RESPONSE OF PAPAYA TO ORGANIC MANURES, PLANT GROWTH PROMOTING MICROORGANISMS AND MULCHING

By

SHIJINI E.M.

(2008-12-104)

THESIS

Submitted in partial fulfilment of the requirement

for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POMOLOGY & FLORICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2010

DECLARATION

I, **Shijini E.M. (2008-12-104)**, hereby declare that this thesis entitled **"Response of papaya to organic manures, plant growth promoting microorganisms and mulching"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title of any other University or Society.

Shijini E.M.

Vellanikkara

CERTIFICATE

Certified that this thesis, entitled **"Response of papaya to organic manures, plant growth promoting microorganisms and mulching"** is a bonafide record of research work done independently by **Miss Shijini E.M. (2008-12-104)** 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.

Vellanikkara

Dr. K. Lila Mathew
(Chairperson, Advisory Committee)
Professor and ADR
RARS, Ambalavayal.

CERTIFICATE

We, the undersigned members of the advisory committee of **Miss Shijini E.M. (2008-12-104)**, a candidate for the degree of **Master of Science in Horticulture**, agree that this thesis entitled **"Response of papaya to organic manures, plant growth promoting microorganisms and mulching"** may be submitted by her in partial fulfillment of the requirement for the degree.

Dr. K. Lila Mathew
(Chairperson, Advisory Committee)
Professor and ADR
RARS, Ambalavayal.

Dr. P.K. Rajeevan
Professor and Head
Dept. of Pomology & Floriculture
College of Horticulture
Vellanikkara, Thrissur.

Dr. Sarah T. George
Professor
Dept. of Pomology & Floriculture
College of Horticulture
Vellanikkara,Thrissur.

Dr. P.K. Sushama
Professor
Dept. of Soil Science & Agricultural Chemistry
College of Horticulture
Vellanikkara, Thrissur.

ACKNOWLEDGEMENT

First and foremost I bow my head before the ***Almighty God*** *who enabled me to successfully complete the thesis work on time.*

With immense pleasure I avail this opportunity to express my deep sense of gratitude and indebtedness to my major advisor ***Dr. K. Lila Mathew****, Professor and ADR, RARS, Ambalavayal, Chairperson of my Advisory Committee for her valuable guidance, constructive suggestions, unfailing patience, friendly approach, affectionate advice and timely help at various stages of my work and thesis preparation.*

I would like to express my extreme indebtedness and obligation to ***Dr. P.K. Rajeevan****, Professor and Head, Department of Pomology and Floriculture, College of Horticulture and member of my Advisory Committee for his meticulous help, unwavering encouragement, forbearance, well timed support and critical scrutiny of the manuscript which has helped a lot for the improvement and preparation of the thesis.*

I sincerely thank ***Dr. Sarah T. George,*** *Professor, Department of Pomology and Floriculture, College of Horticulture and member of my Advisory Committee for her expert advice, constant inspiration, meticulous help and constructive criticisms rendered throughout the study period.*

I express my heartiest gratitude to ***Dr. P.K. Sushama****, Professor, Department of Soil Science and Agricultural Chemistry and member of my Advisory Committee for her ever willing help, valuable guidance and creative suggestions throughout the period of my study.*

I am obliged to ***Dr. P.K. Valsalakumari, Dr. N.K. Parameswaran, Dr. T. Radha, Dr. C.K. Geetha, Dr. P.K. Sudhadevi, Dr. K. Ajithkumar and Dr. Devadas*** *whose constant help and support have helped to complete this venture successfully.*

I wish to express my gratitude to ***Sri. S. Krishnan****, Assistant Professor, Department of Agricultural Statistics for his guidance throughout the statistical analysis of the data.*

I sincerely thank to ***Dr. Girija****,* ***Dr. Nandini, Dr. Baby Lizzy Markose and Dr. Dijee Bsatin*** *for their wholehearted co-operation and immense help extended throughout the study.*

I take this opportunity to thank my seniors ***Mr. Manoj, Mrs. Femina, Dr. Deepthy, Dr. Minisankar, Ms. Sreevidya, Ms. Mittu and Ms. Kanimozhi, Ms. Kaveramma and Mr. Alex*** *for their support and encouragement. The love, support and encouragement of my dear juniors,* ***Renisha, Ance, Adnan and Liju*** *and my roommates* ***Sreeja, Malu and Anju*** *gave me enough mental strength to get through all tedious circumstances.*

I am thankful for ever, to my classmates ***Randeep, Thontadarya, Thamarai, Prathamesh, Gajanan, Sunil, Sambath, Navaneeth, Lakshmi, Shabna, Ambily, Neethu, Anusha, Sudha, Suma, Mridula, Neenu, Neethu and Deepa*** *for extending a helping hand at each and every juncture of my work* **.**

My hearty thanks are expressed to all the staff members of the Department of Pomology and Floriculture, for their co-operation during the course of my research work.

