ORGANIC NUTRIENT MANAGEMENT OF PAPAYA

(*Carica papaya* L.)

by

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THESIS

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requirements for the degree of

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KERALA, INDIA

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DECLARATION

I hereby declare that this thesis entitled "**ORGANIC NUTRIENT MANAGEMENT OF PAPAYA (*Carica papaya* L.)**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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Certified that this thesis entitled "**ORGANIC NUTRIENT MANAGEMENT OF PAPAYA (*Carica papaya* L.)**" is a record of research work done independently by Ms. Divya Hari under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Divya Hari

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LIST OF ABBREVIATIONS

AMF	Arbuscular mycorrizhal fungi
B: C	Benefit cost ratio
Ca	Calcium
CD	Critical Difference
cfu	colony forming unit
cm	centimetre
EC	Electrical Conductivity
et al.	co –workers/co-authors
FAO	Food and Agriculture Organization
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
i.e.	That is
K	Potassium
KAU	Kerala Agricultural University
kg ha^{-1}	kilogram per hectare
kg	kilogram
L	Litre
m	metre
m^2	square metre
MAP	Months After Planting
Mg	Magnesium
Mn	Manganese
MOP	Muriate of Potash
N	Nitrogen
NS	Non Significant
P	Phosphorus

PGPR	Plant growth promoting rhizobacteria
POP	Package of Practices
plant^{-1}	per plant
ha^{-1}	Rupees per hectare
RDF	Recommended Dose of Fertilizers
RH	Relative Humidity
SEm	Standard Error of mean
SOP	Sulphate of Potash
t ha^{-1}	tonnes per hectare
TSS	Total Soluble Solids
viz.	Namely
Zn	Zinc

LIST OF SYMBOLS

@	at the rate of
°C	degree Celsius
%	per cent

Introduction

1. INTRODUCTION

Papaya, is an important fruit crop which is a native of Tropical America and is known as wonder fruit of tropics and sub tropics. Once considered as an exotic fruit, papayas rise in popularity has made them much more available. In Kerala papaya is mainly grown as a homestead crop. It is a rich source of vitamin A, vitamin C, carbohydrates, minerals, pectin and alkaloids. Papaya is also a good source of flavonoids, fibres and minerals like Ca, K, and Fe. The raw fruits are used as vegetable for cooking purposes and the latex of the fruits contain proteolytic enzyme papain , which is used in leather industry, meat tenderisation, cosmetics, pharmaceuticals etc. The availability of fruits at cheaper prices and year round production makes it an ideal fruit for the processing industry.

Due to the neutraceutical properties and multifold uses of papaya it is now slowly emerged as a commercial crop in Kerala. India is the largest producer of papaya in the world occupying an area about 1, 22, 000 hectares and production of 53.06 lakh tonnes with an average productivity of 43.49 t ha^{-1}(NHB, 2016). Gujarat, Maharastra, Kerala, Tamil Nadu and Karnataka are the major papaya growing states in India. In Kerala it occupies an area about 17, 700 ha and production of 80, 700 tonnes and with average productivity of 4.56 t ha^{-1}(NHB, 2016).

Heavy bearing nature and quick growing behaviour makes papaya a highly nutrient exhaustive crop, so judicious fertilizer application is necessary to meet the nutrient requirement of the crop. For sustainable production of crops, it is necessary to improve the soil health and maintain a healthy ecosystem. Application of large quantity of chemical fertilizers can progressively lead to nutrient deficiencies, nutrient imbalance, deteriorating soil health and productivity over time, hence organic farming is the best known alternative in this case. Studies conducted on organic farming showed that quality of agriculture produce is much better for organically grown crops than inorganically produced ones. Although plant nutrients are available in small quantities in organic manures compared to chemical fertilizers, they have a positive influence in building up organic matter, soil

microbes, improvement of soil properties such as aggregation, permeability and related physical properties. Studies also revealed that use of bio inoculants like PGPR and AMF has increased the growth and yield of papaya plants. In addition, there has emerged niche markets for organically produced fruits especially in urban areas where consumers are ready to pay premium price for the same.

Inorder to add on the quality it is essential to cultivate the plant organically. Increased awareness about the contamination of food and consequent negative effect on human health has led a way for the building up of organic farming within the country. The present vision of our state government is to promote organic cultivation practices in different crops. In this context, the present study is initiated to find out the effect of organic nutrient management in growth, yield and quality of papaya.

Review of Literature

2. REVIEW OF LITERATURE

Papaya (2n=18) belonging to the family Caricaceae, is an important tropical fruit crop known for its multifarious uses and high nutritive value. The demand and quality of the fruit seems to be increased when it is cultivated organically. The nutritive and therapeutic value of papaya has made the commercialization of the crop in our state. Papaya has a unique growth habit of continuous flowering and fruiting and thus it requires a continuous supply of proper manures and fertilizers for getting full potential yield from the crop. Any deficiency in the nutrients will be reflected on its growth and yield. Application of organic manures and biofertilizers improves the physical properties of soil, quality of fruit and thereby it increases the market value of the product.

The current experiment was carried out for studying the effect of organic manure application on the biometric characters, quality, yield, nutrient uptake by the plant. The review of literature highlights on the following aspects

Biometric characters

Yield characters

Quality characters

Soil analysis

Plant analysis

Incidence of pest and diseases

Economic analysis

2.1 BIOMETRIC CHARACTERS

Mendonea *et al.* (2006) observed that optimum growth of papaya seedlings occured by application of 40 % organic compost and 10 kg single super phosphate. Araujo *et al.* (2010) suggested that papaya seedlings grows efficiently in media using substrate of goat manure, soil and plantmax.

Amiri *et al.* (2010) reported that treatment with mycorrhiza roots at 20 g/cft of coir pith positively influenced the stem height of papaya seedlings. Srinu *et al.* (2017) reported that application of 10 kg vermicompost along with 100g azotobacter and 100g Phosphorus Solubilising Bacteria per plant gave higher values of growth characters viz., plant height in papaya.

Prakash *et al.* (2010) revealed that application of full dose of NPK and 10 g rhizogold (Vesciculsr Arbuscular Mycorrizha) showed more stem girth per plant in papaya. Chandra (2014) observed 40.90 % increase in foliage by the application of NPK (300:300:300g NPK + FYM 10 kg) and *Pseudomonas striata* in papaya.

Yadav *et al.* (2011) followed integrated nutrient nourishment in papaya by adding vermicompost, 100% NPK and azotobacter which resulted in enhanced plant height, girth and number of leaves. Tandel *et al.* (2017) reported positive influence on growth characters *viz.* plant height, stem girth and number of leaves by the application of 25 % RDN through bio compost, 25 % RDN through castor cake and 50 % RDN through inorganic fertilizer in papaya

An increase in plant height and girth was observed in VAM inoculated papaya variety Coorg Honey Dew (Singh *et al.*, 2007). Singh *et al.* (2010) studied the effect of different levels of micronutrients on papaya and observed maximum growth in terms of plant height and girth with borax at 0.50% and ZnSO4 at 0.25%. A study by Dutta *et al.* (2010) on the effect of bio fertilizers on homestead production of papaya revealed that application of azotobacter along with azospirullum, VAM and 2 kg FYM showed maximum plant height, girth and number of fruits per plant. Chandra (2014) reported that application of

Pseudomonas striata supplemented with NPK (300:300:300 g NPK + FYM 10 kg) showed an increase in plant height and leaf area in papaya.

According to Khade and Rodrigues (2009), AMF application in papaya significantly increased plant height, stem girth, leaf area and root length. An experiment conducted by Srivastava *et al.* (2014) on integrated nutrient management in papaya showed that maximum tree height, girth and number of leaves reported by the application of FYM along with 100% NPK, azotobacter and PSB. Parmer *et al.* (2017) reported that papaya cultivar Red Lady when treated with 100 % recommended dose of N and K and 2 % foliar spray of grade IV micronutrients showed maximum plant characters like plant girth, leaf area and minimum days for the first flower initiation.

Dual microbial inoculation (AMF and bacteria) had synergistic effect on each other and negatively affected the plant growth of papaya and effectiveness of mycorrhiza (Alacron *et al.*, 2002). Mohanbhai (2014) inferred that, combined application of organic and inorganic fertilizer, positively influenced the plant growth characters, physiological attributes, yield as well as quality of papaya cv. Taiwan Red Lady.

2.2 YIELD CHARACTERS

Jayakumar *et al.* (2008) registered maximum fruit weight with the application of N and K 100% RD through drip and 50g P_2O_5 through soil application in papaya. Number of fruits per plant and yield was more with full dose NPK and 15g Rhizogold in papaya cv. Pusa Delicious (Prakash *et al.*, 2010).

In another study it was recognised that application of full dose of NPK along with 10g AMF registered early flowering, increased number of fruits per plant and fruit yield in papaya (Prakash *et al.*, 2010). An investigation carried out in integrated nutrient management of papaya cv. Madhubindu revealed that the applications of 1/2 RDF (100:100:125 NPK g $plant^{-1}$) along with azotobacter at 50 g $plant^{-1}$ and PSB at 2.5 g m^{-2} enhanced yield parameter like fruit length, fruit girth, highest fruit weight, maximum number of fruit $plant^{-1}$ (Singh and Varu, 2013).

According to Ray *et al.* (2008) application of organic manures registered significantly lower number of fruits compared to the plants receiving inorganic fertilizers in papaya variety Pusa Delicious. Tank (2011) noted higher fruit yield, in terms of number of fruits and fruit weight in papaya by application of drip irrigation at 0.8 PEF + N and K_2O at 100 % recommended dose.

Higher number of fruits per tree, fruit weight, fruit yield and shelf life of fruits was obtained by the application of FYM along with 100% NPK, azotobacter and PSB in papaya (Srivastava, 2014).

Shivaputhra *et al.* (2004) reported that application of *Glomus fasciculatum* along with 75 % RDF along with vermicompost will increase the yield and saves RDF by 25% in papaya. Soil inoculation with Trichoderma gave 70% germination and best seedling growth in papaya cv. Maradol Roja (Santana *et al.*, 2002). The yield in papaya was found to be increased by the application of poultry manure (Jacquiline, 2008).

According to Shijini (2010), application of recommended dose of fertilizers (240:240:480 g NPK plant^{-1} year^{-1}) and vermicompost along with Trichoderma and Pseudomonas exhibited superiority in terms of floral characters and recorded highest fruit yield in papaya cv.CO-7. An experiment carried out by Shivakumar *et al.* (2012) on organic cultivation of papaya revealed that application of FYM equivalent to 100% recommended dose of nitrogen (154.3 kg/ha) gave significantly higher fruit yield in cultivar; Surya.

Highest fruit yield was obtained in papaya plants treated with poultry manure and dolomite (Falcao and Borges, 2004). Highest fruit yield in papaya variety Surya was observed when treated with 100 % RDF along with VAM, PSB and azospirillum (Ray *et al.*, 2008). Application of AM fungi *Glomus sp.* along with 75% recommended dose of phosphorus was found to be best in improving the yield characters than 100% recommended dose of phosphorus alone (Prakash *et al.*, 2010).

Study conducted on different levels of micronutrients by Dutta *et al.* (2010) on growth, yield and quality of papaya revealed that application of borax and $ZnSO_4$ was considered as the best treatment and resulted in highest plant growth and fruit yield.

Mitra and Tarafdar (2008) studied the effect of biofertilizers and observed that application of 75% RDF in combination with azospirullum, VAM and PSB resulted in highest fruit yield in papaya.

Chagas *et al.* (2000) compared the conventional and organic system of papaya cultivation and found that higher yield was obtained for the organically grown plants. Rajbhar *et al.* (2010) studied the different doses of NPK application in papaya and found that highest average number of fruits was obtained with application of 250:250:250g NPK $plant^{-1}$. Martelleto *et al.* (2008) reported significantly higher yield under organic cultivation of papaya.

Ravishankar *et al.* (2010) experimented the performance of papaya cv. Coorg Honey Dew, under organic farming system and found that growth and yield characters was influenced by organic manures and intensive farming using chemical fertilizers were on par with organic manure application.

Manjunatha *et al.* (2002) reported that AM fungi *Glomus fasciculatum* applied to plants along with 75% RDP increased the yield and yield parameters in papaya.

Suresh *et al.* (2010) studied the efficacy of phosphate solubilizing microbes and VAM fungi on papaya and noticed highest yield due to the inoculation effect of PSM and 200 g P_2O_5 treatment combination.

Biswas *et al.* (1989) studied the effect of different levels of N and K application on papaya cv. Ranchi and reached conclusion that combined application of with N and K gave highest yield and quality fruits.

Seed germination per cent was found to be highest (92.7%) in papaya treated with vermicompost, pond soil and cocopeat (Bhardwaj, 2013).

2.3 QUALITY PARAMETERS

Nitrogen application significantly increased the ascorbic acid content and yield, but reduced the sugar content and TSS of papaya (Lavania and Jain, 1995). Dutta *et al.* (2010) studied the efficacy of biofertlizers on homestead production of papaya and found that application of azotobacter along with azospirillum, VAM and 2 kg FYM recorded highest TSS, βeta-carotene and total sugar. Application of borax and $ZnSO_4$ in micronutrient study of papaya registered maximum TSS, ascorbic acid, total sugar and TSS: Acid ratio in papaya (Singh *et al.*, 2010).

Application of organic manures improved the TSS and other quality parameters of papaya fruits (Singh and Sharma, 2006). Reddy *et al.* (2010) reported that shelf life of papaya fruits were significantly higher when treated with organic manures compared to inorganic fertilizers. Fruit quality in terms of high TSS, total sugar, reducing sugar, ascorbic acid content and reduced fruit acidity in papaya was observed by soil application of vermicompost, 100% NPK and azotobacter (Yadav *et al.*, 2011).

Application of VAM based products along with chemical fertilizers improved the quality aspect of papaya (Prakash, *et al.*, 2010). Application of FYM along with 100% NPK, azotobacter and PSB enhanced the quality parameters like TSS, total sugar, reducing sugar, ascorbic acid and carotenoid in papaya (Srivastava *et al.*, 2014). Organic fertilizers could improve soil fertility status and quality of the papaya fruits (Srivastava *et al.*, 2015).

Kirad *et al.* (2010) studied on integrated nutrient management on papaya and observed highest shelf life of fruit, vitamin A (2280 IU/100 g pulp) and TSS with the application of 75% RDF, 25% vermicompost and rhizosphere bacteria. Total soluble solids (TSS), ascorbic acid content and total sugars were significantly the highest while, titrable acidity was significantly lowest in the organic module with 20 kg FYM application in papaya cultivar Coorg Honey Dew (Ravishanker *et al.*, 2010).

Bindu (2003) reported that application of 200g nitrogen, 300g phosphorus and 500g potassium tried on papaya raised the carotenoid, total sugar and reducing sugar content of fruits. Shijini (2010) noticed that fruit quality characters like TSS, ascorbic acid, total sugar, overall acceptability and shelf life of fruits were found to be highest with organic manures application in papaya.

Nitrogenous fertilizer application was found to decrease the flesh firmness in papaya in cultivar Solo (Awada *et al.*, 1978) organic manures like broiler manure, farmyard manure, wood ash, and bone-meal used as organic fertilizer to test the efficacy of growth under different treatment application. Bovine bio fertilizers positively influenced the fruit yield and quality of papaya (Mesquita *et al.*, 2007). Integration of 100% RDF and bio fertilisers improved the sweetness and quality of papaya (Supriya, 2013).

2.4 SOIL ANALYSIS

Nguyen *et al.* (1995) found that under organic cropping system sulphatase, phosphatase and urease activity are higher than conventional mixed cropping farms. Increase in available micronutrient status of soil in organically treated plots of papaya was noticed by Sharma *et al.* (2001) and there was a reduction in micronutrient content in the treatments receiving only inorganic fertilizers.

