. The treatment consisting of 15 kg FYM at the time of planting and 180:108:225g of N P K in three split / plant resulted in maximum plant height, pseudo stem girth, number of leaves, leaf area and leaf area index at shooting.

Singh and Singh (2004) reported that the application of *Vesicular Arbuscular Mycorrhiza* significantly increase growth of plants compared to non - mycorrhizal control and was also effective in increasing nutrient uptake by the plants. *Vesicular Arbuscular Mycorrhiza* influenced growth attributing character and yield attributing component. About 50% saving of phosphorus was achieved through the use of VAM.

Ganeshamurthy *et al.* (2004) studied the substitute of nutrients with organics on yield and quality of papaya *cv*. CO - 6 and found that the papaya plant receiving 50 percent (recommended N P K 200 g/plant) inorganic N and P + 25 percent N as FYM and remaining 25 percent N from neem cake while 50 per cent P as sterameal recorded maximum fruit yield as compared to plants receiving fertilizers through inorganic nutrients only.

The application of recommended dose of N P K 300:90:200 g per plant along with *Azotobactor* 6 kg/ha and *PSM* 6 kg/ha had significant effect on growth of banana in respect of plant height, girth and total leaf area in banana *cv*. Grand Naine (Anon., 2005).

Patil *et al.* (2005) reported the application of 75% RDF + 25 Kg FYM + 5kg vermicompost recorded significantly higher fruit yield of 40.04 kg/tree followed by treatment (75% RDF + 25 kg FYM) and (50% RDF + *Azospirillum* + '*P'solubilizer* + 5 kg vermicompost). The maximum numbers of fruits per tree were recorded with 75% RDF +25 kg FYM +5 kg vermicompost (193.60 fruits) as compared to other treatments in mango.

Athani *et al.* (2005) reported that the guava plants were fed with 75 percent RDF + vermicompost (10 kg) per plant produced fruits of significantly fruit weight (221.00g), pulp thickness (2.33cm) and pulp weight (143.00g).

Manjunatha Hebbar *et al.* (2006) studied the effect of vermicompost application with varied levels of recommended dose of fertilizer on yield and quality of 'Kalipatti' sapota and soil properties. Highest fruit yield was recorded under 100% recommended dose of fertilizer and vermicompost application (18.4 kg fruit/plant) which was found best.

Ram *et al.* (2007) reported that the maximum increases in guava plant height, plant spread, number of fruits, yield and quality integrated application of different fertilizers 250g N + 100g P_2O_5 + 250g K_2O, 10 kg FYM and 250g *Azotobacter*.

Patel (2008) studied the integrated nutrient management in banana *cv.* Basrai under high density plantation and found that all growth parameters viz. plant height, girth of pseudo stem, number of leaves and leaf area were recorded higher with the application of 75 percent RDN and RDP (200:90:200 g NPK/plant) along with *Azotobacter* and *PSM* each at 2.4 g/plant and vermicompost @ 2 kg /plant.

Madhavi *et al. (*2008) reported that the maximum plant growth, number of fruits/tree and yield were recorded with application of 1000g each NPK/tree/year in mango.

Bhalerao *et al.* (2009) studied the integrated nutrient management for tissue culture banana cv. Grand Naine, maximum plant height (216.0 cm), stem girth (70.92 cm), minimum days required to flower (258.5 days) and crop duration (356.9 days) were recorded with application of 100% recommended dose of NPK (200:40:200 g NPK/plant) with 10 kg FYM and bio fertilizer (*Azospirillum* and *PSB*) @ 25 g per plant in banana.

Dutta *et al.* (2009) studied the effect of bio - fertilizer along with inorganic fertilizer on growth and productivity of guava cv. L - 49 with different treatments of bio - fertilizers and inorganic fertilizer and found significantly increased the plant height and spread with*Azospirillum* + *Vesicular Arbuscular Mycorrhiza* inoculation along with 100% N + 100% P_2O_5 showed maximum plant height and spread while control recorded minimum.

Syed Ziauddin (2009) was found thatthe application of organic and inorganic fertilizer was more effective than the inorganic fertilizers alone. Among the various combinations 200g N + 150g P_2O_5 + 200g K_2O per plant combined with organic booster slurry @ 6 litre per plant was found the best over all the treatments in respect of producing maximum bunch weight (18.4 kg) and yield per hectare (81.8 t). This treatment also raised the availability of N, P and K in soil and enhanced the nutrient concentration in index leaf tissues in banana.

The effect of integrated nutrient management on growth and yield of banana cv. Jahaji and found significantly increased pseudo stem height, girth, total leaf area, number of functional leaves and shortening of the crop cycle were observed in application of 100 percent recommended doses of NPK (100g N, 33g P_2O_5, 330g K_2O per plant) in combination with farm yard manure @ 12 Kg and bio fertilizer (*Azospirillum* and *phosphate solubilizing bacteria*) @ 50g per plant (Hazarika and Ansari, 2010).

Shivakumar (2010) conducted the experiment on integrated nutrient management in papaya and found that the plant height were recorded higher with the application of FYM @77.15 t/ha along with 150% RDF (250:250:500 g NPK/plant) and Agrigold @ 16.66 t/ha with 150% RDF, whereas control (no organic manure) with 50% RDF recorded least values for all growth parameters.

Singh *et al.* (2010) studied the response of integrated nutrient management on growth and yield of papaya cv. Surya, recommended dose of fertilizer *i.e.* 200: 250: 250 g NPK/ plant, FYM @ 50 kg/plant, vermicompost @ 20 kg /plant, poultry manure 20 kg /plant, rhizosphere bacteria culture 50 g/plant alone and in combination with reduced levels of RDF *viz.*, 75 and 50 percent and found that maximum number of leaves (18.73) and trunk girth (0.26 m) were recorded with 75 percent RDF + 25 percent vermicompost, while maximum plant height (185.35 cm) and petiole length (8.42 cm) were associated with 100 percent RDF alone.

Reddy *et al.* (2010) studied the effect of organic nutrition practices on papaya *cv*. Surya. Results indicated that crop growth and fruit yield were higher in inorganic fertilizer treatment (55 t ha^{-1}) compare to organic treatments (26.9 to 38t ha^{-1}).

Suresh *et al.* (2010) studied the effect of PSM (*Bacillus megatherium* + *Aspergillus awamori*) and VAM (*Glomus mosseae* + *G. fasciculatum*) biofertilizers with graded levels of phosphorus (P_2O_5 at 50, 100, 150 and 200 g per plant) on growth and uptake of papaya and reported that the combined application of PSM and 200 g P_2O_5 recorded highest yield (64.85 t/ha).

Singh *et al.* (2010) reported that the application of 75% RDF + 25% vermicompost + rhizosphere bacteria culture treatment maximum plant height (185.35cm), petiole length (8.42cm), maximum number of leaves (18.73), trunk girth (0.26 m), number of fruits plant (46), fruit weight (0.85kg) and pulp thickness (3.5cm).

Baviskar *et al.* (2011) studied the effect of different combination of organic, inorganic manures and bio fertilizers on yield and growth of sapota. The fruit yield in terms of number of fruits harvested per plant, fruit yield (kg /plant) was recorded maximum in plants which is treated with (1125:750g NPK+ 15 kg vermicompost+250g *Azotobacter* + 250g *phosphate solubilizing bacteria*/ plant).

Yadav *et al.* (2011a) studied the effect of various organic, inorganic and bio fertilizer combinations on the growth and yield attributes of papaya *cv.* Pusa Dwarf and they revealed that the plant height (138.75 and 140.30 cm), girth (36.05 and 37.45 cm), fruit setting (86.24 and 87.15 cm) and fruiting height (35.01 and 34.10 cm) were statistically significant with the soil application of 10 kg vermicompost along with 100% RDF and 25g *Azotobacter* followed by 30 kg FYM along with 100 percent RDF and 25g *Azotobacter*.

Yadav *et al.* (2011b) conducted field experiments during 2008 -2009 and 2009 - 2010 to investigate nutrient nourishment levels on yield of papaya *cv.* Pusa Dwarf. The yield attributes such as days to first flowering, days to maturity, fruit weight and number of fruit per plant and yield kg /plant and q/ha was recorded significantly higher with the application of 10 kg vermicompost along with 100 percent NPK and 25 g *Azotobacter* per plant.

Goswami *et al.* (2012) reported that the application of 225g + 195g + 150g K + 50 kg FYM enriched with *Azospirillum* effective to increase the vegetative growth of plants and maximum leaf N and K in the leaf tissue of guava plant. Maximum leaf content was recorded in treatment consisting of half dose of recommended fertilizers + 50 kg FYM + *Trichoderma* (250) + Pseudomonas fluorescence (250).

Patel *et al.* (2012) results revealed that integration of inorganic nitrogen in combination with castor cake and *Azotobacter* or *Azospirillum* will be always advantageous than application of inorganic nitrogen alone as it produced early vegetative growth and improved yield. The higher doses of nitrogen (300g nitrogen in chemical form with *Azotobacter*) had produced highest yield which is obvious because of Grand Nain cultivar of banana is a tall, vigorously growing in nature, voracious feeder of plant nutrients and respond well to the applied nutrients.

Bhalerao and Patel (2012) conducted the experiment on foliar application of Ca, Zn, Fe and B on physiological attributes, nutrient status, yield and economics of papaya (*Carica papaya* L.) cv. Taiwan Red Lady and revealed that the foliar application of calcium nitrate 1000 mg/liter + borax 30 mg/liter + zinc sulphate 200 mg/liter + ferrous sulphate 200 mg/liter during 60, 90 and 120 days after planting were found better with respect to increase in photosynthetic rate, transpiration rate, leaf temperature and total chlorophyll contents with pronounced results regarding nutrient contents of papaya cv. Taiwan Red Lady.

Kuttimani *et al.* (2013a) reported that the application of 100 percent recommended dose of fertilizer *i.e.* 165:52.5:495 g NPK/plant along with 40% Wellgro soil has recorded the significantly thicker pseudo stem girth, maximum number of leaves and registered shorter crop duration in banana *cv.* Grand Naine.

Dhomane and Kadam (2013) observed that the application of 75% of nitrogen through urea along with 25% nitrogen through neem cake has significantly increased the yield parameters likeweight of fruit (243.80 g), yield per tree (58.1 kg) and yield per hectare (23.26 tonnes), compared to various combinations in guava cv. Sardar.

Singh and Varu (2013) found that the application of 50% RDF (1000:100:125 NPK g/plant) + *Azotobacter* @ 50 g/plant + *phosphate solubilizing bacteria* @ 205 g m^{-2} enhanced the growth and yield parameter like highest survival percentage (98.67%), plant height at flowering and harvesting stage, stem girth at flowering and harvesting stage, number of leaves at harvesting stage (24).

Kuttimani *et al.* (2013b) studied the effect of integrated nutrient management on physiological parameters on banana *cv*. Grand Naine and found that leaf area index, crop growth rate, relative growth rate, net assimilation rate, total chlorophyll and soluble protein showed significantly higher in application of 100 per cent recommended of fertilizer (165:52.5:495 g NPK $plant^{-1}$) along with FYM @ 10 Kg $plant^{-1}$ during both the year of experimentation.

Vandana Dwivedi (2013) reported the effect of integrated nutrient management on yield, quality and economics of guava. The application of 50 % RDF (250:100:250 g NPK) + 25 kg FYM + 5 kg vermicompost/tree and 100% RDF (500:200:500 g NPK) + Zn, B, Mn foliar spray + organic mulching 10 cm thick /tree were found significantly superior than other INM treatments with respect to yield attributes.

Akash Sharma *et al.* (2013) reported that theplant height, fruit yield, fruit length, breadth, weight and pectin content of guava with the application of 25% N through FYM + 75% of N through inorganic fertilizers.

Patil and Shinde (2013) reported that the yield parameters bunch weight (19.31 kg) and per hectare (85.80 t/ha). The application of 50% RDF + FYM + *Azotobacter* (50g/plant) + *phosphate solubilizing bacteria* (50g/plant) + G. fasciculatum (250 g/plant) was found beneficial for growth and yield of banana cv. Ardhapuri.

Shaheen *et al.* (2013) reportedthat the application of 50% (compost, rock phosphate and feldspar) + 50% of the NPK mineral recommended fertilizers N (157 g/vine), P_2O_5 (87 g/vine) and K_2O (112 g/vine) + bio - fertilizer was the best management system for ensuring the best vegetative growth parameters as shoots length, number of leaves/shoot and leaf area and leaf mineral content and achieving the best yield with its components as number of clusters per vine and weight of each individual cluster, improving the physical characteristics of grapevines berries.

Hasan *et al.* (2013) found that the application of vermicompost with combination of 850gN + 425g P_2O_5 +1000g K_2O +250g *Azospirillum* + 250g phosphate-solubilizing bacteria + 100g zinc sulfate + 100 g borax/tree/year appreciably increased fruit weight (273.20g), fruit length (9.53cm) pulp weight (180.20), pulp content (65.96%) in mango.

Jitendra Verma and Rao (2013) observed thatthe application of *Azotobacter* + *phosphate solubilizing bacteria* + vermicompost + 50% RDF was found to more effective in higher organic carbon (1.95 %), available nitrogen (314.64 kg ha^{-1}), phosphorous (17.56 kg ha^{-1}) and potassium (306.33 kg ha^{-1}) in soil after harvest of the crop of strawberry.

Abu Nayyer *et al.* (2014) reported that the application of 100% RDF of NPK+50 g *Azospirillum* + 50 g *phosphate solubilizing bacteria*+50g *Trichoderma harzianum* per plant with earliness in flowering (253.33 days) and flowering to harvesting of bunch (110.00 days) as compared to others treatments in banana.

Tandel *et al.* (2014) reported that the 25% RDN through bio compost + 25% RDN through castor cake + 50% RDN through inorganic fertilizer gave higher values of growth characters viz., plant height, stem girth and number of leaves and this treatment also influenced the physiological parameters viz., photosynthetic rate, total chlorophyll content, transpiration rate and leaf temperature.

Lenka and Lenka (2014) reported that RDF 100% + *phosphate solubilizing bacteria* + *Azospirillum* was superior compared to all the treatments based on pseudo stem height, pseudo stem girth, days taken for shooting, average bunch weight, number of hands per bunch, number of fingers per bunch, finger weight, finger length and finger circumference of banana fruits.

Nidhika Thakur and Thakur (2014) studied the response of plum to integrated nutrient management, various combinations of inorganic fertilizers (Urea, SSP and MOP), farm yard manure, vermicompost, biofertilizers and green manures. Among all the treatments, treatment 75% NPK + biofertilizers (60g each/tree basin) + green manuring (Sunhemp @ 25 g seeds/tree basin) performed best where highest annual shoot growth (55.27 cm), tree height (4.98 m), tree volume (18.62 m^{-3}), fruit set (77.28%), fruit yield (28.11 kg/ tree), net income (Rs. 499.62) and benefit cost ratio (3.75) were observed while the highest trunk girth (71.47 cm) and leaf area (13.12 cm^2) were observed with (50% NPK + biofertilizers (60g each/tree basin) + green manuring (Sunhemp @ 25 g seeds/tree basin) + FYM (40 kg) + vermicompost (11.5 kg).

Asheesh Sharm *et al.* (2014) reported that the integrated nutrient management treatments, comprising 50 percent recommended dose of fertilizers + 50percent N through vermicompost and bio fertilizers (*Azotobacter* 50g + *phosphate solubilizing bacteria* 50g + VAM 20g) was found significantly superior over other treatments including control with respect to growth parameters such as percent increase in plant height, rootstock girth, scion girth, plant spread and number of primary branches per plant *etc*. in custard apple cv. Arka Sahan.

Somasundaram *et al.* (2014) reported that the application of 100% recommended dose of fertilizer (RDF) along with 40% Wellgro soil recorded the maximum number of hands (10.2 and 10.3), number of fingers (136.3 and 145.2), bunch weight (23.9 and 25.3 kg/plant) and total yield (72.8 and 77.1 t/ha) of banana.

Raja Naik *et al.* (2015) studied that the plant treated with FYM + Neem cake + 50% RDF + *Azotobacter* + *PSB* (T_{19}) resulted in higher plant height (3.61m), number of leaves (17.0), pseudostem diameter (50.50 cm), length of leaf (161.80 cm), leaf breadth (63.93 cm), phyllocron (7.00 days), root growth (12.6 cm). From the investigation, it could be concluded that application of FYM + Neem cake + 50% RDF + *Azotobacter* + *PSB* (T_{19}) was appeared to the optimum nutrient combination for better growth of banana *cv*. sugandham.

Neeraj Kumar *et al.* (2015) reported that the effect organic manure (Farm Yard Manure, vermicompost and press mud) and biofertlizers (*Azotobacter, phosphate solubilizing bacteria and Azospirillum*). The combination of vermicompost and *PSB* showed highest plant height (23.59cm), leaves plant^{-1} (12.67), primary branches plant^{-1} (10.50), secondary branches plant^{-1} (27.35), first flowering (61.06 days), flowers plant^{-1} (15.33), first fruit setting (72.80 days) and fruits plant^{-1} (8.33) in strawberry.

Bhatnagar and Sing (2015) studied clearly revealed that the treatment comprising vermicompost in combination with 50% recommended dose of fertilizer (RDF) and biofertilizers attained significantly higher plant height, rootstock girth, scion girth, plant spread (E-W and N-S), leaf area and soil NPK content over other treatments including control. This treatment combination also resulted in significantly better impact with respect to higher vegetative growth parameters over other treatments including the control. The application of vermicompost along with 50% N through RDF and biofertilizers provided better nutrition as it contained all the macro and micro nutrients required for growth and development of custard apple plants.

2.2 EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON QUALITY OF PAPAYA

El-Naby (2000) reported that the plants treated with banana compost along with 75 % chemical fertilizers + 50 % sulfur improved the TSS: acid ratio in banana cv. Maghrabi.

Soorianathasundaram *et al*. (2001) studied the higher level of TSS (26.0%) with the application of 25% FYM +75% inorganic N as urea over the control (RDN alone 200 g N/plant) in banana *cv.* French Plantain (AAB).

Sankat and Maharaj (2001) found that the volatile compound methyl butanoate is considered responsible for the sweetish odor quality of papaya.

Uma Shankar *et al.* (2002) found that the highest fruit yield, total soluble solids, ascorbic acid, reducing sugars and total sugars content with application of N, P_2O_5 and K_2O at 225-150-150 in two split doses, before flowering and after fruit set in guava *cv.* Sardar.

Bhavidoddi (2003) observed that the higher pulp weight, peel weight, pulp to peel ratio, shelf life, TSS and total sugars with application of 25 % N as FYM + 75 % N as inorganic source in banana *cv.* Rajapuri (*Musa AAB*) .

Ganeshamurthy *et al.* (2004) found that quality parameter (reducing sugars, non reducing sugars, TSS, ascorbic acid, acidity and papain) were better in papaya fruit with application of 50 percent inorganic fertilizer (recommended NPK 200 g/plant) + 25 percent through neem cake + 25 percent through FYM with 20 g/plant bio fertilizer application.

Manjunatha Hebbar *et al.* (2006) studied the effect of vermicompost application with varied levels of recommended dose of fertilizer on yield and quality of 'Kalipatti' sapota. Highest fruit yield was recorded under 100% recommended dose of fertilizer and vermicompost application (18.4 kg /plant) which was found best.

Pankaj Kumar *et al.* (2008) recorded the maximum fruit yield and fruit set with application of 150g N, 50g P_2O_5 and 75g K_2O/plant/year. They also reported that treatment combinations with higher nitrogen level recorded maximum yield and combinations with higher potassium level recorded higher ascorbic acid and sugar content in fruits of guava cv. Pant Prabhat.

The experiment conducted on integrated nutrient management in banana *cv.* Basarai under high density plantation and found that higher TSS (22.18 ^{O}Brix), Ascorbic acid (12-32 mg/100 g), Reducing sugars (8.16 %), Total sugars : acidity ratio (82.68) with lower acidity (0.17%) were registered with the application of 75% RDN and RDP (200:90:200 g NPK/plant) along with *Azotobacter* and *PSM* each at 2.4 g/plant and vermicompost @ 2 kg/plant (Patel, 2008).

Madhavi *et al. (*2008) found that the fruit quality in terms of more TSS and acidity were recorded with application of 1/2 RDF+30 Kg FYM+250g *Azospirillum* /tree in guava.

Hazarika and Ansari (2010) reported that the biochemical constituents Reducing sugars, TSS, Non - reducing sugars, Ascorbic acid, and moisture contents of fruit were significantly influenced by different treatments except sugar acid ratio and titratable acidity. The treatments having organic manure and bio - fertilizer along with inorganic fertilizers also produced higher values in physical parameters of banana finger.

Shivakumar (2010) studied the application of organic manures either alone or in combination withchemical fertilizers positively influenced the post harvest parameters (Physiological loss of weight, fruit firmness and shelf life) of papaya fruits. The fruits obtained with the application of organic manures had least physiological loss in weight with higher fruit firmness and longer shelf life. Application of 100 % RDF (250-250-500 g NPK/plant) fertilizer with combination 50 % organic manures (FYM @ 77.15 t/ha or vermicompost @ 30.86 t/ha or pressmud @ 16.05 t/ha, or sheep yard manure @ 55.09 t/ha or agrigold @ 16.66 t/ha) were promoted a shelf life up to 8 days.

Singh *et al*. (2010) studied the effect of integrated nutrient management on growth, yield and quality of papaya *cv.* Surya. Quality parameters of the fruits like pulp thickness (3.5cm), shelf life of fruit (12 days), vitamin A (2280 IU/100g) and TSS (15.8 ^{O}Brix) were found to be superior with 75% RDF (200:250:250 g NPK plant^{-1}) + 25% vermicompost (20kg plant^{-1}) + rhizosphere bacteria culture 50 g plant.

Ravishanker *et al.* (2010) found that the application of FYM 20 kg/plant recorded maximum total soluble solids, ascorbic acid, total sugars and the least value of titrable acidity as compared to intensive farming and other organic treatments in Coorg Honey Dew papaya.

Singh and Banik (2011) reported that the highest total number of fruits/tree, TSS, Reducing sugars and Total sugars recorded in1/2 1000:500:500g N, P, K + 50 Kg FYM + 250g *Azospirillum* in mango fruit.

Yadav *et al*. (2011a) studied the effect of various organic, inorganic and bio fertilizer combination on ascorbic acid, total soluble solids and total sugars content of papaya fruit. The results of the experiment revealed that highest TSS, total sugars, ascorbic acid content and minimum fruit acidity was recorded with the soil application of vermicompost along with 100 per cent RDF and *Azotobacter*.

Baviskar *et al.* (2011) studied the effect of different combination of organic, inorganic manures and bio fertilizers on quality of sapota. The plants which is treated with (1125:750g NPK + 15kg vermicompost + 250g *Azotobacter* + 250g *PSB*/ plant). Superior quality traits evaluated in terms of fruit weight, fruit size, total soluble solids and total sugars with lower acidity.

Reddy *et al*. (2012) reviewed that the ten organic nutrient treatments along with recommended dose of fertilizers and control (no manure/fertilizer) were used totaling twelve treatment combinations of FYM, biofertilizers and vermicompost. Fruitquality parameters such as total carotenoids, lycopene, TSS, average fruit weight and ascorbic acid content were analyzed. Among the treatments, application of 50% recommended dose of fertilizers in the form of farm yard manure (FYM) applied as *Azospirillum* + Phosphate solubilizing bacteria + Mycorrhiza + vermicompost showed high level ofcarotenoids, lycopene and low levels of ascorbic acid. TSS and average fruit weight were not affected by various organic nutrient treatments.

Hasan *et al.* (2013) reported that the application of 850 + 425 + 1000g N P K + 250g *Azospirillum* + 250g *PSB* + 100g $ZnSO_4$ + 100g Borax/tree/year in combination vermicompost gave height TSS, total sugar, vitamin C and lowest acid content of mango fruit. Beta carotene content of fruit was highest with application of 1200 + 600 + 1200g NPK tree/year in combination with vermicompost.

Shaheen *et al.* (2013) reportedthat the application of 50% (compost, rock phosphate and feldspar) + 50% of the NPK mineral recommended fertilizers N (157 g/vine), P_2O_5 (87 g/vine) and K_2O (112 g/vine) + bio - fertilizer was the best management system for ensuring the best vegetative growth parameters and chemical characteristics of berries as total soluble solids, total acidity, TSS/acid ratio and total sugars of berries of Superior Seedless grapevines.

Dwivedi (2013) reported the effect of integrated nutrient management on yield, quality and economics of guava. Application of 50 % RDF (250:100;250 g NPK) + 25 Kg FYM + 5 Kg vermicompost/tree and 100% RDF (500:200:500 g NPK) + Zn, B, Mn foliar spray + organic mulching 10 cm thick /tree were found significantly superior than other INM treatments with respect to yield attributes, yield and economics from guava *cv*. Allahabad Safeda. Total soluble solids were found in the higher range (12.23 to 12.43 ^{O}Brix).

Neeraj Kumar *et al.* (2015) evaluated the effect organic manures (Farm Yard Manure, vermicompost and press mud) and biofertlizers (*Azotobacter, phosphate solubilizing bacteria and Azospirillum*). The treatments combination of vermicompost and *PSB* significantly affected the Total Soluble Solids (10.75 ^{O}Brix), Titrable acidity (0.82), Vitamin C (57.24 mg/100gm fruit), Total sugars (5.95 %) and juice content (79.50 %) in strawberry.

Navneet Kau *et al.* (2016) studied the impact of integrated nutrient management on fruit quality parameters of Cape gooseberry genotype ‘Aligarh’. The treatments consisted of application of biofertilizers (*Azotobacter* and *Azospirillum*) applied alone or in combination with 50%, 75% and 100% NPK +0.70, 1.0, 1.25 and 2.0 t/acre. Results revealed that the seeds inoculated with *Azotobacter* and *Azospirillum* + 50% NPK + 70 t/acre FYM gave maximum fruit size, fruit weight, TSS %, Reducing sugars and Ascorbic acid with minimum acidity respectively.

2.3 EFFECT OF POST HARVEST TREATMENT OF CHEMICALS AND GROWTH REGULATORS ON QUALITY AND SHELF LIFE OF PAPAYA AND OTHER FRUITS

Papaya is one of the most important tropical fruit crops which primarily cultivated in India. Despite the fact that the fruits are nutritionally rich and also giving high monetary returns, this crop could not be exploited at the large scale due to high perishability and poor post-harvest storage facilities. The shelf-life of papaya fruits is relatively shorter than other tropical fruits as a direct consequence of weak cell wall integrity.

The extension of shelf life of papaya fruits with minimum losses during post-harvest handling and storage would enable efficient marketing and export. Papaya fruits have very thin skin and thus rough handling leads to heavy losses due to a number of rots caused by fungi. The estimated post - harvest losses were around 25 percent in ripe fruits and 10 percent in green fruits (Mandal and Dasgupta, 1981). The ripe papaya fruit is perishable and can be kept at room temperature for 4 days only (Mandan and Ullasa, 1993).

Various internal and external factors on the harvested fruits influence physic - chemical changes occurring in the fruits resulting in ripening and finally senescence followed by rotting. Respiration is an enzymatic reaction resulting in loss of food reserves and consequent deterioration.

Efforts have been made by many workers to reduce the extent of post-harvest losses and to extend the storage life of harvested fruits, through application of various post - harvest treatments. A brief review of work carried out by different workers in papaya and a few other fruit crops has been reviewed in this chapter under the following headings.

2.3.1 EFFECT OF CHEMICALS ON PHYSICAL PARAMETERS OF FRUITS

The role of calcium in extending the shelf life of tropical fruits were studied by many workers and reported that calcium plays a major role in limiting respiration activity which was attributed to altered membrane permeability (Bangerth, 1979). Bangerth *et al.* (1972) stated that calcium could have reduced the endogenous substrate catabolism during respiration by limiting the diffusion of substrate from the vacuole to the cytoplasm and favoured the uptake of sorbitol thus disallowing its involvement in reactions related to internal breakdown. Jones *et al.* (1970) contended that calcium controlled the disintegration of mitochondria, endoplasmic reticulum and cytoplasmic membranes and thus helped in retarding respiration rate.

Papaya fruits being highly perishable in nature cannot be stored for a longer period. However, several experiments showed that storage life of fruits can be prolonged by the use of chemicals.