Kind help and whole hearted co-operation extended by ***Mrs. Devaki, Mr. Pradeep, Mrs. Thanka, Mr. Saju*** *and* ***Mr. Unni*** *during the field works and* ***Mr. Sunil,*** *during lab work, are sincerely acknowledged.*

I thankfully remember the services rendered by all the staff members of the Students' computer club and Library, COH and Central library, KAU.

My deepest gratitude goes to my family for their unflagging love and support throughout my life.

A word of apology to those I have not mentioned in person and a note of thanks to one and all who worked for the successful completion of this endeavour.

Shijini E.M.

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

Dedicated to

My Beloved Family and

Department of Horticulture

Introduction

1. INTRODUCTION

India is the largest producer of fruits in the world with 11 per cent production and has wide range of varieties in its basket. Papaya (*Carica papaya* L.) known as 'the wonder fruit of the tropics' which bears throughout the year, gives quick return and adapts itself to diverse agro climatic conditions. The crop was introduced from Central America to Asia and till eighties, it was confined to the homesteads. Due to the recognition of its rich neutraceutical properties and industrial demands for papain, papaya has now emerged as a commercial orchard crop. Among the fruit crops, productivity of papaya is higher which has attracted the growers for its commercial cultivation resulting in a spectacular increase in area and production in last few decades.

Papaya is grown primarily for its delicious fruits and for extraction of papain. The fruit is rich in vitamins, especially vitamin A, C and E. It also contains flavanoides, minerals like Ca, P and Fe and fibre. Fully developed unripe fruits are rich source of papain, a valuable proteolytic enzyme which is used in meat tenderization and preparation of certain digestive medicines. Unripe fruits are also used as vegetable.

Major papaya growing countries are Australia, Brazil, Columbia, Costa Rica, Ecuador, Hawaii, India, Mexico, Nigeria, Malaysia, Thaiwan and Bengladesh. In India papaya is grown in 98,000 ha with an annual production of 36.29 lakh mt (NHB, 2010). Andhra Pradesh, Gujarath, West Bengal, Tamil Nadu and Kerala are the leading states.

Papaya is a fast growing crop with early bearing habit, low input requirement and multipurpose use. Nutritional demand of papaya differs from other fruit crops, because of the unique growth habit of continuous and simultaneous growth of vegetative and reproductive phases. Papaya is sensitive to growing environment and prolonged moisture stress will slow down the growth. The crop needs more irrigation during dry periods to maintain its growth and fruit production. Papaya ring spot virus (PRSV) and mealy bug are other constraints faced by papaya growers.

In Kerala papaya is grown as a homestead crop. The area and production in the state are 17,700 ha and 80,700 mt respectively (NHB, 2010). Recently isolated attempts have been made by some progressive farmers for commercial cultivation of papaya. The major limiting factors for commercial cultivation in Kerala are high rainfall and severe drought in summer. Its roots are often invaded by fungal pathogens and are also prone to many viral diseases and pests like mealy bugs and nematodes. Weeds are another problem which can be controlled either by using weedicides or with suitable mulches.

Since papaya is a nutrient loving plant, sufficient knowledge about the integrated nutrient requirement with appropriate dose, time and frequency of application should be streamlined. In this approach, possibilities of inclusion of organic as well as inorganic fertilizers along with plant growth promoting micro organisms can be explored. Here the feasibility of organic manures *viz;* vermicompost, poultry manure and biovermi and biocontrol agents like *Trichoderma* and *Pseudomonas* can be worked out. In Kerala condition no systematic attempts have been made on these aspects. Many improved varieties grow well in our state. Varietal evaluation studies done in Kerala Agricultural University revealed that CO 7 and Pusa Dwarf come up well in central districts of Kerala. Production technologies like nutrition, mulching and crop protection need standardisation to suit to our conditions.

The present investigation on “Response of papaya to organic manures, plant growth promoting microorganisms and mulching” was thus under taken with the following objectives.

1. To standardise an optimum combination of organic manures, chemical fertilizers and plant growth promoting microorganisms for improving growth, yield and quality of papaya.

2. To study the effect of different mulches on growth, yield and quality of papaya and to select an ecofriendly mulch suited for papaya.
3. To study the effect of different mulches on soil moisture retention and weed growth.
4. To study the influence of the treatments on major nutrient status and total microbial flora of soil.
5. To compare the cost of cultivation of papaya under different nutrient management schedule and mulching.

Review of Literature

2. REVIEW OF LITERATURE

Good yield and quality of fruits are directly linked to a balanced nutrition (Oliveira and Caldas, 2004). The nutritional demand of papaya differs from other fruit crops because of its tremendous yield potential due to precocious bearing and intermediate growth habit with simultaneous vegetative growth, flowering and fruiting. Every growth phase is critical and adequate and efficient manuring of young and mature plant is essential to maintain good health and to obtain profitable yield.

Manurial experiments carried out all over the world have indicated positive response to nitrogen, phosphorous and potassium and to several micronutrients in papaya (Ram, 2005). Kudada and Prasad (2006) reported positive and significant association of fruit yield per plant with plant height, stem girth, number of leaves, fruiting length, number of fruits per plant, fruit weight and fruit circumference in papaya.