Application of 50 % RDF and vermicompost improved soil porosity and reduced bulk-density of the soil (Bandyopadhyay, 2009). Addition of compost, vermicompost, neem cake and poultry manure plant $^{-1}$ at 3rd, 5th and 7th month after planting of papaya improved physical properties of soil (Kumar and Goh, 2003). Oliveria *et al.* (2004) reported that incorporation of organic manures to soil improved the physical, chemical and biological condition of the soil and thus the response of papaya was found to be better under such conditions. Rajasree *et al.* (2005) noted an increase in soil organic carbon with application of farm yard manure.

In the lines with Akinyemi *and* Akande, (2008) noted that papaya plants inoculated with VAM have reported increased nutrient uptake in stressed plants, lowered stomatal resistance, enhanced root hydraulic conductivity thereby facilitated the plants to use water more efficiently.

Application of bio-fertilizers improved the microbial population in rhizosphere soil of papaya and the bacterial count was maximum with the application of Azotobacter, Azospirillum, VAM and 2 kg FYM (Dutta *et al.*, 2010). Biofertilisers and 75% NP applied to papaya increased the nitrogen uptake and microbial count significantly higher than inorganic fertilization.

The dual inoculation of *Glomus ambisporum* and Rhizobium enhanced the amount of Ca, Mg, Na, K, P, Fe, Mn, Zn, and N content in soil and leaf petiole of papaya (Gharge, 2014). Olubode *et al.* (2014) studied the influence of on post field soil fertility status under papaya varieties and observed that papaya orchard treated with organo-mineral fertilizer had significantly higher amount of N, P, K and organic matter in the soil compared to inorganic fertilizers.

AM fungi improved nutrient cycling and soil quality by formation of soil aggregates thus controlling soil erosion and thus improving the growth of plants in nutrient deficient soils (Rodrigues and Rodrigues, 2014).

2.5 PLANT ANALYSIS

In papaya cv. Solo application of phosphorus fertilizer increased the concentration of P and Ca while the amount of Mn, K and Mg got reduced in the leaf petiole (Awada *et al.*, 1978). In papaya cv. Solo maximum yield of fruits was obtained with 1.44 % of nitrogen and 2.52% of potassium on leaf petiole (Awada and Long, 1980).

Application of nitrogen fertilizers increased the composition of N and reduced the concentration of P, K and Ca in the leaf petiole of papaya cultivar Coorg Honey Dew (Reddy *et al.*, 1995). NPK content in leaf petiole of papaya was found

to highest at flowering stage when compared to the vegetative and fruit maturation stage (Krishnakumar, 2005).

The evaluation of nutritional status of papaya in different cultivars can be determined using leaf blade for P, Ca, Mg and leaf petiole for potassium (Sanyal *et al.*, 1990). The concentration of potassium and phosphorus was found to be higher in leaf blades of papaya treated with chicken manure (Munoz *et al.*, 2004).

For high quality fruit production in papaya phosphorus level in petiole had important role compared to nitrogen and potassium (Ghosh and Tarai, 2007). Khade and Rodrigues (2009) revealed that AM fungi, *Glomus mossae* was most effective species which significantly influenced the uptake of potassium and phosphorus in papaya.

Tandel *et al.* (2017) reported that the amount of major nutrients (N, P, K) and micro nutrients (Cu, Zn, Fe, Mn) were higher in plant sample when 25 % RDN through bio compost, 25 % RDN through castor cake and 50 % RDN through inorganic fertilizer was applied.

The concentration of nitrogen was higher in the seedling of papaya when treated with Azotobacter and PSB when compared to inorganic fertilizer application (Mamta *et al.*, 2017).

2.6 PEST AND DISEASE INCIDENCE

Ram (1982) reported that viral diseases like mosaic, ring spot and leaf curl were observed in papaya during the humid and rainy condition when the vectors were in most active stage. Netravathi (2001) noted that soil treatment with neem cake at 100g and application of *Trichoderma harzianum* at 50g per square meter were found to be effective against damping off in papaya seedlings.

Application of poultry manure along with Trichoflow and Trichodry could not reduce the foot rot in papaya (Vawdrey *et al.*, 2002). Fusarium infection in papaya seedling can be reduced by Trichoderma application (Cardenus *et al.*, 2005).

Leaf blight incidence in papaya was significantly reduced by potassium fertilizer application (Li-mingfu and Yang shaocong, 2006).

An improvement in seed germination of papaya cv. Solo was noticed by Amiri *et al.* (2008) when Trichoderma was applied in potting media and produced healthy and disease free seedlings. Application of *Trichoderma viride* and *Pseudomonas fluorescens* incorporated in farm yard manure along the root zone of papaya was found to be effective in reducing the foot rot of papaya (Samiyappan, 2008).

Jonathan *et al.* (2008) reported that application of *Paecilomyces lilacenus* reduced the number of galls in papaya

2.7 ECONOMIC ANALYSIS

In papaya amino acids derived from human hair was used as substitute for 'N', foliar spray of amino acids along with N recorded the highest fruit yield and cost: benefit ratio (Auxcilia and Sathiamoorthy, 2001).

Yadav *et al.* (2010) observed that maximum net profit and highest B: C ratio was obtained in papaya with application of 100% recommended dose of fertilizer along with FYM and azotobacter. Shivakumar *et al.* (2012) noted that application of farm yard manure equivalent to 100 % recommended dose of nitrogen resulted in higher fruit yield in papaya cv. Surya and the B: C ratio was highest with the use of organic manures as against the application of chemical fertilizers in papaya.

Materials and Methods

3. MATERIALS AND METHODS

The study on "Organic nutrient management on papaya (*Carica papaya* L.)" was conducted at Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram during 2016-2018. The objective of the experiment was to study the effect of organic nutrient management on the growth, yield and quality of papaya.

3.1 EXPERIMENTAL SITE

The experimental site is located at 8° 5' North latitude and 77° 1' East longitude at an altitude of 29 meters above the mean sea level. Laterite soil belonging to Vellayani series is predominant in the experimental site. In the experimental site the texture is sandy clay loam and acidic in nature with pH of 4.8.

3.2 EXPERIMENTAL MATERIAL

The experiment was conducted using the papaya variety Surya released from IIHR. The variety is gynodioecious which has greater acceptability because of its quality, taste and red colour flesh.

3.3 EXPERIMENTAL DETAILS

Forty five days old seedlings were transplanted in the main field. Application of organic manures started one month after transplanting of seedlings to main field (plate.1, Plate 2). Organic manures were applied on nitrogen equivalent basis in six splits at an interval of two months. Combination of farm yard manure, poultry manure and Vermicompost in the ratio of 2: 1: 1. Additional phosphorus and potassium requirement were met through the application of rock phosphate and potassium sulphate respectively. Organic manures used for the experiment were analysed for its nutrient compositions and given in Appendix I

Plate 1. General view of the experimental field (3MAP)

Plate 2. General view of the experimental field at fruiting stage

The experimental design adopted was randomised block design

Number of treatments : 11

Number of replications : 3

Number of plants per plot : 4

Plot size- 16 m^2

Spacing- 2 m x 2 m

Table 1. Details of various treatments imposed

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK $plant^{-1}$ $year^{-1}$, FYM-10 kg $plant^{-1}year^{-1}$)

T_{11}- Absolute control

Farm yard manure 10 kg $plant^{-1}$ was applied uniformly to all the treatments except T_9 and T_{11}. AMF was applied at the rate of 5 g $plant^{-1}$ at the time of planting and PGPR Mix-1 was also given at 5 g $plant^{-1}$ twice as basal and one month after planting. Foliar spray of *Pseudomonas fluorescens* (2%) at bimonthly interval and *Trichoderma* enriched cow dung as basal application was given uniformly to all treatments.

3.4 OBSERVATIONS

3.4.1 Biometric characters

3.4.1.1 Height of Plants

Height of the plants were recorded in centimeters from soil level to the tip of growing point at two months interval and average were worked out.

3.4.1.2 Girth of Plants

Girth of the stem was recorded at 10 cm above from the ground level and expressed in centimeters

3.4.1.3 Number of Leaves

Number of fully opened leaves were recorded from all the observational plants and average were worked out

3.4.1.4 Height at First Flowering

Height at which first flower appeared was recorded in centimeters from the ground level

3.4.1.5 Days to Flowering

Number of days from planting to the opening of first female or hermaphrodite flower was recorded and average was worked out.

3.4.1.6 Sex expression of the plant

Total number of hermaphrodite and female flowers in each treatment were noted and expressed in per cent

3.4.1.7 Number of flowers per cluster

Number of flowers found in a cluster was counted and recorded in each plant and average was worked out.

3.4.1.8 Fruit set percentage

Total number of hermaphrodite and female flowers and fruits produced were recorded and expressed in per cent.

3.4.1.9 Time for harvest

The number of days taken from transplanting to the harvest of first formed fruit in each plant was recorded.

3.4.2 Yield characters

3.4.2.1 Fruit weight

Four fruits were selected randomly from each plant and average fruit weight was recorded in grams.

3.4.2.2 Fruit length

Fruit length was measured from the stalk end to the floral end of selected fruits from each observational plant separately and mean length was expressed in centimeters.

3.4.2.3 Fruit girth

Girth at the middle of the fruit selected in each plant was measured in centimeters and average was worked out

3.4.2.4 Fruit volume

The selected fruits were taken and immersed individually into the container which was filled with water and it was placed inside another vessel. The volume of water displaced by the fruit gives the volume of the fruit and was measured with the help of a measuring cylinder.

3.4.2.5 Pulp percentage

Fruit weight was measured before and after peeling and removal of seeds. Pulp percentage was calculated by:

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

3.4.2.6 Flesh thickness

The thickness of the flesh of the selected fruits were measured in centimeters and average was worked out.

3.4.2.7 Number of fruits plant^{-1}

From each observational plant the total number of fruits was counted and average was worked out.

3.4.2.8 Number of seeds fruit^{-1}

Five ripe fruits were taken randomly from each plant and seeds were extracted, counted the number of seeds and average was worked

3.4.2.9 Seed germination percentage

50 seeds for each treatment was collected and made into sets of 5, with 10 seeds per petri plate. The germinated seeds count was taken after 10 days.

$$\text{Germination percentage} = \frac{\text{Number of seed germinated}}{\text{Total number of seeds sown}} \times 100$$

3.4.2.10 Total yield plant^{-1}

Total number of fruits from each plant was multiplied with average fruit weight for getting total yield per plant and expressed in kilogram plant^{-1}.

3.4.2.11 Days taken for maturity

On the day of anthesis flowers were tagged and number of days taken from fruit set to reach harvest maturity was counted.

3.4.3 Quality characters

3.4.3.1 Total soluble solids

Total soluble solids of the ripe fruits were recorded using hand refractometer and expressed in degree brix.

3.4.3.2 Acidity

Titrable acidity of the fruit pulp was determined as per the method described by A.O.A.C. method (1975) and expressed as per cent anhydrous citric acid.

3.4.3.3 Total carotenoids

Total carotenoids present in the fruit was estimated by following the method described by Jensen (1978) and expressed in per cent.

3.4.3.4 Ascorbic acid content

The ascorbic acid content was estimated as per the method proposed by A.O.A.C. method (1975) and expressed as mg per 100 gram of pulp.

3.4.3.5 Total sugars

Total sugars was estimated on fresh weight basis as per the method described by A.O.A.C. method (1975) and expressed in per cent.

3.4.3.6 Reducing sugars

Reducing sugar content on fresh weight basis was estimated as per the method suggested by A.O.A.C. method (1975) and expressed in per cent.

3.4.3.7 Non- reducing sugars

The non-reducing sugar content present in the fruit was estimated by deducting the value of reducing sugars from the value of total sugars (A.O.A.C. method, 1975).

3.4.3.8 Shelf life of the fruits

Days for which the fruit retained the edible qualities without decaying at normal atmospheric conditions was recorded and average was worked out.

3.4.3.9 Colour of pulp and peel

Peel colour was observed when the whole fruit surface attained characteristic colour from green on ripening. Pulp colour was recorded when the ripe fruits were cut open.

3.4.3.10 Firmness of pulp

Firmness of the pulp of fully ripened fruits were assessed by the panel of judges for organoleptic evaluation.

3.4.3.11 Organoleptic evaluation of fruits

The panel judges for sensory analysis at the laboratory level were selected from a group of teachers and students. Ten judges were selected through triangle test as suggested by Mahony (1985). The score chart is furnished in Appendix II

The sensory analysis of panel members were done using the scoring method suggested by Swaminathan (1974). The major quality attributes included in the score were appearance, colour, texture, flavour and taste (APPENDIX III). Scores for overall acceptability was obtained by the average mean scores for each character.

3.4.4 Soil analysis before and after the experiment

The soil sample was collected from the field before transplanting the crop to analyse the soil pH, EC, organic carbon, NPK, micronutrient content and microbial count of the soil. The initial status of the soil is given below.

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

Sl no:	Nutrient estimated	Initial value	Method followed
1.	Soil pH	4.48 (acidic)	Soil water suspension of 1:2.5 and read in pH meter (Jackson, 1973)
2.	Electrical Conductivity ($dS\ m^{-1}$)	0.13	Soil water suspension of 1:2.5 and read in EC meter (Jackson, 1973)
3.	Organic carbon (%)	0.63 (medium)	Walkley and Black method (Walkley and Black, 1973)
4.	Available N ($kg\ ha^{-1}$)	125.44 (low)	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available P_2O_5 ($kg\ ha^{-1}$)	33.22 (high)	Ascorbic acid reduced molybdophosphoric blue colour method (Bray and Kurtz,1945)
6.	Available K_2O ($kg\ ha^{-1}$)	111.85 (medium)	Neutral normal ammonium acetate extract using Flame photometer (Jackson, 1973)

7.	Micronutrients (ppm) Cu Fe Mn Zn	 0.75 13.65 4.73 2.87	Soil sample digestion with 0.5 N HCl and recorded the absorption using Atomic absorption Spectrophotometer (Lindsay and Norwell, 1969).
8.	Microbial count Bacteria (10^7 cfug ^{1}) Fungi (10^4 cfug^{-1}) Actinomycetes (10^5cfug^{-1})	 7 3 25	 Nutrient agar medium (Rao, 1986) Martin's Rose Bengal (Martin, 1950) Kenknight and Munaier's medium (Rao, 1986)

3.4.5 Plant analysis

3.4.5.1 NPK Content of Petiole

Tissue samples (leaf petiole) were collected from the 6th leaf from the top (Index leaf). Modified kjeldahl method (Jackson, 1973) was used for the estimation of nitrogen content in leaf petiole. Phosphorus content was estimated colorimetrically (Jackson, 1973) and Flame Photometric method (Piper, 1966) was used in the estimation of K content in the leaf petiole.

3.4.5.2 Micro nutrient content (Cu, Fe, Zn, Mn) of petiole

The plant sample is digested using nitric-perchloric acid (9:4) and absorbance value was recorded using Atomic Absorption Spectrometer (Jackson, 1973)

3.4.6 Pest and disease incidence

The plants were frequently analysed for the incidence of pest and diseases

3.4.7 Economic analysis

3.4.7.1 Net Income

The economics of cultivation of the crops was worked out

Net income ($Rs.ha^{-1}$) = Gross income – Cost of cultivation

3.4.7.2 B: C ratio

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

3.5 STATISTICAL ANALYSIS

The observations generated from the experiment were analysed statistically in Randomized Block Design and significance was tested using analysis of variance technique (Panse and Sukhatme, 1985).

Results

4. RESULTS

The present study was conducted at Department of Pomology and Floriculture, College of Agriculture, Vellayani. during 2016-2018 for studying the effect of organic nutrient management in papaya. The results of the study are presented below:

4.1 BIOMETRIC CHARACTERS

4.1.1 Height of the plants

Plant height influenced by different organic manure treatments are presented in Table: 2

The height of the plants were taken at 2 MAP, 4 MAP, 6 MAP, 8 MAP, 10 MAP and 12 MAP. Different treatment combinations of organic manures at 100 per cent and 75 percent recommended dose of fertilizers along with bio fertilizers was applied to papaya plants, the output obtained in terms of plant height revealed that there were significant differences in height at 2, 6 and 12 MAP.