2.3.1.1 EFFECT OF CHEMICALS ON PHYSIOLOGICAL LOSS IN WEIGHT OF FRUITS

According to Robert and Nancy (1989), stomatal density on papaya fruit was found to be 2340/cm^2. The stomata are appeared to be open. The maximum weight loss rate was 3500 mg/cm^2/day from the cut stem and it was 220 times greater than that loss through the skin but the total loss was great through the skin as it has largest surface area. They also reported that waxing with lanolin reduced weight loss from 16.4 to 4.4 mg/cm^2*i.e.,* nearly a 71 percent reduction. Further, weight loss from 18.5 percent to 14 per cent with the application of $CaCl_2$ @ 4 per cent (Pathamanabhan *et al.,* 1994).

Physiological loss in weight, indicate the total moisture lost during storage and ripening, which results in desiccation and a shriveled appearance of the fruit (Davies and Hobson, 1981).

Delayed softening of peach fruits following post harvest application of calcium has also been reported by Wills and Mahendra (1989). Lakshmana (1990) reported that post harvest application of calcium chloride (6 %) to sapota fruits *cv*. Kalipatti resulted in lower PLW, lesser spoilage and prolonged shelf life.

Evelin Mary and Sathiamoorthy (2002) tested pre harvest $CaCl_2$ spray @ 2 per centand 3 per cent concentrations on Rasthali banana showed calcium ions binded with the pectin present in the cell walls forming cation cross bridges between pectic acid and therebystrengthening the cell wall.

Choudhury *et al.* (2003) observed that the fruits stored in gunny bags were found to be shriveled and recorded highest weight loss (18%) in sapota crop.

Bharathi and Srihari (2004) reported that the application of Ca $(NO_3)_2$ at 1.0 percent significantly lowest PLW of 7.75% as compared to other calcium compounds in sapota *cv.* Kalipatti.

Jayachandran *et al.* (2007) studied thesignificant differences in PLW of the guava fruits with the application of calcium treatments. Among the treatments, highest PLW was observed in control (21.35) and lowest (11.78 %) was observed by application of Ca $(NO_3)_2$.

Rajkumar *et al.* (2005) observed that the application of $CaCl_2$@ 2.0% recorded significantly lowest level of loss in fruits weight, ripening percentage, extended the shelf - life of papaya.

Mahumud *et al*. (2008) found that Calcium infiltration extend the shelf life and retained the quality as calcium concentrations increased up to 2.5 % and then declined in papaya.

Rajput *et al.* (2008) found that the maximum shelf life, TSS and minimum PLW and titrable acidity of guava fruits was recorded by application of Ca $(NO_3)_2$ @ 2 %.

Mahajan *et al.* (2008) reported that the application of $Ca(NO_3)_2$ @ 2.0 % to the plum fruits maintained minimum weight loss in cold storage.

Ismail *et al.* (2010) observed that the guava fruits treated with $CaCl_2$ + fumigation with lemon grass oil and stored at 8±1ºC recorded the lowest significant value of weight loss (5.00 %).

Nirupama *et al.* (2010) found that application of $CaCl_2$ @ 1.5 % to the tomato fruits recorded the least decay percentage, minimum weight loss and prolonged the shelf life of tomato.

In the studies of Priyanka Singh *et al*, (2012) found that paddy straw; tissues paper and news paper wrapped papaya fruits get ripened in 5 days compared with the control which ripened in 6 days. At the end of storage studies, paddy straw wrapped fruits have shown the best results for TSS, titratable acidity, reducing sugar, total sugar, ascorbic acid and total carotenoids.

Mulagund *et al.* (2015) studied that the exogenous application of chemicals, growth regulators in combination with Thiabendazole significantly decreased post-harvest disease incidence leading to increase in post - harvest fruit quality and shelf life. Among the treatments, post-harvest dipping of fruits in 150 ppm GA_3 + 200 ppm Thiabendazole significantly increased firmness (3.70 Kg cm^{-2}) titrable acidity (0.09%) and storage life of fruits (18.00 days). While the parameters like PLW (13.53%), TSS (25.45^{O}B), total sugars (18.88%), reducing sugars (17.11%) and percent disease incidence (5.55) was observed minimum in the same treatment after 12th day of storage.

2.3.1.2 EFFECT OF CHEMICALS ON FIRMNESS OF FRUITS (Kg cm^{-2})

A major contribution to the loss of firmness of fruit tissue during ripening is made by the disintegration and collapse of pulp tissue due to dissolution of cell wall and middle lamella by the action of hydrolyzing enzymes (Hulme, 1958). The breakdown of middle lamella, which holds the cell firm is brought about the action of pectolytic enzymes mainly polygalacturonase.

The loss of firmness during ripening has been associated with the nature and proportion of the peptic substance. The total pectin increase in ripening of papaya and reached a maximum value in over ripe fruits. The water soluble pectin level was maximum when the fruit ripened (Biswas *et al.*, 1988).

The pectic material extracted from unripe pulp contained D - galactose, D-galacturonic acid and L-arabinose as major constituent sugars with a trace of raminose. The pectic acid was a mixture of linked galacturonase. Selvaraj *et al.* (1982) observed the highest pectin content at ripe stage in papaya cv. Coorg Honey Dew, Sunrise and Thailand, and at pre - ripe stage in cultivars Pink Flesh Sweet and Washington.

Drake and Spayd (1983) found post - harvest treatment of apple fruits by pressure infiltration with 3 percent of calcium solution resulted in the least loss of fruit firmness after prolonged storage

Treatment of mature green papaya with 0, 1 and 5 percent (w/v) concentrations of $CaCl_2$ increase fruit firmness (Chen and Paull, 1986).

Pathmanabhan *et al.* (1994) reported that the papaya fruits exposed to $CaCl_2$ or $CaCO_3$ maintained firm texture and good external appearance.

Tsantili *et al.* (2002) reported that theapplication of calcium ($CaCl_2$) prevented decrease in firmness and the highest firmness retention was achieved with (0.09 Kg cm^{-2}) after 40 days of storageof yellow green fruits of lemon.

Fonseca *et al.* (2006) studied the effects of atmospheres containing different rates of oxygen and carbon dioxide, and the role of relative atmospheric humidity on the postharvest keeping quality of papaya *cv.* Sunrise Solo and noticed that the controlled atmospheres have reduced losses in fruit firmness.

Hassan *et al.* (2004) observed that banana fruit dipped in hot water developed desirable color and firmness characteristics, as did the fungicide treated fruits. The former treatment provides an alternative for those wishing to minimize the use of chemicals in order to achieve market appeal.

Benitez *et al*. (2006) conducted an experiment on mango fruit softening to postharvest heat treatment. For this purpose mango *cv*. Namdokmai at mature green stage were heated by dipping in 50 or 55ºC water for 5 min and stored at 25ºC with 90-95% relative humidity. They reported that softening slowed down in response to heat treatment.

Salvador *et al.* (2007) the results showed that during storage, the change in peel color from green to yellow was gradual in the *M. Cavendish* samples, whereas the *M. paradisiaca* variety presented a different pattern, remaining green for the first 8 days and then changing rapidly to a yellow tone from day 12 onwards. While the flesh texture of the *M. cavendishi* type bananas softened quite rapidly during storage, it evolved more slowly in the *M. paradisiaca* variety and there was little variation in the flesh hardness values over the storage time.

Jagadeesha *et al*. (2015) found that the exogenous application of chemicals, growth regulators in combination with Thiabendazole significantly decreased post-harvest disease incidence leading to increase in post - harvest fruit quality and shelf life. Among the treatments, post harvest dipping of fruits in 150ppm GA_3 + 200ppm Thiabendazole significantly increased firmness (3.70 Kg cm^{-2}).

2.3.1.3 EFFECT OF CHEMICALS APPLICATION ON EXTENDING SHELF LIFE (DAYS) OF FRUITS

Calcium has received considerable attention in recent years because of its beneficial effects in fruits and vegetables. Further many studies have indicated that calcium compounds extend the storage life of fruits by maintaining their firmness and minimizing the rate of respiration, protein break down and rotting incidence (Bengerth *et al.,* 1972). Calcium maintains post - harvest integrity of fruits (Shaples and Johnson, 1976) and depresses the respiratory raise, ethylene production (Poovaiah and Leopold, 1973).

Calcium chloride as post-harvest treatment extended the shelf life of mangoes. The shelf life of fruits dipped in 8 percent Calcium chloride was 14 days compared with a shelf life of 5 days for untreated Julie mangoes (Mootoo, 1991).

Storage studies conducted by Ramakrishna and Haribabu (1999) in papaya cv. CO -2 showed that $CaCl_2$ at 3 percent and was emulsion at 6 percent were effective in increasing the shelf life of fruits upto 10.67 days over control (6.0 days).

Post harvest application of 1 percent Calcium nitrate maintained the edible quality of guava fruits for more than six days as against 3 days in untreated fruits (Singh *et al.*, 1981).

Chandramouli *et al.* (1996) reviewed the use of Calcium in post - harvest treatment and stated that post - harvest dipping or vacuum and pressure infiltration was effective in increasing Calcium level in fruit and subsequent increase in shelf life in banana *cv.* Robusta.

Studied by Suntharalingam (1996) on post harvest treatment of mangoes with Calcium, it was observed that mango fruits treated with 6 percent Calcium chloride had a shelf life of 9 days under ambient conditions and 14 days under cold storage.

Panpatil *et al.* (2000) reported that post harvest dip of Umran and Kadaka fruits in solution of Ca^{+2} salts (0.17 %) was found to be effective in extending the shelf life of ber fruits by 3 more days during ambient storage.

Bharathi and Srihari (2004) studied the effect of Calcium compounds on shelf life of sapota cv. Kalipatti, reported that Calcium nitrate 1.0 % resulted in maximum shelf life of 12.33 days.

Vijayalakshmi *et al.* (2004) reported that Calcium chloride dips at 4 % which recorded a shelf life of 13.5 days with good quality sapota fruits.

Santos *et al.* (2004) reported that 8 percent $CaCl_2$ treatment resulted in the 5 days increase in shelf life of mature green fruits of mango *cv.* Rosa when compared to control.

Raj Kumar *et al.* (2005) conducted an experiment to study the post harvest behavior of papaya by the application of Calcium and Gibberellic acid. The results of the study revealed that Calcium chloride @ 2 % resulted in high shelf life of fruits than the rest of the treatments.

Narayan *et al.* (2007) monitored the physico - chemical changes and organoleptic quality during ripening of banana and the extended green life was observed in 75% mature banana fruits may be due to the shift in the climacteric peak and reduction in chemical changes associated with ripening process.

Mahmud *et al.* (2008) reported that the postharvest dip treatments at different concentrations of calcium prolonged storage life, slowed down the ripening processes and maintained the quality of papaya. Calcium infiltration extended the storage life and retained the quality as calcium concentrations increased up to 2.5%.

Nirupama *et al.* (2010) found that the application of $CaCl_2$ 1.5 % treated tomato fruits recorded the least decay percentage minimum weight loss (5.57%) and prolong the shelf life up to 3 days.

Geetha *et al.* (2010) concluded that the shelf life of the fruits increased under vacuum packing with room and refrigeration temperatures for one and four weeks, respectively. During storage moisture, acidity, vitamin C and total sugar decreased whereas reducing sugars and total soluble solids (TSS) increased in papaya.

Jagadeesha *et al.* (2015) studied the exogenous application of chemicals, growth regulators in combination with Thiabendazole and found that significantly increased the shelf life of fruits treated with 150 ppm GA_3 + 200 ppm Thiabendazole for about 18 days of storage of banana fruit.

Babak Madani *et al.* (2016) reviewed that the higher calcium concentrations (1.5 and 2% w/v) increased calcium concentration in the peel and pulp tissues, maintained firmness, and reduced anthracnose incidence and severity. While leakage of calcium - treated fruit was lower for 1.5 and 2% calcium treatments compared to the control, microscopic results confirmed that pulp cell wall thickness was higher after 6 days in storage, for the 2% calcium treatment compared to the control. Calcium-treated fruit also had higher total antioxidant activity and total phenolic compounds during storage.

2.3.1.4 EFFECT OF CHEMICALS APPLICATION ON SPOILAGE (%) OF FRUIT CROPS

Singh *et al.* (1982) reported that the indicated that post harvest application of Calcium nitrate at 1% controlled the disease incidence in peaches.

Raj Kumar *et al.* (2005) observed that, the percentage of decayed was highest in the control as against the treated fruits in $CaCl_2$ and Ca $(NO_3)_2$ in papaya.

Bharathi (2002) observed that, sapota fruits, the spoilage percentage were least in benzyl adenine treatments with 50 and 25 ppm of 1.48 and 2.59 respectively.

Jagadeesha *et al*. (2015) studied the exogenous application of chemicals, growth regulators in combination with Thiabendazole significantly decreased post-harvest disease incidence leading to increase in post- harvest fruit quality and shelf life of banana. Among the treatments, post harvest dipping of fruits in 150ppm GA_3+200ppm Thiabendazole significantly increased firmness (3.70 Kg cm^{-2}) and titrable acidity (0.09%). While the parameters like PLW (13.53%), TSS (25.45^{O}B), Total sugars (18.88%), Reducing sugars (17.11%) and percent disease incidence (5.55) was observed minimum in the same treatment after 12th day of storage.

2.3.1.5 EFFECT OF CHEMICALS APPLICATIONONTOTAL SOLUBLE SOLIDS (^{O}Brix) OF FRUITS

Ripening is normally accompanied by an increase in TSS with enhanced production of ethylene in the fruit of mango (Subramaniyam *et al.,* 1962).

The increase in TSS during initial stages may be attributed to the fast conversion of starch and other polysaccharides into sugars and decrease in TSS at advanced stage in owing to the increased rate of respiration in guava (Mukherjee and Dutta, 1967).

Sundarajan and Rao (1967) reported that application of $CaCl_2$ @ 2% increased the TSS content of sapota fruits ranged from 18 to 25 percent.

Singh *et al.* (1982) reported that the retention of Total soluble solids was higher in Calcium treated guava fruits during ripening and also in peaches during storage.

Irrespective of treatments, the present findings in general showed that the TSS of papaya increased initially during storage up to few days and later on decreased as the storage period progressed (Selvaraj *et al*., 1982.).

Gorakh Singh (1988) reported that the TSS increased in treated fruits up to 3 days of storage and subsequently increased in fruits treated with 1.0 percent Calcium nitrate up to 6 days of storage and then decreased up to 9 days storage under all the treatments. This decrease in TSS at advanced stage was owing to the increased rate of respiration at later stage of storage.

Roy Choudhary *et al.* (1992) recorded the high total sugar in fruits during storage in litchi with pre harvest application of 0.6% Ca as $CaCl_2$.

Lakshmana and Reddy (1999) studied the pre harvest application of calcium chloride and nitrate through foliar sprays on the post harvest behavior and quality of sapota fruits. Sapota treated with $CaCl_2$ (1%) showed significantly increased TSS in fruits during storage.

Patil *et al.* (2003) studied the effect of pre and post harvest treatment on shelf life of mango fruit and the results showed that the pre harvest spray with calcium chloride (1%) significantly recorded maximum TSS, hence improved the quality of fruits.

Among the Calcium compounds, highest TSS (20.25) was recorded in sapota fruits treated with $Ca(NO_3)_2$ 1.0 percent which as significantly higher than all other treatments and lowest was in control (19.24) reported by Bharathi and Srihari (2004).

The Fig cv. Deanna and Conadria were sprayed with1% $CaCl_2$10days before harvest recorded significantly higher TSS which was gradually increasing during storage (Kardum, 2004).

Raj Kumar *et al.* (2005) observed that the TSS value increased linearly from 3^{rd} day till end of the experiment. Papaya fruits treated in $CaCl_2$@ 2 % had maintained higher TSS during storage.

Gore (2005) observed effect of pre harvest foliar spray of $CaCl_2$ (1%) 10 days before harvest; in fig fruit cv. Dinakar and Poona fig. The treatment increased TSS content continuously throughout storage period irrespective of the treatments and varieties.

Mahumud *et al*. (2008) found that Calcium infiltration treatment at 2.5 % and 3.5 % in papaya fruits significantly lowered contents of TSS compared to other treatments.

Singh *et al.* (2012) to evaluate the effects of various concentrations of $CaCl_2$ (1.0%, 2.0%, 3.0% and 4.0%) on shelf life of papaya fruits when stored under ambient conditions. The treated fruits wereobserved for physiological changes such as loss of fruit weight (%), percentage of ripening, biochemicalaspects such as TSS (^{O}Brix), titratable acidity (%), ascorbic acid content (mg/100g), total sugars (%), reducing sugars (%), total carotenoids (mg/100g) along with sensory evaluation. The observations wererecorded at 3, 6 and 9 days after storage.

Babak Madani *et al.*, (2014) reported that the foliar sprays of 0, 0.5%, 1%, 1.5% and 2% (w/v) calcium chloride were applied six times during the growing season. After harvest, fruits were stored at 12ºC for up to three weeks. Higher calcium concentrations in the sprays coincided with increasing calcium concentrations in peel and pulp tissues, higher firmness and titratable acidity, and reduced respiration rate, ethylene production and soluble solids concentrations, compared with those of the untreated control fruits.

Jagadeesha *et al*. (2015) studied the exogenous application of chemicals, growth regulators in combination with Thiabendazole and found significantly decreased post-harvest disease incidence leading to increase in post- harvest fruit quality and shelf life of banana. Among the treatments, post harvest dipping of fruits in 150ppm GA_3 + 200 ppm Thiabendazole significantly increased banana firmness (3.70 kg/cm^2) and titrable acidity (0.09%). While the parameters like PLW (13.53%), TSS (25.45ºB), total sugars (18.88%), reducing sugars (17.11%) and percent disease incidence (5.55) was observed minimum in the same treatment after 12th day of storage. The shelf life of fruits treated with 150 ppm GA_3 + 200 ppm Thiabendazole could be extended successfully for about 18 days of storage.

2.3.1.6 EFFECT OF CHEMICALS APPLICATIONON SUGARS (%) OF FRUITS

Ripening phase in Co-2 papaya fruits was characterized by increase in the level of total sugars. Fractionation of sugars revealed that sucrose, fructose and glucose were present in papaya fruits (Chittraiselvan and Shanmugavelu, 1977). In five varieties, early development stages registered comparatively more starch which decreased until about 75 days of fruit growth and remained at the same level until ripe stage.

The main feature of the process of ripening in the formation of sugars by the hydrolysis of starch. Irrespective of treatments, it was found that the total, reducing and non-reducing sugars of fruits increased up to certain period of storage and declined thereafter till the end of shelf life. Selvaraj *et al.* (1982) in papaya.

Mahajan and Sharma (1995) reported that the total sugars content which were fairly low initially, increased to the maximum on 9th day of storage and declined thereafter when the Dashehari mango fruits were dipped in Calcium chloride solutions (2, 4, 6 and 8%).

Rokhade and Jagadeesh (1995) reported that the decrease in reducing and non-reducing sugars of guava fruits on post - harvest dipping of Calcium nitrate 1.0 percent and Calcium chloride 2.0 percent.

Bharathi and Srihari (2004) reviewed that the Calcium compounds, the sapota fruits treated with Ca $(NO_3)_2$ 1.0 percent recorded highest total sugars (1.09) and lowest percentage was observed in $CaSO_4$ 1.0 percent (9.73).

2.3.1.7 EFFECT OF CHEMICALS APPLICATION ON ACIDITY (%) OF FRUITS

Singh *et al.* (1981) reported that post harvest application of 0.5 to 1 percent Calcium chloride on guava decreased the tritable acidity. The concentration of total and non-volatile acids decreased during fruit development reaching a minimum at the ripe stage. Citric Acid, Malic acid and Tartatic acid have been identified by Selvaraj *et al.* (1982). The other acids identified are 2-ketoglutaric acid and galacturonic acid. Citric acid was the commonest acid and together with malic acid, formed 32 to 39 percent of non-volatile acidity. A minor amount of tartaric acid was observed at all stages of development (Selvaraj *et al.,* 1982).

Drake and Spayad (1983) observed that Calcium chloride @ 2 percent treated apples had high titratable acidity of 0.29 percent.

Siddiqui and Gupta (1988) observed that, acidity as well as vitamin-C contents decreased up to 14.2 mg g^{-1} as the storage period progressed to 2 days due to post-harvest application of Calcium chloride @ 4 % in ber.

The acidity decreased from 0.33 to 0.27 as the storage period progressed in study on the effect of post harvest application of Calcium chloride @ 2% on storage behavior of ber (Siddiqui and Gupta, 1988).

Raj Kumar *et al.* (2005) studied the effect of post harvest behavior of papaya by the application of Calcium and Gibberellic acid. The results of the study revealed that Calcium chloride @ 2 percent resulted in high titrable acidity (0.28 percent) than the untreated fruits (0.20 percent).

Raj Kumar *et al.* (2005) observed that the papaya fruits treated in GA_3 @ 100 ppm and $CaCl_2$ @ 2 % has maintained higher titrable acidity value at the end of 9th day.

Mahumud *et al*. (2008) observed that the papaya fruits dipped in calcium at 2.5 and 3.5 % showed higher levels of acidity (0.29%).

Rajput *et al.* (2008) found that the maximum shelf life of 8 days whereas, minimum titrable acidity of 0.13 % was obtained under 2.0 % Ca $(NO_3)_2$ pre - harvest spray and 2.0 % Ca $(NO_3)_2$ post-harvest dip in guava fruits.

2.3.1.8 EFFECT OF CHEMICALS APPLICATION ON ASCORBIC ACID OF FRUITS (mg /100g of pulp)

Dhaka *et al.* (2001) reported that the mango treated with $CaCl_2$ (1 percent) and wax emulsion (8 percent) were most effective in reducing ascorbic acid loss. The lower TSS and higher ascorbic acid content in fruits under cool chamber storage.

Borase v*et al.* (2004) reported that the fruit treated with GA_3 had longer shelf life, lower percentage of weight loss and spoilage, increase in total soluble solids and ascorbic acid in papaya.

Raj Kumar *et al.* (2005) conducted an experiment to study the post harvest behavior of papaya by the application of calcium and Gibberellic acid. The results of the study revealed that calcium chloride @ 2 percent resulted in high ascorbic acid than the rest of the treatments.

Rajkumar and Manivannan (2007) reported that the postharvest dipping of papaya fruits either GA_3 or $CaCl_2$ preserved the fruits extending the shelf life upto days without any decline in fruit quality.

Biradarpatil *et al*. (2015) reported that the maximum per cent of total soluble solids and acid ratio (67.57) and ascorbic acid content (3.28 mg/ 100 g pulp) were observed in 2% calcium nitrate bunches followed by 2% calcium chloride and 200 ppm NAA in grape.

2.3.2 EFFECT OF GROWTH REGULATORS ON PHYSICAL PARAMETERS

Post harvest GA_3 treated fruits slowed down the ripening process by retarding the pre - climatric respiration rate and ethylene production and through postponement of their climatric peaks compared to untreated control fruits (Gautam and Chundawat, 1989). It may be attributed to its antagonositc effect on biosynthesis of ethylene (Diller, 1969). Consequently, biochemical changes involved in the ripening process might be retarded (Kharder *et al.,* 1988).Apart from varied functions in the plants it was reported that gibberellins aid in the storage of fruits and vegetables. Certain plant growth regulators have been shown to enhance the storage life of many fruits (Gorakh Singh, 1988). The use of plant growth regulators has now assumed an invaluable significance in fruit crops.

2.3.2.1 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON PHYSIOLOGICAL LOSS IN WEIGHT (%) OF FRUITS

Lowest physiological weight loss of 12.13 percent was observed in post harvest treated banana with GA_3 at 150 ppm and waxol when compared to control on 16^{th} day of storage (Rao and Chundawat, 1984).

The significant reduction in the weight loss was observed in 75 ppm GA_3 treated fruits of sapota packed in polythene bags after 11 days, the loss was 11.89

per cent as against 90.2 percent in untreated open fruits (Kumbhar and Desai, 1986).

Khader *et al.* (1988) reported that mango fruits treated with GA_3 @ 200 ppm retarded the total loss in weight of 16.74 over control fruits of 26.45.

Singh (1988) reported the significant effect of calcium nitrate (1 percent) + NAA (100 ppm) and GA_3 (40 ppm) in minimizing the loss in weight of Allahabad safeda guava during storage.

According to Robert and Nancy (1989), stomatal density on papaya fruit was found to be 2340/cm^2. The stomata are appeared to be open. The maximum weight loss rate was 3500 mg/cm^2/day from the cut stem and it was 220 times greater than that loss through the skin but the total loss was great through the skin as it has largest surface area

Sundbhor and Desai (1991) reported that ber fruits treated with 100 ppm BA and packed in polyethylene had weight loss of 5.35 percent after 8 days of storage.

Saraswathi and Azhakiamanavalan (1997) found that the physiological loss in weight was least (6.30 %) in GA_3@ 50 ppm treated fruits of mandarin oranges during post - harvest storage.

The sapota fruits treated with 150 ppm GA_3 exhibited least percentage 4.87 of physiological loss in weight (Patel and Katrodia, 1998).

Bharathi (2002) observed that the growth regulator GA_3 200 ppm recorded significantly lower PLW (7.89) and control recorded the highest PLW (11.58), which differed significantly with other treatments.

Bharathi (2002) observed that sapota fruits treated with Benzyl adenine 50 and 25 ppm recorded significantly lower PLW 6.04 and 6.77 and the highest was in control (10.96).

Jacomino *et al*. (2003) reported that, waxing delayed ripening and reduced the weight loss and decay incidence in guava cv. Pedro Sato.

Raj Kumar *et al.* (2005) conducted an experiment to study the post harvest behavior of papaya by the application of Calcium and Gibberellic acid. The results of the study revealed that Gibberellic acid @ 100 ppm resulted in minimum physiological loss of weight of 4.21 percent.

Madhavi *et al*. (2005) observed that PLW in sapota fruit with GA_3 200 ppm recorded significantly lower (3.19) where as highest was recorded in control (8.59).

Devi and Arumugam (2008) observed that the bio fungicide (*T. harzianum*) in combination with 8 percent wax recorded the least PLW and extended shelf life of banana under ambient storage condition.

Ansari and Feridoon (2008) reported that the wax treatment minimized fruit weight loss and maintaining higher tissue firmness after 3 months at 6ºC in Valencia and local orange cv. Siavarz.

Raj Kumar *et al*. (2008) evaluated the effect of four levels of paraffin wax emulsions *viz.,* 3, 4, 5 and 6 percentages. It was prepared by adding oleic acid, triethanolamine and hotwater. The wax emulsions were coated on fully matured mangoes to assess the shelflife of wax coated mangoes stored at ambient conditions. The result showed that theshelf life of 6% wax emulsion coated mango fruits could be extended up to 12 daysand for the control it was only 7days.

Singh *et al,* (2012) recorded maximum marketability (89.35 percent) and minimum physiological losses in weight (15.06 percent) in the fruits treated with bavistin @ 500 ppm along with wax emulsion @ 6 percent, with treatment of $CaNO_3$ @ 1.5 percent. Combined application of bavistin (500 ppm) with wax emulsion (6 percent) is the most effective for increasing fruit marketability and quality of Dashehari mango.

Saravanan (2013) reviewed that an indigenous ethylene scrubber made out of filter paper delayed ripening of fruits (35.20) days meanwhile the control fruits ripened within (19.80) days and the peel colour was green with traces of yellow in all the treated fruits. The control fruits were yellow with green tips. Wax coating in combination with hot water and ethylene absorbent had effectively extended green life than when wax alone used at different concentration. Maximum green life was observed in 6 percent wax coated fruits in combination with hot water and ethylene absorbent. Meanwhile green life for control was only (21.80) days. Wax coating also reduced PLW to the minimum (3.02 to 4.84 %) as against (7.27 percent) in the control.

Ali Eskandar *et al.* (2014) reported that the coating of Sweet Lemon fruit with 10 percent Arabic Gum mainly reduced fruit rot and skin color changes after 3 months of storage. But olive oil treatments increased the level of fruits contamination. Maximum weight loss of control treatments was after 1.5 and 3 months of storage. Concentrations of 5 and 10 percent Arabic Gum significantly increased solids soluble and vitamin C and reduced pH, phenolic substances and titratable acidity. concentrations of 30 and 45 percent Olive oil also reduced soluble solids, vitamin C and weight loss, and total phenols increased, but had no significant effect on acidity.

Bibi and Baloch, (2014) reported that coatings basedon starch, olive oil, beeswax and sodium benzoate has been evaluated with referenceto the shelf life and quality of mango (Langra and Samar Bahisht Chaunsa). The fruitwere stored at various temperatures until they ripen. The weight loss & waste percentwas lowest, and the shelf life was longest in beeswax coating, whereas the best qualitywas reported in starch - based coating as compared with others.

Verma *et al*. (2015) reported that the wax emulsion (6 percent) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1 percent) treated mango fruits at the end of storage.