The optimum nutrient status in the petioles of sixth fully opened leaves from the growing point in the six months was as follows: N-1.66 per cent, K-5.21 per cent, Ca-1.8 per cent, Mg-0.67 per cent and S-0.38 per cent with the nutrient removal of NPK as per the ratio 1.66:0.50:5.21 (Kumar *et al.,* 2008a).

2.1. NUTRIENT UPTAKE

The nutrient uptake studies conducted at TNAU (Veerannah and Selvaraj, 1984) indicated significant nutrient uptake after flowering and it attained peak during harvest stage. Kumar and Prasad (1998) found highest level of NPK content in petiole at flowering stage than vegetative and fruit maturation stages. Accumulation of different macro and micro nutrients in papaya was in the order of N>K>Ca>Mg>S>P>Fe>Mn>ZN>B>CU (Viegas *et al*., 1999a). According to Allan *et al*. (2000), 'Solo' papaya showed significant response to NPK at various growth stages.

According to Lopez-Moctezuma *et al.* (2005), during flowering stage, P content was 50 per cent less than in the growing plants. Petiole N content increased with N application rate (Werner, 1993). Singh *et al.* (2006) proposed that application of N, P and K increased the concentration of the respective element in leaves and petioles and the effect of N was more pronounced than that of P and K. Kumar *et al*. (2006a) was of the opinion that leaf nutrient contents and quality of latex enhanced with increased level of potassium.

Ghosh and Tarai (2007) observed that the phosphorus level in petiole was more important for higher production of quality fruits than nitrogen or potassium level. Nath *et al.* (2008) and Suresh *et al.* (2010) reported an increase in P and K content in leaves in papaya with increased P level and biofertilizer inoculation.

Singh *et al.* (2004a) reported that available P concentration was significantly higher in papaya orchards than those in banana and guava orchards.

2.2. PLANT CHARACTERS

Tripathi (1961) reported significant increase in plant height and girth of papaya with the application of higher dose of nitrogen. Luna and Caldas (1984) noted an increase in plant height and trunk diameter by application of N and P.

Deficiency of N and K showed significant reduction in trunk diameter (Thomas *et al.,* 1995). Application of double dose of NPK fertilizers resulted in improved plant growth when infested with *Meloidogyne incognita* and *Fusarium solani* (Khan and Khan, 1995). High rates of N and K advanced flowering while a high rate of P delayed it (Ghanta *et al.,* 1995). Cripps and Allan (1997) reported that higher levels of N, P and K resulted in faster plant growth and larger canopy area. According to Viegas *et al*. (1999a), length and trunk diameter were not affected by N rates.

Bindu (2003) reported an increase in plant height and number of leaves with higher dose of nitrogen. Babu (2003) got higher plant height with higher levels of K application (400g/plant/year) for cv. CO 5. Singh *et al*. (2007) obtained an increase in plant height and girth of cv. Honey Dew with 150 g N and 80 g P per plant under VAM inoculation. The maximum height and stem diameter were reported in cv. Sunrise Solo with the application 330 kg N, 120 kg P_2O_5 and 394 kg K_2O per ha per year (Oliveira *et al*., 2007).

According to Souza *et al*. (2005), application of P increased the growth in cv. Tainung N-1. Higher number of effective roots was found in fertigation treatment with nitrogenous fertilizer (Singh *et al*., 2005a). Root distribution in papaya was affected by high frequency of phosphorus application (Souza *et al.,* 2006). Mendonca *et al*. (2006a) got best quality papaya seedlings by N application, however higher levels showed negative effects.

The highest plant dry matter accumulation was 2184 g per plant with 350 g N per plant (Viegas *et al*., 1999a). Cruz *et al*. (2004) noted a reduction in total dry matter production as well as the values of leaf area, leaf area:leaf mass ratio, stem mass and specific leaf area for plants grown under lower nitrogen availability. Nitrogen deficiency reduced the photosynthetic rate and total dry matter production in cv. Golden (Cruz *et al.,* 2007).

According to Li-MingFu and Yang-Shaocong (2006), K fertilizer significantly reduced the incidence of leaf blight and increased the fruit yield and Mg contents in the root, stem, leaves and petioles of papaya.

2.3. YIELD ATTRIBUTES

Awada and Long (1978) observed an increase in number and yield of fruits in papaya with an increase in the applied N. They further opined that P application increased number of fruits but not the yield of fruits. Later, Awada and Long (1980) reported that between N and K, N had more influence on the yield of papaya.

Maximum fruit yield in cv. Ranchi was reported with 250g N and 600g K2O per plant per year (Biswas *et al*., 1981). In 1989 they obtained highest yield and high quality fruit with higher rates of N and K. Application of N and P in combination increased the fruit yield significantly. Reddy *et al.* (1989) observed in Coorg Honey Dew that average fruit weight was not affected by different levels of N. However, nitrogen in combination with potassium produced maximum individual fruit weight. An increase in applied nitrogen resulted in early flowering and higher fruit yield, the optimum being 250 g per plant (Reddy and Kohli, 1989; Reddy *et al.,* 1990).