At 2 MAP highest plant height (85.16 cm) was recorded for T_6 which was on par with T_{10} (77.83), T_7 (75.33 cm), T_9 (74.06 cm), T_3 (72.73 cm), T_5 (70.33 cm) and T_8 (67.00cm). The lowest value was obtained for absolute control, T_{11} (50.00 cm) which was on par with T_2 (54.33), T_4 (56.33), T1 (61.00 cm), T_8 (67.00 cm)

At 6 MAP the plant height was found to be the highest for T_{10} (169.00) which were on par with T_6 (164.50 cm), T_7 (157.66 cm), T_3 (154.33) and T_9 (138.66 cm) were significantly different from all other treatments. The lowest plant height was recorded for absolute control, T_{11} (100 cm) which was on par with T_2 (119.66 cm) T_1 (124.66 cm) and differed significantly from all the other treatments

Table 2. Effect of organic manures on plant height (cm) of papaya

Treatments	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
T_1	61.00	88.66	124.66	179.66	206.33	244.66
T_2	54.33	106.66	119.66	188.33	218.33	223.33
T_3	72.73	77.33	154.33	198.00	216.33	264.66
T_4	56.33	93.00	129.33	172.66	205.00	254.33
T_5	70.33	91.73	133.33	174.66	214.33	245.33
T_6	85.16	125.66	164.50	199.33	241.00	291.33
T_7	75.33	100.00	157.66	181.33	227.00	267.00
T_8	67.00	86.33	137.00	176.00	217.33	245.33
T_9	74.06	104.00	138.66	186.00	226.33	254.33
T_{10}	77.83	115.66	169.00	209.33	243.66	263.00
T_{11}	50.00	68.66	100.00	170.33	192.33	217.33
SEm±	9.19	6.46	13.07	13.33	15.40	13.38
CD(0.05)	19.172	NS	27.273	NS	NS	27.919

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

At 12 MAP, T_6 (291.33) showed the highest plant height which was on par with T_7 (267.00 cm) and T_3 (264.66 cm). Absolute control, T_{11} showed lowest plant height of 217.33 cm which was on par with T_2 (223.33 cm) and T_1 (244.66 cm).

It was noticed that application of 75% recommended dose of nitrogen as organic along with AMF increased the height of papaya at all stages of growth.

4.1.2 Girth of the plant

Data of plant girth influenced by organic manures are presented in Table: 3

The girth of the plants were taken regularly at 2 MAP, 4 MAP, 6 MAP, 8 MAP, 10 MAP and 12 MAP. The significant variation in the girth of the plants were observed in different treatments at bimonthly observations from 2 MAP to 12 MAP.

At 2 MAP, the highest mean girth of the stem was observed for treatment T_7 (17.10 cm) which was significantly different from all other treatments .This was followed by T_6 (13.73 cm) and T_5 (13.60 cm) which were on par. The lowest stem girth observed at 2 MAP was for absolute control T_{11} (8.46cm) which was on par with T_1 (9.23 cm), T_2 (10.90 cm) and T_8 (10.63 cm).

Observations recorded at 4 MAP showed that T_7 (22.36 cm) recorded the highest plant girth which was on par with T_6 (22.16 cm), T5 (20.70 cm) and T_{10} (20.03 cm) which differed significantly from all other treatments. The lowest plant girth was recorded by absolute control T_{11} (12.03 cm) which was on par with T_1 (12.06 cm) and T_2 (14.66 cm).

Results of data on plant girth at 6 MAP showed that the highest girth was recorded for T_7 (33.03 cm) which was on par with T_6 (31.20 cm) differed significantly from all other treatments and followed by T_5 (27.36 cm). The girth was found to be lowest for T_{11} (20.03 cm) which was on par with T_1 (21.40 cm), T_3 (21.70 cm) and T_2 (21.73 cm).

At 8 MAP, the highest girth of the plants was observed for T_7 (40.00 cm) which was on par with T_6 (39.36 cm) and is significantly different from all other

Table 3. Effect of organic manures on girth (cm) of papaya plants

Treatments	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
T_1	9.23	12.06	21.40	28.33	37.33	42.70
T_2	10.90	14.66	21.73	29.03	37.40	43.33
T_3	12.36	17.50	21.70	31.06	38.70	50.03
T_4	13.16	18.40	24.33	31.06	39.20	44.73
T_5	13.60	20.70	27.36	34.06	41.66	50.00
T_6	13.73	22.16	31.20	39.36	41.03	54.70
T_7	17.10	22.36	33.03	40.00	48.83	55.03
T_8	10.63	16.03	25.70	32.03	40.43	44.00
T_9	12.70	18.06	26.36	32.70	40.03	46.00
T_{10}	13.30	20.03	27.03	33.00	40.73	50.00
T_{11}	8.46	12.03	20.03	27.03	34.00	38.00
SEm±	1.27	2.24	1.39	1.63	1.72	1.72
CD(0.05)	3.667	3.682	2.919	3.409	3.592	3.603

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

treatments. The lowest value for girth was observed for absolute control treatment T_{11} (27.03 cm) which was on par with T_1 (28.33 cm) and T_2 (29.03 cm).

At 10 MAP, the mean girth was found to be the highest for T_7 (48.83 cm) which differed significantly from all other treatments and followed by T_5 (41.66 cm) which was on par with T_6 (41.03 cm). Absolute control, T_{11} (34.00 cm) recorded the lowest girth for papaya plants.

At 12 MAP, treatment T_7 (55.03) on par with T_6 (54.70 cm) recorded the maximum plant girth and differed significantly from all other treatments. It was followed by T_5 (50.03 cm) and T_{10} (50.00cm). The lowest mean plant girth was recorded for T_{11} (38.00 cm).

In general in all stages of growth, the plant girth was found to be the highest with application of organic treatment of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF.

4.1.3 Number of Leaves

Number of leaves influenced by the effect of organic manures are illustrated in Table: 4.

The number of leaves were noted at bimonthly intervals from 2 MAP to 12 MAP and differed significantly.

At 2 MAP, the highest leaf number was noted in T_7 (15.41) which was on par with T_5 (14.36) and T_6 (14) and differed significantly from all other treatments. The least number of leaves was observed in absolute control T_{11} (9. 64) which was on par with T_2 (10.52), T_4 (11.16) and T_1 (11.32).

Number of leaves recorded at 4 MAP showed that T_7 (19.32) reported the highest number of leaves, which was on par with T_5 (18.69) and differed significantly from all other treatments. The least number of leaves was counted for T_{11} (13.41) which was on par with T_1 (14.00), T_9 (14.00) and T_2 (14.32).

Table 4 Effect of organic manures on number of leaves of papaya

Treatments	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP
T_1	11.32	14.00	16.66	19.33	22.41	23.00
T_2	10.52	14.32	16.33	18.33	21.00	23.50
T_3	13.12	15.32	17.00	23.33	23.70	24.06
T_4	11.16	16.00	17.33	21.00	21.83	21.66
T_5	14.36	18.69	19.66	23.33	25.27	28.43
T_6	14.00	17.45	18.33	20.00	21.44	22.66
T_7	15.41	19.32	20.33	24.00	25.81	28.90
T_8	12.00	15.32	18.00	22.00	24.41	27.33
T_9	13.00	14.00	16.00	22.00	23.90	25.33
T_{10}	12.31	15.00	18.00	23.33	24.00	24.66
T_{11}	9.64	13.41	15.33	17.00	18.60	18.53
SEm±	0.99	0.51	0.71	1.599	0.65	0.40
CD(0.05)	1.852	1.075	1.443	2.745	1.355	0.831

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Results recorded during the 6 MAP showed that the highest number of leaves was reported for treatment T_7 (20.33) which was on par with T_5 (19.66) and was significantly different from all other treatments. T_{11} (15.33) reported lowest number of leaves.

At 8 MAP, the leaf number counted was found to be the highest in T_7 (24.00) which was on par with T_5 (23.33), T_3 (23.33) and T_{10} (23.33) and was significantly different from other treatments. The lowest number of leaves was recorded in absolute control T_{11} (17.00) which was on par with T_2 (18.33) and T_1 (19.33).

Statistical analysis at 10 MAP revealed that T_7 (25.81) recorded highest number of leaves and was on par with T_5 (25.81). T_{11} (18.60) registered the lowest number of leaves and was significantly different from all other treatments

At 12 MAP, highest leaf number was observed for T_7 (28.90) which was on par with T_5 (28.43). The lowest value was recorded for T_{11} (18.33) which differed significantly from all other treatments.

In general the highest number of leaves was noted with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF.

4.1.4 Height at first flowering

The data regarding the height at first flowering is inscribed in Table no: 5

The height at first flowering was lowest in T_7 treatment (71.67cm), which was on par with T_5 (78.67 cm), T_6 (75.67 cm) and T_4 (77.00 cm). The highest height at first flowering was observed in T_2 (96.00 cm) which was on par with T_{11} (93.66 cm), T_{10} (93.67) and T_1 (90.33) differed significantly from other treatments.

The different combinations of organic manures applied had significant effect on the height at first flowering of the papaya plants.

Table 5. Effect of organic manures on height at first flowering and days to flowering in papaya

Treatments	Height at first flowering (cm)	Days to flowering
T_1	90.33	178.00
T_2	96.00	179.33
T_3	86.00	172.67
T_4	77.00	173.00
T_5	78.67	163.33
T_6	75.67	156.67
T_7	71.67	153.33
T_8	87.00	166.67
T_9	86.67	166.67
T_{10}	90.00	166.00
T_{11}	93.67	183.67
SEm±	3.53	2.97
CD(0.05)	7.382	6.212

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

4.1.5 Days to flowering

The data regarding the days to flowering is inscribed in Table no: 5

Results of the statistical analysis showed that number of days taken for flowering in papaya showed significant difference on the doses of organic manures and biofertilizers applied to the plant. Least number of days for first flowering was observed in treatment T_7 (153.33), which was on par with T_6 (156.67) and the higher number of days for flowering was observed for T_{11} (183.67) absolute control which was on par with T_2 (179.33) and T_1 (178.00).

4.1.6 Sex expression of the plant

The sex expression of the plant influenced by the effect of organic manures are presented in Table. 6

The number of bisexual plants were the highest in treatment T_1 (66.67 %) and T_{11} (66.67%) which were on par with all the treatments except T_4 (33.33%), T_6 (33.33%) and T_8 (33.33%). The lowest number of bisexual plants was observed in T_7 (25.00 %). The number of female plants were found to be highest in T_7 (75.00 %) and lowest number of female plants was noted in T_{11} (33.33%) and T_1 (33.33%), which was on par with T_{10} (41.67%) and T_2 (41.67%).

It was noted that the sex expression of the plants was significantly influenced by the amount of organic manures and bio fertilizers applied and more femaleness was reported in plants applied with 100% of recommended dose of N as organic along PGPR Mix –I and AMF.

4.1.7 Number of flowers per cluster

The different doses of organic fertilizers applied had no significant influence on the number of flowers per cluster in papaya (Table No: 7).

Table 6. Effect of organic manures on the sex expression of papaya plant

Treatments	Bisexual plants (per cent)	Female plants (per cent)
T_1	66.67	33.33
T_2	58.33	41.67
T_3	50.00	50.00
T_4	33.33	66.67
T_5	50.00	50.00
T_6	33.33	66.67
T_7	25.00	75.00
T_8	33.33	66.67
T_9	50.00	50.00
T_{10}	58.33	41.67
T_{11}	66.67	33.33
SEm±	47.40	47.40
CD (0.05)	22.116	22.116

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Table 7. Effect of organic manures on number of flowers per cluster, fruit set per cent and time for harvest in papaya

Treatments	Number of flowers per cluster	Fruit set %	Time for harvest (days)
T_1	2.00	70.00	254.33
T_2	1.67	71.33	249.67
T_3	1.33	73.00	247.33
T_4	2.33	78.00	250.33
T_5	1.33	79.00	232.67
T_6	1.67	74.66	219.33
T_7	2.67	83.66	220.67
T_8	1.67	73.00	238.67
T_9	2.33	73.33	242.33
T_{10}	1.67	75.33	233.67
T_{11}	1.33	62.66	254.67
SEm±	0.52	2.90	3.11
CD(0.05)	NS	6.062	6.503

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

4.1.8 Fruit set per cent

The fruit set percent influenced by the organic manures are presented in Table. 7.

The fruit set in papaya was the highest in treatment T_7 (83.66 %) which was on par with T_5 (79.00 %) and T_4 (78 %) which differed significantly from all other treatments and the lowest fruit set was observed in absolute control T_{11} (62.66 %).

Application of 100% recommended dose of N as organic + PGPR Mix -I+ AMF increased the fruit set percentage in papaya.

4.1.9 Time for Harvest

The data on time for harvest influenced by organic manure treatments are presented in Table. 7

The time for harvest varied significantly based on the treatments provided to the plants. The least number of days required for harvest of papaya fruits was recorded in T_6 (219.33) which was on par with T_7 (220.67) which differed significantly from other treatments. The highest number of days for harvest was reported in absolute control T_{11} (254.66) which was on par with T_1 (254.33), T_4 (250.33) and T_2 (249.67) was significantly differed from all other treatments.

4.2 YIELD CHARACTERS

4.2.1 Fruit weight

Fruit weight influenced by organic manure treatments are presented in Table. 8

The fruit weight recorded from the different organic treatments showed significant difference in papaya. The highest fruit weight was recorded for T_7 (804.86 g) which was significantly different from all other treatments, followed by T_5 (666.63 g) which also differed significantly from other treatments. The lowest fruit weight was reported for absolute control T_{11} (311.19 g) which differed significantly from other treatments.

Table 8. Effect of organic manures on fruit weight, fruit length and fruit girth in papaya

Treatments	Fruit weight (g)	Fruit length(cm)	Fruit girth (cm)
T_1	507.24	16.50	30.67
T_2	483.33	16.16	29.00
T_3	587.46	17.83	37.06
T_4	518.31	16.93	31.33
T_5	666.63	20.23	37.06
T_6	596.59	18.56	32.50
T_7	804.86	20.63	40.33
T_8	621.89	17.83	32.90
T_9	640.70	18.53	32.50
T_{10}	624.44	18.67	37.11
T_{11}	311.19	15.03	26.13
SE	1.28	0.65	1.17
CD(0.05)	2.682	1.33	2.441

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF recorded maximum fruit weight in papaya.

4.2.2 Fruit length

Fruit length influenced by organic manure treatments are presented in Table. 8.

Fruit length from various organic treatments varied significantly, the highest fruit length was recorded for T_7 (20.63 cm) which was on par with T_5 (20.23 cm). The lowest fruit length was noted in T_{11} (15.03 cm) which was on par with T_2 (16.16 cm).

4.2.3 Fruit girth

Fruit girth influenced by organic manure treatments are presented in Table. 8.

From statistical analysis of fruit girth it was observed that the fruit girth of T_7 (40.33 cm) reported the highest value and was followed by T_{10} (37.11) which was on par with T_3 (37.06) and T_5 (37.06) which also differed significantly from all other treatments. The lowest fruit girth was recorded for T_{11} (26.13 cm) which differed significantly from all other treatments.

4.2.4 Fruit Volume

Fruit volume influenced by organic manure treatments are presented in Table. 9.

The fruit volume recorded showed significant difference among the organic treatments. The highest volume recorded was for T_7 (705.71 cc) which had significant difference from other treatments. This was followed by T_5 (582.58 cc) which also differed significantly from other treatments and T_{11} (271.32 cc) recorded the least volume among the fruits.

Table 9. Effect of organic manures on fruit volume, pulp (%) and flesh thickness in papaya

Treatments	Fruit volume (cc)	Pulp %	Flesh thickness(cm)
T_1	445.98	67.00	2.33
T_2	422.32	68.67	2.20
T_3	514.77	69.67	2.33
T_4	448.88	76.83	2.46
T_5	582.58	79.83	3.16
T_6	521.44	73.00	2.53
T_7	705.71	82.43	3.36
T_8	545.57	77.00	3.00
T_9	560.14	72.00	2.90
T_{10}	547.65	80.23	3.10
T_{11}	271.32	60.00	1.86
SEm±	3.93	2.87	0.14
CD(0.05)	8.211	6.002	0.333

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

4.2.5 Pulp per cent

Pulp per cent influenced by organic manure treatments are presented in Table. 9.