Pradeep Raj Rokay *et al.* (2016) reported that the wax in combination with bavistin was found as the most effective in reducing the physiological loss in weight, whereas bavistin proved to reduce decay loss up to four weeks of storage.

Thana *et al.* (2017) reviewed that all treatments helped to minimize the deterioration of quality Navel orange in all storedperiods of cold storage. All treatments decreased weight loss, decay and delayed the changes inpercentage of juice, total soluble solids, titratable acidity, carotene content and vitamin C compared with untreated fruits especially rosemary extract at 4% exhibited the best results in preserving fruit quality during the storage, thus prolongs postharvest shelf life during shipping and marketing also safe on human health and environmental.

2.3.2.2 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON FIRMNESS (Kg cm^{-2}) OF FRUITS

Desai and Deshpande (1978) observed that, firmness of banana fruit was maintained for longer period by GA_3@ 100 ppm reflecting the retarded nature of ripening.

Gibberellic acid @ 100 ppm resulted in highest fruit firmness (2.5 kg cm^{-2}) than untreated papaya fruits (Rajkumar *et al.*, 2005).

Prasanna Lakshmi (2005) reported that, mango cv. Baneshan treated with benzyl adenine reduced the loss in weight.

Jayachandran *et al.* (2007) observed that the guava fruits treated with benzyl adenine (50 ppm) recorded the highest firmness (4.03 kg cm^{-2}) over the control (1.93 kg cm^{-2}).

Ansari and Feridoon (2008) reported that the wax treatment minimized fruit weight loss and maintaining higher tissue firmness after 3 months at 6^{o}C in Valencia and local orange cv. Siavarz.

Singh *et al,* (2012) reviewed that the recorded maximum marketability (89.35%) and minimum physiological losses in weight (15.06 percent) in the fruits treated with bavistin @ 500 ppm along with wax emulsion @ 6 percent, with treatment of $CaNO_3$ @ 1.5 percent. Combined application of bavistin (500 ppm) with wax emulsion (6 percent) is the most effective for increasing fruit marketability and quality of Dashehari mango.

Babak Madani *et al.*, (2014) reported that the foliar sprays of 0, 0.5 percent, 1 percent, 1.5 percent and 2 percent (w/v) calcium chloride were applied six times during the growing season. After harvest, fruits were stored at 12^{o}C for up to three weeks. Higher calcium concentrations in the sprays coincided with increasing calcium concentrations in peel and pulp tissues, higher firmness.

Pradeep Raj Rokay *et al.* (2016) reported that the mandarin fruits treated with wax alone and with combination of bavistin retained maximum firmness and juice percentage.

2.3.2.3 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON SHELF LIFE (DAYS) OF FRUITS

Plant growth regulators have become an important input in fruit production for their modifying effects on plant development especially on post harvest shelf life of fruits.

Sundararaj *et al*. (1971) observed that, two coatings with wax emulsion greatly retarded the rate of ripening and extended the shelf life of Dwarf Cavendish banana.

Sadasivam and Muthuswami (1973) observed that, Dwarf Cavendish banana with double coating of 12 percent wax emulsion prolonged the storage life and reduced the weight loss of whole bunches held at 58ºF. The wax coating also increased the storage period by 5 days at room temperature and by 10-12 days at refrigerated temperature in detached hands of banana.

Bhullar and Farmahan (1980) observed that, the treatment of Safeda guava fruits with 6 per cent wax emulsion retarded the rate of ripening and prolonged the storage life up to 10 days with minimum physiological loss in weight (8.2 percent).

Mehta *et al.* (1986) found that the post-harvest application of GA_3 at 100 ppm extended shelf life of papaya fruits up to 15 days whereas the control fruits exhibited shelf life of 9 days without adverse affects on palatability.

Patel and Katrodia (1996) reported that fruits treated with 150 or 200 ppm Gibberllic acid or 2000 ppm Maleic hydrazide in combination with bavistin 500 ppm delayed ripening and extended shelf life of 3.57 days in sapota.

In order to extend the shelf life of sapota fruits *cv.* Kalipatti under ambient conditions they were dipped in GA_3 at 300 ppm and Kinetin at 100 ppm. These treatments extended the ripening period by 2.5, 1.5 and 1.0 day respectively over the untreated fruits which were ripened in 5.2 days (Gautam and Chundawat, 1990).

Patel and Katrodia (1998) observed an extension of shelf life of sapota fruits *cv.* Kalipatti for 7 days compared to control when the fruits were treated with 150 ppm Gibberellic acid.

Bharathi (2002) reported that fruits treated with GA_3 200 ppm resulted in maximum shelf life of 11.66 days whereas untreated fruits recorded 6.82 of days in sapota.

The highest shelf life over the untreated fruits was observed with the application of Gibberellic acid @100 ppm (Rajkumar *et al.*, 2005) in papaya crop.

Lakshmi (2005) observed that fruits treated with BA 50 ppm resulted maximum shelf life (18.59 days) which was on par with BA 25 ppm (18.09 days) followed by GA_3 200 ppm (16.79 days) in mango.

Akath Singh Yadav *et al.* (2006) observed that the use of wax emulsion (paraffin liquid light) and lining materials (polyethylene or newspaper) with or without ethylene absorbent ($KMnO_4$, 100 ppm) on banana at ambient conditions The shelf life (21 days) including the green life (12 days) and yellow life (9 days) were highly enhanced in fruits with wax coating along with polyethylene wrapping and ethylene absorbent.

Sudha *et al.* (2007) studied that the post harvest dipping of GA_3 @ 50 ppm along with 0.2 percent bavistin recorded the lowest physiological loss of weight (1.39 percent), increased shelf life (12.67 days) in sapota.

Jayachandran*et al.* (2007) reported that the fruits treated with benzyl adenine recorded higher shelf life of 14.0 days and 13.33 days at 50 ppm and 25 ppm in guava cv. Lucknow - 49 respectively. While untreated fruits recorded the lowest shelf - life of 7 days.

Sunil *et al.* (2009) observed the effect of wax coating, combined with packing in polyethylene bags (with 2 percent and no ventilation) of yelakki banana at ambient condition. The fruits waxed with 1:1 dilution increased the shelf life, both in polyethylene bags packing (13 days) and without packing (10 days).

Alam *et al.* (2010) found that among growth regulator treatments the maximum (13.21 days) shelf life was observed in Benzyl adenine treated papaya fruits followed by GA_3 (12.26 days).

Jawadagi (2013) reported that the most effective post harvest treatment to extend the storage life of custard apple fruits. The application of the wax emulsion at 10 % recorded significantly minimum PLW (7.51 percent) as compare to other treatments. The treatment also recorded the highest acidity, lowest TSS, Lowest rotting and maximum marketable fruits after five days.

Virgilio Cruz *et al*. (2015) reported thatcoated pears coded as T_{13} (Candelilla wax 3 percent, gum arabic 4 percent, jojoba oil 0.15 percent, and pomegranate polyphenols 0.015%) extended and improved their shelf life quality due to the minimization of the physic - chemical changes and sensorial properties. Therefore, the results indicated that the formulated edible coating has potential to extend the shelf life and maintain quality of pears. It was probed that coated pears were accepted for consumers as a good product. Edible coating application represents a good alternative to keep pears freshness for longer periods.

The individually shrink wrapped, lac-wax and citrashine coated fruits could be stored up to 21 days in ambient conditions without much loss of quality. However, control fruits developed shriveling and slight off-flavour after 14 days of storage of Kinnow reported by Goutam Mandal, (2015).

2.3.2.4 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON TOTAL SOLUBLE SOLIDS (^{O}Brix) OF FRUITS

Mehta *et al.* (1986) observed that an increase in TSS (13.87 ^{O}Brix) in fruits when treated with 100 ppm GA_3 and 100 ppm Kinetin in papaya.

Patel and Katrodia (1998) found that post - harvest treatment of GA_3 at 150 ppm exhibited increase in total soluble solid content in fruits after five days of treatment when compared to untreated fruits of sapota.

Raj Kumar *et al.* (2005) reported the highest total soluble solids (13.56 ^{o}Brix) with the application of 100 ppm of Gibberellic acid when as control reduced 12.03^{o} Brix in papaya.

Hassan *et al.,* (2014) reported that the combination of 12 percent wax coating and storage at 5^{O}C was the most effective treatment in maintaining the quality of tangerine citrus var. Siam Banjar, which was significantly ($p<0.05$) indicated by the lowest percentage incidence of fruit rot (17.67 percent). There are no significantly changes ($p>0.05$) in term of quality attributes of the fruits (titratable acidity, total soluble solids, ascorbic acid), although physio-chemical analysis revealed that this treatment had higher level of titratable acidity (0.53 citric acid/100 ml), lower level of TSS (9°Brix), and the higher level of ascorbic acid (38.2 mg ascorbic acid/100g) compared to the other treatments.

Verma *et al*. (2015) reported that the wax emulsion (6 percent) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1 percent) treated mango fruits at the end of storage.

Pradeep Raj Rokay *et al.* (2016) reported that the mandarin fruits treated with wax alone and with combination of bavistin retained maximum firmness, juice percentage, vitamin C and palatability rating during the storage. The minimum total soluble solid and maximum titrable acidity were recorded in the fruits treated with wax plus bavistin.

2.3.2.5 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON SUGARS (%) OF FRUITS

Mehta *et al.* (1986) reported that the decrease in the level of total sugars (10.73 %), when papaya fruits were treated with Gibberellic acid at 100 ppm during storage when compared to control fruits (13.38 percent).

Desai *et al.* (1990) reported that, Thompson seedless variety treated with Benzyl adenine and Naphthalene acetic acid @ 75 ppm showed better sugar content (11.08 %) over control (10.02) even after 6 days of treatment in grapes.

Rao and Chundawat (1984) reported that post-harvest treatment of banana *cv.* Basrai with $GA_3$150 ppm and waxol 12 percent increased the content of total sugars (13.04%) during storage period.

Saraswathi and Azhakiamanavalan (1997) found that post-harvest treatment of mandarin orange fruits with GA_3 exhibited increased content of reducing sugars (8.70 percent) and total sugars during storage period when compared to the control (7.88 percent).

Firmin (1997) reviewed that the starch content decreased while the total sugar, reducing sugar and ascorbic acid increased.

Bharathi (2002) observed that untreated fruits recorded the highest total sugars of 11.14 and least was recorded in GA_3 200 ppm.

The exogenous supply of Gibberellins did not alter the respiration or the ethylene profile but delayed sucrose accumulation by at least 2 days during banana ripening (Rossetto *et al.*, 2004).

Sahoo and Munsi (2004) observed that the sugars was highest (10.4 percent and 9.8 percent) in sapota fruits treated with GA_3 (100 ppm) and $AgNO_3$ (50 ppm) respectively with perforated polythene bags.

Madhavi *et al*. (2005) observed that sugars was found to be significantly low (9.35 percent) in fruits treated with 2, 4 - D @ 4 ppm followed by GA_3 @ 200 ppm in sapota.

Bharadwaj *et al.* (2005) reported that the mandarin cv. Nagpur Santra fruits treated with 100 ppm BA showed lowest increase in TSS (13.20 ^{O}Brix) and total sugars (7.80 percent) on 42 day of storage when compared to the untreated fruits (10.47 ^{O}Brix).

Jayachandran *et al.* (2007) reported that the least reducing sugars (15.02 percent) content was found in untreated fruits, while benzyl adenine treated fruits recorded the highest reducing sugars (17.57 percent) in guava cv. Luknow-49.

Bharadwaj *et al.* (2010) reported that the total sugars content was increased with the advancement of storage period from 5.65 to 7.21 percent and minimal increase in fruits treated with 20 percent neem leaf extract with 100 ppm Benzyl adenine during storage in citrus fruits.

Verma *et al*. (2015) reported that the wax emulsion (6 percent) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1%) treated mango fruits at the end of storage.

Pradeep Raj Rokay *et al.* (2016) reported that the wax in combination with bavistin was found as the most effective in reducing the physiological loss in weight, whereas bavistin proved to reduce decay loss up to four weeks of storage. The mandarin fruits treated with wax alone and with combination of bavistin retained maximum firmness, juice percentage, vitamin C and palatability rating during the storage. The minimum total soluble solid and maximum titrable acidity were recorded in the fruits treated with wax plus bavistin.

Thana *et al.* (2017) reviewed that all treatments helped to minimize the deterioration of quality Navel orange in all storedperiods of cold storage. All treatments decreased weight loss, decay and delayed the changes inpercentage of juice, total soluble solids, titratable acidity, carotene content and vitamin C compared with untreated fruits especially rosemary extract at 4% exhibited the best results in preserving fruit quality during the storage, thus prolongs postharvest shelf life during shipping and marketing also safe on human health and environmental.

2.3.2.6 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON ACIDITY (%)

Khader *et al.* (1988) reported that maximum titratable acidity of 0.35 percent was observed that fruits treated with GA_3 at 200 mg lit^{-1}, while control fruits recorded 0.23 percent in mango.

Kumbhar and Desai (1986) reported continuous decrease in acidity of sapota fruits in all treatments. However, the decreases as slow in treated fruits as against untreated fruit. GA_3 showed slow decreases in acidity.

Jagadeesh *et al*. (2001) reviewed that the acidity was higher with 6 and 9 per cent waxol treatments than with other treatments in guava cv. Sardar

Jain *et al*. (2001) reported that the maximum acidity was recorded with wax emulsion (8 percent) plus cool chamber storage in mango *cv*. Langra

The TSS/Acid ratio was found to be higher in mango fruits treated with ascorbic acid 500 ppm and least was observed with sodium benzoate (Vanajalatha, 2001).

Among growth regulators treatments, fruits showed the highest acidity was observed in GA_3 200 ppm (0.254) and lowest in control (0.106) by Bharathi (2002).

Bharathi (2002) observed that among antioxidants, the titrable acidity decreased significantly from 0.241 on day 1 to 0.159 on 7 day. The highest (0.235) being in fruits treated with BA 50 ppm followed by BA 25 ppm (0.224) and control recorded the least percentage of titrable acidity (0.091).

Sahoo and Munsi (2004) observed that the rate of decreases in acidity was more in sapota fruits treated with 100 ppm GA_3 (0.103 percent) and 50 ppm $AgNO_3$ (0.115 percent) respectively and kept in perforated polyethylene bags.

Vijayalakshmi *et al.* (2004) observed that the maximum acidity was recorded with the fruits dipped in 150 ppm GA_3 in sapota fruits.

In papaya Rajkumar *et al.* (2005) observed the highest titrable acidity (0.08 percent) with the application of Gibberellic acid @ 100 ppm when compared to control (0.05 percent).

The rate of decreases in acidity was found to be significantly slow in sapota fruits treated with 4 ppm 2, 4-D and 200 ppm GA_3 indicating retarded tissue respiration compared to the other treatments by Madhavi *et al.* (2005).

Rajkumar *et al.* (2005) observed that the papaya fruit treated with GA3 @ 100 ppm has maintained higher titrable acidity value at the end of 9^{th} day.

Jayachandran *et al.* (2007) reported the maximum acidity of 0.73 in control guava fruits while BA treatment recorded minimum acidity.

Jawadagi (2013) reported that the most effective post harvest treatment to extend the storage life of custard apple fruits. The application of the wax emulsion at 10 % recorded significantly minimum PLW (7.51%) as compare to other treatments. The treatment also recorded the highest acidity and maximum marketable fruits after five days.

Hassan *et al.* (2014) reported thatthe combination of 12% wax coating and storage at 5 ^{O}C was the most effective treatment in maintaining the quality of tangerine citrus var. Siam Banjar. Physio - chemical analysis revealed that this treatment had higher level of titratable acidity (0.53 citric acid/100 ml), lower level of TSS (9 ^{O}Brix) and the higher level of ascorbic acid (38.2 mg ascorbic acid/100g) compared to the other treatments.

Abhay Bisen *et al*. (2012) was conducted an experiment was conducted to assess theinfluence of chemical and oil coatings on storage life of kagzi lime fruits. The edible oil emulsion coatingparticularly coconut oil had significantly effect onmaximum total solublesolids (8.43%), ascorbic acid (49.93 mg/100 ml juice), acidity (1.52 percent) and juice content (42.34 percent) of fruits.

Verma *et al*. (2015) reported that the wax emulsion (6 percent) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1%) treated mango fruits at the end of storage.

Pradeep Raj Rokay *et al.* (2016) reported that the mandarin fruits treated with wax alone and with combination of bavistin retained juice percentage, vitamin C and palatability rating during the storage. The minimum total soluble solid and maximum titrable acidity were recorded in the fruits treated with wax plus bavistin.

2.3.2.7 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON SPOILAGE (%)

Bharathi (2002) observed that, sapota fruits, the spoilage percentage were least in benzyl adenine treatments with 50 and 25 ppm of 1.48 and 2.59 respectively. Growth regulator, GA_3 200 ppm recorded lower percentage of spoilage (4.44%) and control recorded the highest percentage (15.55).

Prasanna Lakshmi (2005) observed that, post harvest application of growth regulators BA 20; 50 ppm and GA_3 200 ppm reduced the spoilage in mango.

Bhardwaj *et al*. (2005) observed that, the rotting percent increased with the advancement of storage period and benzyl adenine treated Nagpur santra recorded less rot incidence and decay.

Rajkumar*et al.* (2005) observed that, the percentage of decayed was highest in the control as against the treated fruits in $CaCl_2$, Ca $(NO_3)_2$, GA_3 in papaya.

Verma *et al*. (2015) reported that the wax emulsion (6%) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1%) treated mango fruits at the end of storage.

Pradeep Raj Rokay *et al.* (2016) reported that the wax in combination with bavistin was found as the most effective in reducing the physiological loss in weight, whereas bavistin proved to reduce decay loss up to four weeks of mandarin storage.

2.3.2.8 EFFECT OF GROWTH REGULATORS AND WAX EMULSION ON ASCORBIC ACID (mg/100g pulp) OF FRUITS

Harris and Poland (1937) made a comparative study on variation in ascorbic acid content of banana and reported a decrease during ripening.

Garg *et al*. (1976) studied the chemical changes during ripening of mango with wax treatment at room temperature and at low temperature (5.5 -7.2^{O}C). It was noticed that vitamin - C recorded higher in wax treated fruits (15.0 mg/100 gm) when compared to control of 3.5 mg/100g on 24th day. Likewise at room temperature, skin coating singly or in combination with pre - packing and showed greater retention of vitamin - C content.

Jain and Chitkara (1980) conducted a study on the effect of different packing material in transportation and quality of ber fruits (umran) and observed lower retention of vitamin - C in fruits packed with mulberry baskets.

Tripathi *et al*. (1983) showed that, variation ranged from 11.6-15.6 mg/100 g vitamin - C in raw banana fruits different varieties. The minimum vitamin C content at maturity was observed in Dudhia Hal Bhog (15.6 mg/100 g).

Verma *et al*. (2015) reported that the wax emulsion (6 percent) was the best treatment to minimize the weight loss and spoilage of fruits. Retention of the original TSS and total sugars was also best in the same treatment. While, maximum acidity and ascorbic acid were found in GA_3 (200 ppm) and calcium nitrate (1%) treated mango fruits at the end of storage.

Aml *et al.* (2015) review that chitosan coating at 1 percent and mango leaves extract with gelatin at 2 percent could be more effective in keeping fruit firm with the least respiration rate, titratable acidity and the highest value for soluble solid content, ascorbic acid, weight of juice and volume during storage period at 5^{O}C than all other coating treatment compared with untreated fruit (control).

Pradeep Raj Rokay *et al.* (2016) reported that the mandarin fruits treated with wax alone and with combination of bavistin retained maximum firmness, juice percentage, vitamin C and palatability rating during the storage.

Thana *et al.* (2017) reviewed that all treatments helped to minimize the deterioration of quality Navel orange in all storedperiods of cold storage. All treatments decreased weight loss, decay and delayed the changes inpercentage of juice, total soluble solids, titratable acidity, carotene content and vitamin C compared with untreated fruits especially rosemary extract at 4% exhibited the best results in preserving fruit quality during the storage, thus prolongs postharvest shelf life during shipping and marketing also safe on human health and environmental.

2.4 EFFECT OF DIFFERENTPACKAGING MATERIAL ON SHELF LIFE AND QUALITY OF PAPAYA

Normally in fruit crops during the peak period of harvest there is a glut in the market. In order to gain considerable time to market the produce and to avoid glut, it becomes essential to extend the shelf life of the fruits for a considerable period. Extension of shelf life may be possible by reducing the rate of transpiration and respiration, besides checking the microbial infection. The latest technique which is gaining ground in Indian food industry is modified atmosphere packaging.

2.4.1 PHYSIOLOGICAL LOSS IN WEIGHT (%)

Packaging is a vital component of post - harvest management to assemble the produce into convenient units and to protect it from deterioration during handling and marketing.

Adequate packaging protects the fruits from physiological pathological and physical deterioration in marketing channels and retains their attractiveness (Mani *et al*. 1993). The packaging should provide a convenient unit for marketing and packaging must maintain strength and shape of fruits for long periods (Wasker, 1997).

Papaya fruits are individually wrapped in newspaper and then packed in baskets stuffing the space between them with straw or saw dust (Anonymous, 1986).

Paull and Chen (1989) observed that weight loss could be reduced by 90 per cent of shrink wrapped ‘Solo’ papaya when stored at 10 ^{O}C. fruit ripening was delayed by one to two days after the fruit were ripened in air, however, some off - flavour was also developed.

The fruits are packed in used CFB cartons. Each carton contains 25-30 fruits weighing a total of 30 kg. The cartons are lined with neem or papaya leaves, both at the bottom and at the top. The packaging is done in the field itself. However, for the short distance transport, the fruits wrapped in newspaper are closely staked in the truck (Chelvan, 1989).

Mango cv. 'Kent' fruits individually sealed in LDPE and HDPE films having thickness 0.01 and 0.02 mm respectively, for four weeks at $20^{O}C$, delayed ripening, reduced weight loss and did not result in any off-flavor (Gonzalez *et al*. 1990).

Mosca and Durigan (1995) investigated that 'Sunrise Solo' papayas wrapped individually with PVC stretch film or sealed individually under partial vacuum in PE bags and stored at $12^{O}C$, reduced weight loss, delayed development of external color and decay and increased storage life at least 11days compared with control.

Emerald *et al.* (2001) reported that the fruits packed in 400 gauge low density polyethylene bags under various modified atmospheres and stored at ambient conditions and resulted the changes in physiological loss in weight during storage. All the treatments slowed down the process of ripening compared to the control. Fruits recorded the minimum changes in physicochemical characteristics and extending the shelf life of sapota fruits by about 4-5 times compared to the control.

Mia (2003) conducted an experiment on the postharvest behavior of papaya and reported that unperforated polythene bag and wax coated fruits showed minimum weight loss during storage, whereas the untreated fruits exhibited maximum weight loss.

Gonzalez-Aguilar *et al.* (2003) studied methyl jasmonite and modified atmosphere packaging (MAP) in combined action which resulted in the reduction ofprevented water loss and maintained post-harvest quality of papaya fruits of Sunrise variety.

Raheel Anwar *et al.* (2008) reviewed that the fruits were packed in traditional wood packaging with newspaper liner (WP) and corrugated cardboard packaging (CBP) for comparison. In first experiment, CaC_2 (2g kg^{-1} of fruit) was used for ripening of mangoes in comparison with ethylene (C_2H_4) application (100 ppm, 20 ^{O}C, 48 h), followed by ripening at ambient conditions (33±1^{O}C and 60-65% RH). CBP fruit showed significantly lower fresh fruit weight loss (FWL) and better shelf life compared with WP fruit treated with or without CaC_2.

Singh Akath *et al.* (2011) reported that shelf life of paraffin wrapped (m.p 60-62 ^{O}C) fruits was 25 days when packed in CBF boxes using high density polythene (0.03mm) pad, as well as decreases of weight loss, decay loss and juice content was also slowed down with paraffin waxing.

Ali *et al.* (2011) conducted an experiment and reported that papaya fruits coated with chitosan and stored at 12±1^{O}C and 85 - 90% relative humidity reduced weight loss, maintained firmness, delayed changes in the peel colour and soluble solids concentration during 5 weeks of storage.

Ricardo *et al.* (2013)studies indicate that edible coating of candelilla wax and polyphenols, affect significantly in the shelf life of fruit ($p \leq 0.05$). However, the best treatment were papaya with edible coating with polyphenols (CP) due to the minor weight loss and preserve the better visual appearance in comparison with the others treatments, but the use of edible coating - CC (without polyphenols) was able to improve the shelf life and quality considerably.

Periyanthambi *et al.* (2013) reported that the mango fruits were wrapped individually in perforated low density polyethylene bags (LDPE) or heat shrinkable cryovac film D 995 after dipping in aqueous solution of calcium chloride and calcium nitrate (2.0 and 4.0%, each) for five minutes to minimize the post harvest loss. Fruit treated with calcium compounds and packed in LDPE film substantially retarded the ripening processes and maintained lower physiological loss in weight (PLW) as compared to untreated fruits.

Bhuvaneswari *et al*. (2017) reviewed that thepapaya *cv.* Red lady harvested at two streak stage, packaged in customized Corrugated Fibre Board box of size 450×300×300 mm, 5ply rate, 20 kg/cm² bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg cm^{-2} bursting strength. The fruits packaged in these boxes and stored at 18°C had less weight loss (3.75 percent), more firmness (2.38 kg cm^{-2}) less spoilage (14.27 percent), TSS (12°Brix), Acidity (0.16 percent) and carotenoids content (1.13 mg/100g) in subsequent storage compared to those other packages. The papaya fruits had a shelf life and marketability of 12 days at low temperature storage (18 ^{O}C, 80% RH) and 6 days at ambient storage condition (28-30 ^{O}C, 55% RH).

2.4.2 SPOILAGE (%)

Mathur (1963) observed low rate of ripening anddecay of guava fruits packaged individually in polyethylene bags and stored at room temperature (26-35°C, 60-75% RH).

Gonzalez-Aguilar *et al.* (2003) studied methyl jasmonite and modified atmosphere packaging (MAP) in combined action which resulted in the reduction of spoilage and maintained post-harvest quality of papaya fruits of Sunrise variety.

Gautam and Neeraja (2005) reported the shelf-life and quality of mango *cv*. Banganapalli fruits by using polythene bags of different gauges (150, 250 and 350) with different ventilation levels (0, 0.5, 1.0 and 2.0%). The maximum shelf-life of Banganapalli mangoes was observed in polythene bags of 250 gauges with 1 percent ventilation, which delayed ripening (9.75), rotting and maintained fruit quality.

Hailu *et al*. (2014) reported that the decay loss for unpackaged banana fruits was16 % at the end of date 15, whereas the decay loss of fruits packaged using high density and low density polyethylene bags were 43.0 percent and 41.2 percent, respectively at the end of the 36th day of the experiment. It can, thus, be concluded that packaging of banana fruits in high density and low density polyethylene bags resulted in longer shelf life and improved quality of the produce followed by packaging in dried banana leaf and *teff* straw.

Bhuvaneswari *et al.* (2017) reviewed that thepapaya cv. Red lady harvested at two streak stage, packaged in customized Corrugated Fibre Board box of size 450×300×300 mm, 5ply rate and 20kg cm^{-2} bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg cm^{-2} bursting strength. The fruits packaged in these boxes and stored at 18°C had less weight loss (3.75 percent), more firmness (2.38 kg cm^{-2}) less spoilage (14.27 percent).

2.4.3 SHELF LIFE (DAYS)

Gaikwad *et al*. (2000) reported that the shelf life of papaya (var. Taiwan-786) could be extended to 15 days when packed in polyethylene film under ambient conditions.

Oosthuyes *et al*. (2000) studied on the storage behavior of papaya fruits cv. Bentong and Taiping. The papaya was placed in cool storage (12.5°C for 28 days) at 12, 36, 60 or 84h after harvest. Shelf life was higher of the fruits in the cold storage, but it decreased with delay prior to storage.

A study was conducted by Naher (2000) to evaluate the pattern of physio-chemical changes and shelf life of papaya under different storage conditions including cold temperature and reported that low temperature increased shelf life (16.17 days) compared to room temperature (6.83 days).

Hassan (2000) found that an extended shelf life of 62 days was achieved when organically grown Cavendish bananas were packed in polythene bags containing $KMnO_4$ and stored at $14^{O}C$ temperature. When $KMnO_4$ was omitted from the bags, storage life was extends to 55 days, yet acceptable taste and other quality were maintained.