Ghanta *et al.* (1995) reported a positive and significant correlation between plant height and girth at flowering and yield per plant. Best response with respect to number of fruits per plant, yield per plant and yield per ha was obtained with the highest rates of P and K and medium rate of N.

Harjadi *et al*. (1995) observed that an increase in K level significantly increased the total fruit weight and prolonged the shelf life of fruits. Bertuzzi *et al.* (1996) reported significant increase in total fruit yield with increase in rates of applied N, P and K. Maximum fruit yield (98.46 t/ha) was recorded with application of 250 g N and 300 g P per plant per year (Singh and Sharma, 1996). According to Cripps and Allan (1997), a commercial crop of 100 tons would require 250 kg N, 20 kg P and 340 kg K.

Vallejo (1999) obtained highest yield of 66 kg per plant with 366 kg N per ha. Number of fruits per plant and fruit weight obtained at one year after transplanting in Sunrise Solo papaya were 23 and 518 g respectively with 343 g N per plant (Viegas *et al*., 1999b). According to Kumar *et al*. (2000), growing tomato as intercrop and with 25 per cent increased fertilizer level (62.5 g each of NPK/plant) recorded highest yield of papaya (170.36 and 99.77 kg of fruit/tree). These treatments had little or no significant effects on quality parameters of papaya.

Auxcilia and Sathiamoorthy (1999 ; 2001) used amino acid derived from human hair as a substitute for 'N' for papaya variety CO 2. They observed that foliar spray of 0.4 per cent amino acid along with 300 g N and 25 mg PP 333 recorded the highest fruit yield with high cost-benefit ratio.

According to Marinho *et al*. (2001) increasing N rates enhanced the fruit yield. Shukla *et al.* (2001) obtained highest fruit yield with 100 g N per plant among three levels of nitrogen; 200,100 and 0 g. According to the study conducted by Shukla and Singh (2001), 200 g N was found best for profuse flowering, fruit size and pulp content in cv. Pusa Delicious. Allan (2002) reported highly significant correlation between seed weight/number and fruit weight of papaya.

Application of 13.5 kg urea and 10.5 kg of muriate of potash per week through fertigation and soil application of super phosphate 278 g per plant in bimonthly intervals improved growth, yield and quality characteristics in papaya (Jeyakumar *et al*., 2001). Application of 400 g each of NPK per plant at monthly interval resulted in maximum yield in cv. CO 2 (Ravitchandirane, 1999 ; Ravitchandirane *et al*., 2002).

According to Zang-Xiaoping and Xu-Xuerong (2002), for the production of 100 tons of fruits, 250 kg N, 20 kg P and 340 kg K per hectare year are needed. Treatment with 100 per cent RDP (625 kg/ha) recorded significantly higher number of fruits (28.24 fruits/plant), mean fruit weight (0.445 kg) and fruit yield (38.85 t/ha) compared to 75 per cent RDP in cv. Sunset Solo (Manjunatha *et al*., 2002). Misra *et al.* (2003) recorded higher yield and quality fruits with a dose of 250 g N, 250 g P and 500 g K per plant per year. Babu (2003) got higher number and size of fruits with higher levels of K application (400g/plant/year) for cv. CO 5.

A fertilizer dose of 220 kg N and 145 kg P_2O_5 per hectare gave highest fruit yield (Buenzo-Jaquez *et al.*, 2005). Mellado-Vazquez *et al.* (2005) recorded an average fruit yield of 30.4 tons per hectare under fertigation in papaya.

Kumar *et al.* (2008b) found that yield-contributing characters were highest with 300 g K per plant. Use of higher levels of potassium nitrate increases the number of fruits per plant until certain level, from which the value starts to decrease (Viana *et al*., 2008).

Rajbhar *et al.* (2008) studied the influence of NPK on growth and yield of papaya and application of 250:250:250 g NPK per plant resulted in maximum number of fruits. Kumar *et al.* (2008c) proposed balanced fertilization with 300 kg each of NPK per hectare per year for higher yield with quality fruits in papaya.

Use of 75 per cent RDF in combination with Azospirillum, VAM and PSB produced higher fruit yield (Mitra and Tarafdar, 2008). Ray *et al.* (2008) reported highest fruit yield (43.4 kg/plant) in cv. Surya when 100 per cent RDF was applied along with VAM-*Glomus mosseae* (50 g/plant), PSB (25 g) and Azospirillum (50 g/plant). Application of full dose of NPK and 10 g rhizogold (VAM) per plant promoted plant growth, advanced flowering and improved fruit quality and yield (Prakash *et al.*, 2008).

Papaya plants (cv. CO 2) which received 60 per cent of the RDF along with application of NPK (100:25:25 g per plant) during transplanting to flower emergence + NPK (0:50:50 g per plant) from flowering to first harvest +NPK (0:25:25 g per plant) from first harvest to end of first cropping period recorded the highest fruit yield, highest fruit weight, fruit girth, fruit length , TSS and low fruit cavity index (Auxcilia *et al.,* 2008a ; Anon., 2008).