The data recorded for pulp per cent indicated that the highest pulp content was obtained for T_7 (82.43%) which was on par with T_{10} (80.23%), T_5 (79.83 %) T_8 (77.00%) and T_4 (76 83%). The lowest pulp content was noticed in absolute control, T_{11} (60.00 %) which was significantly different from other treatments.

The pulp content was recorded highest with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF.

4.2.6 Flesh thickness

Flesh thickness influenced by organic manure treatments are presented in Table. 9

The different organic treatments given to papaya plant had significant effect on flesh thickness recorded. The thickness was found the highest for T_7 (3.36 cm) which was significantly different from other treatments. This was followed by T_5 (3.16 cm) which was on par with T_{10} (3.10 cm), T_8 (3.00 cm) and T_9 (2.90 cm) and the flesh thickness was found to be least in T_{11} (1.86 cm) which differed significantly from other treatments.

4.2.7 Number of fruits plant^{-1}

Number of fruits per plant influenced by organic manure treatments are presented in Table. 10.

The data on number of fruits plant^{-1} showed that the highest number of fruits was observed in T_{10} (50 82) which was on par with T_9 (50.48), T_7 (49.78) and T_3 (49.26). The lowest number of fruits was observed on T_{10} (38.72) which was on par with T_6 (38 85) and T_2 (40.10).

Plate 3. T_7 at bearing stage

4.2.8 Number of seed fruit^{-1}

Number of seeds per fruit influenced by organic manure treatments are presented in Table. 10.

The statistical analysis on number of seeds fruit^{-1} showed that treatment T_5 (833.33) had more number of fruits and was on par with T_4 (782.66) and differed significantly from all other treatments. The minimum number of seeds were counted for T_{11} (342.67) and was on par with T_1 (372.33).

4.2.9 Seed germination %

Seed germination per cent influenced by organic manure treatments are presented in Table. 11.

Seed germination per cent among different treatments revealed that T_6 (88.33) which was on par with, T_7 (84.00 %), T_9 (84.00 %), T_5 (83.67%) and T_4 (83.00 %) recorded the highest germination percent and was significantly different from other treatments. The lowest germination per cent was observed in T_{11} (74.33 %) which was on par with T_{10} (76.66 %).

4.2.10 Total yield plant^{-1}

Total yield per plant influenced by organic manure treatments are presented in Table. 11.

The organic nutrition given to the plants had shown significant variation among the different treatments in terms of total yield plant^{-1}. The highest yield plant^{-1} was recorded for T_7 (39.91 kg) which was significantly different from other treatments (plate. 3) and was followed by T_9 (34.12 kg) which was on par with T_{10} (33.66 kg). The total yield plant^{-1} was the lowest for absolute control T_{11} (15.26 kg plant^{-1}) which differed significantly from other treatments.

Table 10. Effect of organic manures on number of fruits per plant and number of seeds per fruit

Treatments	Number of fruits Plant^{-1}	Number of seeds fruit^{-1}
T_1	48.33	372.33
T_2	40.10	476.67
T_3	49.26	436.67
T_4	40.56	782.66
T_5	48.27	833.33
T_6	38.85	643.33
T_7	49.78	700.00
T_8	47.20	606.67
T_9	50.48	603.33
T_{10}	50.82	693.33
T_{11}	38.72	342.67
SEm±	0.81	36.90
CD(0.05)	1.686	76.982

T_1-100% of recommended dose of N as organic
T_2-75% of recommended dose of N as organic
T_3-100% of recommended dose of N as organic + PGPR Mix-I
T_4-75 % of recommended dose of N as organic + PGPR Mix-I
T_5-100% of recommended dose of N as organic + AMF
T_6-75% of recommended dose of N as organic + AMF
T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF
T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F
T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)
T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})
T_{11}- Absolute control

Table 11. Effect of organic manures on seed germination (%) and total yield per plant

Treatments	Seed germination %	Total yield plant^{-1}(Kg)	Days to maturity
T_1	80.66	24.61	127.66
T_2	81.67	21.28	129.00
T_3	81.33	32.49	122.66
T_4	83.00	20.28	122.66
T_5	83.67	32.63	125.33
T_6	88.33	23.41	119.66
T_7	84.00	39.91	118.33
T_8	81.00	29.54	125.66
T_9	84.00	34.12	129.66
T_{10}	76.66	33.66	128.33
T_{11}	74.33	15.26	130.66
SEm±	2.69	1.04	0.73
CD(0.05)	5.621	2.034	1.538

T_1-100% of recommended dose of N as organic
T_2-75% of recommended dose of N as organic
T_3-100% of recommended dose of N as organic + PGPR Mix-I
T_4-75 % of recommended dose of N as organic + PGPR Mix-I
T_5-100% of recommended dose of N as organic + AMF
T_6-75% of recommended dose of N as organic + AMF
T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF
T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F
T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)
T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})
T_{11}- Absolute control

4.2.11 Days taken for maturity

Days taken for maturity influenced by organic manure treatments are presented in Table. 11.

The least number of days to fruit maturity was reported in T_7 (118.33) which was on par with T_6 (119.66) and differed significantly from other treatments. The highest number of days for fruit maturity was recorded for T_{11} (130.66) which was on par with T_9 (129.66) and differed significantly from other treatments.

4.3 QUALITY CHARACTERS

4.3.1 TSS

Data on TSS of fruit influenced by organic manure application is inscribed in Table. 12.

The organic manures applied to the plants in different combinations had shown significant difference in TSS of the fruits. The treatment T_7 (14.32 °brix) which was on par with T_5 (14.00 °brix) showed the highest TSS, which was significantly different from other treatments. The lowest TSS was observed for T_{11} (11.21 °brix) which differed significantly from other treatments.

4.3.2 Acidity

Data on acidity of fruit influenced by organic manure application is inscribed in Table. 12

Organic manures and bio fertilizers applied at different doses had significant effect on acidity of papaya fruits The lowest value for acidity was recorded for T_7 (0.116 %) which differed significantly from other treatments. This was followed by T_5 (0.126 %) which also differed significantly from other treatments. The fruits were found to be highly acidic in absolute control, T_{11} (0.243 %) which differed significantly from other treatments. This was followed by T_1 (0.026 %), T_2 (0.20 %) and T3 (0.196 %) which were on par.

Table 12. Effect of organic manures on TSS acidity, total carotenoids and ascorbic acid of papaya

Treatments	TSS(°brix)	Acidity (%)	Carotenoids (mg 100 g^{-1})	Ascorbic acid (mg 100 g^{-1})
T_1	12.42	0.206	1.89	54.67
T_2	12.39	0.203	1.70	55.00
T_3	13.00	0.196	2.03	57.00
T_4	13.10	0.164	1.95	60.67
T_5	14.00	0.126	2.20	62.67
T_6	13.21	0.141	2.14	56.67
T_7	14.32	0.116	2.24	63.67
T_8	13.31	0.153	1.99	57.67
T_9	12.86	0.153	2.08	58.33
T_{10}	12.16	0.152	2.18	60.67
T_{11}	11.21	0.243	1.41	45.33
SEm±	0.28	0.03	0.11	2.15
CD(0.05)	0.611	0.061	0.285	4.495

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK $plant^{-1}$ $year^{-1}$, FYM-10 kg $plant^{-1}year^{-1}$)

T_{11}- Absolute control

4.3.3 Total Carotenoids

Data on total carotenoid of fruit influenced by organic manure application is inscribed in Table. 12

Carotenoid content in pulp of papaya were found to be highest for T_7 (2.24 mg 100 g^{-1}) which was on par with T_5 (2.20 mg 100 g^{-1}), T_6 (2.14 mg 100 g^{-1}), T_{10} (2.18 mg 100 g^{-1}), T_9 (2.08 mg 100 g^{-1}), T_3 (2.03 mg 100 g^{-1}) and T_8 (1.99 mg 100 g^{-1}). The least value for carotenoid content in pulp was recorded for T_{11} (1.41 mg 100 g^{-1}) which differed significantly from other treatments.

Plants supplied with 100% of recommended dose of N as organic along with PGPR Mix –I and AMF reported highest carotenoid content in fruits.

4.3.4 Ascorbic acid

Data on ascorbic acid on fruit influenced by organic manure application is inscribed in Table. 12

The ascorbic acid content in papaya was noticed to be highest in T_7 (63.67 mg 100 g^{-1}) which was on par with T_5 (62.67 mg 100 g^{-1}), T_4 (60.67 mg 100 g^{-1}) and T_{10} (60.67 mg 100 g^{-1}). The least mean value of ascorbic acid was recorded for absolute control T_{11} (45.33 mg 100 g^{-1}) which was significantly different from other treatments.

4.3.5 Total sugar

Data on total sugar content on fruit influenced by different organic manure application is inscribed in Table. 13

The total sugar content of papaya was significantly influenced by the different doses of organic manures applied. Total sugar was found to be maximum for T_7 (9.88 %) which was on par with T_5 (9.52 %) which was significantly different from other treatments. The lowest amount of total sugar was recorded for T_{11} (6.77 %) which was on par with T_1 (7.19 %).

Table 13. Effect of organic manures on total sugar, reducing sugar and non-reducing sugar on papaya

Treatments	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)
T_1	7.19	6.00	1.19
T_2	9.21	8.13	1.08
T_3	8.21	6.38	1.83
T_4	8.76	7.2	1.59
T_5	9.52	8.19	1.33
T_6	8.85	7.43	1.45
T_7	9.88	8.56	1.32
T_8	8.16	6.82	1.34
T_9	8.69	7.81	0.62
T_{10}	7.21	5.71	1.50
T_{11}	6.77	5.16	1.39
SEm±	0.20	0.30	0.25
CD(0.05)	0.423	0.649	0.531

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

4.3.6 Reducing sugar

Data on reducing sugar content on fruit influenced by different organic manure application is inscribed in Table. 13.

Reducing sugar was highest in T_7 (8.56 %) which was on par with T_5 (8.19 %) and T_2 (8.13 %) and was significantly different from other treatments. The lowest amount of reducing sugar was reported in T_{11} (5.16 %) which was on par with T_{10} (5.71%).

4.3.7 Non reducing sugar

Data on non-reducing sugar content on fruit influenced by different organic manure application is inscribed in Table. 13.

Non reducing sugar was lowest for treatment T_9 (0.62 %) which was on par with T_2 (1.082 %). Highest amount of non-reducing sugar was reported in T_3 (1.83 %) which was on par with all the treatments except T_1 (1.19 %).

4.3.8 Shelf life of fruits

Shelf life fruit influenced by organic nutrient management is presented in Table. 14.

The doses of organic manures applied on nitrogen equivalent basis seemed to have no significant effect on the shelf life of papaya fruits at ambient conditions.

4.3.9 Colour of the peel and pulp

The data on colour of pulp and peel influenced by organic nutrient management is presented in Table. 14.

The peel colour of the fruit was found to be deep yellow for T_4, T_6, T_9, and T_{10}. The colour of the peel was yellow for rest of the treatments. The colour of the peel varied based on the doses of organic manures applied to the papaya plant.

Table 14. Effect of organic manures on colour of peel and pulp, firmness of fruit and shelf life

Treatments	Colour of peel	Colour of pulp	Firmness of fruit	Shelf life(days)
T_1	Yellow	Orange	Firm	4
T_2	Yellow	Red	Firm	4.66
T_3	Yellow	Red	Fairly firm	4.00
T_4	Deep yellow	Deep red	Firm	5.50
T_5	Yellow	Red	Fairly firm	5.66
T_6	Deep Yellow	Orange	Fairly firm	4.66
T_7	Yellow	Deep red	Fairly firm	6.50
T_8	Yellow	Deep red	Fairly firm	5.00
T_9	Deep yellow	Orange	Firm	5.16
T_{10}	Deep yellow	Orange	Fairly firm	6.16
T_{11}	Yellow	Orange	Firm	4.83
SEm±				0.82
CD(0.05)				NS

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Table 15. Organoleptic qualities of papaya

Treatments	Appearance	Colour	Flavour	Taste	Texture	Papain odour	Overall acceptability
T_1	2.34	2.11	2.11	2.89	2.30	2.26	14.01
T_2	2.10	2.58	2.16	3.00	2.80	2.60	15.24
T_3	2.12	2.33	2.43	2.54	3.02	2.96	15.4
T_4	3.52	3.13	2.43	3.12	2.81	2.99	18.00
T_5	3.50	3.20	3.12	3.00	2.98	2.92	18.72
T_6	2.88	3.12	2.74	2.88	2.13	2.52	16.27
T_7	3.56	3.66	3.36	3.86	3.20	3.10	20.74
T_8	3.00	2.46	2.66	3.10	2.43	2.46	16.11
T_9	2.32	3.00	2.85	3.02	2.26	3.10	16.55
T_{10}	2.30	2.10	2.68	2.96	2.31	1.98	14.33
T_{11}	1.32	2.13	2.10	2.63	1.86	2.00	12.04

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

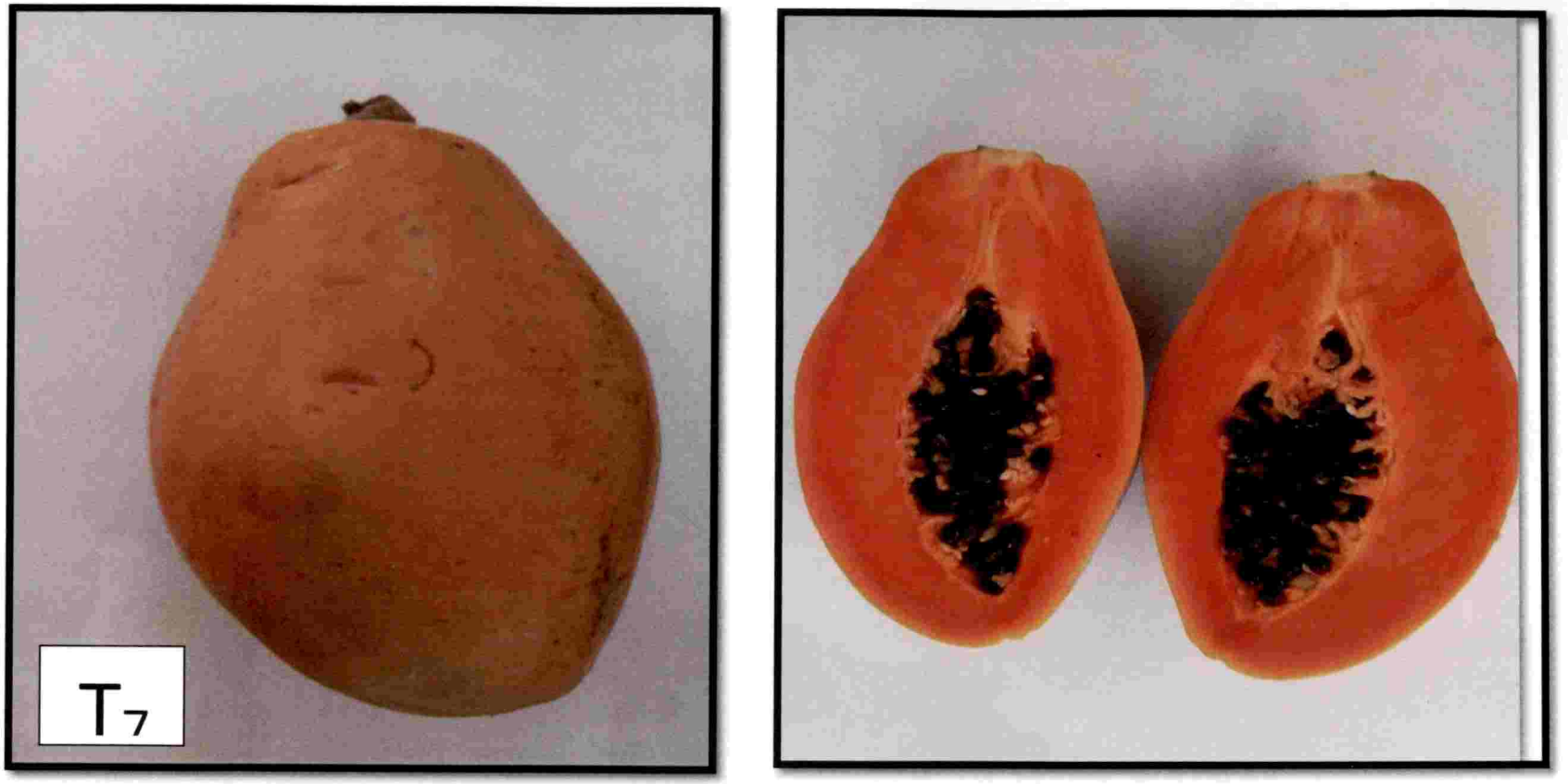


Plate 4: Fruit from T_7 (best treatment)

Plate 5. Fruits of absolute control, T_{11}

The treatments T_2, T_3 and T_5 had red flesh colour. The treatments T_4, T_7 and T_8 had deep red flesh colour. The colour of the pulp was orange for T_1, T_6, T_9, T_{10} and T_{11}.