Emerald *et al.* (2001) reported that the fruits packed in 400 gauge low density polyethylene bags under various modified atmospheres and stored at ambient conditions and resulted the changes in total soluble sugars and physiological loss in weight during storage. All the treatments slowed down the process of ripening compared to the control. Fruits recorded the minimum changes in physicochemical characteristics and extending the shelf - life of sapota fruits by about 4-5 times compared to the control.

Kannan and Susheela (2003) reported that moisture, acidity, ascorbic acid content and total sugar content decreased, whereas total soluble solids and reducing sugars increased and shelf life increased up to 3 weeks in sapota fruits (*Manilkara achras*) under vacuum packaging and waxing in polyethylene bags (200 gauge thickness) with vacuum packaging showed to maintain most of the quality parameters.

Singh Sukhvinder Pal (2003) reported that the papaya fruits shelf life increased up to 3 weeks under vacuum packaging. Of the treatments, waxing in polyethylene bags (200 gauge thickness) before vacuum packaging showed to maintain most of the quality parameters.

Among the various packing materials used for assessing the storage behaviour the fruits stored in paper cartoons with polythene bags (100 gauge) having 2 % vent showed the best result with shelf life of sapota (10.66 days) and high TSS (19.2^{O}Brix) with normal physical appearance and good marketability (Choudhury *et al.* 2003).

Gautam and Neeraja (2005) reported the shelf-life and quality of mango Cv. Banganapalli fruits were studied using polythene bags of different gauges (150, 250 and 350) with different ventilation levels (0, 0.5, 1.0 and 2.0 percentages). The maximum shelf - life of Banganapalli mangoes was observed in polythene bags of 250 gauges with 1% ventilation, which delayed ripening (9.75), rotting and maintained fruit quality.

Masalkar and Garande (2005) reported that the shelf life of custard apple fruits could be extended upto 7 days when treated with waxol or waxol + $KMNO_4$ or waxol + NAA (30 ppm) and packed in individual wrapping polyfilm of 75 gauge at ambient storage conditions as against 4 days in untreated and unpacked fruits.

Raheel Anwar *et al.* (2008) reviewed that the fruits were packed in traditional wood packaging with newspaper liner (WP) and corrugated cardboard packaging (CBP) for comparison. In first experiment, CaC_2 (2g kg^{-1} of fruit) was used for ripening of mangoes in comparison with ethylene (C_2H_4) application (100 ppm, 20 ^OC, 48 h), followed by ripening at ambient conditions (33±1^OC and 60-65% RH). CBP fruit showed significantly lower fresh fruit weight loss (FWL) and better shelf life compared with WP fruit treated with or without CaC_2.

Sunil *et al.* (2009) observed the effect of wax coating, combined with packing in polyethylene bags (with 2 percent and no ventilation) of yelakki banana at ambient condition. The fruits waxed with 1:1 dilution increased the shelf life, both in polyethylene bags packing (13 days) and without packing (10 days).

Alam *et al*. (2010) studied the effect of packaging material and growth regulators on quality and shelf life of papaya. Among packaging treatments, straw packaged fruits were found to be best for extending the shelf life of papaya followed by newspaper. Among the growth regulator treatments the maximum shelf life was observed in Benzyl adenine treated fruits followed by GA_3.

Effect of skin coatings on prolonging shelf life of kagzi lime fruits (*Citrus aurantifolia* Swingle) is reported by Abhay Bisen *et al.* (2012).

Kumar *et al.* (2013) reported that the fruits harvested at M_2 (M_2-8-9°Brix) stage and packed in Xtend® bags had better quality. Shelf life can be extended up to 28 days at 12.5±1^OC with further storage for 4 days of ambient conditions.

Mahajan and Rupinder Singh (2014) reported that the shrink film improved the shelf life and maintained the quality of Kinnow fruits for 20 days under supermarket conditions (18-20 ^OC, 80-85% RH) as against 10 days only in case of unpacked control fruits.

Mulualem Azene *et al*. (2014) the packaged and cooled fruits remained firmer than unpackaged and evaporatively cooled fruits. Higher chemical compositions were recorded in the control fruits stored under ambient conditions during the earlier times of storage. Packaging and cooling maintained the chemical quality of papaya fruits better than the control sample fruits towards the end of storage periods. The evaporatively cooled storage combined with packaging improved the shelf life of papaya fruits by more than two fold. The polyethylene bag packaging combined with evaporatively cooled storage maintained the superior quality of papaya fruit for a period of 21 days.

Geetha Padmanaban *et al.* (2014) reviewed that the papayafruits were pretreated with waxing, oil application, purafilpackets, tissue paper wrapping given along with control andwere packed in 150 gauge thickness polyethylene film bagsunder vacuum and another set of these samples underwithout vacuum.The shelf life of the fruitsincreased under vacuum packing with room and refrigeration temperatures for one and four weeks respectively.

Rameshwar Prasad *et al.* (2015) reported that the packaging of banana fruits in high density and low density polyethylene bags resulted in longer shelf life and improved quality of the produce followed by packaging in dried banana leaf and teff straw.

Hossain and Iqbal (2016) observed that the chitosan coating reduced respiration activity, thus delaying ripening and the progress of decay due to senescence. Chitosan coatings delayed changes in weight loss, total soluble solids, titratable acidity and external colour compared to untreated samples. Bananas coated with 1 percent chitosan exhibited less weight loss and reduced darkening than other treatments and control sample. Disease incidence and disease severity was remarkably reduced by chitosan coating application. Chitosan coating extended banana up to the shelf life of more 3 to 4 days. This study showed that 1 percent chitosan was more suitable in prolonging the shelf-life and quality of banana during ripening and storage.

Amulya *et al.* (2016) studied that the use of edible coating along with MAP condition could reduce the respiration rate and there by extend the shelf life of mango by one to three weeks. From the studies it was able to conclude that bee wax coated mango fruits in combination with MAP condition created by LDPE bags of 210±1 gauge thickness (0 percent perforation) could store for 20 days in cold storage under set condition with acceptable quality. While the fruits under ambient condition of same treatment lasted only for seven days.

Bhuvaneswari *et al.* (2017) reviewed that thepapaya *cv.* Red lady harvested at two streak stage, packaged in customized Corrugated Fibre Board box of size 450×300×300 mm, 5ply rate and 20 kg cm^{-2} bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg cm^{-2} bursting strength. The fruits packaged in these boxes and stored at 18 ^{O}Chad less weight loss (3.75 percent), more firmness (2.38 kg cm^{-2}) less spoilage (14.27 percent). The papaya fruits had a shelf life and marketability of 12 days at low temperature storage (18 ^{O}C, 80% RH) and 6 days at ambient storage condition (28-30 ^{O}C, 55% RH).

2.4.4 FIRMNESS (Kg cm^{-2})

Waxing resulted in firmer fruits compared to the unwaxed control of "Solo" papaya fruits (Quintana and Paull, 1993).

Mohadded (1995) stated that percentage of marketable fruits after 12 days was 71, 38, and 22 for LDPE (low density polythene bags) + KMnO4, LDPE and control treatments, respectively. Fruits stored at 20^{O}C in LDPE bag with KMnO4 scored the highest overall quality. The presence of KMnO4 reduced the ethylene concentration in LDPE bags after 12 days from 0.61 and 0.41 µmol for Grosmichel and Lacatan, respectively, to zero for both cultivars. KMnO4 also increased firmness, greenness (i.e. retarded ripening) and reduced decay.

Jayachandran *et al.* (2007) observed that, the guava fruits treated with benzyl adenine (50ppm) recorded the highest firmness (4.03 Kg cm^{-2}) over the control (1.93 Kg cm^{-2}).

Mulualem Azene *et al.* (2014) reported that the packaged and cooled fruits remained firmer than unpackaged and evaporatively cooled papaya fruits.

Mondh *et al.* (2016) studied it was concluded that the samples packed in HDPE and stored at refrigerated temperature had better retention of sensory attributes such as color, flavor, texture, appearance and overall acceptability. LAF was found best for untreated samples stored at refrigerated temperature. It was also concluded that, the osmotic processing could process papaya into intermediate moisture products. The process is economical, simple and nondestructive with least wastage of fruit during processing.

Bhuvaneswari *et al.* (2017) reviewed that thepapaya *cv.* Red lady harvested at two streak stage, packaged in customized Corrugated Fibre Board box of size 450×300×300mm, 5ply rate, 20 kg/cm² bursting strength with inbuilt cushioning papaya withstood vibration and drop test as compared to those packaged in CFB boxes of 18 kg cm^{-2} bursting strength. The fruits packaged in these boxes and stored at 18°C had less weight loss (3.75%), more firmness (2.38 kg cm^{-2}) and less spoilage (14.27%). The papaya fruits had a shelf life and marketability of 12 days at low temperature storage (18^{O}C, 80% RH) and 6 days at ambient storage condition (28-30 ^{O}C, 55% RH).

2.4.5 TOTAL SOLUBLE SOLIDS (^{O}Brix)

Increase of TSS is one of the most striking changes which occur during post harvest ripening of fruits. There is a gradual increase in the TSS of banana upto ripening and then decreases slightly at the end of shelf life.

Sandhu (1983) observed that the maximum level of TSS in Kinnow mandarin fruits treated with GA_3 100 ppm stored in polythene covers at 16-17^{O}C and 70-80 per cent relative humidity.

Emerald *et al.* (2001) reported that the fruits packed in 400 gauge low density polyethylene bags under various modified atmospheres and stored at ambient conditions and resulted the changes in total soluble sugars and physiological loss in weight during storage. All the treatments slowed down the process of ripening compared to the control. Fruits recorded the minimum changes in physicochemical characteristics and extending the shelf-life of sapota fruits by about 4 - 5times compared to the control.

Singh *et al.* (2001) noticed that most of the wrapping papers or bags significantly reduced the percentage of physiological weight loss in the fruits. Total soluble solids content of ripe fruits was improved when the mango fruits were stored and packed in bags and papers.

Jones (2002) conducted an experiment to assess respiration and chemical changes of papaya fruit in relation to temperature (40, 45, 50, 55 and 60^{O}F) and reported that titratable acidity, weight loss, moisture content, total and reducing sugar and TSS decreased with decreasing temperature. Similar results were also reported by Correa *et al*. (2008) in papaya.

Among the various packing materials used for assessing the storage behaviour the sapota fruits stored in paper cartoons with polythene bags (100 gauge) having 2% vent showed the best result with shelf life (10.66 days) and high TSS (19.2ºBrix) with normal physical appearance and good marketability of sapota fruit (Choudhury *et al.* 2003).

Optimization of an edible coating formulation based on chitosan on 'Sekaki' papaya (*Carica papaya cv*. Sekaki) to reduce water loss and delay changes in TSS and firmness is explained by Osman *et al.* (2011).

Kannan and Susheela (2003) reported that moisture, acidity, ascorbic acid content and total sugar content decreased, whereas total soluble solids and reducing sugars increased and shelf life increased up to 3 weeks in sapota fruits (*Manilkara achras*) under vacuum packaging and waxing in polyethylene bags (200 gauge thickness) with vacuum packaging showed to maintain most of the quality parameters.

Individual shrink wrapping of L - 49 guavas in 9µ LDPE film extended the storage life to 12 days under ambient conditions and 18 days under evaporative cool chamber with negligible loss in ascorbic acid (Sukhvinder Pal Singh. 2006).

Vijayalakshmi *et al.* (2004) reported that the effects of various postharvest treatments, hot water treatment, pre-cooling, $CaCl_2$ and GA_3 dips and storage of fruits in air - tight containers, polyethylene bags, brown paper covers and corrugated fiber board boxes with ethylene absorbent resulted changes in the shelf life and quality parameters of sapota cultivars CO-1 and CO-2.

The second best treatment was $CaCl_2$ dips at 4% which recorded a shelf life of 13.5 days with good fruit quality of sapota (Vijayalakshmi *et al*. 2004).

Rajkumar *et al.* (2005) observed that the TSS value increased linearly from 3rd day till end of the experiment. Papaya fruits treated in GA_3 @ 100 ppm and $CaCl_2$ @ 2 percent recorded higher TSS during storage.

Chauhan *et al.* (2006) studied the synergistic effects of modified atmosphere and minimal processing on the keeping quality of pre-cut papaya where they used anti - microbial, polyethylene pouches stored at 6±1 ^{O}Cresulted in the reduction of respiration rate, reduced losses of texture and ascorbic acid, delayed increases in electrical conductivity and in color co-ordinates, without impeding the sensory quality of the product. Pre-treated papaya slices, kept under different modified atmospheres and had storage lives of 44 - 60 days at 6±1 ^{O}C, which may facilitate bulk storage and long-distance transportation.

Chunprasert *et al*. (2006) reported that chitosan coating, individual wrapping with linear low density polyethylene (LLDPE), and polyethylene (PE) bagging were applied to 'Neang' sugar apple fruit in attempt to delay ripening and extend the quality at 13^{O}C and 95% RH. Chitosan coating at 0.5 and 1.0 percent and LLDPE wrapping did not delay fruit softening and soluble solids increasing but PE bagging did. PE bags extremely reduced weight loss from the fruit following by plastic wrapping while chitosan slightly reduced.

Porat *et al.* (2009) studied that the MA / modified humidity packaging for preserving pomegranate fruit during prolonged storage and transport where it maintained the fruit quality for 3 - 4 months after harvest and it has proven to be a successful means of reducing water loss.

Periyanthambi *et al.* (2013) reported that the mango fruits were wrapped individually in perforated low density polyethylene bags (LDPE) or heat shrinkable cryovac film D 995 after dipping in aqueous solution of calcium chloride and calcium nitrate (2.0 and 4.0 percent, each) for five minutes to minimize the post harvest loss. Fruit treated with calcium compounds and packed in LDPE film substantially retarded the ripening processes and maintained higher firmness as compared to untreated fruits.

Vyas *et al.* (2014) studied the effect of two carbohydrates- based coating materials, carboxymethylcellulose and carrageenan, on the storage life and qualitative characteristics of papaya fruits stored at 25±5^{O}C for 21 days. Carboxymethylcellulose and carrageenan delayed the changes in ascorbic acid, titrable acidity and TSS in papaya.

Mahajan and Rupinder Singh (2014) reviewed the shrink film packaging proved quite effective in reducingthe weight and firmness loss and maintained the various quality attributes like total soluble solids, acidity,ascorbic acid and carotene content of the fruit during shelf life period. It was noticed that shrink filmimproved the shelf life and maintained the quality of kinnow fruits for 20 days under supermarketconditions as against 10 days only in case of unpacked control fruits.

2.4.6 ASCORBIC ACID (mg/100g pulp)

Jain and Chitkara (1980) conducted a study on the effect of different packing material in transportation and quality of ber fruits (Umran) and observed lower retention of vitamin C in fruits packed with mulberry baskets.

Pal *et al*. (2004) found individual shrink wrapping of L-49 guavas in 9µ LDPE film extended the storage life to 12 days under ambient conditions and 18 days under evaporative cool chamber with negligible loss in ascorbic acid.

Alam *et al*. (2010) studied the effect of packaging material and growth regulators on quality and shelf life of papaya. Among packaging treatments, straw packaged fruits were found to be best for extending the shelf life of papaya followed by newspaper. Among the growth regulator treatments the maximum shelf life, ascorbic acid was observed in Benzyl adenine treated fruits followed by GA_3.

Vyas *et al.* (2014) the effect of two carbohydrate- based coating materials, carboxymethylcellulose and carrageenan, on the storage life and qualitative characteristics of papaya fruits stored at 25±5^{O}C for 21 days. Carboxymethylcellulose and carrageenan delayed the changes in ascorbic acid in papaya.

2.4.7 ACIDITY (%)

Rao and Rao (1979) reported that the acidity was higher in banana stored in sealed polythene bags.

The effect of kinetin, GA_3 and wax has significant effect on titrable acidity. Rao and Madhava Rao (1987) reported that kinetin, GA_3 and waxol treatment on Basrai banana higher acidity indicating the retarded tissue respiration.

Sandhu *et al*. (1983) reported that the maximum level of titrable acidity was recorded with polythene bag + 10 ppm GA_3 in kinnow mandarin fruits stored at 16-17^{O}C and 70-80 % RH.

Acidity was higher with 6 and 9 percent waxol treatments than with other treatments in guava cv. Sardar (Jagadeesh *et al*., 2001).

Maximum acidity was recorded with wax emulsion (8 percent) plus cool chamber storage in mango cv. Langra (Jain *et al*., 2001).

Bharathi (2002) observed that the sapota fruits in cold storage, BA 50 ppm recorded highest tritable acidity. Among growth regulators treatments; fruits recorded the highest acidity in GA_3 200 ppm (0.254) and lowest in control (0.106). Among antioxidants, the titrable acidity decreased from 0.241 on day 1 to 0.159 on 7th day. The highest (0.235) recorded in fruits treated with BA 50 ppm followed by BA 25 ppm (0.224) and control recorded the least percentage of titrable acidity (0.091).

Prasanna Lakshmi (2005) observed that Benzyl adenine treated mango fruits recorded higher acidity over control.

Jayachandran *et al.* (2007) reported the maximum acidity of 0.73 in control guava fruits while BA treatment recorded minimum acidity.

Alam *et al*. (2010) studied the effect of packaging material and growth regulators on quality and shelf life of papaya. Among packaging treatments, straw packaged fruits were found to be best for extending the shelf life of papaya followed by newspaper. Among the growth regulator treatments the maximum shelf life, ascorbic acid and reducing acidity was observed in Benzyl adenine treated fruits followed by $GA_{3.}$

Marpudi *et al.* (2011) treated freshly harvested papaya fruits were coated with Aloe gel/AG coating (50 percent), papaya leaf extract/PLE incorporated Aloe gel (1:1) and 2.5% chitosan. The coated and uncoated (control) fruits were stored at 30±3^{O}C for 15days. Physical (PLW, fruit size), chemical (titrable acidity and TSS) and sensory characteristics (colour, taste & firmness). Aloe gel based antimicrobial coating has been identified as suitable method to extend the shelf life of papaya fruits.

Vyas *et al.* (2014) the effect of two carbohydrate - based coating materials, carboxymethylcellulose and carrageenan, on the storage life and qualitative characteristics of papaya fruits stored at 25±5^{O}C for 21 days. Carboxymethylcellulose and carrageenan delayed the changes in ascorbic acid and titrable acidity in papaya.

2.4.8 SUGARS (%)

The important chemical changes occurring during ripening process hydrolysis of starch and accumulation of sugars.

Rao and Rao (1979) reported that, reducing and non-reducing sugars were slightly higher in the banana fruits stored in sealed polythene bags containing ethylene and $Ca(OH)_2$.

Sandhu *et al.* (1983) reported that the levels of total sugars and reducing sugars were maximum with GA_3 30 ppm in Kinnow fruits and held at 16-17^{O}C at 70-80 percent RH.

Ragava Rao and Chundawat (1984) showed that, post-harvest treatments of Basrai banana with GA_3 resulted in lower sugar content of (12.93) as against the control of 15.30 percent; on 17th day of storage suggesting lower metabolic rate in treated fruits.

Shantha Krishnamurthy (1989) reported that, Robusta banana stored at l5^{o}C has 2.0 percent of total sugars when compared at 20^{o}C (11.6 percent) suggesting the delay in ripening process of banana at lower temperature.

Vijaya Raju (1989) studied that the combination of polythene bags and wax treatment found significant effect on the total sugar content. Fruit treated with 4 percent wax emulsion and kept in polythene bags and banana treated with 4 percent wax plus GA_3 and stored in polythene bags recorded significantly higher total sugar when compared to control (18.40 per cent).

Rao and Chundawat (1984b) reported that, postharvest treatment of banana cv. Basrai with $GA_3$150 ppm and waxol 12 percent increased the content of total sugars during storage period.

Sharma and Dashora (2001) reported that after 8 days of storage minimum total sugars (7.96 percent) were recorded in 2 percent mustard oil emulsion + 100 ppm BA treated guava fruits while the maximum (8.25 percent) in control.

Bharathi (2002) observed that, sapota fruits under control recorded the highest total sugars (11.14) and least was recorded in GA_3 200 ppm. Further observed that sapota fruits highest total sugars among the antioxidants were found in BA 50 ppm (11.30) and least were found in control.

Sahoo and Munsi (2004) observed that, the sugars was highest (10.4 percent and 9.8 percent) in fruits treated with GA_3 (100 ppm) and $AgNO_3$ (50 ppm) respectively with perforated polythene bags.

Bharadwaj *et al.* (2005) reported that, the mandarin cv. Nagpur santra treated with 100 ppm BA have minimum increase in TSS (13.20 ^{O}Brix) and total sugars (7.80 percent) on 42 day of storage.

Jayachandran *et al.* (2007) reported that, the least reducing sugars content was found in untreated fruits, while Benzyl adenine treated fruits recorded the highest reducing sugars in guava cv. Luknow - 49.

Rathore *et al.* (2009) reviewed that the Chausa mango fruits treated with Wax + $CaCl_2$ + Polythene packed can be stored up to 30 days at room temperature with good Physico - chemical as well as Organoleptic Quality.

Kumar *et al.* (2013) reviewed that the mango fruits packed using polypropylene bags of 12.5 micron (50 gauge), 25 micron (100 gauge), 37.5 micron (150 gauge) and StePac Xtend® bags. Unpacked fruits were treated as control. Head space gases analysis for O_2 %and CO_2 percent were carried out after 24 - hour intervals and packages were opened after 14, 28 and 42 days. Further observations were conducted for four days at ambient temperature (25°C) by evaluating the weight loss, firmness, visual colour, pH, total soluble solids, acidity, reducing and total sugars. Overall, results indicated that fruits harvested at M_2 stage and packed in Xtend® bags had better quality. Shelf life can be extended up to 28 days at 12.5±1^{o}C with further storage for 4 days of ambient conditions.

Chapter - III

MATERIALS AND METHODS

The experiment entitled "Studies on Integrated nutrient management on growth, yield, quality and effect of Post harvest treatments, Packaging materials on shelf life and quality of papaya (*Carica papaya* L.) *cv*. Red lady under southern Telangana" was conducted at College of Agriculture, PJTSAU, Horticulture experimental field Rajendranagar, Hyderabad. Further post harvest studies were conducted at College of Horticulture Rajendranagar, Hyderabadduring the period of 2014 - 2015 and 2015 -2016. The details of the material used and techniques adopted in the present studies are briefly presented.

3.1 Experiment Location and Soil characters

3.2 Materials

3.3 Experimental details

3.4 Treatmental details

3.5 Observation recorded

3.6 Statistical analysis

3.1 EXPERIMENT LOCATION AND SOIL CHARACTERS

The present experiment was carried out during the year 2014-2015 and 2015 - 2016 at PJTASU, Horticulture Experimental Field, Rajendranagar, Hyderabad.Rajendranagar lies in the Deccan Plateau of Telangana between 17^{o}32'N latitude and 78^{o} 40'E longitude and 515 meters above mean sea level (MSL) with an average annual rainfall of 803mm. The mean maximum temperature is more than 32.3^{o}C throughout the year exception December. The relative humidity is high during monsoon months from July to September and low during summer months from March to May. The experimental location falls semi - arid tropical climate zone. The data on the weather conditions during the period of experimentation recorded at meteorological station presented in Appendix - I.

3.1 SOIL CHARACTERS

The soil of the experiment site is a sandy loam with a pH of 7.2 and electrical conductivity of 0.37 dSm^{-1}. It had 195 kg, 95 kg and 175 kg ha^{-1} of available nitrogen, phosphorus and potassium contents respectively. The experiment site has a uniform topography (Appendix – III).

3.2 MATERIALS

3.2.1 Field preparation

The experimental field was prepared by deep ploughing and harrowing. The pits of 30 × 30 × 30 cm were dug out at a spacing of 2.5m × 2.5m and well decomposed FYM @ 20 kg pit^{-1} was applied at time of planting. Common application of *Azotobacter* and *PSB* culture @100g/ plant each was applied at the time of planting and 2 months after planting.

3.2.2 Source of planting material

For present study 6 to 8 week (15 - 20 cm height) old and healthy seedlings of papaya *cv*. Red Lady were raised at Horticulture Nursery PJTSAU, Department of Horticulture, Rajendranagar, Hyderabad.

3.2.3 Transplanting

Transplanting was carried out in the second week of September during the year of 2014 - 15 and 2015 - 16 at evening time. Before removal of the plants from the bags, made sure that the bags are properly watered, which prevent the loosening the soil from the roots. The bag was then cut down from both sides and the plants with the soil attached to the roots were taken out and placed in pits and the soil around it gently firmed.

3.2.4 Cultural practices and fertilizer application

Standard cultural practices and fertilizer application were adopted as per the recommendation.

3.2.5 Weed management

Weed management was done by hand weedingat regular intervals.

3.2.5 Application of manures and fertilizers

The NPK content in FYM, Vermicompost and Castor cake used as a source of plant nutrients are given in Appendix - IV. The quantity of organic manures was determined for application on N equivalent basis. Organic fertilizer was applied in two split (basal and 45 DAP) as per treatments.

Inorganic fertilizers were applied at 2^{nd}, 4^{th}, 6^{th} and 8^{th} month after transplanting.

3.2.6 Irrigation

Papaya crop is highly sensitive to excess ofwater. Papayacrop was irrigated in October - November for 5 days interval, December -January for 3days and February - March for at alternate day interval.

3.2.7 After cares

Earthing up was carried out as and when required during the fruiting period.

3.2.8 Crop protection

In papaya, the damping-off, leaf curl and papaya ring spot virus (PRSV) are the major diseases which observed during experiment and are described as under:

3.2.8.1 Dampingoff (*Rhizoctonia solani*)

This is a disease of young seedlings. Lesions areseen on the stem at or just above soil level. Thestem becomes watery and shrinks, followed by death of the plant. For control of dampingoff applied *Tricoderma viridae* powder @ 0.5g/pit at the time of transplanting. After transplanting of seedlings in actual field, the soil drenching of Redomil @ 5g and copper oxychloride (COC) @ 20g per 10 liter water was applied within 10-15 days intervals for 3 - 4 times for control of damping off disease.

3.2.8.2 Leaf curl of papaya

This disease is transmitted by the vector white fly (*Bemisia tabaci*). Severe curling, crinkling and deformation of the leaves characterize the diseases. Destruction of the affected plants along with removal was carried to reduce the spread of disease. An alternate foliar spray of pesticides Dimethoate 30% EC, Trizophose 20% EC and Imidacloprid 17.8% SL at an interval of 25 days was used to control the white fly population.

3.2.8.3 Papaya ring spot virus (PRSV)

The virus is spread from plant to plant by aphids.The symptoms of yellowing and vein-clearing of the young leaves and on the ripe fruit as darker orange - brown rings. In control measures, early detection of infected plants and prompt removal was done to check the spread of the disease. Aphids were controlled by application of two foliar sprays of Acephate 75 percent SP at an interval of 21 days starting from 45-50 days after transplanting.

3.2.9 Chemicals

All chemicals used in experimentation and analysis were of analytical grade, purchased from Standard Indian Chemical companies.

3.2.10 Papaya cv. Red Lady

The cultivar Red Lady is a Tai - variety developed by Known - You Seed Company. It has replaced all our commercial papaya varieties like CO-2, Coorg Honey Dew and others. It is an early, vigorous, productive variety with long shelf life. Plants of this variety bear fruits at 80cm height on the trunk and normally bear over 30 fruits per plant in each fruit setting season. It is a gynodioecious variety. Fruits are short - oblong on female plants and rather long - oblong shaped on bisexual plants. Flesh is thick, aromatic and red with more than 13 percent sugar. It has good export quality and itis tolerance to papaya ring spot virus.

3.2.11 Packaging materials

Packaging materials such as news paper and tissues paper (Kimwipes) with size of 40 × 30cm were used for packing of papaya fruits.

3.3 Experimental details

Three experiments were conducted with integrated nutrient management, postharvest treatments of papaya with chemicals and growth regulatorsand packaging. The treatment details in each experiment are presented below. The abbreviations/connotations used for each treatment is given in the parenthesis and these abbreviations are used while presenting results and discussion.

3.3.1 Experiment NO - I

Effect of integrated nutrient management on growth, yield, quality and shelf life of papaya (*Carica papaya* L.) cv. Red Lady.

T_1- RDF (200 N: 200 P_2O_5: 250 K_2O g/plant)

T_2- RDF + 20 kg FYM plant^{-1}

T_3- RDF + 10kg vermicompost plant^{-1}

T_4- RDF + 5 kg neem cake plant^{-1}

T_5 - RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1}

T_6 - RDF + 10 kg vermicompost +100g *Azotobacter* + 100g *PSB* plant^{-1}

T_7 - RDF + 5 kg neem cake +100g *Azotobacter* + 100g *PSB* plant^{-1}

T_8 - 75% RDF +20 kg FYM plant^{-1} + 100g *Azotobacter* +100g *PSB* plant^{-1}

T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}

T_{10} - 75% RDF + 5 kg neem cake + 100g *Azotobacter* + 100g *PSB* plant^{-1}

The experiment was conducted for two years (*i.e.,* 2014 - 15 and 2015-2016).