Sadarunnisa *et al.* (2008) reported that 75 per cent N and K when applied through drip recorded high fruit yield (100.60 kg/tree) which was on par with the yield of the plants receiving 100 per cent RDF (102.60 kg/tree). Jeyakumar *et al.* (2008) found maximum fruit yield in cv. CO 7, when 100 per cent recommended dose of N and K was given through drip in addition to soil application of 50 g P_2O_5 at bimonthly intervals.

Soil application of 200 g N + 100 g P_2O_5 per plant along with foliar sprays of urea (1 %) + B (0.2 %) and IAA (50 ppm) on ring spot infected papaya plants resulted in better yield of 32.84 kg per plant (Lokhande and Moghe, 1991).

2.4. QUALITY ATTRIBUTES

Application of NPK not only increased the growth and yield of papaya but also improved the quality of fruits (Jauhuri and Singh, 1971). Fruit TSS, sugar, acid, ascorbic acid and total carotene contents increased with K and P rates, but were adversely affected by the highest N rate (Ghanta *et al.,* 1995). Best quality fruits were obtained with intermediate NPK (Singh *et al*., 1998).

An increase in total sugar content of papaya fruits due to phosphorous application was observed by Jayaprakash *et al.* (1992). Lavania and Jain (1995) found a significant increase in ascorbic acid content and yield and a decrease in TSS and sugar content of fruits in cv. Pant Papaya-1 with N application.

According to Marinho *et al*. (2001) fruit weight and acidity were not affected with increasing N rates. Singh *et al.* (2004b) found maximum plant growth and fruit yield of papaya cv. Ranchi with 400 g N, 350 g P and 600 g K per plant per year and qualitative parameters like TSS, total sugar and ascorbic acid contents of fruits were also high.

Kumar *et al*. (2006b) reported that quality parameters of the fruits, *viz;* TSS, pulp thickness and cavity index were increased (except acidity) with the increase in K level. Application of NPK fertilizers (1:0.8:1.5) along with organic manure improved the yield and quality of fruits in papaya cv. Eksotika (Xianghong *et al*., 2006).

Application of RDF along with biofertilizers improved the fruit quality of Dwarf Cavendish banana cv. Giant Governor (Suresh and Hasan, 2001).

2.5. EFFECT OF ORGANIC MANURES

Soil fertility is a function of balanced physical properties, chemical reactions and biological activities of soil. Organic manures are eco-friendly and besides supplying nutrients to the current agricultural crops, they often leave substantial residual effects to succeeding crops. They also supply sufficient amount of micro nutrients in available form to crops and improve the quality of the agricultural produces. Beneficial effects of humic substances and steady mineralization of organic N available in the organic substances was reported in papaya orchards (cv. CO 6) (Rani, 1995). The addition of organic mulches and organic manures have shown to have beneficial effects on plant growth through the supply of nutrients, by improving soil structure and by the addition or stimulation of microorganisms that are antagonistic to soil-borne pathogens (Ribeiro and Linderman, 1991; Aryantha *et al.,* 2000).

Rajput and Sharma (1970) indicated that the application of nutrients to papaya should be 50 per cent as organic manures and 50 per cent as inorganic fertilizers. Chundwat (1979) also opined that fertilization should be a combination of chemical fertilizers and organic manures. The organic manure in combination with inorganic NPK fertilizer had a significantly greater effect on enzyme activities and microbial populations than NPK fertilizer alone and therefore the additions of organic matter is advisable to obtain maximum benefits from NPK fertilizer in the soil (Tiwari, 1996). Papaya responds well to the incorporation of organic compost, which improves the physical, chemical and biological conditions of the soil (Oliveira *et al.,* 2004).

Akinyemi and Akande (2008) studied the effect of organic and inorganic fertilizers on growth and yield of papaya and the results showed that application of inorganic fertilizers gave highest plant height where as other morphological characters like stem girth, leaf area and days to first flowering was better with organic fertilizers and gave a higher fruit yield of 83.5 t per ha per year. Nitrogen and organic matter content of the soil were slightly higher where as potassium remain unchanged in organic plots.

Mendonca *et al*. (2006b) opined that application of 40 per cent organic compost and 10 kg simple superphosphate per m^3 was optimum for the growth of papaya seedlings (cv. Formosa). Mendonca *et al*. (2007) found better growth of papaya seedlings (cv. Formosa) when grown on substrate composited with 40 per cent organic compost. Use of fermented organic matter in the substrate for the production of papaya seedlings showed a positive effect on the precocity and plant height (Hafle *et al.*, 2009).

Chagas *et al.* (2000) compared the yield of papaya (cvs. Hawaii and Formosa) under organic (50.4 fruits/plant) and conventional production systems (37.2 fruits/plant). Significant increase in the fruit yield was reported, when papaya (cv. Solo) grown organically in green houses (Martelleto *et al*., 2008). According to Ray *et al.* (2008), application of organic manures registered significantly lower number of fruits compared to the treatment receiving inorganic fertilizers in papaya cv. Pusa Delicious.