4.3.10 Firmness of the fruit

Firmness of pulp influenced by organic nutrient management is presented in Table. 14.

The fruits in T_1, T_2, T_4, T_9, T_{11} were appeared to have firm fruits and the rest of the treatments had fairly firm fruits.

4.3.11 Organoleptic qualities of papaya

The score of papaya for the organoleptic qualities are presented in Table. 15.

The mean score for overall acceptability of papaya fruits ranged from 12.04 in T_{11} to 20.74 in T_7 (plate. 4).

The mean score recorded for appearance (3.56), colour (3.66), flavour (3.36), taste (3.86), texture (3.20) and freeness from papain odour was the highest for T_7. The lowest mean score for appearance was recorded for T_{11} (1.32), (plate. 5). The lowest score for colour of the pulp and peel was noticed in T_{10} (2.10) followed by T_{11} (2.11). With regard to the flavour the lowest mean score was obtained for T_{11} (2.10) and followed by T_1 (2.11). The lowest mean score for taste of the fruit was recorded by T_3 (2.54) followed by T_{11} (2.63). Considering the texture of the pulp lowest mean score was reported for T_{11} (1.86). The papain odour of the fruit which was a less preferred character was reported to be maximum for T_{10} (1.98) followed by T_{11} (2.00).

4.4 SOIL ANALYSIS

The data on Soil pH, EC, organic carbon influenced by the different organic manures are presented in Table.16.

\4.4.1 Soil pH

The organic manures applied to the soil had significant effect on soil pH. Soil pH of 5.64 was obtained for T_5 which was on par with T_6 (5.53), T_7 (5.62) and showed significant difference among the treatments. Lowest pH was registered for T_{11} (4.82) which was significantly different from other treatments.

4.4.2 Soil EC

The soil EC was analysed and highest EC was recorded for T_6 (0.25 dSm^{-1}), which was on par with T_3 (0.24 dSm^{-1}), T_9 (0.24 dSm^{-1}) and was significantly different from all other treatments. The EC was lowest for absolute control T_{11} (0.10 dSm^{-1}) which differed significantly from other treatments.

4.4.3 Soil organic carbon

T_{11} reported the lowest value for organic carbon was significantly different from other treatments, the highest organic carbon content was reported for T_6 (2.98%) which had significant difference over other treatments. This was followed by T_7 (2.79%) which was also significantly different from other treatments.

4.4.4 Soil available N, P, K

The data on soil NPK content influenced by the organic manures are presented in Table. 17.

The nitrogen content in soil was estimated and the results revealed that T_6 (250.87 kg ha^{-1}) recorded the highest nitrogen content which was on par with T_7 (284.00 kg ha^{-1}) and significantly differed from other treatments. The least nitrogen content was observed for T_{11} (115 kg ha^{-1}) which differed significantly from other treatments.

Data on soil phosphorus content as influenced by the organic nutrient application revealed the highest soil phosphorus was noticed for T_5 (145.48 kg ha^{-1}) which was on par with T_7 (138.25 kg ha^{-1}), T_8 (130.81 kg ha^{-1}) and T_6 (123.25 kg ha^{-1}) which was significantly different from other treatments.

Table 16. Effect of organic manures on soil pH, soil EC, and soil organic carbon

Treatments	Soil pH	Soil EC (dSm^{-1})	Soil organic carbon (%)
T_1	4.81	0.14	2.01
T_2	4.10	0.14	2.17
T_3	5.20	0.24a	2.13
T_4	4.92	0.13	2.62
T_5	5.64	0.23	2.31
T_6	5.53	0.25	2.98
T_7	5.62	0.18	2.79
T_8	4.73	0.14	2.23
T_9	4.82	0.24	2.13
T_{10}	4.62	0.21	1.90
T_{11}	4.82	0.10	0.66
SEm±	0.19	0.01	0.05
CD(0.05)	0.415	0.021	0.064

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240.240:480 g NPK $plant^{-1}$ $year^{-1}$, FYM-10 kg $plant^{-1}year^{-1}$)

T_{11}- Absolute control

Table 17 Effect of organic manures on nitrogen, phosphorus and potassium content in soil

Treatments	Soil Nitrogen (Kg ha^{-1})	Soil Phosphorus (Kg ha^{-1})	Soil Potassium (Kg ha^{-1})
T_1	175.00	88.32	257.65
T_2	181.06	93.92	298.32
T_3	193.00	106.32	311.74
T_4	241.00	117.92	310.83
T_5	236.00	145.48	283.08
T_6	250.87	123.25	348.30
T_7	248.00	138.24	330.32
T_8	213.37	130.81	342.36
T_9	202.00	109.56	300.21
T_{10}	208.00	114.24	327.46
T_{11}	151.00	35.11	113.34
SEm±	2.43	10.92	10.39
CD (0.05)	5.088	22.786	21.693

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

The lowest soil phosphorus content was observed for T_{11} (35.11 kg ha^{-1}) which differed significantly from other treatments.

Statistical analysis on potassium content of soil due to the addition of organic manures and bio fertilizers revealed that the amount was highest for T_6 (348.30 kg ha^{-1}) which was on par with T_8 (342.36 kg ha^{-1}), T_7 (330.32 kg ha^{-1}), and T_{10} (327.26 kg ha^{-1}) significantly differed from all other treatments. The lowest amount of soil potassium was recorded for T_{11} (113.34 kg ha^{-1}) which had significant difference among the treatments.

4.4.5 Micronutrient content

The data on soil micronutrient content influenced by the organic manures are presented in Table. 18.

The micronutrient analysis on soil revealed there exist significant difference on the organic nutrient application to the soil .The copper content was highest for T_5 (2.10 ppm) which was on par with T_7 (2.09 ppm) and T_4 (1.92 ppm) was significantly different from all other treatments. The lowest copper content was recorded for absolute control T_{11} (0.83 ppm) which differed significantly from other treatments.

The highest amount of iron content was recorded for T_5 (32.00 ppm) and was on par with T_4 (30.42 ppm), T_7 (31.81 ppm) and T_6 (29.86 ppm) which was significantly different from other treatments. The lowest iron content was registered for T_{11} (12.35 ppm) which differed significantly from other treatments.

The soil manganese content was registered highest for T_5 (14.36 ppm) which was on par with T_4 (13.12 ppm) and differed significantly from other treatments. The manganese content in soil was reported lowest for T_{11} (4.10 ppm) which was significantly different from other treatments.

In case of zinc content highest value was recorded for T_5 (4.61 ppm) which was significantly different from all the other treatments and lowest zinc content was recorded for T_{11} (2.20 ppm) which was significantly different from other treatments.

Table 18 Effect of organic manures on micronutrient content in soil

Treatments	Soil Cu (ppm)	Soil Fe (ppm)	Soil Mn (ppm)	Soil Zn (ppm)
T_1	1.18	22.91	7.89	3.35
T_2	1.20	24.38	9.64	3.01
T_3	1.23	26.42	10.36	2.61
T_4	1.92	30.42	13.12	3.31
T_5	2.10	32.00	14.36	4.61
T_6	1.86	29.86	11.00	3.65
T_7	2.09	31.81	12.60	4.32
T_8	1.86	28.59	8.55	3.89
T_9	1.45	26.31	10.34	3.61
T_{10}	1.39	22.01	8.78	3.18
T_{11}	0.83	12.35	4.10	2.20
SEm±	0.109	1.22	0.76	0.06
CD(0.05)	0.192	2.566	1.602	0.131

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

From the overall assessment of micronutrient content in soil (Cu, Fe, Mn, Zn) after the addition of organic manures and bio fertilizers it was observed that the highest amount of micronutrient content was recorded for T_5 which was on par with and minimum for T_{11}

4.4.6 Microbial count

The data on soil microbial (bacteria, fungi, actinomycetes) count are presented in Table 19.

The assessment of microbial count indicated that the beneficial microbes present in the soil after the application of organic manures and bio fertilizers showed significant difference among the treatments. The microbial count of bacteria, fungi and actinomycetes present in the soil were taken.

The highest bacterial count was recorded for T_5 (24.69×10^7cfug^{-1}) which was significantly different from other treatments, followed by T_7 (20.08×10^7cfug^{-1}) which was on par T_8 (20.01×10^7cfug^{-1}), T_9 (19.59×10^7cfug^{-1}) and least number of bacterial colonies was recorded for T_{11} (7.28×10^7cfug^{-1}).

The fungal colonies was found to be highest for T_5 (16.21×10^4cfug^{-1}) which was on par with T_8 (15.11×10^4cfug^{-1}) and differed significantly from other treatments. The lower number of fungal colonies was noticed for T_{11} (6.23×10^4cfug^{-1}) which was significantly different from other treatments.

The actinomycetes colony was highest for T_5 ($27.89\ 10^5$ cfug^{-1}) which showed significant difference among treatments and followed by T_8 (25.68×10^5 cfug^{-1}) which was on par with T_7 (24.32×10^5 cfug^{-1}) and was significantly different from other treatments. The least number of actinomycetes colonies was counted for T_{11} (10.620×10^5 cfug^{-1}) which had significant difference from other treatments.

Table 19. Effect of organic manures on microbial count in soil

Treatments	Bacteria (10^7cfug^{-1})	Fungi (10^4cfug^{-1})	Actinomycetes (10^5 cfug^{-1})
T_1	14.62	12.36	15.31
T_2	15.31	13.51	17.23
T_3	16.14	13.98	20.13
T_4	18.21	14.96	23.12
T_5	24.69	16.21	27.89
T_6	17.51	13.98	21.01
T_7	20.18	14.28	24.32
T_8	20.01	15.11	25.68
T_9	19.59	10.02	18.68
T_{10}	17.69	11.68	19.65
T_{11}	7.28	6.23	10.62
SEm±	0.25	0.92	0.39
CD(0.05)	1.787	1.931	2.068

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

4.5 PLANT ANALYSIS

The data on NKP content of plant petiole influenced by organic manure are inscribed in Table. 20

4.5.1 NPK content

The statistical report on plant analysis showed that, in the leaf petiole of papaya percentage of nitrogen was found to be the highest in treatment T_5 (2.95%) which was significantly different from all the other treatments, followed by T_6 (2.48 %) which was on par with T_3 (2.32 %). The lowest amount of nitrogen in petiole was observed in T_{11} (1.41 %) which had significant difference from other treatments.

The phosphorus content was highest in treatment T_7 (0.43 %) which was on par with T_6 (0.38 %) and differed significantly from other treatments. the lowest phosphorus content was registered for T_{11} (0.14 %) which was significantly different from all other treatments.

The potassium content was highest for T_7 (3.31 %) which was on par with T_6 (3.22 %) and T_4 (3.16 %) and differed significantly from all other treatments. The lowest potassium value was noted for T_{11} (0.68 %) and differed significantly from other treatments.

4.5.2 Micronutrient content

The data on micronutrient (Cu, Fe, Mn, Zn) content of plant petiole influenced by organic manure are inscribed in Table. 21.

The organic nutrient management of papaya showed significant difference in the micronutrient (Cu, Fe, Mn, Zn) content of leaf petiole of papaya. The micronutrient content in leaf petiole recorded significant difference among the treatments.

The copper content in leaf petiole was the highest for T_7 (29.30 ppm) and differed significantly from other treatments. This was followed T_6 (28.20 ppm)

Table 20. Effect of organic manures on NPK content of petiole

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	2.12	0 23	1.08
T_2	1.98	0.28	1.00
T_3	2.32	0.26	2.41
T_4	1.94	0.31	3.16
T_5	2.95	0.31	2.93
T_6	2.48	0.38	3.22
T_7	2.10	0.43	3.31
T_8	2.00	0.31	3.00
T_9	2.03	0.29	2.69
T_{10}	2.14	0.24	2.85
T_{11}	1.41	0.14	0.68
SE(±)	0.10	0.01	0.072
CD(0.05)	0.211	0.034	0.158

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Table 21. Effect of organic manures on micronutrient content in leaf petiole

	Micronutrients in leaf petiole (ppm)			
Treatments	Cu	Fe	Mn	Zn
T_1	22.20	297.66	28.31	15.59
T_2	23.16	300.66	27.86	17.62
T_3	21.33	347.00	30.14	17.65
T_4	22.38	408.00	36.36	22.45
T_5	26.43	388.00	32.14	18.93
T_6	28.20	420.00	43.00	25.38
T_7	29.30	460.00	45.00	29.50
T_8	24.20	411.00	34.40	24.83
T_9	23.23	341.00	31.39	15.42
T_{10}	21.30	325.00	30.14	15.08
T_{11}	16.66	167.00	12.26	9.39
SE(±)	0.21	4.42	1.10	0.61
CD(0.05)	0.453	9.22	2.30	1.27

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

which also differed significantly from other treatments. The lowest copper content was registered for T_{11} (16.66 ppm), which differed significantly from other treatments.

The iron content in petiole was highest for T_7 (460.00 ppm) which differed significantly from other treatments. It was followed by T_6 (420.00 ppm) which was on par T_9 (411.00 ppm), which also differed significantly from other treatments. The lowest iron content in leaf petiole of papaya was noted for T_{11} (167.00 ppm) which was significantly different from other treatments.

The manganese content was registered the highest for T_7 (45.00 ppm) which was on par with T_6 (43.00 ppm) and differed significantly from other treatments. The lowest manganese content recorded for T_{11} (12.26 ppm) which was significantly different from other treatments.

The zinc content in leaf petiole was highest for T_7 (29.50 ppm) and was significantly different from other treatments. It was followed by T_6 (25.38 ppm) which was on par with T_8 (24.83 ppm) and differed significantly from other treatments. The lowest zinc content was recorded for T_{11} (9.39 ppm) which was significantly different from other treatments.

In general application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF increased the plant micronutrient content (Cu, Fe, Mn, Zn) than other treatments.

4.6 PEST AND DISEASE INCIDENCE

There was no major pest incidence noticed in the field. The disease observed in the field was foot rot of papaya and the incidence was less than 1.0 %.

4.7 ECONOMIC ANALYSIS

The data on net income and B: C ratio influenced by organic manures are presented in Table. 22 and Table. 23 respectively.

4.7.1 Net income

The effect of organic manures on application in papaya exhibited notable difference in the net income. The highest net income was obtained for treatment T_7 (Rs. 2,99,292.00 ha^{-1}) which was significantly different from other treatments. This was followed by T_{10} (Rs. 2,46,657.00 ha^{-1}) which also differed significantly from other treatments. The lowest net income was recorded for absolute control treatment T_{11} (Rs.1,143,00 ha^{-1}) which also differed significantly from other treatments.