Number of treatments **:** 10

Number of replications**:** 3

Location**:** PJTASU, Horticulture Experimental Field, Rajendranagar.

Spacing **:** 2.5 x 2.5 m

Experimental design**:** Randomized Block Design (RBD)

3.3.2 Experiment NO - II

Effect of post harvest treatments with chemicals and growth regulators on shelf life of papaya (*Carica papaya* L.) cv. Red Lady.

T_1 - Fruits dipped in GA_3@ 100 ppm

T_2 - Fruits dipped in GA_3 @ 200 ppm

T_3 - Fruits dipped in GA_3 @ 300 ppm

T_4 - Fruits dipped in $CaCl_2$ @ 1.0 %

T_5 - Fruits dipped in $CaCl_2$ @2.0 %

T_6 - Fruits dipped in $CaCl_2$ @ 3.0 %

T_7 - Fruits dipped in Wax emulsion @ 4.0 %

T_8 - Fruits dipped in Wax emulsion @ 5.0 %

T_9- Fruits dipped in BA @ 150 ppm

T_{10} - Fruits dipped in BA @ 250 ppm

T_{11} - Control (without any dipping)

After treatments fruits are taken out air dried and stored at ambient temperature

Number of treatments : 11

Number of replications : 3

Location : College of Horticulture, Rajendranagar.

Experimental design : CRD

Observation interval : 3 Days

3.3.3 Experiment NO - III

Effect of packaging materials on quality and shelf life of papaya (*Carica papaya* L.) cv. Red Lady.

T_1 - First best treatment of Experiment II fruits + News paper

T_2 - First best treatment of Experiment II fruits + Tissues paper

T_3 - Second best treatment of Experiment II fruits + News paper

T_4 - Second best treatment of Experiment II fruits + Tissue paper

T_5 - Undipped fruits + News paper

T_6 - Undipped fruits+ Tissue paper

T_7 - Control (No dipped and no pack)

Number of treatments : 7

Number of replications : 4

Location : College of Horticulture, Rajendranagar.

Experimental design : CRD

Observation interval : 3 Day

3.4 Experimental design and layout

The experiment was laid out in a Randomized Block Design and is depicted in **Plate: 1**

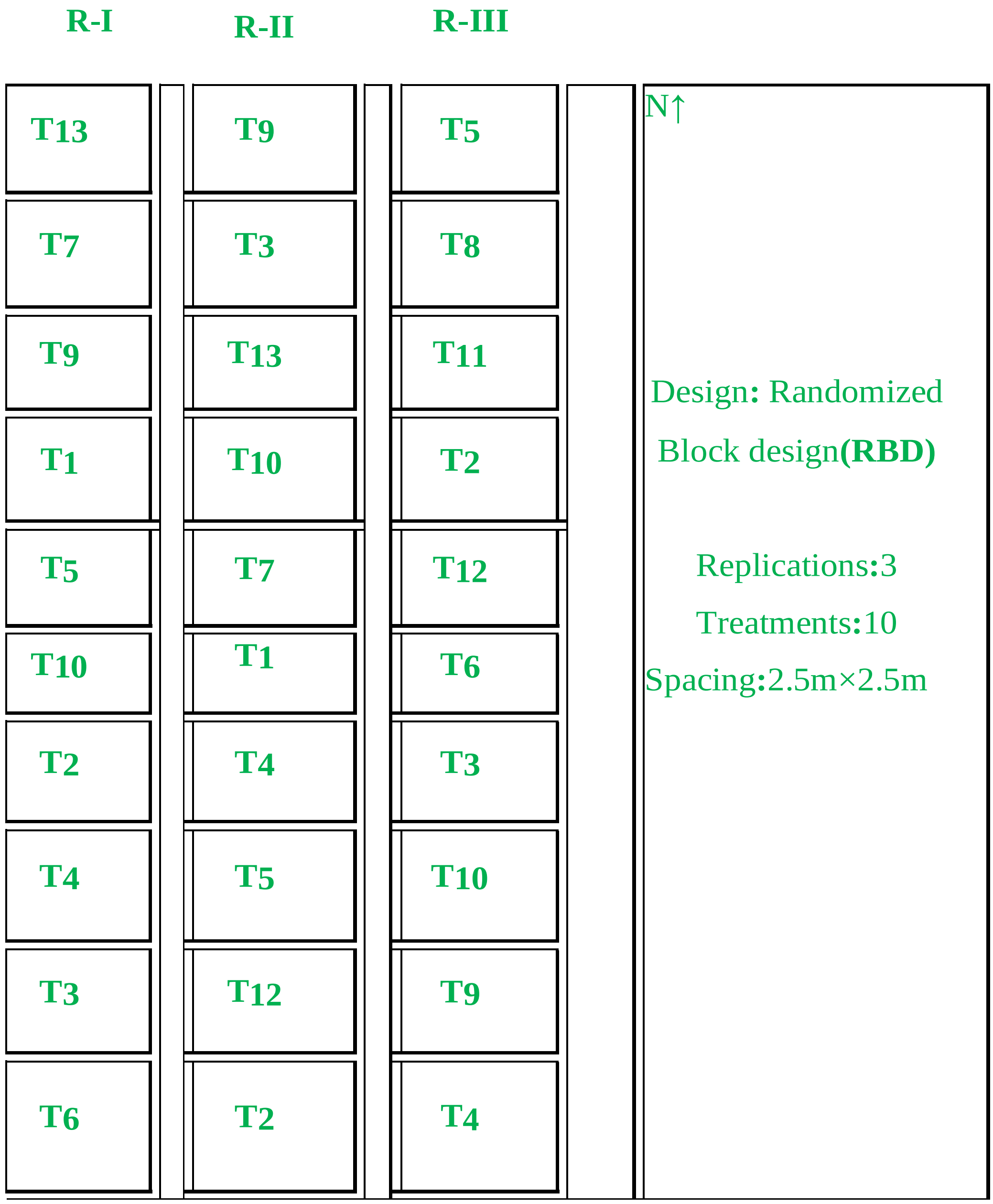

Plate: 1. Layoutof Experimental Field

3.4 Treatment details

3.4.1. Preparation of treatment solutions

Solutions of benzyl adenine 150 ppm and 250 ppm are prepared by dissolving 150 mg, 250 mg of benzyl adenine respectively in small volume of distilled water and finally it was made upto 1 litre with distilled water. Benzyl adenine was first dissolved in absolute alcohol, later dissolved in distilled water.

3.4.2.Preparation of wax emulsion

Wax emulsion was prepared by melting paraffin wax in an emulsifier (glycerol stearate) and addition of boiling water. 40 g and 50g of wax were dissolved in 1 litre of water with 10ml of an emulsifier to get 4.0 percent and 5.0 percent wax emulsion.

3.4.3 Gibberellic acid (GA_3)

100mg, 200mg and 300mg of GA_3 was weighed and dissolved in small amount of ethanol at slight warm state and made upto one liter with distilled water to get 100 ppm, 200ppm and 300ppm solution.

3.4.4 Calcium chloride

Calcium chloride at 1.0 percent, 2.0 percent and 3.0 percent concentrations were prepared by dissolving 50, 100 and 150 of Calcium chloride in five liters of distilled water and made the volume of required quantity for application.

3.4.5 Method of application

Mature, colour break stage fruits of papaya cv. Red Lady of uniform size fruits picked from the field were brought to college of horticulture, Rajendranagar. The fruits were washed thoroughly under running tap water to remove the adherent dirt material. The fruits were surface disinfected with 0.1 % (w/v) bavistin solution for 2 minutes. After the moisture on the surface of the fruits was air dried and the fruits were stored at a room temperature.

The chemicals were taken in the beakers and the fruits were dipped completely in that solution for 5 minutes. The details of treatments are mentioned under experiment - II and III.

3.5 Observations recorded

The details of methods applied for various growth, yield and quality characters with post harvest treatments are given below with appropriate heads.

3.5.1 Plant growth and fruit characters

The growth parameters such as plant height (cm) and trunk girth (cm), Number of leaves / Plant and Petiole length (cm), were recorded at 30, 90, 150, 210, 270 and 330 days after transplanting.

3.5.1.1 Plant height (cm)

The plant height was measured in centimeter from ground to base of the newly emerged leaf with the help of measuring tape (Plate no: 4).

3.5.1.2 Circumference (cm)

The circumference was measured in centimeter at 10 cm above from ground level with help of measuring tape (Plate no: 4).

3.5.1.3 Numberof leaves per plant

The number of leaves (fully open) was counted on the labeled plant and average was worked out at 30, 90, 150, 210, 270 and 330 days after transplanting and total leaf during life span was calculated.

3.5.1.4 Petiole length (cm)

The petiole length was measured in centimeter at 30, 90, 150, 210, 270 and 330 days after transplanting. For calculation of total petiole length, randomly three leaves, one from base, second from middle and third from new emerged leaves were selected from one plant

(Plate no 4).

3.5.1.5 Days taken to first flowering (days)

The number of days from transplanting to emergence of first flower was recorded and thenaverage was worked out.

3.5.1.6 Fruit maturity (days)

Number of days required from fruit set to harvesting of fruit in each treatment was recorded to work out maturity period.

3.5.1.7 Fruit weight (g)

The weight of twenty fruits was recorded for each treatment plant and from this average weight of fruit was worked out and expressed in gram.

3.5.1.7 Pulp thickness (cm)

The pulp thickness of the twenty randomly selected fruit was measured with the help by verneer calipers and the average pulp thickness per fruit was measured in cm.

3.5.1.9 Fruit length (cm)

Fruit length was measured by using measuring tape and expressed in centimeters.

3.5.1.10 Number of fruit per plant

Number of fruit harvested per plant at every event of harvesting was counted and from this the total number of fruits harvested per plant, during the season was worked out (Plate no: 5).

3.5.1.11 Yield per plant (kg)

The weight of fruit harvested per plant at each harvesting was recorded and from the same, the total yield per plant was worked out and expressed in kilogram.

3.5.1.12 Benefit cost ratio

The cost of the following items was considered for working out the cost of cultivation for experiment.

1. Labour charges
2. Fertilizers
3. Manures
4. Plant protection chemicals
5. Miscellaneous (marketing charges, etc.)

The prices of the input that were prevailing at the time of their use were taken into account to work out the cost of cultivation. Gross returns were calculated using the total fruit yield per hectare and the prices of fruit at the time of marketing were taken into accounts. The labour wages cost of inputs and outputs are furnished in (Appendix-II).

Net returns

The net returns per hectare were calculated by deducing the cost of cultivation from gross returns per hectare.

Benefit cost ratio

The benefit cost ratio was calculated as follows.

$$\text{Benefit cost ratio} = \frac{\text{Net profit (Rs.ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs.ha}^{-1}\text{)}}$$

3.5.2 Physical parameters

3.5.2.1 Physiological loss in weight (%)

The weight of the fruits was recorded on every third day and subtracted from the initial weight. The loss of weight in grams in relation to initial weight was calculated and expressed as percentage.

$$\text{PLW (\%)} = \frac{\text{Initial weight of fruit - subsequent day weight of fruit}}{\text{Initial weight}} \times 100$$

3.5.2.2 Fruit firmness ($kg.cm^{-2}$)

The fruit firmness was measured by using Penetrometer by pressing at the center of the fruit.

3.5.2.3 Spoilage (%)

The extent of rot was determined by weighing the decayed fruits on each day of observation and the percentage was calculated on the basis of total weight of the fruits stored. It was calculated by using the following formula.

$$\text{Spoilage (\%)} = \frac{\text{Weight of decayed fruits}}{\text{Weight of fruit stored}} \times 100$$

3.5.2.4 Shelf life (Days)

The shelf life of fruits was determined by recording the number of days the fruits remained in good condition during storage without spoilage. When the spoilage of fruits exceeded 50 percent, it was considered as the end of shelf life or storage life (Yelluri Samba Siva Rao, 2004).

3.5.2 Quality parameters

The quality parameters were recorded at ripestage of papaya fruits.

3.5.2.1 Total soluble solids (^{o}Brix)

The total soluble solids of the pulp for each treatment was recorded with the help of Hand Refractometer of 0-30 ^{o}Brix range and expressed as per cent total soluble solids of the fruit (A.O.A.C., 1970).

3.5.2.2 Reducing sugars

The titrimetric method of Lane and Eynon described by Ranganna (1986) was adopted for estimation of reducing sugar. The method is based on the principle that invert sugar or reducing sugar reduces the copper in the Fehling's solution to red insoluble cuprous oxide. Sugar in a sample was estimated by determining the volume of unknown sugar solution required to completely reduce a measured volume of Fehling's solution. Before using the mixture (1:1) of Fehling's solution A and B (5ml of A and 5ml of B) was standardized against standard glucose for obtaining glucose equivalent and to arrive at a conversion factor

3.5.2.1 Sample preparation

Twenty five gram of the homogenized pulp was taken in a 250 ml volumetric flask and 2 ml of 45% basic lead acetate solution was added for clarification. After 10 minutes, the solution was diluted by adding potassium oxalate crystals in excess (added till excess of crystals remained undissolved) and the volume was made up to a known amount with distilled water and filtered through Whatman No. 1 filter paper. The filtrate was taken in a burette and titrated against boiling Fehling's mixture (5ml of Fehling's solution A + 5ml of Fehling's solution B) till the blue colour faded. Then 1 ml of methylene blue indicator (1%) was added and titration was continued till the contents attained a brick red colour and titre value was noted. The percentage of reducing sugar was calculated according to following formula.

$$\text{Reducing sugar (\%)} \quad \frac{\text{Glucose Eq. (0.05)} \times \text{Total volume made up}}{\text{Titre} \times \text{weight of the pulp}} \times 100$$

3.5.2.2 Total sugars

For estimation of total sugars, the filtrate obtained in the above estimation was used. An aliquot from the filtrate was taken and to one -fifth of its volume, hydrochloride acid (1:1) was added and the inversion was carried out at room temperature for 24 hours. Subsequently, the contents were cooled and neutralized with 40 percentage of sodium hydroxide using phenolphthalein as an indicator and the final volume was made. The solution was filtered through Whatman No. 1 filter paper and titration was carried out using filtrate as detailed for reducing sugars. The total sugar content was expressed as percentage in terms of invert sugars according to the following formula.

$$\text{Total sugars (\%)} = \frac{\text{Fehling's Sol. (0.05)} \times \text{Total Vol. made up} \times \text{Vol. made up after inversion}}{\text{Titre} \times \text{Wt. of sample} \times \text{Aliquot taken for inversion}} \times 100$$

3.5.2.3 Non-reducing sugars

The percentage of non-reducing sugars was worked out by deducting the percentage of reducing sugars from the percentage of total sugars.

Non-reducing sugars (%) = Total sugars (%) – Reducing sugars (%)

3.5.2.4 Ascorbic acid (mg/100g of pulp)

Titrimetric method described by Ranganna (1986) was adopted for estimation of ascorbic acid.

3.5.2.4.1 Sample preparation

Ten gram of homogenized pulp was taken and transferred to 100 ml volumetric flask. The volume was made up with 4% oxalic acid solution. After 30 minutes, the suspension was filtered through Whatman No.1 filter paper. Before actual titration the 2, 6-Dichlorophenol indophenol (Dye solution) was standardized by titrating against standard ascorbic acid solution and the dye factor was calculated. Five ml of the aliquot was taken from the filtrate and titrate against standardized dye solution through a burette. The titration was continued till the light pink colour persisted for 15 seconds. The ascorbic acid content was calculated adopting the following formula.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Vol. made up}}{\text{Wt. of sample} \times \text{Aliquot taken}} \times 100$$

$$\text{Dye factor} = \frac{0.5}{\text{Titre}}$$

3.5.2.4 Titratable acidity

The method described by Ranganna (1986) was adopted for estimation of titratable acidity. To obtain acidity (%), 10 g of homogenized pulp was taken in a 100 ml volumetric flask and the volume was made up with distilled water to a known amount. After thirty minutes, the suspension was filtered through Whatman No. 1 filter paper and 10 ml of filtrate was taken by pipeting and titrated against 0.1 N NaOH by using phenolphthalein as an indicator. Appearance of colourless to pink colour denotes the end point. The reading of burette was noted. The titratable acidity percentage was calculated by adopting the following formula.(Eq. wt. of citric acid = 0.064)

$$\text{Acidity (\%)} = \frac{\text{Titre x Normality of NaOH} \times \text{Eq. wt. of acid} \times \text{Vol. made up}}{\text{Wt. of sample} \times \text{Aliquot taken}} \times 100$$

3.5.2.6 Statistical analysis and the interpretation of data

The data collected for all the characters involved under study were subjected to the statistical scrutiny (analysis) for proper interpretation. The standard method of analysis of variance technique appropriate to the Randomized Block Design (RBD) as described by Panse and Sukhatme (1985) was used. The data was analyzed with the technical help from computer centre of Prof. Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad. The treatment differences were tested by employing "F" test at five per cent level of significance on the basis of null hypothesis. The appropriate standard errors (S. Em.±) were calculated in each case and the critical difference (CD) at five per cent level of probability was worked out to compare the two treatment means, where the treatment effects were found significant under “F” test. The co - efficient of variation percentage (CV %) was also worked out for all the cases.

Chapter - IV

RESULTS AND DISCUSSION

The nutritional requirement of papaya is quite typical in view of its continuous growth behavior like vegetative, flowering and fruiting habit. Papaya requires continuous nutrients in large amount and use of large quantity of chemically formulated fertilizers alone is not only feasible but also costly to the farmers, as majority of them are small and marginal farmers. Apart from this, heavy use of fertilizers causes environmental hazards and deleterious effect on soil structure, microflora and quality of water and also productivity on long term basis (Anon., 1995). The present investigation entitled "Studies on Integrated nutrient management on growth, yield, quality and effect of Post harvest treatments, Packaging materials on shelf life and quality of papaya (*Carica papaya* L.) *cv*. Red lady under southern Telangana" was carried out at the PJTSAU, Horticulture Experimental Field, Agricultural University, Rajendranagar, Hyderabad, during the year 2014 - 15 and 2015 - 16, respectively. The results pertaining to growth parameters, physiological parameters, yield attributes, quality parameters during the course of present study. The results along with statistical inferences are presented in this following heads.

4.1. Effect of integrated nutrient management on growth, yield, quality and shelf life of papaya.

4.2. Effect of post harvest treatments with chemicals and growth regulators on shelf life of papaya.

4.3. Effect of packaging materials on quality and shelf life of papaya

4.1. EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD, QUALITY AND SHELF LIFE OF PAPAYA.

The growth parameters like Plant height (cm), Circumference (cm), Number of leaves, Petiole length (cm), Days to first flower initiation (days) and Days taken to maturity (days) were recorded and presented below.

4.1.1 Plant height (cm)

The mean data concerning plant height (cm) of papaya *cv.* Red Lady at 30, 90, 150, 210, 270and 330days after planting as influenced by various treatments are presented in Table -4.1and graphically represented in Fig:-1.

The effects of various treatments on the plant height are furnished in Table -1 and Plate: - 4a. In this investigation, it was observed that the application of organic manures, inorganic fertilizers and bio fertilizers had significantly influenced the height of the plant at different stages of the crop growth during 2014 - 2015 and 2015 - 2016. The plant height increased with the age of the crop in a linear trend reaching maximum at harvest stage. Further, a rapid rate of increase was observed upto 90days after planting. There after, the plant height increased slowly upto 300 - 360 DAP and marginally between 270 Days after planting upto harvest.

4.1.1.1 Plant height (cm) at 30days after planting

The data pertaining to plant height at 30days after planting is presented in Table -4.1 and Fig- 1. During 2014 -2015 at 30days after planting; plant height was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost +100g *Azotobacter* + 100g *PSB* plant^{-1} (47.77cm) and followed by the treatment T_1-200 N: 200 P_2O_5: 250 K_2O g/plant (43.28cm). Significantly lower value for plant height was recorded in T_7 - RDF + 5kg neem cake + 100 g *Azotobacter* + 100g *PSB* plant^{-1} (23.65cm) and it was on par with T_6(25.39 cm) and following treatment was T_{10} (27.87 cm).

During 2015 - 2016 at 30 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher plant height (48.38cm) and followed by T_1 - 200 N: 200 P_2O_5: 250 K_2O g/plant (43.97 cm). The T_6 – RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded significantly lower plant height (28.19cm) and it was on par with T_{10} treatment (29.62 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant height treatments T_9 and T_1 recorded higher plant height of (48.08 cm) and (43.63 cm) respectively. Significantly lower plant height was recorded with T_7 (25.99cm) and it was on par with T_6 (26.79 cm) and the plant height ranged from (48.08 cm) to (25.99 cm).

4.1.1.2 Plant height (cm) at 90 days after planting

The data pertaining to plant height at 90 days after planting is presented in Table - 4.1 and Fig- 1. During 2014 - 2015 at 90 days after planting, the plant height was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} (90.03cm) as compared to other treatments and it was on par with T_6 and T_8. The following treatments wereT_1 and T_{10} treatments. The plant height was significantly with lower values were observed in T_3- RDF +10kg vermicompost plant^{-1} (77.73 cm) and it was on par with T_4 (78.81 cm), T_5 and T_7 treatments.

During 2015-2016 at 90 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded higher plant height (92.33 cm) and it was on par with T_6 - RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (89.40 cm). The treatment T_3 - RDF + 10kg vermicompost plant^{-1} recorded significantly lower plant height (79.81cm) and it was on par with T_2 (80.01 cm), T_4 (80.04 cm), T_7 (80.42 cm) and T_5 (81.22 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant heightand it was recorded higher in T_9 (91.18cm) and followed byT_6 treatment (88.78 cm). The significantly lower plant height was recorded in T_3 (78.77cm) and followed by treatment T_4 (79.43 cm). Plant height ranged from (78.77 cm) to (91.18 cm).

4.1.1.3 Plant height (cm) at 150 days after planting

The data pertaining to plant height at 150 days after planting is presented in Table - 4.1. During 2014 - 2015 at 150 days after planting, plant height was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost +100g *Azotobacter* +100g *PSB* plant^{-1} (130.57cm) as compared to other treatments and the following treatment was T_4 (124.33cm). Significantly lower values for plant height were observed in T_3 - RDF + 10kg vermicompost plant^{-1} (106.32 cm) and followed by T_7 treatment (111.39 cm).

During 2015-2016 at 150 days after planting, T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher plant height (132.06 cm) and followed by the treatment T_4 (125.30 cm). The T_7 treatment recorded significantly lower plant height (113.02cm) and following treatment was T_3 (113.25 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant height and it was highest in T_9 (131.32cm) followed by T_4 (124.82cm) respectively. Significantly lower plant height was recorded with T_3 (109.78cm) and the plant height ranged from (109.67 cm) to (131.32 cm).

4.1.1.4 Plant height (cm) at 210 days after planting

The data pertaining to plant height at 210days after planting is presented in Table - 4.1. During 2014 - 2015 at 210 days after planting, plant height was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} (171.98 cm) as compared to other treatments and following treatment was T_4 treatment (167.16 cm). Significantly lower value for plant height was observed in T_3- RDF + 10kg vermicompost plant^{-1} (142.38 cm) which was on par with T_2 (144.42 cm).

During 2015 - 2016 at 210days after planting, T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1}) recorded higher plant height (172.42 cm) and it was on par with T_4 treatment (168.34 cm). T_3 - RDF +

10kg vermicompost plant^{-1} recorded significantly lower plant height (143.83cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant height. T_9 treatment recorded highest plant height (172.20 cm) and followed by T_4 (167.75 cm). Significantly lower plant height was recorded with T_3 treatment (143.11cm) followed by T_2 treatment (145.03 cm) and the plant height ranged from (143.11 cm) to (172.20 cm).

4.1.1.5 Plant height (cm) at 270 days after planting

The data pertaining to plant height at 270 days after planting is presented in Table - 4.1. During 2014 - 2015 at 270 days after planting, plant height was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (193.22cm) as compared to other treatments and followed by T_8 treatment (181.17 cm). Significantly lower value for plant height was recorded in T_1 (154.27 cm).

During 2015-2016 at 270 days after planting, T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher plant height (194.67cm) and followed by T_8 treatment (187.63 cm). T_3 - RDF + 10 kg vermicompost plant^{-1}) recorded significantly lower plant height (160.53cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant height. The treatment T_9 was recorded higher plant height (193.94 cm) and followed by T_8 treatment (184.40 cm). Significantly lower plant height was recorded with T_1 treatment (163.38 cm) and it was on par with T_2 treatment (164.86 cm), T_3 treatment (165.54 cm) and T_6 treatment (168.64).The plant height ranged from (163.38 cm) to (193.94cm).

4.1.1.6 Plant height (cm) at 330 days after planting

The data pertaining to plant height at 330 days after planting is presented in Table -4.1. During 2014 - 2015 at 330 days after planting plant height was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (198.78cm) as compared to other treatments and followed by T_8 treatment (186.93 cm). Significantly lower value for plant height was recorded in T_1 treatment (160.35 cm), followed by T_4 treatment (175.26 cm) which was at par with T_2, T_3, T_5, T_6 and T_7 treatment.

During 2015 - 2016 at 330 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher plant height (226.93 cm) and it was followed by T_8 treatment (213.00 cm). T_1- RDF, 200 N: 200 P_2O_5: 250 K_2O g/plant recorded significantly lower plant height (196.01cm) and it was on par with T_5 treatment (196.01 cm), T_6 and T_7 treatment.

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the plant height. The higher plant height was recorded in T_9 (212.85 cm) and followed by T_8 treatment (199.97 cm). Significantly lower plant height was recorded with T_1 treatment (178.18 cm) it was on par with T_7 treatment (182.06 cm). Plant height ranged from (178.18 cm) to (212.85 cm).

The plants treated with T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded maximum plant height. The increase in plant height may be due to improvement of physical properties of soil, higher nutrient uptake and increased activity of micro organisms which were manifested in the form of enhanced growth and higher carbohydrates production (Yadav *et al.*, 2011a). Secondly, it could be because of continuous supply of available nutrient from organic and inorganic form and effect of bio active substance produced by common application of bio fertilizers. Organic manures along with biofertilizers also improve the aeration in the soil which ultimately might have improved the physiological activities inside the plant like plant height. The similar result was reported by Aneesa Rani and Sathiamoorthy (1997), Tandel *et al.* (2014), Shivakumar (2010), Suresh *et al.* (2010) and Singh *et al.*(2010) in papaya and Jeyabaskaran *et al.* (2001), Soorianathasundarum *et al.* (2001), Tirkey *et al.* (2002), Bhavidoddi (2003), Kanamadi *et al.* (2004), Nachegowda *et al.* (2004), Patel (2008), Bhalerao *et al.* (2009), Hazarika and Ansari (2010) and Kuttimani *et al.* (2013a) in Banana.

4.1.2.1 Circumference (cm) at 30 days after planting

The data pertaining to circumference at 30 days after planting is presented in Table - 4.2 and Fig: - 2. During 2014 - 2015 at 30 days after planting (Plate: 4c), circumference was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost +100g *Azotobacter* + 100g *PSB* plant^{-1} (11.65 cm) as compared to other treatments and followed by T_8 - 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} (10.07cm). Significantly lower values for circumference were recorded in T_1- RDF 200 N: 200 P_2O_5: 250 K_2O g plant^{-1} (8.56 cm) and it were on par with T_3 treatment (8.69 cm) and T_6 treatment (8.82 cm).

During 2015-2016 at 30 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded significantly higher circumference (12.89 cm) and followed by T_8 - 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} (11.74 cm). T_5 - RDF + 20kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded significantly lower trunk girth (7.89 cm) and it was on par with T_4 treatment (8.41cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference. T_9 treatment recorded highest circumference (12.27 cm) and followed by T_8 treatment (10.91 cm) respectively. Significantly lower circumference was recorded with T_5 treatment (8.45 cm) and it was on par with T_3 treatment (8.72 cm) and T_5 treatment (8.45 cm) and the circumference ranged from (8.45 cm) to (12.27 cm).

4.1.2.2 Circumference (cm) at 90 days after planting

The data pertaining to circumference at 90 days after planting is presented in Table - 4.2 and Fig- 2. During 2014 - 2015 at 90 days after planting, circumference was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100 g *PSB* plant^{-1} (12.95 cm) as compared to other treatments and followed by T_8 treatment (11.75 cm). Significantly lower values for circumference were observed in T_1 (10.19 cm) and it was on par with T_5 (10.55 cm) and T_6 (10.64 cm).