Soil Ca application did not always increase fruit mesocarp Ca concentration, while K and N fertilization decreased it (Qiu *et al*., 1995). Ca was highest (22.4 μg/g) in papaya leaves treated with organic fertilizers and boron in leaves treated with organic (0.133 μg/g) and mineral (0.130 μg/g) fertilizers (Garcia *et al.,* 2003). It was observed that the fruits that are rich in Ca are more resistant to mechanical injury and post harvest losses (Rajkumar *et al*., 2005).

2.5.1. **Farmyard Manure**

The nutrient content of seedlings was significantly affected by the composition of the growing media. Papaya seedlings grown on media composed of FYM, mushroom compost and rice hull compost contained high concentrations of nutrients (Tsai-Yifong, 1996). Borges-Gomez *et al.* (2003) noted that substrate containing 25-100 per cent hog manure was best for papaya seedling production.

Yamanishi *et al.* (2004) recorded higher germination rate in papaya cvs. Sunrise Solo and Tainung-1 in the growth medium fertilized with composted cattle manure, osmocote and humus. Seedling growth, plant height, number of leaves and root dry matter were higher when papaya cv. Formosa seedlings were grown in 1:1:1:1:2 cow manure:coffee peel:vegetable coal:sand:soil (Mendonca *et al*., 2004; Mendonca *et al*., 2005; Mendonca *et al*., 2006c). Araujo *et al*. (2010) suggested the use of substrate composed of goat manure, soil and plantmax for efficient growth of papaya seedlings.

Muller *et al*. (1979) reported that in papaya variety Sunrise Solo, plant growth and development improved by raising proportion of FYM in soil up to 20 per cent. Higher FYM levels showed no advantages. In a trial carried out in papaya cv. Washington, plant height at which the first flower formed was least (85 cm) with 30 g N as FYM and greatest (120 cm) with 30 g each of N, P and K (Patil *et al*., 1995). Saraf *et al.* (2004) found that application of 10 kg FYM per plant alone or in combination with NPK and poultry manure (5 Kg/plant) in combination with bone meal (1 kg) and N:P:K as the effective treatments to enhance the growth of pomegranate plants.

Hossain *et al.* (1990) investigated the morphological, biochemical and yield responses of papaya to different sources of nitrogen. Highest number of fruits per plant (59.2) was obtained with decomposed cowdung (equivalent to 100 g N/plant) treatment. Highest fruit yield (23.05 kg/plant) and total and reducing sugar contents of ripe fruits were obtained with cowdung + mustard oil cake (to give 100 g N/plant) treatment.

Patil *et al.* (1997) recorded a highest fruit yield (70.2 kg/tree) with 15 g N per tree as FYM in cv. CO 1. Combined application of cattle manure (7.5 kg/ plant at six months interval) with RDF was found appropriate for papaya (Jayasundara and Huruggamuwa, 2005). Mesquita *et al*. (2007) reported the positive effects of bovine biofertilizers on 'Baixinho de Santa Amalia' papaya cultivar in relation to yield and fruit quality.

Ravishankar and Karunakaran (2008) studied the effect of organic manures on growth, yield and quality of Coorg Honey Dew papaya in the hill zones of Karnataka. They found that application of FYM (20 kg/plant/year) recorded maximum TSS, ascorbic acid, reducing sugars and total sugars. Application of 2 kg FYM along with Azotobacter, Azospirillum and VAM produced maximum yield with quality fruits (Dutta *et al.*, 2008).

Bovine biofertilizer application increased the contents of B, Cu, Fe and Zn in papaya leaves. But there was no significant effect on soil organic matter, exchangeable minerals and pH (Menezes-Junior *et al*., 2008).

Different organic manuring treatments gave significantly higher microbial population (bacteria, fungi and actinomycetes) and enzymatic activities in soil and application of FYM (20 kg/plant) is best for improving soil quality (Ravishankar *et al.*, 2008).

A reduction in viral infection was observed with a heavy manurial dose consisting of 10 kg FYM, 2 kg castor cake, 200 g each of N, P and K per plant per year applied in two splits and transplanting in October (Ray *et al*., 1999).

2.5.2. Vermicompost

Vermicompost is a highly nutritive organic fertilizer and plant growth promoter, with high porosity, aeration, drainage and water holding capacity. It contains most of the nutrients in plant available forms and is rich in microbial population and diversity.

Vermicompost works as a soil conditioner and its continued application lead to total improvement in the quality of soil (Sinha *et al.,* 2009). Radhakrishnan (2009) reported that vermicompost contained appreciable count of beneficial microorganisms like *Pseudomonas*, *Azospirillum*, PSB, yeast, moulds and actinomycetes.

Shivaputra *et al*. (2004a) reported highest per cent relative water content (67.87 %) in plants applied with vermicompost + *Sclerocystis dussii*. The highest soil water content value (9.62 %) was recorded in pots treated with vermicompost + *Glomus fasciculatum.*

Shivaputra *et al.* (2004b) reported an increase in the NPK and chlorophyll content of plants treated with vermicompost. Pire and Acevedo (2005) noted that increasing vermicompost rates increased P levels but produced variable responses of N and K in papaya leaves.