4.7.2 B: C ratio

The B: C ratio of organic nutrient management of papaya showed that T_7 (1.98) recorded the highest B: C ratio of which differed significantly from all other treatments. This was followed by T_{10} (1.82) which also differed significantly from other treatments. The minimum B: C ratio was observed with T_{11} (1.01) which had significant difference from other treatments.

Table 22. Net income obtained under organic manure application in papaya

Treatments	Net income (Rs. ha^{-1})
T_1	108144.00
T_2	93746.00
T_3	212380.00
T_4	98963.00
T_5	234003.00
T_6	112194.00
T_7	299292.00
T_8	189165.33
T_9	180400.00
T_{10}	246657.00
T_{11}	1143.00
SEm±	330.10
CD(0.05)	688.604

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Table 23. B: C ratio obtained under application of organic manures in papaya

Treatments	B: C ratio
T_1	1.36
T_2	1.39
T_3	1.70
T_4	1.41
T_5	1.77
T_6	1.46
T_7	1.98
T_8	1.78
T_9	1.63
T_{10}	1.82
T_{11}	1.01
SEm±	0.02
CD(0.05)	0.046

T_1-100% of recommended dose of N as organic

T_2-75% of recommended dose of N as organic

T_3-100% of recommended dose of N as organic + PGPR Mix-I

T_4-75 % of recommended dose of N as organic + PGPR Mix-I

T_5-100% of recommended dose of N as organic + AMF

T_6-75% of recommended dose of N as organic + AMF

T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF

T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AM F

T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP)

T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1} FYM-10 kg plant^{-1}year^{-1})

T_{11}- Absolute control

Discussion

5. DISCUSSION

Papaya is an important fruit crop which has gained wide popularity and cultivation due to the recognition of its nutritive and therapeutic values. Papaya being a heavy feeder needs continuous application of balanced nutrients. Several studies related to application of organic manures showed its ability to increase the quality of the fruit and thereby increase the demand of papaya fruit in the market. In the present study treatments with different doses of organic manures and bio fertilizers were applied to the plant for standardising the organic nutritional requirement for plant. The results in terms of growth, yield, quality, economics and the soil nutrient status have been analysed and are discussed below:

5.1 BIOMETRIC CHARACTERS

The investigation carried out revealed that, the height of the plant showed significant difference in 2 MAP, 6 MAP and 12 MAP. Application of 75 % recommended dose of nitrogen as organic along with AMF and 100 % recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF showed an increase (Fig. 1) in plant height which were on par.

Organic manure application along with AMF was found to increase the plant height in papaya. The increase in growth character like height of the plant may be attributed to the fixation of nitrogen by the microorganism and regulation of nitrogen supply (Babu, 2003) Ravishankar *et al.* (2010) reported an increase in plant height of papaya with the organic treatment of rock phosphate 300 g plant^{-1} along with sun hemp 40 kg plant^{-1}. The AMF inoculation increased the plant growth of papaya by increased mycelial biomass which explore large soil volume and thus resulting in higher uptake rates (Gharge *et al.*, 2014).

A number of studies have been registered on different fruit crops based on the improved growth of plant and soil biological activity by the addition of organic manures (Singh *et al.*, 2004; Ratan *et al.*, 2008). The results given by Chandra (2014) also was in corroboration with findings of present study, where the application of NPK fertilizers and *Pseudomonas straita* resulted in more uptake of

Fig. 1 Effect of organic manures on plant height of papaya

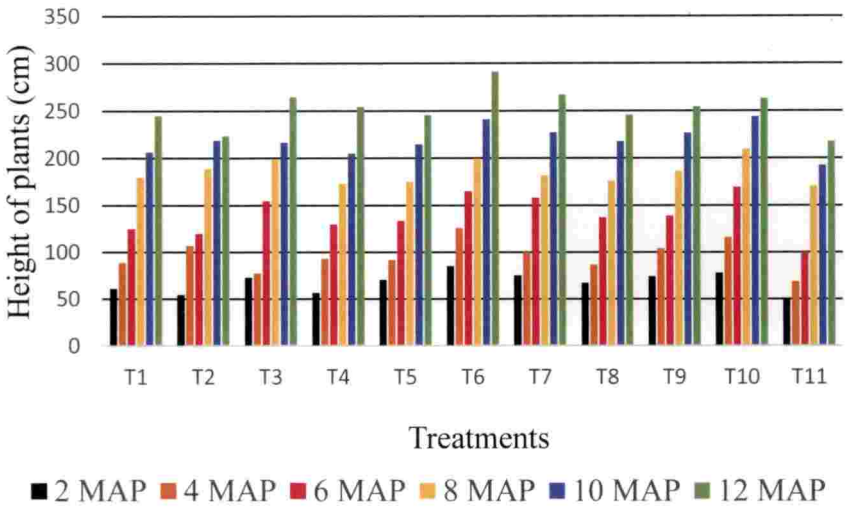
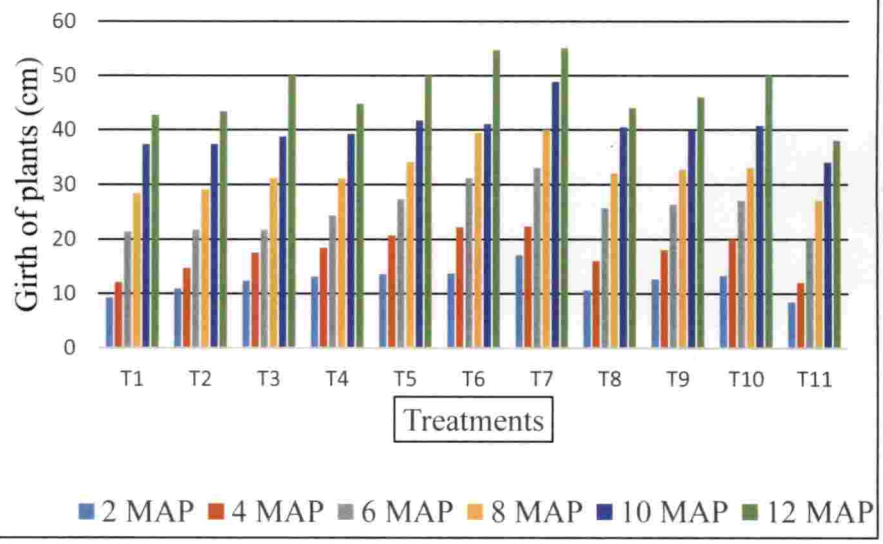


Fig.2 Effect of organic manures on girth of the plant.



nutrients by the plant ,thereby increasing the height of the plants, girth, number of leaves.

Growth parameters including girth of the plant and number of leaves were found to increase with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF (Fig. 2).

Dutta *et al.* (2010) agreed with similar result in papaya, where the biometric parameters like stem girth and number of leaves were increased with the treatment of Azotobacter, Azospirillum and VAM along with 2 kg FYM. Prakash *et al.* (2010) reported enhanced growth and yield parameters when VAM based products were added along with fertilizers in papaya. Acevedo and Pire (2004) registered similar results. The increased growth in papaya may also be attributed to the use of bio active substances produced by the application of bio fertilizers (Chandra, 2014).

Application of 100% recommended dose of nitrogen as organic along with PGPR Mix -1 reduced the height at first flowering and number of days taken for flowering. Number of flowers per cluster was insignificant with respect to the organic manures applied to papaya. The results were in harmony with the reports of Shijini (2010), who noted that application of vermicompost, Trichoderma, along with RDF in papaya reduced the height at first flowering (Fig. 3) and number of days for flowering. Results were also correlated with the findings of Lima and Hawa (2007), Reddy and Kohli, (1989).

The sex expression of the plant was studied based on the morphology of the flower and it was found that, the bisexual plants were significantly higher in absolute control treatment and also in plants receiving 100 % recommended dose of nitrogen as organic. Female plants were significantly higher in the plants receiving 100% recommended dose of nitrogen as organic along with PRPR Mix - 1 and AMF. The results were in harmony with the observation of Oliveira *et al.* (2004) where high nitrogen availability to papaya plants increased the femaleness of the plant.

Fig. 3 Effect of organic manures on height at first flowering in papaya

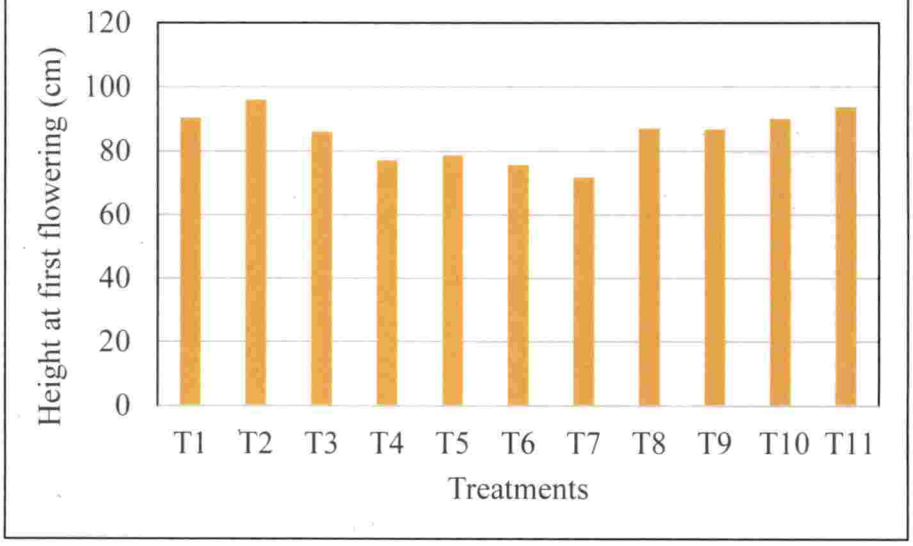
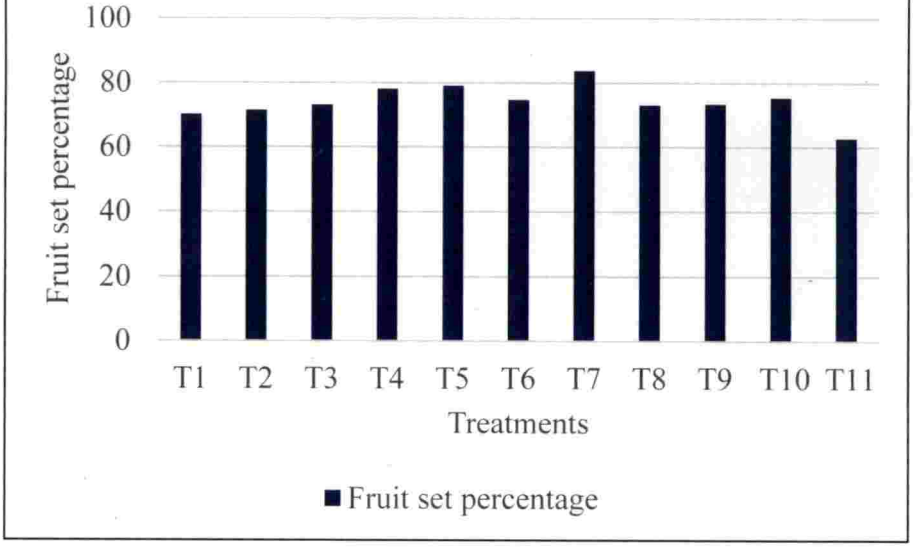


Fig. 4 Effect of organic manures on fruit set percentage (%)



The percent of fruit set in the current study showed that highest fruit set percent was obtained with 100% recommended dose of nitrogen as organic along with PGPR Mix -1 and AMF (Fig 4). Results of Shijini (2010) was in harmony with the results of the current study in papaya, where plants treated with poultry manure exhibited high fruit set percentage.

Least number of days taken for harvesting the fruits was reported from plants receiving 75% recommended dose of nitrogen as organic along with AMF and also in plants receiving 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Similar results was reported by the findings of Dutta *et al.* (2010).

5.2 YIELD PARAMETERS

Results of the present experiment revealed that among the yield parameters of the papaya, highest fruit weight, fruit length and fruit girth was obtained with the application of 100 % recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF which was significantly different from all other treatments (Fig. 5). The increase in fruit weight obtained under organic manure application in papaya may be due to the high biological activity in the soil thus improving the organic matter content and aggregation of soil (Pinamouti and Sicher, 2001). Similar findings also was noted by Ravishakar *et al.* (2010) in papaya, where fruit weight was maximum with application of FYM 20 kg plant^{-1} along with neem cake 4 kg and wood ash 2.5 kg plant^{-1}.

Reddy and Kohli (1989) reported that accumulation of biomass was more to the vegetative parts than to fruit production for the plants with less nitrogen availability. Similar finding was seen in guava, where application of bio fertilizers and organic manures improved the fruit size and fruit yield (Rajput and Ram, 1998).

Results of trial of Dutta *et al.* (2010) was also in agreement with the findings of the present study, where the incorporation of Azotobacter, Azospirillum and VAM along with 2 kg FYM improved the fruit weight, fruit length and fruit girth

Fig. 5 Effect of organic manures on fruit weight (g) of papaya

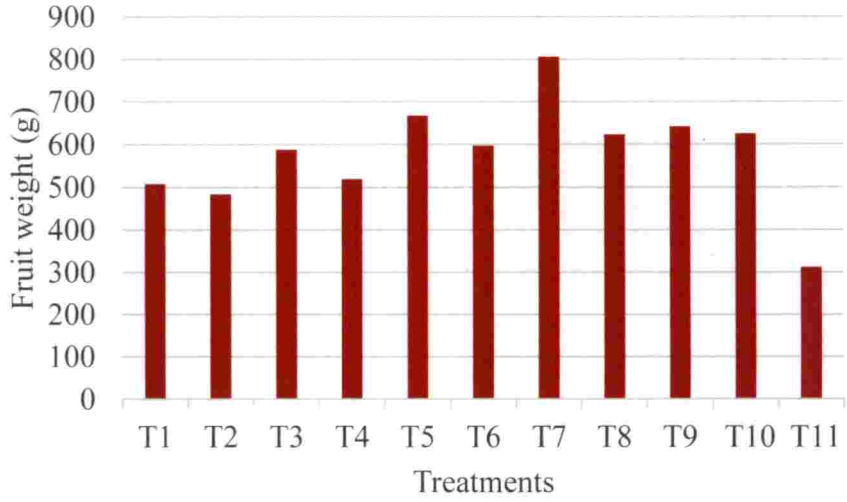
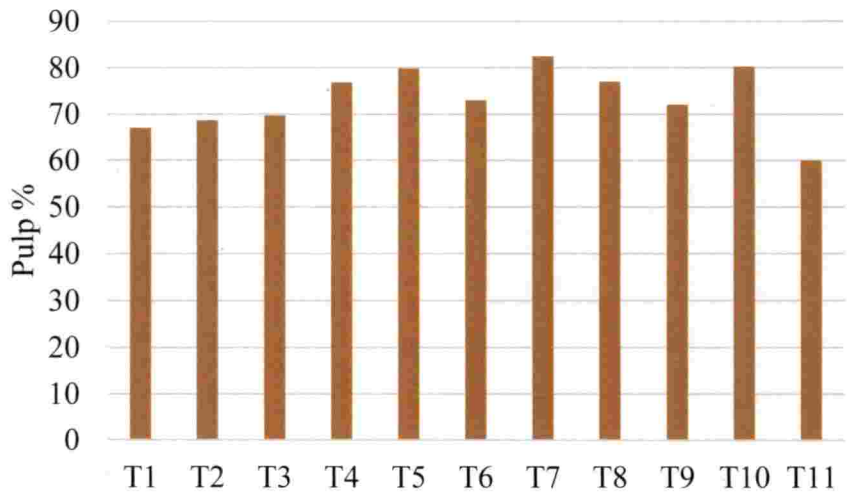


Fig. 6 Effect of organic manures on pulp %



in papaya. The soil aeration was improved by the application of organic manures and increased physiological activities of soil, thus increased the yield attributes in banana (Hazarika and Ansari, 2010).