During 2015-2016 at 90 days after planting, T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100 g *PSB* plant^{-1} recorded higher circumference (13.07 cm) and followed by T_8 treatment (11.84 cm). T_1 treatment recorded significantly lower circumference (10.76 cm) and it was on par with T_5 treatment (10.98 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference. T_9 treatment recorded higher circumference (13.01cm) and followed by T_8 treatment (11.80 cm). Significantly lower circumference was recorded with T_1 treatment (10.48 cm). The circumference ranged from (10.48 cm) to (13.01 cm).

4.1.2.3 Circumference (cm) at 150 days after planting

The data pertaining to circumference at 150 days after planting is presented in Table - 4.2. During 2014 - 2015 at 150 days after planting, circumference was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (18.98 cm) treatment as compared to other treatments and followed by T_{10} treatment (17.15cm). Significantly lower value for circumference was recorded in T_1 treatment (11.87 cm) and it was on par with T_2 treatment (12.10 cm).

During 2015 - 2016 at 15 days after planting T_9 - 75% RDF + 10 kg vermicompost +100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher circumference (20.01 cm) and it was on par with T_{10} treatment (17.73 cm). T_2 - RDF + 20 kg FYM plant^{-1} recorded significantly lower circumference (12.48 cm) and it was on par with T_1 treatment (12.74 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference.T_9 recorded higher circumference of (19.49 cm) and followed by T_{10} treatment (17.44 cm) respectively. Significantly lower circumference was recorded with T_2 treatment (12.29 cm) and the circumference ranged from (12.29 cm) to (19.49 cm).

4.1.2.4 Circumference (cm) at 210 days after planting

The data pertaining to circumference at 210days after planting is presented in Table - 4. 2. During 2014 - 2015 at 210 days after planting, circumference was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (47.84 cm) as compared to other treatments and it was followed by T_8 treatment (44.72 cm). Significantly lower value for circumference was recorded in recommended dose of fertilizer treatment T_1 (26.53 cm) and followed by T_2 treatment (29.71 cm).

During 2015 - 2016 at 210 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}) recorded higher circumference (48.17 cm) and followed by T_8 treatment (44.95 cm). Significantly lower circumference recorded in T_1 treatment (27.05 cm) and it was followed by T_2 treatment (30.20 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference and recorded more in T_9 treatment (48.00 cm) followed by T_8 treatment (44.84 cm) respectively. Significantly lower circumference was recorded with T_1 treatment (26.79 cm) it was followed by T_2 treatment (29.96 cm) and the circumference ranged from (26.79 cm) to (48.00 cm).

4.1.2.5 Circumference (cm) at 270 days after planting

The data pertaining to circumference at 270 days after planting is presented in Table - 4.2. During 2014 - 2015 at 270 days after planting, circumference was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (50.66 cm) as compared to other treatments, followed by T_{10} treatment (46.35 cm). Significantly lower values for circumference were observed in T_1 treatment (34.59 cm).

During 2015 - 2016 at 270 days after planting T_9 -75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded higher circumference (51.14 cm) and it was on par with T_8 treatment (49.74 cm). Treatment T_1 recorded significantly lower circumference (35.68 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference. T_9 recorded highest circumference of (50.90 cm) and followed by T_8 treatment (47.63 cm). Significantly lower circumference was recorded with T_1 treatment (35.13 cm) and it was followed by T_3 (40.27 cm). Circumference ranged from (35.13 cm) to (50.90 cm).

4.1.2.6 Circumference (cm) at 330 days after planting

The data pertaining to circumference at 330 days after planting is presented in Table - 4. 2. During 2014 - 2015 at 330 days after planting, circumference was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (51.20 cm) as compared to other treatments andit was followed by T_8 treatment (48.91 cm). Significantly lower value for circumference was recorded in T_1 treatment (40.73 cm).

During 2015 - 2016 at 330 days after plantingin treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher circumference (53.77 cm) and it was on par with T_7 treatment (51.16) and T_8 treatment (52.59 cm). The T_1 treatment recorded significantly lower circumference (41.43 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the circumference. The treatment T_9 recorded higher circumference of (52.48 cm) and followed by T_8 treatment (50.75 cm) respectively. Significantly lower circumference was recorded with T_1 treatment (41.08 cm) and the trunk girth ranged from (41.08 cm) to (52.48 cm).

The plant treated with T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} resulted in maximum circumference of papaya plant. The circumference may be due to improvement of physical properties of soil, higher nutrient uptake and increased activity of micro organisms which were manifested in the form of enhanced growth and higher carbohydrates production (Yadav *et al*., 2011a). It could because of continuous supply of available nutrient from organic and inorganic form and effect of bio active substance produced by common application of bio fertilizer. Organic manure application along with bio fertilizers also improves the aeration in the soil, which ultimately might have improved the physiological activities inside the plants. The similar result was reported by Aneesa Rani and Sathiamoorthy (1997), Tandel *et al.* (2014) Shivakumar (2010), Suresh *et al.* (2010) and Singh *et al.* (2010) in papaya and Jeyabaskaran *et al.* (2001), Soorianathasundarum *et al.* (2001), Tirkey *et al.* (2002), Bhavidoddi (2003), Kanamadi *et al.* (2004), Nachegowda *et al.* (2004), Patel (2008), Bhalerao *et al.* (2009), Hazarika and Ansari (2010) and Kuttimani *et al.* (2013a) in Banana.

4.1.3.1 Petiole length (cm) at 30 days after planting

The data pertaining to petiole length at 30days after planting is presented in Table - 4.3 and Fig: - 3. During 2014 - 2015 at 30 days after planting (Plate: 4b), petiole length was significantly higher in the treatment T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} (37.62cm) as compared to other treatments and it was followed by T_8 - 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} (34.46 cm). Significantly a lower value for petiole length was recorded in T_4- RDF + 5 kg neem cake plant^{-1} (21.44 cm).

During 2015 - 2016 at 30days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded more petiole length (38.34 cm) and it was followed by T_8 - 75% RDF + 20kg FYM plant^{-1} +100g *Azotobacter* + 100g *PSB* plant^{-1} (36.06 cm). The treatment T_4- RDF + 5kg Neem cake plant^{-1} recorded significantly lower petiole length (26.68 cm) and it was on par with T_2, T_3, T_5, and T_6 treatments.

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the petiole length T_9 treatment and this treatment recordedhigher petiole lengthof (37.98 cm). Significantly lower petiole length was recorded with T_4 treatment (24.06 cm) and it was on par with T_6 treatment (25.44 cm) and T_{10} treatment (25.40 cm) and the petiole lengthranged from (24.06 cm) to (37.98 cm).

4.1.3.2 Petiole length (cm) at 90 days after planting

The data pertaining to petiole length at 90days after planting is presented in Table -4.3. During 2014 - 2015 at 90 days after planting, petiole length was significantly higher in the T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (41.93 cm) as compared to other treatments and it was on par with T_8 treatment (37.64 cm). Significantly lower values for petiole length were observed in T_4 treatment (23.35 cm).

During 2015 - 2016 at 90 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded higher petiole length (43.67 cm) and it was followed by T_8 - 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* +100g *PSB* plant^{-1} (38.81 cm). The treatment T_4 recorded significantly lower petiole length (27.72 cm) and it was on par with T_6 treatment (27.98) and treatment T_7 treatment (28.94).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the trunk girth.The T_9 treatment (42.80 cm) followed by T_8 treatment (38.22cm) treatments recorded greater petiole lengthrespectively. Significantly lower petiole length was recorded with T_4 treatment (25.53 cm). The petiole length ranged from (25.53 cm) to (48.80 cm).

4.1.3.3 Petiole length (cm) at 150 days after planting

The data pertaining to petiole length at 150 days after planting is presented in Table - 4.3 and Fig- 3. During 2014 - 2015 at 150 days after planting, petiole length was significantly higher in the treatment T_9 - 75% RDF

+ 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (45.52 cm) as compared to other treatments and it was followed by T_8 treatment (40.26 cm). Significantly lower values for petiole length were observed in T_4 treatment (26.88 cm) and followed by T_{10} treatment (29.54 cm).

During 2015 - 2016 at 150 days after planting the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded higher petiole length (47.63 cm) and it was followed by T_8 treatment (43.06 cm). The treatment (T_4) RDF + 5 kg neem cake plant^{-1} recorded significantly lower petiole length (33.29 cm) and it was on par with T_2 treatment (33.47 cm) and T_{10} treatment (33.55 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the petiole length and T_9 treatment (45.43 cm) recorded higher petiole length and followed by T_8 treatment (41.66 cm) respectively. Significantly lower plant height was recorded with T_4 treatment (30.09 cm) and followed by T_{10} treatment (31.54 cm) and the petiole lengthranged from (46.57 cm) to (30.09 cm).

4.1.3.4 Petiole length (cm) at 210 days after planting

The data pertaining to petiole length at 210 days after planting is presented in Table - 4.3. During 2014 - 2015 at 210 - 240 days after planting, petiole length was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (49.33 cm) as compared to other treatments and it was followed by T_8 treatment (43.54 cm). Significantly lower value for petiole length height was recorded in T_4 treatment (30.87 cm) and it was on par with T_{10} treatment (33.75 cm).

During 2015 - 2016 at 210days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher petiole length (51.73 cm) and it was followed by T_8 treatment (44.87 cm). The treatment T_4 recorded significantly lower petiole length (34.32 cm) and followed by T_6 treatment (37.64 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the trunk girth. The treatment T_9 recorded higher petiole length of (50.53cm) and followed by T_8 treatment (44.21 cm) respectively. Significantly lower petiole lengthwas recorded with T_4 (32.60 cm) and the petiole length ranged from (32.60 cm) to (50.53 cm).

4.1.3.5 Petiole length (cm) at 270 days after planting

The data pertaining to petiole length at 270 days after planting is presented in Table - 4.3. During 2014 - 2015 at 270 days after planting, petiole length was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100 g *PSB* plant^{-1} (51.56 cm) as compared to other treatments and it was followed by T_8 treatment (46.41cm). Significantly lower values for petiole length were observed in T_4 (32.45 cm) followed by T_6 treatment.

During 2015-2016 at 270 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} treatment recorded higher petiole length (53.36 cm) and it was followed by T_8 treatment (52.35 cm). T_1 recorded significantly lower petiole length (46.64 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the petiole length in T_9 treatment (52.46 cm) recorded higher petiole length and followed by T_8 treatment (49.38 cm) respectively. Significantly lower petiole length was recorded with T_4 treatment (41.35 cm) it was on par with T_1,T_2,T_3,T_5,T_6 and T_7 and the petiole length ranged from (41.35 cm) to (52.46 cm).

4.1.3.6 Petiole length (cm) at 330 days after planting

The data pertaining to petiole length at 330 days after planting is presented in Table - 4.3. During 2014 - 2015 at 330days after plantingpetiole length was significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (52.09 cm) as compared to other treatments and it was followed by T_8 treatment (48.08 cm). Significantly lower value for petiole length was recorded in T_4 treatment (38.07 cm) and it was at par with T_{10} treatment (39.08 cm).

During 2015 - 2016 at 330 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher petiole length (53.77 cm) and it was followed by T_8 treatment (52.59 cm). The treatment T_4 recorded significantly lower petiole length (41.43 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the petiole length and in T_9 treatment recorded highest (52.93 cm) and followed by T_8 treatment (50.34 cm). Significantly lower petiole length was recorded T_4 treatment (39.75 cm), T_3 treatment (42.21 cm) and the petiole length ranged from (39.75 cm) to (52.93 cm).

4.1.4.1 Number of leaves per plant at 30 days after planting

The data pertaining to number of leaves per plant at 30 days after planting is presented in Table - 4.4 and graphically presented Fig: - 4. During 2014 - 2015 at 30 days after planting, the number of leaves per plantwas significantly higher in the T_4 - RDF + 5kg neem cake plant^{-1} 23.87was compared to other treatments and it was on par with T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (22.41). Significantly lower value for number of leaves per plant was recorded in T_2 - RDF + 20 kg FYM plant^{-1} (14.97) and it was on par with T_3 treatment (15.56).

During 2015 - 2016 at 30days after planting T_4- RDF + 5kg neem cake plant^{-1} recorded more number of leaves per plant (25.27) and it was followed by T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (22.78). The treatment T_2 - RDF + 20 kg FYM plant^{-1} recorded significantly lower number of leaves per plant (15.46) and it was on par with T_1 treatment (16.04).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plantandin T_4 treatment recordedmaximum number of leaves per plantof (24.57). Significantly lower number of leaves per plant was recorded with T_2 treatment (15.22) and it was followed by T_3 treatment (15.81). Number of leaves per plantranged from (15.22) to (24.57).

4.1.4.2 Number of leaves per plant at 90 days after planting

The data pertaining to number of leaves per plant at 90 days after planting is presented in Table - 4.4. During 2014 - 2015 at 90 days after planting, the number of leaves per plant was significantly higher in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (24.64) as compared to other treatments and followed by T_4 treatment (21.47). Significantly lower number of leaves per plant was observed in T_8 treatment (18.42).

During 2015 - 2016 at 90 days after planting T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded maximum number of leaves per plant (25.32) and followed by T_6 treatment (22.81). The treatment T_1recorded significantly minimum number of leaves per plant (19.01) and it was on par with T_8 treatment (19.08).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plant andin T_9 treatment (24.98) recorded maximum number of leaves and followed by T_6 treatment (22.02) respectively. Significantly lower number of leaves per plantwas recorded with T_8 treatment (18.75) and it was on par with T_1 treatment (18.77). The number of leaves per plant ranged from (18.75) to (24.98).

4.1.4.3 Number of leaves per plant at 150 days after planting

The data pertaining to number of leaves per plant at 150 days after planting is presented in Table - 4.4. During 2014 - 2015 at 150 days after planting, the number of leaves per plantwas significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (30.23) as compared to other treatments. Significantly lower values for number of leaves per plantwere observed in T_4 treatment **(**20.57) and it was on par with T_4 treatment (20.57) and which was on par with T_3 treatment.

During 2015-2016 at 150 days after planting, T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher number of leaves per plant (33.34). The T_1 recorded significantly lower number of leaves per plant (22.83) and it was on par with T_2, T_3, T_5 and T_6.

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plantandin treatment T_9 recordedmore number of leaves per plantof (31.79). Significantly lower number of leaves per plant was recorded with T_3 (22.20) and at par with T_2 treatment (22.24) and the number of leaves per plantranged from (22.20) to (31.79).

4.1.4.4. Number of leaves per plant at 210 days after planting

The data pertaining to number of leaves per plant at 210 days after planting is presented in Table - 4.4. During 2014 - 2015 at 210 days after planting, the number of leaves per plantwas significantly higher in the T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (35.56) as compared to other treatments and it werefollowed by T_8 treatment (33.87). Significantly lower value for number of leaves per plant was recorded in T_{10} treatment (27.64) and it was followed by T_1 treatment (28.68).

During 2015 - 2016 at 210 days after planting T_9 - 75% RDF + 10 kg vermicompost +100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher number of leaves per plant (36.06) and it was followed by T_8 treatment (34.67). The treatment T_{10} treatment (28.31) recorded significantly lower number of leaves per plantandit was on par with T_1 treatment (29.21).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plant and T_9 treatment recorded maximum number of leaves per plant (35.81) and followed by T_8 treatment (34.27). Significantly lower number of leaves per plantwas recorded with T_{10} treatment (27.97) and the number of leaves per plantranged from (27.97) to (35.81).

4.1.4.5 Number of leaves per plant at 270 days after planting

The data pertaining to number of leaves per plantat 270 days after planting is presented in Table - 4.4. During 2014 - 2015 at 270 days after plantingthe number of leaves per plantwas significantly higher in the treatment T_8 - 75% RDF + 20kg FYM plant^{-1} + 100g *Azotobacter* +100g *PSB* plant^{-1} (40.34) as compared to other treatments and it were followed by T_9 treatment (39.96). Significantly lower values for number of leaves per plant were observed in T_1 treatment (30.95).

During 2015-2016 at 270 days after planting T_8 - 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher number of leaves per plant (41.34) and it was on par with T_9 treatment (40.70). T_1 recorded significantly lower number of leaves per plant (34.12) and it was on par with T_2 treatment (34.88).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plantin T_8 treatment recordedmaximumnumber of leaves per plant (40.84) and it was on par with T_9 treatment (40.33) respectively. Significantly lower number of leaves per plant was recorded with T_1 treatment (32.53) it was followed by T_2 treatment (33.96) and the number of leaves per plant ranged from (32.53) to (40.84).

4.1.4.6 Number of leaves per plant at 330 days after planting

The data pertaining to number of leaves per plant at 330 days after planting is presented in Table - 4.4. During 2014 - 2015 at 330 days after planting, number of leaves per plant was significantly higher in the T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (45.38) as compared to other treatments and followed by T_1 treatment (44.40). Significantly minimum number of leaves per plant was recorded in T_4 treatment (37.12) and it was followed by T_2 treatment (39.70).

During 2015-2016 at 330 days after planting T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded maximum number of leaves per plant (48.31) and followed by T_1 treatment (45.39). T_2 treatment (41.23) recorded significantly lower number of leaves per plant**.**

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of leaves per plant and in T_9 treatment (46.85) recorded maximum number of leaves per plantand it was on par with T_1 treatment (44.90). Significantly lower number of leaves per plantwas recorded with T_4 treatment (40.34). The number of leaves per plant ranged from (41.23) to (46.85).

In present investigation, there was significant effect of different treatments on number of leaves per plant Table - 4.4 and Fig- 4 and petiole length Table - 4.3 and Fig - 3 were recorded with application T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}. The organic manure application with varied doses of inorganic fertilizers produced higher mean value for number of leaves and petiole length compared to recommended dose of fertilizer. When organic manuresare added to soil along with inorganic fertilizers, complex nitrogenous compound slowly break down and make steady N supply throughout the growth period of the crop. This might have attributed to more availability of nutrient particularly nitrogen and subsequent uptake by crop. This result in higher biomass production has reflected by production of additional leaves and simultaneously increased the petiole length (Kuttimani *et al*., 2013a).

These findings are in conformity with above mentioned growth parameters have also been reported by Tandel *et al.* (2014), Yadav *et al*. (2011a), Shivakumar (2010), Suresh *et al*. (2010), Singh *et al.* (2010), Ray *et al*. (1999), Aneesa Rani and Sathiamoorthy (1997) in papaya and Hazarika and Ansari (2010), Bhalerao *et al*. (2009), Patel (2008), Nachegowda *et al.* (2004), Kanamadi *et al.* (2004), Bhavidoddi (2003), Tirkey *et al*. (2002), Jeyabaskaran *et al*. (2001) and Soorianathasundarum *et al*. (2001) in Banana.

4.2 Yield parameters

4.2.1 Days to first flowering (days)

The data pertaining to days taken first flowering is presented in Table - 4.5 and Fig- 5. During 2014 - 2015, significantly lowest days to first flowering were recorded in the T_9 treatment (135.44 days) as compared to other treatments and followed by T_7 treatment (161.95 days). Higher days to first flowering were observed in T_1 treatment (169.59 days) and it was at par with T_3 treatment (169.58 days).

During 2015 - 2016, T_9 - RDF + 5kg neem cake + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded lowest days taken to first flowering (143.84 days) and was followed by T_7 treatment (163.35 days). Treatment T_1 (170.65) recorded higher days to first flowering and it was on par with T_3 treatment (170.09 days).

It is evident from the pooled data the application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the days to first flowering and in T_9 treatment recorded lower days to first flowering of (139.64 days). Higher days to first flowering was recorded with T_1 treatment (170.12 days) and which was on par with T_2 treatment (168.83 days) and the days to first flowering ranged from (139.64 days) to (170.12 days).

The initiation of flowering was early (139.64 days) in the treatment receiving 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}. The earliness in flowering might be due to the higher net assimilation rate on account of better growth leading to the production of endogenous metabolites earlier in optimum level enabling early flower as reported by Singh and Varu (2013) and (Yadav *et al.,* 2011a) in papaya. These results are in conformity with the findings reported by Shivakumar (2010) and Suresh *et al*. (2010) in papaya and Jeyabaskaran *et al.* (2001), Soorianathasundarum *et al*. (2001), Tirkey *et al*. (2002), Bhavidoddi (2003), Kanamadi *et al.* (2004), Nachegowda *et al.* (2004), Patel (2008), Bhalerao *et al*. (2009), Hazarika and

Ansari (2010) and Kuttimani *et al*. (2013a) in Banana. Whereas, the control *i.e*. RDF recorded maximum days for flowering in papaya cv. Red Lady.

4.2.2 Days to fruit maturity (days)

The data pertaining to days to fruit maturity at presented in Table - 4.6 and Fig - 6. During 2014 - 2015, lowest days taken to fruit maturityin T_9- 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (196.11days) as compared to other treatments and it was on par with T_8 treatment (203.28 days). Higher days to fruit maturity were observed in T_4 (218.53 days) and it was at par with T_1 (216.72 days) and followed by T_6 (214.54 days).

During 2015 - 2016, T_9 - 75% RDF +10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded minimum days taken to maturity (205.54 days) and it was on par with T_2 (208.82 days). Treatment T_4 (218.70 days) recorded significantly maximum days to maturity and it was on par with T_7 treatment (217.14) and T_6 treatment (216.81 days).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the days taken to maturity and in T_9 treatment recorded lower days to maturity (200.82 days). This might be due to early flowering recorded in the treatment Table - 4.6. Significantly higher days taken to maturity were recorded with T_4 treatment (218.61days) and it was on par with T_6 treatment (215.67days). The days taken to maturity ranged from (200.82 days) to (218.61 days).

4.2.3 Number of fruit per plant

The data pertaining to number of fruit per plant is presented in Table - 4.7 and Fig- 7. During 2014 - 2015, higher number of fruit per plant (Plate:5b) was recorded in the treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} (32.98) as compared to other treatments and it was followed by T_8 treatment (30.26). Significantly lower number of fruit per plant was recorded in T_1 treatment (22.71) and it was followed by T_2 treatment (24.50).

During 2015 - 2016, T_9 - 75% RDF +10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} recorded higher number of fruits per plant (31.45) and which was followed by T_8 treatment (28.00). The T_1 treatment recorded (21.41) significantly lower number of fruit per plant (Plate: 5a) and which was on par with T_2 and T_3 treatment.

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the number of fruit per plant and in T_9 treatment recording higher number of fruits per plantof (32.22) and it was followed by T_{10} (28.81). Significantly lower number of fruit per plant was recorded with T_1 (22.06). The number of fruit per plant ranged from (22.06) to (32.22).

The number of fruits per plant was recorded maximum with the application of T_9 -75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100 g PSB plant^{-1} during both years of experimentation. The significant response of *Azotobacter,* organic manure with part supplementation with inorganic fertilizers had positively and significantly influenced the yield attributes. It is well known that efficiency of bioagent can be well exploited with the use of organic manure with inorganic fertilizers (Suther, 2009) which might have improved the yield parameters by better availability and uptake of nutrient by plant roots and enhancing the source - sink relationship by increasing the movement of carbohydrates from the leaves to the fruit. Similar findings have been reported by Yadav (2006), Srivastava (2008) and Sha and Karuppaiah (2010).

4.2.4 Fruit length (cm)

The data pertaining to fruit lengthis presented in Table - 4.8 and Fig- 8. During 2014 - 2015, Higher fruit length was recorded in the T_9 (27.23 cm) as compared to other treatments and it was followed by T_1 (25.21 cm) and T_5 (24.93 cm). Lower fruit length was observed in T_4 (20.18 cm) and it was at par with T_2 (21.09 cm).

During 2015 - 2016, T_9 treatment recorded higher fruit length (25.45 cm) and which was on par with T_5 treatment (23.97cm). T_4 treatment (17.84 cm) recorded significantly lower fruit lengthand which was on par with T_2 treatment (18.21cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the fruit length and in T_9 treatment recorded higher fruit length of (26.34 cm) and it was followed by T_5 treatment (24.45 cm). Significantly lower fruit lengthwas recorded with T_4 treatment (19.20 cm) and on par with T_2 treatment (19.47 cm). The fruit length ranged from (19.20 cm) to (26.34 cm).

The effect of integrated nutrient management has significantly influenced the fruit length and highest fruit length was recorded in T_9 treatment. The notable improvement with respect to growth parameter with use of bio fertilizers, organic manures and inorganic fertilizers may be attributed to sufficient availability of nitrogen, phosphorus, potassium and other essential nutrients. Besides, *Azotobacter* is also associated with the production of growth promoting substance, antifungal compounds and cytokinins which in turn might have lead to better root development, better transport and uptake of nutrients which resulted in increasing growth parameters. This might have helped in increasing the fruit characters like fruit length. Results are in close conformity with the findings of Singh (2013), Yadav (2006) and Srivastava (2008).

4.2.5 Pulp thickness (cm)

The data pertaining to pulp thicknessis presented in Table - 4.9. During 2014 - 2015, lower pulp thickness was recorded in the T_7 treatment (1.69 cm) as compared to other treatments and it was followed by T_4 treatments (1.73 cm). Higher pulp thickness was observed in T_9 treatment (2.66 cm) and it was at par with T_8 treatment (2.57cm) and T_2 treatment (2.27 cm).

During 2015 - 2016, T_9 treatment recorded higher pulp thickness (2.02cm) and which was on par with T_8 treatment (1.86 cm). The T_7 treatment

(1.07 cm) recorded lower pulp thickness and which was followed by T_1 (1.27 cm).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the pulp thickness in T_9 treatment recording higher pulp thickness of (2.34 cm) and it was on par with T_8 treatment (2.22 cm). Lower pulp thickness was recorded with T_7 treatment (1.38 cm) and followed by T_6 treatment (1.54 cm). The pulp thickness ranged from (1.38 cm) to (2.34 cm).

4.2.6 Fruit weight (g)

The data pertaining to fruit weightis presented in Table -4.10 and Fig- 9. During 2014 - 2015, lower fruit weight was recorded in the T_5 treatment (1630.89g) as compared to other treatments and it was on par with T_4 treatment (1632.50g). Significantly higher fruit weightwas observed in T_9 - 75% RDF + 10 kg vermicompost + 100 g *Azotobacter* + 100g *PSB* plant^{-1} (2018.00 g) and it was at par with T_8 treatment (1954.03 g) and T_6 treatment (1949.87g).

During 2015 - 2016, T_9 treatment recorded higher fruit weight (1840.24 g) and which was on par with T_8 treatment (1769.67g). T_4 recorded significantly lower fruit weight (1281.67 g).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the fruit weight in T_9 treatment recording higher fruit weight (1929.12 g) and it was on par with T_8 treatment (1861.85 g). Significantly lower fruit weight was recorded with T_4 treatment (1473.85 g) it was on par with T_5 treatment (1577.45 g). The fruit weight ranged from (1457.09 g) to (1929.12 g).

The application of organic manures, bio fertilizers along with major nutrients increased the growth parameters like plant height and number of leaves in this treatment. Growth parameter especially leaves play an important role in photosynthesis (metabolites) and this might have paved way for increases higher fruit weight. The results also in close conformity with the findings of papaya by Ravishanker *et al.* (2010) and Chaudhri *et al*. (2001).

4.2.7 Fruit yield (kg plant^{-1})

The data pertaining to fruit yieldat presented in Table - 4.11 and Fig- 10. During 2014 - 2015, higher fruit yieldwas recordedin the T_9 treatment (31.34 kg plant^{-1}) as compared to other treatments and it was followed by T_{10} treatment (29.62 kg plant^{-1}). Significantly lower fruit yieldwas recorded in T_1 treatment (20.49 kg plant^{-1}) and it was followed by T_2 treatment (22.63 kg plant^{-1}).

During 2015- 2016, T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} recorded higher fruit yield (32.10 kg plant^{-1}) which was followed by T_8 treatment (30.14 kg plant^{-1}) and which was on par with T_{10} (29.95 kg plant^{-1}). T_1 treatment (20.82 kg plant^{-1}) recorded significantly lower fruit yieldand which was followed by T_2 treatment (22.26 kg plant^{-1}).

It is evident from the pooled data that application of organic manures, inorganic fertilizers and *biofertlizers* in combination significantly influenced the fruit yield T_9 treatment recording higher fruit yield of (31.72 kg plant^{-1}) and it was followed by T_8 treatment (29.81 kg plant^{-1}) it was on par with T_{10} treatment (29.79 kg plant^{-1}). Significantly lower fruit yield was recorded with T_1 (20.66 kg plant^{-1}) and followed by T_2 treatment (22.45 kg plant^{-1}). The fruit yield ranged from (20.66 kg plant^{-1}) to (31.72 kg plant^{-1}).