According to Acevedo and Pire (2004), largest plant growth was found with highest rate of vermicompost, without any N fertilizer. With N fertilizer, intermediate rates of vermicompost were more efficient.

Anilkumar *et al.* (2007) opined that enriched coirpith-vermicompost can be used as a substitute for FYM in the preparation of potting mixture. It also promoted the activity of bioinoculants in the rhizosphere soil.

Papaya seedlings (cv. CO 2) grown in the potting mixture prepared with vermicompost resulted in early flowering (86.69 days) with minimum plant height (90.93 cm) and first bearing height (96.95 cm) (Rajamanickam *et al.*, 2008). The substrates containing vermicompost produced best seedling growth (Andrade-Rodriguez *et al*., 2008). Kusdra *et al*. (2008) suggested the possibility of using earthworm casting in the traditional production of papaya.

Ushakumari *et al*. (1997) recorded highest bunch yield, sweetness and sugar-acid ratio in banana when vermicompost was applied to supply the recommended dose of nitrogen. According to Shivaputra *et al.* (2004c), vermicompost at two tons per ha + 75 per cent RDF + *Glomus fasciculatum* resulted in higher yield and early reproductive phase in papaya cv. Sunset Solo.

Though sole application of vermicompost improves the physico-chemical properties of soil, the yield was better when vermicompost was applied along with chemical fertilizers in many crops (Bandyopadhyay, 2009). Athani *et al.* (2009) reported the significant effect of vermicompost and organic fertilizers on growth and yield response of banana (*Musa paradisiaca*).

Integrated nutrient management studies in papaya cv. Surya showed that quality parameters of the fruits were increased with decreasing level of chemical fertilizers and treatment receiving 25 per cent vermicompost and 75 per cent RDF along with rhizosphere bacteria culture (50 g per plant) was found superior and economically viable (Kirad *et al.*, 2010).

2.5.3. Poultry Manure

Application of 2.5 per cent chicken manure increased growth of papaya seedlings (Tan *et al*., 2002) and improved the yield (CIMMYT, 2006). In a trial using compost made from combinations of chicken dung, burnt husk, rice hull and sawdust, the yield of papaya was 50 per cent less when 100 per cent of the compost was used compared to treatments with incorporation of inorganic fertilizers (Zabedah, 2001). Falcao and Borges (2006) obtained maximum fruit yield when papaya plants were supplied with 3 kg chicken manure and 300 g dolomite per plant.

N and K uptake were more and organic matter, total N, exchangeable K, Ca and Mg content in soil were increased with an increase in dry matter production by the application of poultry manure in papaya (Seripong, 1993). Use of chicken manure increased available phosphorous in soil by preventing phosphorous fixation (Munoz *et al*., 2004). Application of poultry manure increased the soil concentration of P, Ca, Mg and Zn and petiole concentration of P, Ca, Mg and K and increased the yield in papaya (Jacquiline, 2008).

Nkana *et al*. (1998) proposed that wood ash act as a neutralizer of soil acidity and as a supplier of nutrients for tropical acid soils. Foliar application of lignite fly ash dust at two kg per plant increased the resistance mechanism of papaya plant and ultimately increased the fruit yield (Eswaran and Manivannan, 2007). Addition of wood ash amended organic composts increased soil pH, soil organic matter, water holding capacity, electrical conductivity, total C and N (Bougnom *et al*., 2009).

Addition of municipal solid waste compost affected yield, precocity and fruit quality of papaya (Basso-Figuere *et al.*, 1994). Among the organic amendments, neem cake resulted in the lowest root knot index (2.7) and the greatest stem girth (29.5 cm), leaf number (44.2) and fruit number (58.6) in papaya. The highest fruit yields were obtained with the application of neem cake and mahua cake (51.8 and 51.7 kg/tree). Biogas sludge gave the tallest plants (130.8 cm) (Srivastava, 2002). Corral manure can be used for papaya seedling production and it supplied the nutrients (N, P, K, Mg and Ca) until transplanted to the main field (Canesin *et al.*, 2006).

2.6. WATER MANAGEMENT

Unlike other fruit crops, papaya does not require a rest period in order to flower and set fruit and therefore it requires available water to grow and bear continuously. More over it is a shallow rooted crop where the root surface is limited to first 60 cm soil profile.

Aiyelaagbe *et al.* (1986) reported that $^{-}$0.2 bar soil water potential as the critical level for normal growth and reproductive development of papaya. The stressed plants were stunted in growth and prevented fruit formation by flower abscission. Balasubramaniam and Rao (1988) investigated the water requirement of CO 2 papaya in sandy loam soils. It was found that total water requirement decreased from 2191 mm per day at 20 per cent depletion of available soil moisture to 1815 mm per day at 80 per cent depletion of available soil moisture. Increasing the evaporation-replenishment rates from 20 to 120 per cent increased the relative leaf water content by 13.2 per cent, transpiration rate by 18.8 per cent, plant height by 21.9 per cent, stem girth by 12.5 per cent, fruit number by 88.3 per cent and yield by 34.6 per cent.