Singh *et al.* (2010) reported that continuous supply of higher rate of organic manure improved the productiveness of papaya. Chandra (2014) reported increased fruit weight as an outcome of the increase in height of plant, number of leaves, fruit volume and fruit number.

Fruit volume of papaya plant was highest in the plants supplied with 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Hofmeyr (1936) suggested that smaller fruits have higher weight than the larger fruits because of their smaller seed cavities. Addition of poultry manure raised the fruit yield in papaya plants (Zabedah, 2001). Faicao and Borges (2006) also arrived to similar conclusion.

The flesh thickness and pulp percentage (Fig .6) of papaya in the present investigation increased with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Kirad *et al*, (2010) reported that, application of 75% RDF along with 25% vermicompost and rhizosphere bacterial culture improved the flesh thickness and pulp percentage along with other yield parameters.

Total fruit yield per plant was found to be highest with the application of 100% recommended dose of nitrogen as organic along with AMF and PGPR Mix-1 (Fig. 8). The results was in uniformity with the findings of Shivakumar *et al.* (2012) who noticed that application of farm yard manure along with 100% recommended dose of nitrogen resulted in high fruit yield in papaya variety Surya.

The number of seeds per fruit was found to be maximum with the application of 100% recommended dose of nitrogen as organic along with AMF, which readily increased the fruit weight. Sulladmath *et al.* (1981) reported similar findings in papaya. The number of fruits per plant was found to be maximum in the

Fig. 7 Effect of organic manures on number of fruits plant-1

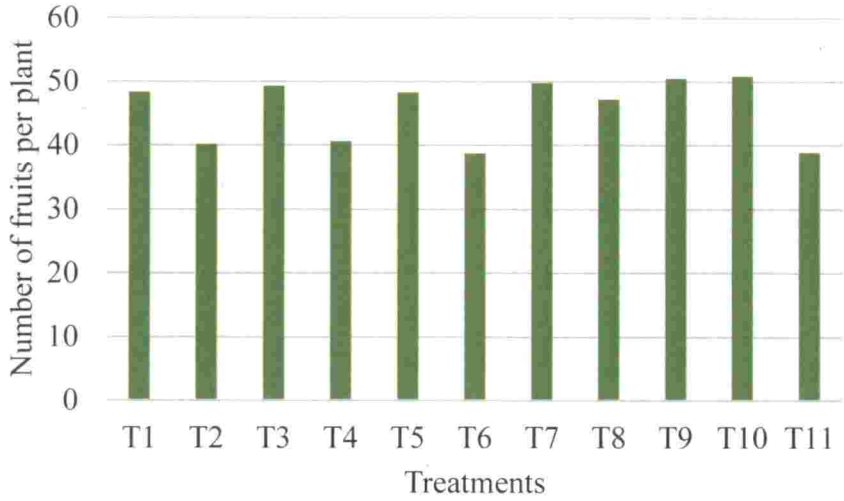
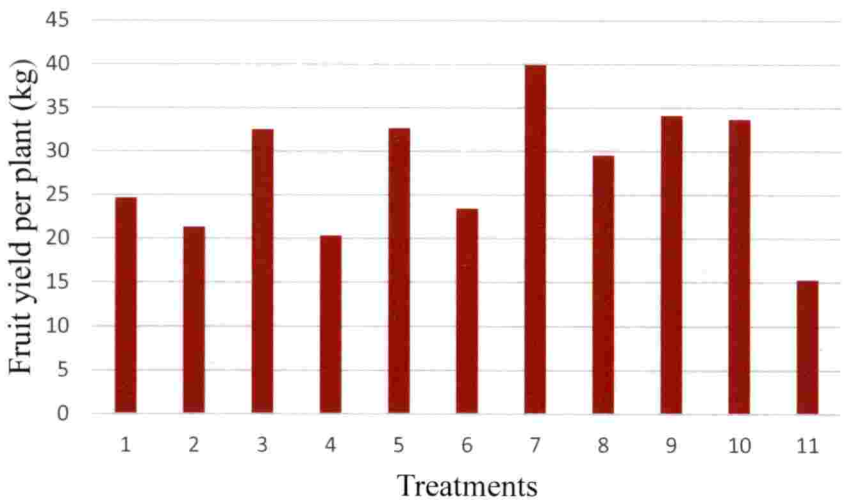


Fig . 8 Effect of organic manures on fruit yield per plant (kg)



immediate study with the application of inorganic fertilizers along with FYM (Fig. 7). Bindu (2003) recorded that maximum number of fruits in papaya was obtained with 100% recommended dose of fertilizer along with FYM.

The fruit set percent was found to be maximum with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Report given by Shijini (2010) was in conformity with the present study.

The least number of days taken from flowering to fruit maturity was obtained with application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Similar results was reported by Dutta *et al.* (2010) where the application of FYM along with biofertilizers resulted in early fruit maturity in papaya.

5.3 QUALITY PARAMETERS

The fruit quality analysis recorded in papaya showed that, TSS, total carotenoid, ascorbic acid, total sugar, reducing sugar and overall acceptability of the fruit was highest with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. The application of organic manures increased the quality parameters of papaya fruit when compared to the chemical fertilizer application. The result obtained was in conformity with the findings of Dutta *et al.* (2010) noted that the TSS, ascorbic acid content, total sugar, reducing sugar was highest with the application of organic manure treatment with Azotobacter, Azospirillum and VAM along with 2 kg FYM in papaya.

Kirad *et al.* (2010) reported that application of vermicompost and rhizosphere bacterial culture improved the TSS, vitamin A, vitamin C of papaya fruits. Similar observations recorded in strawberry also, microbial inoculation with AMF and pseudomonas increased the fruit quality parameters (Bellone and de Bellone, 1995). Rajput and Ram (1998) also reported similar findings.

The acidity of the fruit decreased with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF.

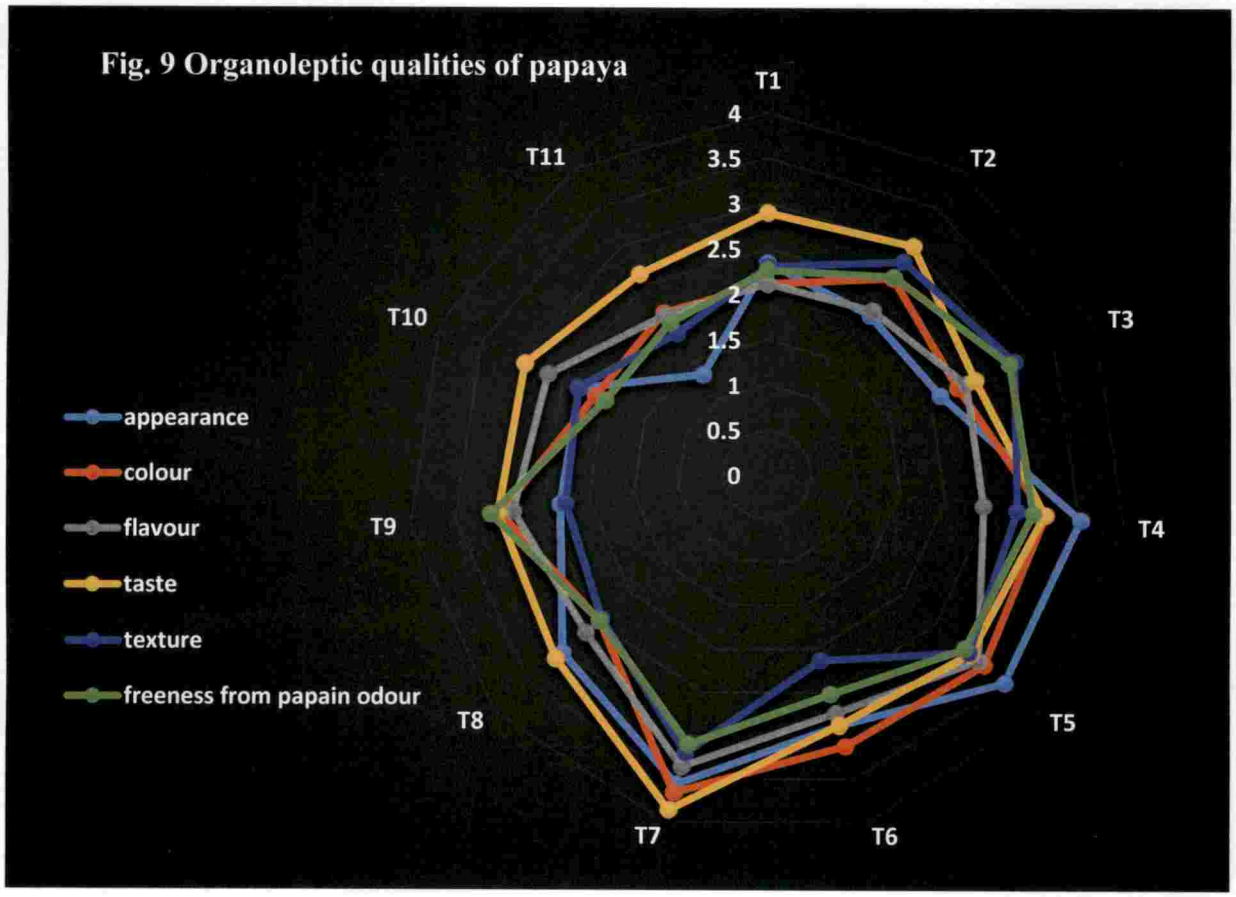


Fig. 9 Organoleptic qualities of papaya
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
4
3.5
3
2.5
2
1.5
1
0.5
0
appearance
colour
flavour
taste
texture
freeness from papain odour

Maximum acidity was shown by fruits under absolute control treatment. The findings of Jayasundara and Huruggamuwa (2005) corroborated with the above results.

Yadav *et al.* (2011) reported that, increased fruit TSS, total sugar, ascorbic acid and reduced acidity were registered with the application of Vermicompost and Azotobacter, this was in conformity with the findings of the present study. The increase in fruit quality might be due to the regular nutrient supply, high soil enzyme concentration and increased uptake of nutrients. Similar results was recorded in guava by Athani *et al.* (2009).

The colour of peel and pulp was recorded through visual observation. The peel colour was found to be uniform deep yellow for T_4, T_6, T_9, and T_{10} and the rest of the treatments had uniform yellow colour. The pulp colour ranges from orange to deep red. The colour of the fruit pulp might be in accordance with the amount of carotenoid present in the fruit pulp. Deep red coloured pulp was observed for T7, T8 and T4 treatments. This was in line with the findings of Patil *et al.* (1995), who noticed that in papaya variety Washington, application of organic manures and groundnut cake resulted in the production of fruits with good pulp colour on ripening.

Firmness of fruit pulp of papaya varied from firm to fairly firm. The fruits from treatment T_1, T_2, T_4, T_9, T_{11} had firm flesh and rest of the treatments had fairly firm fruits. The organic manures applied to papaya did not show any significant difference in the shelf life of the fruits. The result was in contradictory with the findings of Rajkumar *et al.* (2005).

The organoleptic acceptability of the fruit in terms of colour, flavour, texture, appearance, taste and freeness from papain odour was found best with the application of 100 % recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF (Fig. 9). The lowest score was obtained for absolute control treatment. The second highest score registered for overall acceptability was for T_5 (100 % recommended dose of nitrogen as organic along with AMF). This implied

that completely organic manure with balanced nutrition might increase the overall fruit quality of papaya. The results obtained was in line with the findings of Shijini (2010).

5.4 SOIL ANALYSIS

The soil analysis on present work revealed that soil organic carbon value increased with the application of 75% recommended dose of nitrogen as organic along with AMF. The highest soil pH of 5.64 was noted in plants receiving 100% recommended dose of nitrogen as organic along with AMF. EC of the soil was found to be highest (0.25) which was on par with T_3 and T_5 and differed significantly from other treatments. These results was in conformity with observations made by Tandel *et al.* (2017) where the organic carbon content of soil was significantly influenced by addition of Vermicompost and bio compost added to the soil. The organic matter in the soil also showed a positive correlation with the amount of organic manures and biofertilizers applied to the soil. Seripong (1993) reported similar findings in papaya.

The present investigation showed that use of 100% recommended dose of nitrogen as organic along with AMF increased the NPK content of soil (Fig. 10), the report was in agreement with conclusion of Kennedy and Smith (1995) where the highest nitrogen content in soil might be due to the accelerating growth rate of microbes in soil as a result of continuous supply of organic manures, which convert the organically bound nitrogen into inorganic forms and made available to the plants.

Mamta *et al.* (2017) reported that higher nitrogen content in soil by the application of phosphate solubilising bacteria and Azotobacter. Srivastava *et al.* (2015) findings was in agreement with the study reported that the amount of AMF in the soil upgraded the organic carbon, available P, available K and a negative correlation with EC.

The high phosphorus content in soil might be attributed to the increase in enzymatic activities and acid production favoured by the microbes, thus solubilising

Fig. 10 Effect of organic manures on NPK content in soil

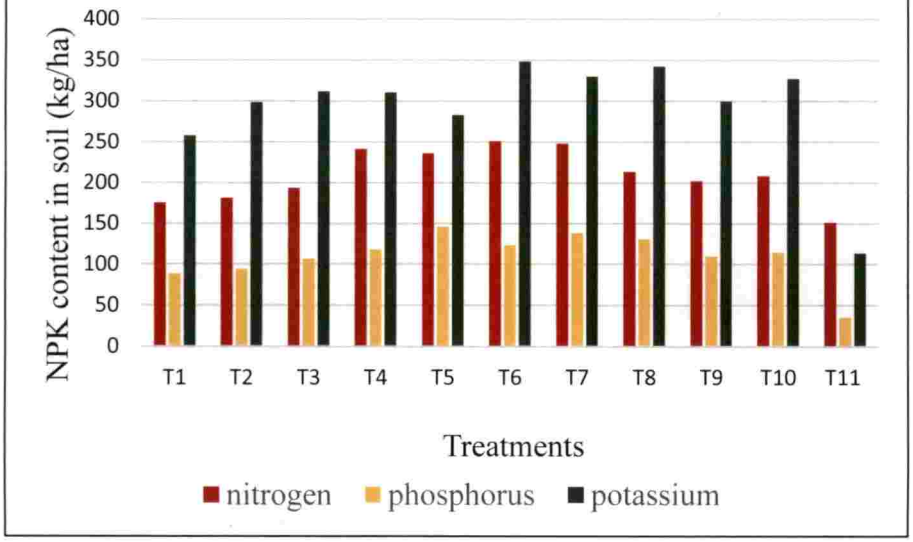
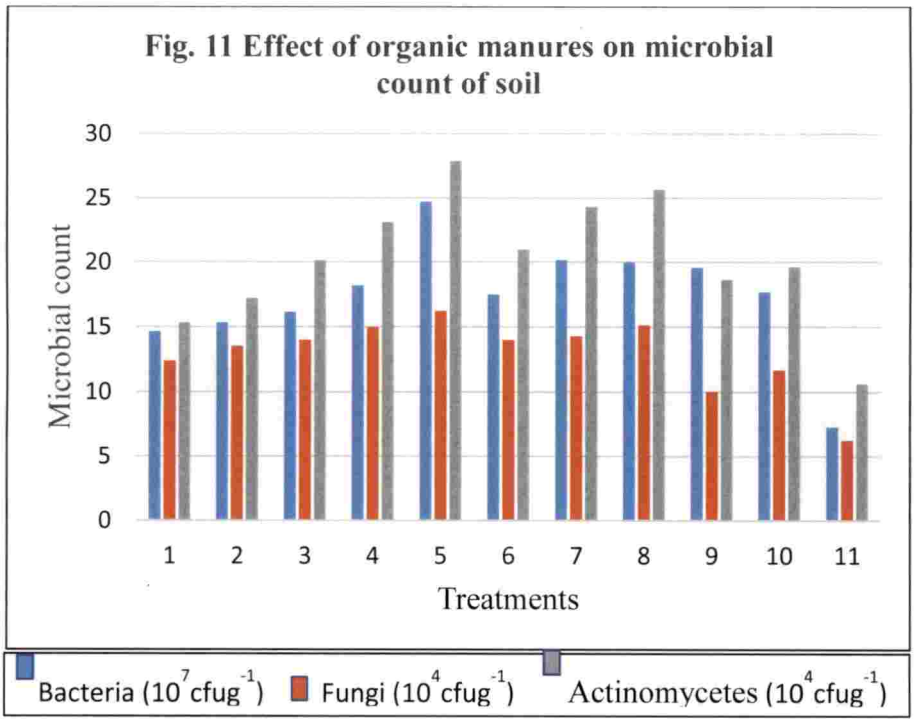


Fig. 11 Effect of organic manures on microbial count of soil



the phosphorus and made its transport to the root system through hyphae. The available form of potassium in soil might be increased by the organic acid production during the decomposition of organic manures (Tandel *et al.*, 2017). Savithri *et al.* (1993) reported that incorporation of coir pith boost the K content in soil.