The results of present study envisaged that effect of integrated nutrient management on yield of papaya (*Carica papaya* L.) *cv*. Red Lady gave significant increase in the yield over control**.** The yield and yield attributes like fruit weight Table - 4.10 and Fig -10 and fruit yield per plant Table - 4.11 and Fig.-11 are considered to be an important factor to judge the yield and yield attributes in papaya crop. Fruit weight (g) and fruit yield per plant (kg) were maximum with treatment T_9 -75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}. Fruit yield increased with application of organic manures in combination with chemical fertilizers as against the straight fertilizer application. Increase in fruit attributes could be due to the increase in morphological traits such as plant height, girth, number of leaves, faster rate of leaf production and also higher nutrient uptake by the plant. Increased number of leaves might have increased the photosynthetic activity resulting in higher accumulation of carbohydrates. Relatively higher carbohydrates could have promoted the growth rate and in turn increased yield. Higher fruit yield (t. ha^{-1}) in papaya was realized due to increase in fruit number and fruit weight per plant. Higher yield response owing to application of organics ascribed to improved physical, chemical and biological properties of soil resulting in better supply of plant nutrients, which turn led to good crop growth and yield (Shivakumar, 2010). The higher fruit yield /plant might be due to increased fruit length, fruit number, fruit weight and volume of fruit with application of organic manures in combination with chemical fertilizers as against the straight fertilizer application. The organic manures being the store house of all plant nutrients including trace elements might have released them gradually and steadily and this contributed towards the balanced nutrition of crop throughout the cropping period which results in enhancement in yield attributes (Hazarika and Ansari, 2010). Steady and continuous availability of essential plant nutrients by the addition of organic manures along with chemical fertilizers which supplements all the essential nutrients, enhances the availability of more amount of primary nutrients and growth promoting substances from the beginning of the initial vegetative stage up to completion of cropping period (Yadav *et al*., 2011b). These results are in conformity with the findings reported be Ganeshamurthy *et al*.(2004), Shivaputra *et al.* (2004), Singh *et al*. (2010) and Suresh *et al*. (2010) in papaya and Athani *et al*. (1999), Ray *et al*. (1999), Chezhiyan *et al.* (1999), Jeyabaskaran *et al.* (2001), Soorianathasundarum *et al*. (2001), Naresh and Anamika (2002), Tirkey *et al*. (2002), Bhavidoddi (2003), Gogoi *et al.* (2004), Kanamadi *et al*. (2004), Nachegowda *et al.* (2004), Sabarad *et al*. (2004), Patel (2008), Bhalerao *et al.* (2009), Ziauddin (2009) , Hazarika *et al*. (2010) and Kuttimani *et al* .(2013a) in Banana.

4.3 Qualitative characters

The effect of different of INM treatments on quality parameters like Physiological loss in weight (%), Fruit firmness (kg cm^{-2}), Spoilage (%), Total soluble solids (°Brix), Reducing sugars (%), Total sugars (%), Ascorbic acid (mg/100g pulp) and Titratable acidity (%) were estimated. The data of quality characters are presented in table.

4.3.1 Physiological loss in weight (%)

The data pertaining to physiological loss in weight (%) of papaya fruits as influenced by various INM treatments are presented in Table - 4.12 and Fig-11). The application of different treatments had found significant effect on weight loss of papaya fruits during first year, second year as well as in pooled mean also (Table - 4.12). Treatment application of T_9 - 75% Recommended dose of Fertilizer + 10 kg vermicompost + 100g *Azotobacter* + 100 g *PSB* plant^{-1}had significantly minimum loss in weight (8.81% and 10.61%) during first year and second year, respectively. Whereas the maximum weight loss (16.18% and 20.39%) was recorded in T_1 (control) during both the years of investigation.

In pooled analysis, significantly minimum loss of weight was recorded in T_9 treatment (9.71%) and maximum value of weight loss was observed in control treatment T_1 treatment (18.29%).

The significance of optimum plant nutrition is well known for the production of good quality fruits. Among these entire characters were significantly influenced by the various Integrated Nutrient Management treatments. The physiological loss in weight (PLW) were minimum in the plants treated with 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} which helps in higher firmness and thereby increase the shelf life of papaya fruit. This might be due to high population of microbes, organic manures usually help to degrade and mobilize the nutrients to available form. The presence of vital nutrients and some unidentified metabolites as ripening retardants leading to reduced respiration, transpiration and weight loss with extended shelf life (Shivakumar, 2010).

4.3.2 Firmness (kg cm^{-2})

The data bearing on firmness (kg cm^{-2}) of papaya fruits were influenced by various INM treatments are presented in Table - 4.13 and Fig- 12. The application of different treatments had found significant effect on firmness of papaya fruits during first year, second year as well as in pooled mean also (Table-4.13). Treatment application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} had significantly maximum firmness (8.37 kg cm^{-2} and 8.36 kg cm^{-2}) and it was followed by T_5 during first year and second year. Whereas, the minimum (5.85 kg cm^{-2} and 5.91 kg cm^{-2}) firmness was recorded in T_1 treatment (control) during both the years of investigation and it was followed by T_{10} treatment.

In pooled analysis, significantly minimum firmness was recorded in treatment T_1 (control) and maximum value of firmness was obtained with the treatment T_9.

Firmness of fruits is an important characteristic that is used to determine stabilityand it is predominantly determined by structure and composition of cell wall. Calcium is essential for structural integrity of both the cell wall and plasma membrane.

The organic manure treatments indicating their effectiveness in the controlling the weight loss, which might be due to presence of higher calcium content, reduced rate of respiration and transpiration from fruit surfaces.

The decrease in the respiration could be further attributed to lowering of succinate and malate dehydrogenises activities associated with TCA cycle (Shivakumar, 2010).

Presence of epicuticular wax on the fruit skin also reduces respiration and transpiration during post harvest period by partially blocking the lenticels, cuticle and consequently retards the moisture loss caused by transpiration. Higher availability of secondary nutrients, metabolite s like GA_3 and reduced gaseous exchange effects delay in ripening, senescence, less tissue break down and softening of tissue which increases firmness and extends storage life. These results are in conformity with the findings reported by Singh *et al.* (2010) in papaya and Bhavidoddi (2003) and Patel (2008) in Banana.

4.3.3 Spoilage (%)

The data presented on spoilage of papaya fruits were influenced by various INM treatments are presented in Table - 4.14 and Fig - 13. The application of different treatments had found significant effect on spoilage of papaya fruits during first year, second year and as well as in pooled mean also (Table - 4.14). Treatment application control (T_1) had significantly maximum spoilage (75.25% and 53.62%) and it was followed by T_6 and T_3 treatment during first and second year respectively. Whereas the minimum (48.82% and 42.04%) spoilage was recorded in T_9 treatment during both the years of investigation.

In pooled analysis, minimum spoilage was recorded in treatment T_9 (45.43%) and maximum value of spoilage was observed in T_1 treatment (64.43%).

4.3.4 Total soluble solids (^{O}Brix)

The data recorded on total soluble solids of papaya fruits were influenced by various INM treatments presented in Table - 4.15 and Fig - 14. The application of different treatments had found significant effect on total soluble solids of papaya fruits during first year, second year as well as in pooled mean also. The application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} had recorded significantly maximum total soluble solids (11.08 ^{O}Brix and 10.75 ^{O}Brix) and it was followed by T_8 during first year and second year, respectively. Whereas, the minimum total soluble solids were recorded in T_1 (8.56 ^{O}Brix and 8.79 ^{O}Brix) during both the years of investigation, respectively and it was followed by treatment T_2 treatment.

In pooled analysis, significantly minimum total soluble solids were recorded in control (8.68 ^{O}Brix) and maximum value of total soluble solids were obtained with treatment T_9 (10.91 ^{O}Brix).

4.3.5 Reducing sugars (%)

The data presented on reducing sugars of papaya fruits were influenced by various INM treatments presented in Table - 4.16 and graphically presented in Fig-15. The application of different treatments had found significant effect on reducing sugars of papaya fruits during first year, second year as well as in pooled mean also. The application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} had significantly maximum reducing sugars (9.08 %) and it was at par with T_3 and T_8 treatment during 2014 - 15. In second year, maximum Reducing sugars were recorded in T_8 (9.10%) which was at par with T_3, T_7 and T_9 treatment respectively. Whereas the minimum (7.58%) reducing sugars were recorded in T_1 (control) during both the years of investigation.

In pooled analysis, significantly minimum reducing sugars were recorded in treatment T_1 treatment (7.68%) and Maximum value of reducing sugarswere obtained with treatment T_8 (9.01%) and which was on par with T_9 treatment (8.97 %).

4.3.6 Total sugars (%)

The data presented on total sugars (%) of papaya fruits were influenced by various INM treatments presented in Table - 4.17 and Fig- 16. The application of different treatments had found significant effect on total sugars of papaya fruits during first year, second year as well as in pooled mean also Table - 4.15. The application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} had significantly maximum total sugars (10.25% and 10.99%) during both the year. Whereas, the minimum (6.87% and 7.03%) total sugars was recorded in T_1 (control) during both the years of investigation, respectively and it was followed by T_8 treatment during 2014 - 15 and 2015 - 16.

In pooled analysis, significantly minimum total sugars was recorded in treatment T_1 treatment (6.95%) and maximum value of total sugars was obtained with treatment T_9 (10.62 %) which was followed by T_7 treatment.

4.3.7 Ascorbic acid (mg/100g pulp)

The data recorded on Ascorbic acid of papaya fruits wasinfluenced by various INM treatments are presented in Table - 4.18 and Fig- 17. Application of different treatments had found significant effect on ascorbic acid of papaya fruits during first year, second year as well as in pooled mean also (Table - 4.18). Application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (T_9) treatment had recorded significantly maximum ascorbic acid (24.45 mg/100 g pulp and 22.82 mg/100 g pulp) during first year and second year respectively. Whereas, the minimum (20.41 mg/100g pulp) ascorbic acid was recorded in T_1 and T_2 during the year of 2014 - 15. During 2015 - 16 minimum ascorbic acid was recorded in T_{10} treatment (19.96 mg/100 g pulp) treatment.

In pooled analysis, significantly minimum ascorbic acid was recorded in control (20.52 mg/100g pulp) and maximum value of ascorbic acid was obtained with treatment T_9 (23.51 mg/100 g pulp).

4.3.8 Titrable Acidity (%)

The data presented on titrable acidity of papaya fruits wasinfluenced by various INM treatments is presented in Table - 4.19 and Fig- 18. The application of different treatments had no significant effect on acidity of papaya fruits during first year, second year as well as in pooled mean also Table - 4.19.

The significantly higher Total soluble solids (^{O}Brix), Total sugars (%), Reducing sugars (%), Ascorbic acid (mg/100g pulp) and Titrable acidity (%) were minimum in the fruit of papaya by the treatment combination T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1}. The quality in general was superior in the plants treated with integration of organic, bio fertilizers and inorganic fertilizers. It might be due to the addition of organic manures supplements ample of nutrients, moisture and growth promoting substances which enhances metabolic and hormonal activity of the plant and that promotes production of more photosynthates which was stored in fruits in the form of starch and carbohydrates. It is an established fact that the transformation of mature fruit into ripe form i.e., during the process of ripening in storage the fruit undergoes physical, physiological and biochemical changes. The increase in TSS, Total sugar and ascorbic acid content of papaya fruits could be attributed to the conversion of reserved starch and other insoluble carbohydrates into soluble sugars. The reduction of titratable acidity of papaya fruits through application of different organic manure with inorganic fertilizer might be due to the positive influence of boron and zinc in conversion of acids into sugar and their derivatives by the reaction involving glycolytic path way or be used in respiration (Singh *et al*., 2010). These results elucidate the findings of Singh *et al.* (2013), Ganeshamurthy *et al*. (2004), Shivakumar (2010), and Yadav *et al.* (2011a) in papaya and El-Naby (2000), Soorianathasundarum *et al*. (2001), Bhavidoddi (2003) and Patel (2008) in Banana.

4.3.9 Benefit and Cost Ratio

Benefit and cost ratio of various treatments Table - 4.20 shows maximum net returns are in treatment T_9 - 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (Rs/- 3,46,565) and Benefit and cost ratio (2.15), followed by treatment T_{10} - 75% RDF + 5kg NC + 100g *Azotobacter* + 100g *PSB* plant^{-1} (Rs/- 3,10,615) and T_6 - RDF + 10kg VC + 100g *Azotobacter* + 100g *PSB* plant^{-1} (Rs/- 2,72,260) However, Minimum net returns were recorded in T_1 treatment (Rs/- 1, 72,560) and low Benefit Cost ratio (1.09).

These results are in conformity with results reported by Shivakumar (2010), and Yadav *et al.* (2011b) in papaya and Ray and Yadav (1996), Anon. (2005), Bhavidoddi (2003), Patel (2008) and Bhalerao *et al*. (2009) in banana.

4.2 EFFECT OF POST HARVEST TREATMENTS WITH CHEMICALS AND GROWTH REGULATORS ON SHELF LIFE OF PAPAYA (*Carica papaya* L.) cv. RED LADY.

The effect of postharvest treatments on physico - chemical parameters *viz*. physiological loss in weight, firmness, spoilage, total soluble solids, titrable acidity, Reducing sugars, non reducing sugars and total sugars in papaya cv. red lady during ripening and storage are presented in Tables 4.21, 4.22, 4.23,4.24, 4.25, 4.26, 4.27 and 4.28.

4.2.1 Physiological loss in weight (%)

The data on percent physiological loss in weight of papaya fruits during storage as influenced by post harvest treatments with different chemicals and growth regulators are presented in Table - 4.21 and graphically depicted in Fig - 19.

There was significant difference in fruit weight loss among different days of storage period. Fruit mean weight loss increased from 3rd day (2.19 %) to 15th day (16.70 %) of storage period.

Physiological weight loss increased considerably in all the treatments with increase in storage period. However, the increase was at a reduced rate in all the treated fruits as compared to control Table - 4.21. Further, it was observed that on 3rd days of storage, the lowest physiological loss in weight (%) was recorded in T_6 (1.06%) and followed by T_8 treatment (1.27%) and highest in T_{11} treatment (3.12%) and followed by T_{10} treatment (2.85%) which was on par with T_9 treatment (2.75).

On 6th days of storage, lower physiological loss in weight was recorded in T_6 treatment (2.97) which was on par with T_8 treatment (3.03) and T_9 treatment (3.07) and higher physiological loss in weight was recorded in T_{11} treatment (7.55) and followed by T_{10} treatment (5.55).

On 9th day of storage, lower physiological loss in weight was recorded in T_6 (6.34%) which was on par with T_8 treatment (6.64 %) and higher PLW was recorded in T_{11} treatment (8.13%) and at par with T_{10} treatment (7.96 %).

On 12th day T_8 treatment recorded the lowest physiological loss in weight (12.34%) which was followed by T_6 treatment (12.88) and highest in T_{10} (16.75%) followed by T_1 (15.57%).

Similarly, on 15th day minimum physiological loss in weight was recorded in T_8 treatment (14.97%) which was followed by T_6 treatment (15.12%) and maximum physiological loss in weight T_3 treatment (17.83%).

It is observed that generally calcium treated fruits are having lower physiological loss in weight value. This might be due to effective in terms of membrane functionality and integrity which might be resulted for lower weight loss with calcium treated fruits. Similar results have also been reported by Singh *et al*. (2012) and Rajkumar and Manivannam (2007). The reduction in weight loss may also be due to reduced loss in moisture through transpiration. Similar results have also been reported by Yadav *et al.* (2006) in Nagpur mandarin and orange and Singh *et al.* (2008) in papaya.

4.2.2 Fruit firmness (kg cm^{-2})

The changes in fruit firmness during ripening and storage in papaya cv. Red lady treated with different chemicals and growth regulators treatments are presented in Table - 4.22 and graphically depicted in Fig - 20.

There was significant difference in fruit firmness among different days of storage period. Fruit mean firmness decreased from 3rdday (6.23 kg cm^{-2}) to 15th day (1.59 kg cm^{-2}) of storage period.

On 3rd day of storage highest firmness was observed in T_6 treatment (7.15 kg cm^{-2}) which was on par with T_2 treatment (6.81 kg cm^{-2}) and T_8 treatment (6.78 kg cm^{-2}) and lowest in control (4.98 kg cm^{-2}) which was on par with T_1 treatment (5.26 kg cm^{-2}).

On 6th day of storage highest firmness was observed in T_6 treatment (6.51 kg cm^{-2}) which was on par with T_5 treatment (6.45 kg cm^{-2}) and T_2 treatment (6.34 kg cm^{-2}) and lowest in control (4.59 kg cm^{-2}) which was followed by T_1 treatment (4.92 kg cm^{-2}). Similar trend of firmness was recorded in 9th and 12th day.

On 15th of storage highest firmness was observed in T_6 treatment (2.03 kg cm^{-2}) which was on par with T_4 treatment (1.68 kg cm^{-2}) and T_3 treatment (1.65 kg cm^{-2}) and lowest in T_1 treatment (1.05 kg cm^{-2}) which was followed by T_5 treatment (1.32 kg cm^{-2}).

The fruit firmness decreased significantly with advancement of storage period in all the postharvest treatments. Solubilization of insoluble pectins by increased pectinesterase activity appears to be one of the reasons for the development of fruit softening which is associated with ripening (Selvaraj and Pal, 1982). The retention of higher fruit firmness in calcium treated fruits was also due to higher mechanical strength offered by the calcium as it was a part of the cell wall as calcium pectate. There may also be a possibility that, lignification mediated by calcium may serve to prevent membrane deterioration by restricting rapid peroxidation and its autocatalytic production. Retention of high fruit firmness with $CaCl_2$ 3.0 % was reported in papaya by (Chen and Paull, 1986) and in lemon by (Tsantili *et al.*, 2002).

4.2.3 Spoilage (%)

The changes in fruit spoilage during ripening and storage in papaya cv. Red lady treated with different chemicals and growth regulators treatments are presented in Table - 4.23 and graphically depicted in Fig - 21.

There was significant difference in fruit spoilage among different days of storage period. Fruit mean spoilage increased from 3rd day (0.00 %) to 15th day (48.95%) of storage period.

On 3rd day there was no spoilage observed. On 6th day of storage highest spoilage was recorded in control (15.94%) and followed by T_4 treatment (14.29%) and lowest spoilage was recorded in T_2 treatment (10.62 %). which was at par withT_6 treatment (11.32 %).

On 9th day of storage highest spoilage was recorded in T_{11} treatment (20.21%) which was at par with T_1 treatment (20.38 %) and lowest spoilage was recorded in T_6 treatment (15.56%) which was at par with T_8 treatment (16.73 %). Similar trend was followed on 12th day also.

On 15th days of storage highest spoilage was recorded in T_4 treatment (58.93 %) which was at par with T_1 treatment (58.88 %) and lowest spoilage was recorded in T_6 treatment (33.49 %) followed by T_8 treatment (49.48 %).

Lowest spoilage of fruits was recorded in $CaCl_2$@ 3.0% and followed by wax emulsion @ 5.0%. This may be due to controlled transpiration and respiration rates which might have delayed the disintegration of ripening of fruits. The similar findings were reported by Yadav *et al.* (2006) in mandarin, Patel *et al*. (2011) in custard apple.

4.2.4 Total soluble solids (^{O}Brix)

The changes in total soluble solids (TSS) during ripening and storage in papaya cv. Red lady treated with different chemicals and growth regulators treatments are presented in Table - 4.24 and graphically depicted in Fig - 22.

There were significant differences in total soluble solids among different days of storage period. The mean total soluble solids content was increased gradually from 3rd day (9.44 ^{O}Brix) to upto 12th day (11.36 ^{O}Brix) and there after declined to (10.83 ^{O}Brix) 15th days after storage period.

On 3rd day there was no significant difference among treatments. On 6th day highest total soluble solids was recorded in T_6 treatment (10.74 ^{O}Brix) and which was on par with T_1 treatment (10.33 ^{O}Brix) and T_2 treatment (10.54 ^{O}Brix) and lowest total soluble solids was observed in T_{11} treatment (9.60 ^{O}Brix) and which was at par with T_3 treatment (9.66 ^{O}Brix).

On 9th day highest total soluble solids was observed in T_{11} (11.76 ^{O}Brix) followed by T_2 treatment (11.07 ^{O}Brix) while lowest total soluble solids in T_3 treatment (10.27 ^{O}Brix). On 12th day highest total soluble solids was observed in T_2 treatment (12.36 ^{O}Brix) which was on par with T_6 treatment (12.14 ^{O}Brix) and lowest in T_3 treatment (10.79 ^{O}Brix) and which was on par with control (10.87 ^{O}Brix). Similarly on 15th day highest total soluble solids were recorded in T_6 treatment (11.28 ^{O}Brix) and lowest total soluble solids were recorded in T_7 treatment (10.55 ^{O}Brix).

Total soluble solids content of the fruits reached maximum at the ripe stage and started declining towards the end of shelf life. The increase in the total soluble solids during ripening is due to breakdown of starch into sugars. Further due to over ripening / senescence the sugar are degraded to CO_2 because of respiration (Wills *et al.,* 1989). Similar results were reported in Sapota (Singh *et al.,* 2000). It was further reported that, a very low cellulose activity was recorded in papaya fruit pulp during ripening (Pal and Selvaraj, 1987).

4.2.5 Titrable acidity (%)

The changes in titrable acidity during storage in papaya cv. Red lady treated with different chemicals and growth regulators treatments are presented in Table - 4.25and graphically depicted in Fig - 23.

There were significant differences in acidity among different days of storage period. The mean acidity decreased from 3rd day (0.43%) to 15th day (0.05%) of storage period.

On 3rd day highest titrable acidity was observed in T_6 treatment (0.53%) which was on par with T_8 treatment (0.52%) and T_3 treatment (0.51%) while lowest acidity in T_{11} treatment (0.30%) which was followed by GA_3@ 100ppm (0.37 %).

On 6thday highest titrable acidity was observed in T_3 treatment (0.50%) which was on par with T_8 (0.48%) while lowest titrable acidity in T_{11} treatment (0.27 %) and followed by T_1 treatment (0.32 %). Similar trend of titrable acidity was recorded on 9th day.

On 12th day highest titrable acidity was observed in T_{10} (0.19%) which was on par with T_7treatment (0.17%) while lowest titrable acidity in T_1 and T_3 treatment (0.12 %).

On 15th day of storage highest titrable acidity was observed in T_6 treatment (0.11 %) while lowest acidity in T_4 treatment (0.03 %).

The reduction in titrable acidity during storage might be associated with the conversion of organic acid into sugar and their derivatives or their utilization in respiration. Similar results have also been reported by Singh *et al.* (2008) and Hoda *et al.* (2000) in Mango, Sudha *et al.* (2007) in Sapota.

4.2.6 Reducing Sugars (%)

The changes in reducing sugars during storage in papaya cv. Red lady treated with different chemicals and growth regulators treatments are presented in Table - 4.26.

There were significant differences in reducing sugars among different days of storage period. The initial mean reducing sugars content was (7.06%)

which increased gradually upto 12th day (8.98%) and there after declined trend follows upto end of shelf life.

On 3rd day of storage higher reducing sugars content was observed in GA_3@ 200 ppm (7.80%) which was on par with T_1 treatment (7.65%) and lowest in BA @ 150 ppm treated fruits (6.30%).

On 6thday of storage higher reducing sugars content was observed in T_1 treatment (8.77%) which was on par with T_2 treatment (8.65%) and lowest in T_9 treatment (7.54 %).

On 9th day of storage higher reducing sugars content was observed in T_2 (9.01%) which was on par with T_1 treatment (8.98%) and lowest in T_{10}treatment (8.41 %) which was on par with T_3 treatment (8.55 %).

On 12th day of storage higher reducing sugars content was observed in T_1 treatment (9.26%) which was on par with T_2 treatment (9.18%) and lowest in T_7 treatment (8.78 %).

On 15th days of storage higher reducing sugars content was observed in T_1 treatment (8.65%) and lowest in T_5 treatment (8.16%).

Higher reducing sugars content was recorded in GA_3 @ 200 ppm. It was also found that sugars were increase with increasing the storage period up to 12th days of storage, but at 15th days of storage it reduced drastically. The initial raise in sugars content may be due to conversion of starch into sugars, while later the decrease was due to consumption of sugars for respiration during storage. The results are also conformation with those of Patel *et al.* (2011) in Custard apple and Yuvraj *et al.* (1999) in Mango.

4.2.7 Non reducing Sugars

The changes in non reducing sugars during storage in papaya cv. Red lady treated with various chemicals and growth regulators treatments are presented in Table - 4.27.

There was a significant difference in non reducing sugars content among different days of storage. Mean non reducing sugarsincreased from 3rd day (1.50%) to 12th day (2.83%) and then declined (2.52%) by 15th day of storage period.

The different treatments and days of storage were also found differed significantly. On 3rd day storage the higher non reducing sugars content was recorded in control (2.08) which was at par with T_7 treatment (1.80) and lowest in T_8 treatment (1.33). On 6th day highest non reducing sugars content was recorded in control (2.24) which was on par with T_7 treatment (1.88) and lowest in GA_3@ 200 ppm (1.05). Similar pattern of non reducing sugars content was observed on 9th day also.

On 12th day storage the higher non reducing sugars content was recorded in T_8 treatment (3.11) and lowest in T_4 treatment (2.56).

On 15thday storage the higher non reducing sugars content was recorded in T_5 treatment (2.83) and lowest in T_4 treatment (2.27).

4.2.8 Total sugars (%)

The changes in total sugars during storage in papaya cv. Red lady treated with various chemicals and growth regulators treatments are presented in Table - 4.28.

There was a significant difference in mean total sugars content among different days of storage. The mean total sugars increased from 3rd day (8.46%) to 12th day (11.82%) and then declined to (10.93%) by 15th day of storage period.

The different treatments and days of storage were also found differed significantly. On 3rd day storage the higher total sugars content was observed in control (9.17%) followed by $CaCl_2$ @ 1.0% (8.87%) and lowest in T_9 treatment (7.94%).

On 6th day, highest total sugars content wererecorded in control (10.09%) which was on par with T_8 treatment (9.76%) and lowest total sugars recorded in BA @150 ppm (8.79%). On 9th day, highest total sugars content was found in control (10.98%) which was on par T_9 treatment (10.75%) and lowest in T_{10} treatment (10.04%). On 12th day highest total sugars recorded in T_6 (11.97%) and lowest total sugars were recorded in T_3 treatment (10.55%).

On 15th day highest total sugars were recorded in T_2 treatment (11.00%) and lowest total sugars were recorded in T_3 treatment (10.05%).

Highest total sugars were recorded in control which was on par withGA_3 @200 ppm. It was also found that total sugars were increased with increasing the storage period up to 12th days of storage, but at 15th days of storage it reduced drastically. It may be due to break down of physiological process. The results are also conformation with those of Patel *et al.* (2011) in Custard apple and Yuvraj *et al*. (1999) in Mango. Singh *et al.* (1988) in Mango.

4.2.9 Shelf Life (days)

The effect of different chemicals and growth regulators on shelf life of papaya cv. Red lady stored at room temperature was presented in Table 4.29and graphically represented in Fig- 24 (Plate:7). The fruits treated with different treatments differed significantly and highest shelf life (15.32 days) observed in fruits treated with $CaCl_2$ @ 3.0% and which was followed by GA_3 @200 ppm (14.02 days) and 5.0% wax emulsion (13.32 days). Lowest shelf life was recorded in Control (9.78 days). Reduction in water loss of papaya fruits during storage with application of calcium chloride was expected as calcium sprays play an important role in maintaining cellular organization and regulating enzyme activities and thereby helping in reducing water loss. Similar results were reported by Singh *et al*. (1987) and Garg and Ram (1976). The increase in shelf life is due to reduction in respiration rate and moisture loss as shown by Narayana *et al.*(2002). GA_3 is a growth promoter which might have suppressed the concentration of ethylene may be reason for delayed ripening. Similar trend was also reported by Ramakrishna *et al.* (2001) and Rajput *et al*. (2008) in Papaya.

4.2.10 Ascorbic acid (mg/100g pulp)

The changes in ascorbic acid during storage in papaya cv. Red lady treated with various chemicals and growth regulators treatments are presented in Table - 4.30 and graphically represented in Fig- 25.

There was a significant difference in ascorbic acid content among different days of storage. Mean ascorbic acid increased from 3rd day (30.18

mg/100g pulp) to 12th day (39.62 mg/100g pulp) and then declined to (37.55) by 15th day of storage period.