The micronutrient content in the soil was upgraded with the application of 100 % recommended dose of nitrogen as organic along with AMF. Tang *et al.* (1984) reported similar results that, the mycorrizhal application in citrus improved the uptake of micronutrients (Cu, Fe, Mn, Zn). Tandel *et al*, (2017) reported hike in Cu, Fe, Mn content in soil with the application of organic manures along with AMF.

Microbial count (bacteria, fungi, actinomycetes) in the soil increased with the application of 100% recommended dose of nitrogen as organic along with AMF (Fig. 11). Shijini (2010) reported a positive correlation with microbial population and organic matter addition in soil. Krishnakumar *et al.* (2005) also reported similar results.

5.5 PLANT ANALYSIS

The NPK content in the leaf petiole increased with the application of 100% recommended dose of nitrogen as organic along with AMF and PGPR Mix-1 in the present study. Reports of Munoz *et al*, (2004) was in conformity with the result of the present trial. Analysis of petiole content of papaya showed increased N and K content with the application of chicken manure.

The micronutrient content (Cu, Fe, Mn, Zn) in the leaf petiole was added on with the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. This might be due to the VAM inoculation in soil increased the uptake of micronutrient (Cu, Fe, Mn, Zn) from the soil Abd El-Raheem *et al* (1989) reported that tomato plants inoculated with Glomus or Azotobacter individually or in combination increased the content of Na, K, Ca, Mg and Fe. Tandel *et al.* (2017) worked on papaya cv. Taiwan red lady reported that the

micronutrient content in leaf petiole was upgraded with the application of biocompost and castor cake.

Kennady and Rangarajan (2001) also reported that inoculated with VAM (*Glomus mossae*) had shown increase in N, P, K and micronutrient content (Cu, Fe, Mn) in the leaf petiole. The mycorrizhal infection might increase the phosphatase activity in the soil and resulted in increased uptake of phosphate. *Glomus versiforme* inoculated seedlings of citrus pointed out considerable growth characteristics with higher concentration of P, K, Ca in the leaves and Fe in the roots (Tang *et al.*, 1984).

5.6 PEST AND DISEASE

The disease incidence in the present study was negligible, and occurrence of foot rot disease was less than one per cent in the field. There was no major pest incidence noticed in the field. Samiyappan (2008) also reported similar results in which application of Pseudomonas and Trichoderma around the basins of papaya plant reduced the infection of foot rot in papaya. Chandra (2014) reported that application of *Pseudomonas striata* along with NPK reduced the incidence of LCMV in papaya plants.

5.7 ECONOMIC ANALYSIS

The maximum net income (Rs. 2, 99,292.00 ha^{-1}) was obtained for the plants that received the application of 100 % recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF. Shivakumar *et al*, (2012) also reported that B: C ratio was highest with the use of organic manures as against the application of chemical fertilizers in papaya.

Summary

6. SUMMARY

The present experiment entitled "Organic nutrient management of papaya (*Carica papaya* L.)" was carried out to study the effect of organic nutrient management on growth, yield and quality of papaya and to assess the soil nutrient status under organic cultivation. The investigation was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2016-2018. Surya variety released from IIHR was used as the experimental material. The major results recorded are summarised below.

The biometric parameters recorded indicated that treatment T_6 (application of 75% recommended dose of nitrogen as organic along with AMF) registered maximum height.

The data on girth of the plant showed that during all stages of growth, application of 100% recommended dose of nitrogen along with PGPR Mix-1 and AMF (T_7) significantly increased the girth of the plant.

The number of leaves recorded during the growth period significantly differed among the treatments and the highest number of leaves was observed for treatment T_7 (100% recommended dose of nitrogen along with PGPR Mix-1 and AMF).

The data on height at first flowering indicated that it was lowest in T_7 (100 %) recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF) which was on par with T_6 (75% recommended dose of nitrogen as organic along with AMF), T_5 (100% recommended dose of nitrogen as organic along with AMF) and T_4 (75% recommended dose of nitrogen as organic along with PGPR Mix-1)

In the present study it was observed that least number of days for flowering was recorded for T_7 (100 % recommend dose of nitrogen as organic along with

PGPR Mix-1 and AMF), which was on par with T_6 (75% recommended dose of nitrogen as organic along with AMF).

The sex expression of the plant recorded based on the morphology of the flower showed that female plants were found to be the highest in the treatment T_7 and bisexual plants were found the highest in T_1 (100% recommended dose of nitrogen as organic) and T_{11} (absolute control) which was on par with T_2, T_3 ,T_5 T_6, and T_9.

The number of flowers per cluster had no significant influence on the doses of organic manures applied to the plant.

Fruit set % calculated for papaya grown under organic nutrient management was found to be maximum for treatment T_7 (83.66 %) which was on par with T_5 (74.01%) followed by T_4 (71.57%)

The time for fruit harvest in papaya had significant influence on the dose of organic manures applied to the plant. The harvest of fruits in T_6 was earlier which was on par with T_7.

The data recorded on fruit weight of papaya showed significant variation among the treatments. The highest fruit weight was recorded with the application of 100 % recommend dose of nitrogen as organic along with PGPR Mix-1 and AMF (T_7) which was significantly different from all other treatments followed by T_5.

From the statistical analysis of yield it was shown that the fruit length (20.63 cm) and fruit girth (40.33 cm) of papaya was found to be the highest with T_7.

The fruit volume of papaya had significant influence on the doses of organic manures applied to the plant. The highest fruit volume was recorded for 100 % recommend dose of nitrogen as organic along with PGPR Mix-1 and AMF.

The influence of organic manures on pulp per cent and flesh thickness indicated that, highest value for pulp per cent was recorded for T_7 which was on par with T_4, T_5, T_8 and T_{10} and the flesh thickness was found to be highest for T_7 which significantly differed from all other treatments.

The results on the present study regarding the number of fruits per plant showed the highest number of fruits was obtained with the application of treatment T_{10} 100% RDF (240:240:480 g NPK/plant/year, FYM-10 kg/plant/year) which was on par with T_3, T_7 and T_9

The number of seeds per fruit recorded from different treatments showed significant difference and the highest number of seeds was counted for T_5 which was on par with T_4.

The data on seed germination % among different treatments of organic manure showed significant difference, the highest germination per cent was recorded for T_6 which was on par with T_4, T_5, T_7 and T_9.

The data on total yield per plant showed significant difference among the treatments, the highest yield per plant was noticed by the T_7 which differed significantly from other treatments and was followed by T_{10}. The lowest number of days taken for maturity was also recorded by the application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF.

With regard to the quality parameter of the fruit, TSS, total carotenoid, ascorbic acid, total sugar, reducing sugar and organoleptic qualities of the fruit was found to be maximum with the application treatment T_7 100 % recommended nitrogen as organic along with PGPR Mix-1 and AMF.

The non-reducing sugar content was found to be highest with T_3 (100 % recommended nitrogen as organic along with PGPR Mix-1 which was on par with T_3 (1.59%), T_6 (1.45 %), T_7 (1.32 %), T_8 (1.34 %), and T_{10} (1.50%).

Deep yellow coloured peel was obtained for T_4, T_6, T_9, and T_{10} and the colour of the peel was yellow for rest of the treatments at ripened stage.

The colour of the pulp at ripened stage of fruit was appeared to be deep red flesh for T_4, T_7 and T_8. Colour of the pulp was found to be orange for T_1, T_6, T_9, T_{10} and T_{11}.

The data regarding the fruit firmness showed that T_1, T_2, T_4, T_9, T_{11} were having firm fruits and rest of the treatments showed fairly firm fruits. The shelf life of the fruits seemed to have no significant effect on the doses of organic manures applied to the plant.

Scoring was given for the overall acceptability of the fruit based on the appearance, colour, flavour, texture, taste and freeness from papain odour and it was found the highest for T_7 (100 % recommended nitrogen as organic along with PGPR Mix-1 and AMF) followed by T_5 (100 % recommended nitrogen as organic along with AMF)

The statistical analysis of soil nutrient content revealed that soil pH was recorded the highest (5 64) for T_5 (100 % recommended nitrogen as organic along with AMF) which was on par with T_6 and T_7. The soil electrical conductivity and soil organic carbon content were found to be highest for T_6 (75% recommended dose of nitrogen as organic with AMF).

In the present study, the NPK analysis of soil revealed that nitrogen and potassium content in soil increased in treatment T_6 which was on par with T_7. The phosphorus content in the soil was the highest with T_5 which was on par with T_6 and T_7.

Application of AMF along with 100% recommended dose as organic in soil found to have increased the micronutrient content (Cu, Fe, Mn, Zn) in soil which was on par with T_4.

The microbial count under the organic cultivation was analyzed and highest count of bacteria, fungi and actinomycetes colony was recorded for T5 (100% recommended dose N as organic along with AMF).

Plant analysis report showed that the organic manures applied to the plant had significant effect on the NPK content of the leaf petiole. The nitrogen content in leaf petiole was the highest with T_5 (100 % recommended dose of nitrogen as organic along with AMF). The highest phosphorus and potassium content was

recorded with the application of T_7, 100% recommended dose as organic along with PGPR Mix-1 and AMF.

The present study on the influence of organic nutrition of papaya plants revealed that significant difference existed in the micronutrient content of leaf petiole. Application of 100% recommended dose organics along with PGPR Mix-1 and AMF (T_7) recorded highest content of micronutrients (Cu, Fe, Mn, Zn).

The economic analysis of organic cultivation of papaya showed significant difference in the net income and B: C ratio. Highest net income and B: C ratio recorded in T_7 which was significantly different from all the other treatments.

Overall assessment of organic nutrition of papaya revealed that application of 100% recommended dose of nitrogen as organic along with PGPR Mix-1 and AMF improved the growth, yield and quality of papaya.

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Appendices

Appendix-1

Nutrient content of organic manures used during the experiment .

Manures	Nitrogen (%)	Phosphorus (%)	Potassium (%)
FYM	0.80	0.50	0.60
Poultry manure	1.8	0.31	1.0
Vermicompost	1.6	0.40	1.8

APPENDIX-II

SCORE CARD FOR ORGANOLEPTIC QUALITIES OF PAPAYA

	Criteria	Treatments										
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11
1.	Appearance											
	Very good 4											
	Good 3											
	Fair 2											
	Poor 1											
2.	Colour											
	Most acceptable 4											
	Acceptable 3											
	Fairly acceptable 2											
	Not acceptable 1											
3.	Flavour											
	Most acceptable 4											
	Acceptable 3											
	Fairly acceptable 2											
	Not acceptable 1											
4.	Taste											
	Very good 4											
	Good 3											
	Fair 2											
	Poor 1											
5	Texture											
	Firm, crisp, melting 4											
	Firm, crisp, not melting 3											
	Fairly firm, crisp, not melting 2											

	Too soft or too hard 1											
6.	Papain odour											
	Not at all present 4											
	Very mildly present 3											
	Mildly present 2											
	Strongly present 1											

APPENDIX-III

Evaluation card for triangle test

In the triangle test three sets of sugar solution of different concentrations were used. Of the three sets, two solutions were of identical concentrations and the members were asked to identify the third sample which was of different concentration.

Name of product: Sugar solution

Note: Two of the three samples are identical, identify the odd sample

SL. No.	Code no. of the sample	Code no: of the identical samples	Code no: of the odd samples
1	XYZ		
2	ABC		
3	PQR		

APPENDIX –IV

WEATHER DATA DURING THE CROPPING PERIOD

Standard week	Temperature (°C)		Relative Humidity (%)		Bright sunshine hours	Rainfall (mm)	Evaporation (mm)
	Max.	Min.	Max.	Min.			
April-17	34.57	26.18	87.62	72.62	9.77	0	5.62
May-17	33.66	25.54	89.25	76.12	9.02	17.92	4.51
June-17	31.4	24.5	92.29	80.5	7.90	11.6	3.90
July-17	31.6	24.7	90.61	77.00	8.50	3.75	4.00
Aug-17	30.5	24.6	92.16	78.32	7.70	9.30	3.70
Sep-17	31.5	24.5	92.50	78.93	7.70	13.50	3.60
Oct-17	31.1	24.9	94.50	84.90	7.20	12.30	3.60
Nov-17	30.8	24.2	94.90	82.50	5.20	14.90	3.00
Dec-17	31.8	23.4	94.66	77.38	7.20	43.40	3.30
Jan-18	31.70	21.79	93.54	73.73	8.51	0	3.98
Feb-18	32.47	23.62	92.89	75.42	9.13	0	4.07
March-18	33.23	24.28	92.94	74.72	8.08	2.95	4.12
April-18	34.00	26.19	87.78	72.00	9.06	0	5.60

ORGANIC NUTRIENT MANAGEMENT OF PAPAYA

(*Carica papaya* L.)

by

DIVYA HARI

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Abstract of the

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ABSTRACT

The present study entitled "Organic nutrient management in papaya (*Carica papaya* L.)" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2016-2018, with an objective to study the effect of organic nutrient management on growth, yield and quality of papaya. The experiment was conducted in RBD with 11 treatments and 3 replications using papaya variety Surya.

The treatments included in the study are: T_1-100% of recommended dose of N as organic, T_2-75% of recommended dose of N as organic, T_3-100% of recommended dose of N as organic + PGPR Mix-I, T_4-75 % of recommended dose of N as organic + PGPR Mix-I, T_5-100% of recommended dose of N as organic + AMF , T_6-75% of recommended dose of N as organic + AMF, T_7-100% of recommended dose of N as organic + PGPR Mix-I+ AMF , T_8-75% of recommended dose of N as organic + PGPR Mix-I+ AMF, T_9-Full NPK of KAU POP + Vermicompost (N equivalent to FYM of KAU POP), T_{10}- 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1} year^{-1}) , T_{11}- Absolute control.

The present study revealed that, application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF increased the girth of the plant, number of leaves, fruit set percentage with lowest height for first flowering and reduced the number of days for flowering. The highest plant height was obtained by the application of 75% of recommended dose of N as organic along with AMF.

With regard to the yield characters studied, highest fruit weight, fruit length, fruit girth, fruit volume, pulp percentage, flesh thickness, total yield plant^{-1} (39.91 kg plant^{-1}) and minimum number of days for maturity were recorded by the application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF. Number of fruits plant^{-1} was found to be highest with application of 100% RDF (240:240:480 g NPK plant^{-1} year^{-1}, FYM-10 kg plant^{-1} year^{-1}).

The study on quality parameters of fruit revealed that TSS, ascorbic acid, carotenoids, total sugar, reducing sugar and the organoleptic qualities were highest with the application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF.

Analysis of soil nutrient status revealed that soil organic carbon, soil EC, nitrogen and potassium content were highest with the application of 75% recommended dose of N as organic along with AMF. Phosphorus, micronutrient content and microbial count were highest with the application of 100% recommended dose of N as organic along with AMF.

The leaf petiole analysis of papaya indicated that the highest phosphorus, potassium and micronutrient content increased with the application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF.

Regarding the B: C ratio and net income obtained, application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF recorded the highest.

Overall assessment indicated that application of 100% of recommended dose of N as organic along with PGPR Mix-I and AMF in 6 splits at bimonthly interval improved the growth, yield, quality of papaya.