The different treatments and days of storage were also differed significantly. On 3rd day storage the higher ascorbic acid content was observed in T_6 treatment (32.07 mg/100g pulp) which was at par with T_8 treatment (31.88 mg/100g pulp) and lowest ascorbic acid in T_1 treatment (26.70 mg/100g pulp). On 6th day highest ascorbic acid content was observed in T_6 (35.74 mg/100g of pulp) which was on par with T_8 treatment (34.41 mg/100g pulp) and lowest in T_7 treatment (29.51 mg/100g pulp). On 9th day highest ascorbic acid content was observed in T_6 treatment (39.91 mg/100g pulp) which was on par with T_{11} treatment (37.85 mg/100g pulp) and lowest in T_1 treatment (31.48 mg/100g pulp) and which was on par with T_{10} treatment (31.86 mg/100g pulp) and T_5 treatment (31.96 mg/100g pulp).

On 12th highest ascorbic acid recorded in 5.0% wax emulsion (41.25 mg/100g pulp) and lowest ascorbic acid recorded in T_{10} treatment (37.81 mg/100g pulp) at par with T_1 treatment.

On 15th day of storage highest ascorbic acid recorded in T_6 treatment (44.66) and lowest recorded in $CaCl_2$ @2.0% (38.68 mg/100g pulp) days of storage.

Highest ascorbic acid recorded in $CaCl_2$@ 3.0% treated fruits. It was also found that sugars were increased with increasing the storage period up to 12th days of storage, but at 15th days of storage it reduced drastically. It may be due to break down of physiological process. As the results is also conformation with those of Yuvraj *et al*. (1999) in Mango and Patel *et al.* (2011) in custard apple.

4.3. EFFECTOF PACKAGING MATERIALS ON QUALITY AND SHELF LIFE OF PAPAYA (*Carica papaya L.*) cv. RED LADY

4.3.1 Physiological loss in weight (%)

The data on physiological loss in weight (PLW) as influenced by combination ofdifferent packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table 4.31 and graphically represented in Fig- 26.

The mean physiological loss in weight increased significantly with each successive storage interval from 3rd day (5.10%) to end of storage day.

The physiological loss in weight of any treatment increased significantly with successive storage interval. At any given interval, on 3rd day fruits treated with T_1 - $CaCl_2$ @3.0% and packed in news paper recorded significantly lower weight loss (4.42%) and which was followed by T_3 treatment (4.75%) and it was on par with T_2 treatment (4.91%) treatment. The weight loss was significantly recorded higher in T_4 treatment (6.07%) and followed by T_7 treatment (5.27 %).

On 6th day higher weight loss was recorded in T_6 treatment (6.07%) and followed by T_7 treatment (5.55%). Lower weight loss recorded in T_1 treatment (4.85%) which was on par with T_3 treatment (5.01%).

On 9th day of storage higher weight loss was recorded in T_7 treatment (6.65%) and followed by T_6 treatment (6.35%). Lower weight loss was recorded in T_1 treatment (5.16 %) followed by T_3 treatment (5.50%). On 12th day of storage higher weight loss was recorded in T_5 treatment (11.15%) and followed by T_2 treatment (7.75%) treatment. Lower weight loss recorded in T_1 treatment (6.68%) and followed by T_3 treatment (6.70%). On 15th higher weight recorded in T_4 treatment (8.85%) and lowest recorded in T_1 treatment (7.85%). On 18th day of storage higher weight loss recorded in T_4 (24.43%) and lowest recorded in treatment T_1 (16.35%).

The lowest weight loss was recorded in fruits packed in news paper with fruits dipped in $CaCl_2$ @3.0 % may be possible due to slow rate of transpiration caused by wrapping with news paper because they reduce the temperature between outer and inner atmosphere. Reduction in the rate of transpiration is one of the major criteria for reducing weight loss and extending the post harvest life of fruits (Priyanka Singh *et al.*, 2012 in papaya) and similar results confirm with Ben-Yahoshua (1969) in orange, Bhullar *et al.* (1980) in Anab-e-Shahi grapes, Nanda *et al.* (2001) in pomegranate. Singh and Rao (2005) reported lowerweight loss in shrink wrapped papaya fruits during storage.

4.3.2 Firmness (kg cm^{-2})

The data on firmness is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.32 and graphically represented in Fig - 27.

The mean firmness decreased significantly with each successive storage interval from 3rd day (2.70 kg cm^{-2}) to 18th day (0.47 kg cm^{-2}).

The firmness any treatment decreased significantly with successive storage interval. On 3rd day of storage fruits treated with T_1 - $CaCl_2$ @3.0% and packed in news paper recorded significantly higher firmness (3.09 kg cm^{-2}) and which was on par with T_2 (2.90 kg cm^{-2}), T_3 and T_4 and the firmness was significantly recorded lower in control (2.12 kg cm^{-2}).

On 6th day higher firmness was recorded in T_1 treatment (2.99 kg cm^{-2}) which was on par with T_3treatment (2.72 kg cm^{-2}) and lower firmness was recorded in control (1.86 kg cm^{-2}) followed by T_6 treatment (2.13 kg cm^{-2}). Similar trend of firmness was recorded on 9th day. On 12th days of storage lower firmness was recorded in T_5 treatment (0.82 kg cm^{-2}), higher firmness was recorded in T_1 treatment (1.75 kg cm^{-2}). On 15thday higher firmness was recorded in T_1 treatment (1.21 kg cm^{-2}) and 18th day higher firmness was recorded in T_1 treatment (0.87 kg cm^{-2}) and lowest firmness was recorded in treatment T_2 treatment (0.25 kg cm^{-2}) of storage.

The variation in firmnessof fruits was also observed, significant and highest Firmness was recorded in $CaCl_2$ 3.0% and packed in news paper.The newspaper also maintained firmness of papaya fruits better than the control. These effects ofpackaging materials may be attributed to their retardationeffects of ripening and reduction of water loss (Yamashital *et al.* 2002; Manrique and Lajolo, 2004).

The major cause of loss in firmness during ripening is due to dissolution of the cell wall and middle lamella by the action of hydrolyzing enzymes (Hulme, 1958). Breakdown of middle lamella (which holds the cell firmly) is brought about by the action of pectolytic enzymes, mainly, polygalacturonase. The inhibitory effect of Ca^{2+} on the process of softening may have been due to an applicable degree of Ca^{2+} binding during pectin solubilization (Shear, 1975).

4.3.3 Spoilage (%)

The data on spoilage is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.33 and graphically represented in Fig - 28.

The mean spoilage increased significantly with each successive storage interval from 6th day (6.09 %) to 18th day (56.37%).

The spoilage of any treatment increased significantly with successive storage of interval. On 3rd day no spoilage was recorded.

On 6th day of storage higher spoilage was recorded in T_7 treatment (8.18%) on par with T_6 treatment (7.90%) and lower spoilage was recorded in T_1 treatment (4.60%) which was on par with T_3 treatment (4.93%). On 9th day of storage higher spoilage was recorded in T_6 treatment (30.98%) on par with T_7 treatment (30.24%) and lower spoilage was recorded in T_1 treatment (10.35%) which was followed by T_3 treatment (14.82 %).

On 12th day of storage higher spoilage was recorded in T_5treatment (50.11%) and lower spoilage was recorded in T_1 treatment (24.72%).On 15thday of storage higher spoilage was recorded in T_4 treatment (55.45%) and lower spoilage was recorded in T_1 treatment (48.79 %) and lower spoilage was recorded in (51.56%), higher spoilage was recorded in T_4 treatment (60.70 %) on 18th days of storage.

The variation in spoiled fruits was also observed significant and lowest spoiled fruits was recorded in T_1 - $CaCl_2$@3.0% and packed in news paper. This may be due to treatment effect which might have retarded ripening and reduced weight loss through controlled transpiration and respiration rate and delayed the disintegration of spoilage. The similar findings were reported by Yadav *et al.* (2006) in Mandarin and Patel *et al*. (2011) in Custard apple.

4.3.4 Total soluble solids (^{O}Brix)

The data on total soluble solids is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table- 4.34 and graphically represented in Fig - 29.

The mean total soluble solids increased significantly with each successive storage interval from 3rd day (9.38 ^{O}Brix) to 12th day (11.30 ^{O}Brix) and then it was decreased trends follows upto storage life.

On 3rd day significantly higher total soluble solids recorded in T_7 treatment (10.05 ^{O}Brix) and which was followed by T_6 treatment (9.68 ^{O}Brix) it was on par with T_2 and $T_4$and the total soluble solids was significantly recorded lower in fruits treated with $CaCl_2$ @3.0% and packed in news paper (8.85^{O}Brix) which was on par with T_5 treatment (9.12 ^{O}Brix). Similar trend of total soluble solids was recorded on 6th day.

On 9th days of storagesignificantly higher total soluble solids recorded in T_7 treatment (11.34 ^{O}Brix) and which was followed by T_6 treatment (10.68 ^{O}Brix) it was on par with T_1 and T_4 treatment. The total soluble solids were significantly recorded lower in T_2 treatment (9.75 ^{O}Brix) which was on par with T_3 treatment (10.08 ^{O}Brix).

On 12th day higher total soluble solids were recorded in T_5 treatment (11.75 ^{O}Brix) and lower total soluble solids were recorded in T_4 treatment (10.85 ^{O}Brix).

On 15th day higher total soluble solids were recorded in T_1 treatment (9.98 ^{O}Brix), whereas lower total soluble solids were recorded in T_3 treatment (9.19 ^{O}Brix). On 18th day of storage higher total soluble solidswere recorded in T_1 treatment (9.55 ^{O}Brix) and lower total soluble solids were recorded in T_4 treatment (8.85 ^{O}Brix).

The total soluble solids showed a progressive increasing trend upto 12th day after storage. Thereafter decline in total soluble solids was observed. The fruits packed in news paper and dipped in $CaCl_2$@3.0% had shown the maximum total soluble solids might be due to increase in sugar during storage and it may possibly due to break down of complex organic metabolites into sugars. The decline in the sugar content at the later stage of the storage may be due attributed to the reason after completion of hydrolysis of starch, no further increase in sugars occurred and subsequently a decline in these parameters is predictable as they along with their organic acids are primary substrate for respiration (Wills *et al.*, 1989). Similar results conformity with Chittiraiselvan *et al.* (1977) in Banana, Kodikara *et al.* (1996) in Papaya.

4.3.5 Ascorbic acid (mg/100g pulp)

The data on ascorbic acid is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.40.

The mean ascorbic acid increased significantly with each successive storage interval from 3rd day (29.02 mg/100g pulp) to 12th day (46.41 mg/100g pulp) there after a decline in ascorbic acid was observed.

The ascorbic acid of any treatment increased significantly with successive storage interval. On 3rd day of storage fruits treated with $CaCl_2$ @ 3.0% and packed in news paper (T_1) recorded significantly higher ascorbic acid content (33.32 mg/100g pulp) and which was followed by T_3 treatment (30.42 mg/100g pulp) it was on par with T_5 treatment (30.08 mg/100g pulp) and the ascorbic acid content was significantly recorded lower in T_6 treatment (26.14 mg/100g pulp) it was on par with T_7 treatment (26.43 mg/100g pulp).

On 6th day of storage higher ascorbic acid content was recorded in T_1 treatment (46.85 mg/100g pulp) it was followed by T_3 treatment (42.42 mg/100g pulp) and lower ascorbic acid was recorded in T_6 treatment (32.31 mg/100g pulp). Similar trend of ascorbic acid was recorded on 9th day. On 12th day higher ascorbic acid was recorded in T_1 treatment (51.20 mg/100g pulp) and lowest in T_4 treatment (42.45 mg/100g pulp) days of storage. The decline in the ascorbic acid content at later stage of storage period was observed. On 15th day of storage ascorbic acid content was highest recorded in T_1 treatment (48.02 mg/100g pulp) and lowest in T_4 (38.30 mg/100g pulp).On 18th day higher ascorbic acid content was recorded in T_1 treatment (46.82 mg/100g pulp) and lowest in T_4 treatment (29.90 mg/100g pulp)

The maximum value was achieved under the fruits packed in news paper with fruits dipped in $CaCl_2$ @3.0 %. Similar result was reported by Alam *et al.* (2010) in Papaya. The decrease in ascorbic acid content after 12th day it may be due to oxidation of ascorbic acid. Similar results were obtained with Nazeeb and Broughton (1978) in Papaya.This fall in ascorbic acid during storage might be due to its oxidation (Lin *et al.*, 1988). Ladaniya and Singh (2001) also reported in Sweet orange. The loss in Ascorbic acid on prolonged storage might be mainly due to rapid conversion of L - ascorbic acid into dehydro ascorbic acid in the presence of enzyme ascorbinase (Mapson, 1970). These findings are in agreement with the results of Chaudhary and Farooqui (1969) and Tripathi (1989) in mango.

4.3.6 Titrable acidity (%)

The data on titrable acidity is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.35.

The mean titrable acidity decreased significantly with each successive storage interval from 3rd day (2.59%) to 18th day (0.02%).

On 3rd day significantly higher titrable acidity recorded in control (2.94%) and which was followed by T_4 treatment (2.80%) and the titrable acidity content was significantly recorded lower in T_2 treatment (2.35%) which was on par with T_3 and T_6 treatment.

On 6th day higher titrable acidity content was recorded in T_1 treatment (2.01%) it was on par with T_3 treatment (1.92%) and lower titrable acidity content was recorded in control (0.95%). On 9th day higher titrable aciditycontent was recorded in T_1 treatment (0.48%) and it was on par with T_3

treatment (0.47%) and lower titrable acidity content was recorded in control (0.28%) and which was on par with T_4 treatment (0.31%). On 12th day of storage higher titrable acidity was recorded in T_1 treatment (0.25 %) and lowest in T_5 treatment (0.03%). On 15th day of storage higher titrable acidity was recorded inT_1 treatment (0.09%) and lowest in T_4 treatment (0.03%). On 18th day of storage higher titrable acidity was recorded in T_1 treatment (0.04%) and lowest in T_2 treatment (0.01 %).

Packaging of papaya fruits in tissue paper showed minimum acidity compare to news paper may be due over ripening at the end of storage in present study is in agreement with the findings of Firmin *et al.* (1997) and Singh *et al*. (2012) in papaya. The reduction in acidity during storage might be associated with the conversion of organic acids into sugar and their derivatives or their utilization in respiration. Similar results have also been reported by Singh *et al.* (2008) and Hoda *et al.* (2000) in mango, Sudha *et al.* (2007) in Sapota.

4.3.7 Reducing sugars

The data on reducing sugars is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.36.

The mean reducing sugars increased significantly with each successive storage interval from 3rd day (5.83%) to 12th day (8.88%), and then it was decreased.

On 3rdday of storage significantly higher reducing sugars content were recorded in T_3 treatment (6.45%) it was followed by T_4 treatment (6.25%) and the reducing sugars content were significantly recorded lower in T_5 treatment (5.42%) which was followed by T_2 treatment (5.65%).

On 6th day of storage higher reducing sugars content were recorded in T_7 (8.33%) which were on par with T_6 treatment (8.18%) and lower reducing sugars content were recorded in T_1 treatment (6.55%) followed by T_3 treatment (7.05%). Similar trend of reducing sugars contentwere recorded on 9th day of storage. On 12th day lower reducing sugars content were recorded in T_1treatment (8.17%) and higher reducing sugars were recorded in T_2 treatment (9.48%). On 15th day of storage higher reducing sugars content were recorded in T_4 treatment (8.55%) and lower reducing sugars content were recorded in T_1 treatment (7.55%). On 18th day of storage lower reducing sugars content was recorded in T_4 treatment (7.37%) and higher reducing sugars content were recorded in T_3 treatment (7.58%).

The reducing sugars showed progressive increasing trend upto 12th day of storage. There after decline in reducing sugarscontent was observed. The fruits packed in news paper and dipped in GA_3@ 200 ppm had shown the maximum reducing sugars, it may be due to increase in sugar during storage may possibly due to break down of complex organic metabolites into sugars. The decline in the sugar content at the later stage of the storage may be attributed to the reason after completion of hydrolysis of starch, no further increase in sugars occurres and subsequently a decline in these parameters is predictable as they along with their organic acids are primary substrate for respiration (Wills *et al.,* 1989). Similar results conformity with Chittiraiselvan *et al.* (1977) in Banana, Kodikara *et al.* (1996) in Papaya.

4.3.7 Non - Reducing sugars

The data on non reducing sugars is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.37.

The mean non reducing sugars increased significantly with each successive storage interval from 3rd day (1.61) to 9th day (2.69).

On 3rd day significantly higher non reducing sugars recorded in T_7 treatment (2.23) followed by T_2 treatment (1.70) and the lower non reducing sugars were recorded in T_1 treatment (1.30) which was on par with T_3treatment (1.39). On 6th day higher non reducing sugars content were recorded in T_5 treatment (1.17) which was on par with T_4 treatment (1.16) and lower non reducing sugars content were recorded in T_6 treatment (0.69) which was followed by T_7 treatment (0.71).

On 9th day higher non reducing sugars content were recorded in control (3.75) and which was on par with T_6 treatment (3.60) and lower non reducing sugars were recorded in T_1 treatment (1.89) which was on par with T_3 treatment (2.00).On 12th day higher non reducing sugars content was recorded in T_3 treatment (3.52) and lower non reducing sugars content were recorded in T_4 treatment (0.58).

On 15th day higher non reducing sugars content were recorded in T_1 treatment (4.30) and lower non reducing sugars were recorded in T_4 treatment (0.30). On 18th days of storage lower non reducing sugars content were recorded in T_2 treatment (2.33) higher non reducing sugars content were recorded in T_1 treatment (3.83).

The non reducing sugars showed a progressive increasing trend upto 9th days after storage. Thereafter decline in non reducing sugars was observed. The fruits packed in news paper and dipped in $CaCl_2$@ 3.0% had shown the maximum non reducing sugarsmay possibly due to break down of complex organic metabolites into sugars. The decline in the sugar content after climacteric peak stage of the storage may be attributed to the reason after completion of hydrolysis of starch.A decline in these parameters is predictable as they along with their organic acids are primary substrate for respiration (Wills *et al.*1989). Similar results with Chittiraiselvan *et al.* (1977) in Banana, Kodikara *et al.* (1996) in Papaya.

4.3.9 Total sugars (%)

The data on total sugars is influenced by combination of different packaging materials and growth regulators on papaya cv. Red lady stored at room temperature is presented in Table - 4.38 and graphically represented in Fig - 30.

The mean total sugars content was decreased significantly with each successive storage interval from 3rd day (7.46%) to 12th day (11.17%).

On 3rd day significantly higher total sugars content were recorded in control (7.95%) and which were on par with T_4 treatment (7.82%) and T_3 treatment (7.94%), lower total sugars content were recorded in T_1 treatment (6.92%) followed by T_5 treatment (7.07%).

On 6th day higher total sugars were recorded in T_7 treatment (9.04%) which were followed by T_6 treatment (8.87%), lower total sugars were recorded in T_1 treatment (7.75%) followed by T_3 treatment (8.12%). On 9th day higher total sugars content were recorded in T_7 treatment (10.62%) which was on par with T_6 treatment (10.32%) and lower total sugars content were recorded in T_2 treatment (9.28%) it was on par with T_1 treatment (9.71%). On 12th day higher total sugars content were recorded in T_1 treatment (11.60%) and lower total sugars content was recorded in T_4 treatment (9.75%). On 15th day of storage T_1 treatment (9.85%) recorded higher total sugars content were observed during storage period and lowest was T_4 treatment (8.85 %). On 18th day of storage T_1 treatment (9.33%) registered higher Total sugars content and lowest in T_4 treatment (8.15%).

The total sugars showed a progressive increasing trend upto 12th days after storage. There after decline in total sugars was observed. The fruits packed in news paper and dipped in $CaCl_2$@ 3.0% had shown the maximum total sugars, it may be due to increase in sugars during storage may possibly due to break down of complex organic metabolites into sugars. The decline in the sugars content at the later stage of the storage may be due attributed to the reason after completion of hydrolysis of starch, no further increase in sugars occurres and subsequently a decline in these parameters is predictable as they along with their organic acids are primary substrate for respiration (Wills *et al.,*1989). Similar results conformity with Chittiraiselvan *et al.* (1977) in Banana, Kodikara *et al.* (1996) in Papaya.

4.3.10 Shelf life (days)

The data on shelf life as influenced by combination of different packaging materials and growth regulators or treatments on papaya cv. Red lady stored at room temperature is presented in Table - 4.39 and graphically represented in Fig - 31 (Plate:- 9, 10). There were significant differences among the treatments for shelf life with the fruits and fruits packed in news paper which was dipped in $CaCl_2$ @ 3% recorded higher storage (17.58 days) which was on par with fruits treated with GA_3 @ 200ppm and packed in tissues paper (16.25 days). The fruits under control recorded the minimum shelf life of (9.00 days).

The fruits dipped in $CaCl_2$ @ 3% packed in news paper improved the shelf life (17.58 days) by maintaining the physio-chemical characters of the fruit, which are important for the fruits quality. Similarly, application of the growth regulator GA_3 @ 200 ppm also increased shelf life in papaya fruits upto 16.25 days, with the best physical and physico - chemical attributes.

Chapter - V

SUMMARY AND CONCLUSIONS

The present investigation entitled "Studies on Integrated nutrient management on growth, yield, quality and effect of Post harvest treatments, Packaging materials on shelf life and quality of papaya (*Carica papaya* L.) *cv*. Red lady under southern Telangana" was carried out at the PJTSAU Horticulture Experimental Field, Agricultural University, Rajendranagar, Hyderabad during the year 2014 - 15 and 2015 - 16. The results pertaining to growth parameters, physiological parameters, yield attributesand quality parameters during the course of present study. The features of findings are summarized and concluded here under.

- ❖ The growth parameters of plants were significantly influenced by the integrated nutrient treatments as compared to control. Maximum plant height, circumference, higher petiole length and maximum number of leaves per plant during both years and pooled analysis recorded with application of T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100 g *PSB* plant^{-1} which was also superior to other treatments and control.
- ❖ Plants received 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} in T_9 treatment showed earliness in initiation of flowering (days) and lowest days taken to fruit maturity during the both years and pooled analysis.
- ❖ There was significant difference in number of fruits per plant with respect to different treatments. Higher number of fruits per plant was recorded in 75% RDF + 10kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} during both the years and pooled analysis.
- ❖ The yield parameters of plant were significantly influenced by the integrated nutrient treatments as compared to control. Maximum fruit weight, higher pulp thickness and maximum fruit length during both years and pooled analysis recorded with application of 75% RDF + 10 kg

vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} which was also superior to other treatments and control.

- ❖ There was significant difference in fruit yield (kg plant^{-1}) with respect to different treatments. Higher fruit yield was recorded in T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} during both the years and pooled analysis.
- ❖ The integrated nutrient treatments had significantly influenced the physico - chemical parameters of the fruit over the control. Minimum physiological loss in weight, spoilage and maximum fruit firmness were recorded with the application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (T_9) during both the years andpooled analysiswhich was also superior to other treatments and control.
- ❖ The integrated nutrient treatments significantly influenced the quality parameters of the fruit over the control. Maximum total soluble solids, Total sugars, Ascorbic acid and Minimum titrable acidity were recorded with the application of 75% RDF + 10kg vermicompost + 100g *Azotobacter* +100g *PSB* plant^{-1} (T_9) during both the years and pooled analysis which was also superior to other treatments and control.
- ❖ Higher reducing sugars were recorded in first year with the application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (T_9) where as in second year and pooled analysis higher reducing sugarswere recorded with application of 75% RDF + 20 kg FYM plant^{-1} + 100g *Azotobacter* + 100g *PSB* plant^{-1} (T_8).
- ❖ The highest Benefit Cost Ratio (2.15) was recorded with the application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} (T_9) having net returns of Rs/- 3,46,565 ha^{-1}.

Experiment - II. Effect of post harvest treatments with chemicals and growth regulators on shelf life of papaya (*Carica papaya* L.) *cv.* Red Lady.

- ❖ The physiological loss in weight of the fruits increased with increase in storage period. The treatment 5% wax emulsion (T_8) has recorded minimum weight loss (14.97%) and which was followed by $CaCl_2$ @ 3.0% (15.12%) as compared to other treatments.

- Fruit firmness decreased with increase in storage period. Among different treatments $CaCl_2$ @ 3.0% recorded significantly higher firmness (2.03 kg cm^{-2}) and it was low in control.
- Fruits dipped in $CaCl_2$ @ 3.0% recorded significantly minimum spoilage (33.49%) as compare to control.
- The total soluble solids and ascorbic acid content increased from 3^{rd} day to 12^{th} day and after that decreased at 15^{th} day of storage. The maximum TSS was recorded in $CaCl_2$ @ 3.0% (11.28 ^{O}Brix).
- Minimum titrable acidity was recorded in T_4 (0.03 %).
- Significantly more total sugars in GA_3 200 ppm (11.00%), reducing sugars in T_1 (8.65%) and non reducing sugars in T_5 (2.83%) were recorded.
- Among the different post harvest treatments fruits dipped in $CaCl_2$ @ 3.0% recorded significantly higher shelf life (15.32 days) and followed by T_2 (14.02 days) over other treatments and control (9.00 days).

Experiment- III. Effect of packaging materials on quality and shelf life of papaya (*Carica papaya* L.) cv. Red Lady.

- Among the different chemical treatments and combined with packaging materials imposed in the present investigation showed lowest physiological loss in weight (PLW) in fruits treated with $CaCl_2$ @ 3.0% and packed in news paper (16.35%), whereas, highest PLW was found in control.
- Maximum fruit firmness was observed in the fruits treated with T_1-$CaCl_2$ @ 3.0 % and packed with news paper (0.87 kg cm^{-2}), whereas untreated fruits recorded less firmness as compared to other treatments.
- The post harvest treatment of fruits treated with $CaCl_2$ @ 3.0% and packed with news paper (T_1) recorded significantly minimum spoilage (51.56 %) over other treatments.

- The total soluble solids content increased from 3rd to 12th day and after that decreasing trend was observed. Maximum total soluble solids recorded in T_1 (9.55 ^{O}Brix).
- Ascorbic acid is influenced by containing different packaging materialswith post harvest treatments on papaya. Ascorbic acid increased significantly with each successive storage interval from 3rd dayto 12th day thereafter a decline trends was observed. Maximum ascorbic acid was recorded in fruits treated with T_1 - $CaCl_2$ @ 3.0% and packed with news paper (46.82 mg/100 g pulp).
- Physico - chemical attributes such as total sugars were found highest with T_1 (9.33%), Reducing sugars were found highest in T_2 (7.58%) and where as non reducing sugars were found highest in T_1 - fruits treated with $CaCl_2$ 3.0% and packed with news paper (3.83%).
- Highest titrable acidity was observed in T_1 (0.04%). Lowest acidity was found in fruits dipped in $CaCl_2$ @ 3.0% and packed with tissue paper (0.01%).
- The post harvest shelf life was found maximum in T_1 - fruits dipped in $CaCl_2$ @ 3.0% and packed with news paper (17.58 days) and followed by T_3- GA_3 @ 100 ppm and packed in news paper (16.25 days). However, control has shown poor shelf life (9.00 days).

CONCLUSIONS

The results of two year study shows that the application of 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} influenced the plant growth characters, physiological attributes, yield as well as quality of papaya cv. Red Lady. Based on the performance of growth, yield, quality and economical aspects observed in present study, it can beconcluded that combined application of organic, inorganic and bio fertilizers in treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100g *PSB* plant^{-1} had given higher yields (31.72 kg plant^{-1}) with better qualities fruits in Papaya over control. Highest benefit - cost ratio was also recorded in the same treatment T_9 - 75% RDF + 10 kg vermicompost + 100g *Azotobacter* + 100 g *PSB* plant^{-1} (2.15).

Under normal ambient conditions the papaya fruits can be stored up to 8 days without much deterioration, beyond this period the fruits shows very quick spoilage. But during the present study, application of chemicals such as $CaCl_2$ @ 3.0 % had shown beneficial effect on shelf life of papaya fruits and increased shelf life up to 15.32 days without much loss in both physical and physico - chemical properties of fruits. Similarly, combination of $CaCl_2$ @ 3.0 % and packaging news paper had shown superiority and improved the storage life of papaya fruits up to 17.58 days with good physical and physico - chemical properties as compared to control (9.00 days).

Suggestion for further work

1. Similar studies with other new different combination of organic, inorganic and biofertilizers need to be studied in papaya.
2. Effect of post harvest treatments with other different chemicals and growth regulators on shelf life of papayaneed to be studied.
3. Effect of other different packaging materials on shelf life and qualities also need to bestudied.