According to Masri *et al.* (1990), water deficit significantly reduced number of flowers and fruit by 86 per cent and 58 per cent, respectively in papaya cv. Eksotika. Water stress also retarded growth and development of the fruits. Water deficit arrested plant growth, induced leaf abscission and drastically decreased photosynthetic rate in papaya seedling (cv. Baixinho de Santa Amalia) (Mahouachi *et al*., 2006). Excessive light intensity, high temperature and water deficit (less than 82 %) experienced during summer months influenced the physiological processes in papaya. Water stress induced maleness and poor fruit set where as excess moisture caused carpelloidy (Jeyakumar *et al*., 2007). According to Allan (2007), irrigation is needed when the tension reaches -20 to -30 bar and this is essential as water stress leads to small fruit abscission during the fruit set period.

Marte (1993) suggested that papaya in its productive stage requires 25 mm water in a week. Khondaker and Ozava (2007) proposed that papaya plants need regular rain fall or irrigation with good drainage while flooding for 48 hours is fatal and a balance between soil water and soil air is important for root growth of papaya. A minimum monthly rainfall of 100 mm is ideal for growth and production of papaya plants (Balamohan *et al.,* 2008).

Santana *et al.* (2008) observed the growth parameters of papaya under drip irrigation and opined that the plants were highest with bigger stems and more leaves under highest irrigation treatment ($1.1E_0$). Fruit yield differences above 60 per cent evaporation replenishment rates were not significant in papaya (Srinivas, 1996). Trials taken up have revealed that irrigation at 60 to 80 per cent ASM depletion is optimum for papaya (Soorianathasundaram, 2002; Singh and Singh, 2003; Mitra, 2007). Reddy (2008) found that 60 per cent evaporation replenishment was optimum with the use of 2900 mm water.

Drip irrigation studies conducted at IIHR, Banglore revealed that plants receiving frequent irrigation with 75 and 100 per cent evaporation replenishment maintained higher relative water content, transpiration rate, low diffusive resistance and higher yield in papaya cv. Coorg Honey Dew (Srinivas and Prabhakar, 1993). Biswas *et al*. (1999) reported highest yield and water use efficiency with drip irrigation at an IW:CPE ratio of 0.8.

According to Silva *et al*. (2001), average weight of fruits was not affected by irrigation intervals, but the number of fruits per plant was affected.

Almida *et al.* (2003) recorded highest fruit yield in cv. Improved Sunrise Solo 27/12, with a total water depth of 2937 mm. Goenaga *et al.* (2004) proposed that papaya grown under semi-arid conditions should be irrigated according to a pan factor of not less than 1.25.

Maximum number of fruits per plant, mean fruit weight of, yield per plant and productivity were obtained with an irrigation depth of 1769.5 mm for cv. Formosa (Garcia *et al*., 2007). Irrigation with 50 to 75 mm water in every three to four weeks is recommended for papaya and the average fruit yield was highest with 100 per cent evaporation replacement (Srinivas, 2008). Posse *et al*. (2009) obtained fruit yield of 38.78 t per ha and 49.42 t per ha with the replacement of reference-evapotranspiration by 100 per cent and 150 per cent respectively in papaya hybrid UENF/CALIMAN 01.

Fruit yield and quality (TSS, sugar and ascorbic acid contents) were not significantly affected by irrigation frequency (Jayaprakash *et al*., 1992). The quantity of irrigation water supplied had a positive and significant effect on banana fruit yield and the ideal IW/CPE ratio is 1.0 (Selvakumari *et al*., 1992).

2.7. MULCHING

Mulching is an agricultural technique that involves placing organic or synthetic materials on the soil around plants to provide a more favorable environment for growth and production. The beneficial effects of mulches on conservation of soil moisture, lowering of soil temperature, suppression of weed growth were reported by several workers. In papaya, weed is a serious problem due to the frequent irrigation requirement of the crop. Use of mulching not only checks the weed growth but also enhances the interval of irrigation scheduling resulting in saving of water. Therefore, present study was performed to determine the beneficial effect of mulch materials on soil moisture, plant growth, fruit yield and quality of fruits.

Compared with bare ground, mulch treatments provided higher yield and delayed papaya ring spot virus incidence in yellow squash (Conway *et al*., 1989). The highest average number of fruits per plant (24.1), highest average fruit weight (0.97 kg) and yield (23.2 kg/plant) were obtained in papaya with mulching along with drip irrigation. The B:C ratio (10.6) was also highest (Suresh and Saha, 2004).

Akinyemi *et al.* (2006) proposed that intercropping with white pumpkin is a suitable strategy for weed control in papaya plots. Several weed species have been identified as host plants of major virus vectors to papaya plants, such as *C. benghalensis* and *S. americanum* (Ronchi *et al*., 2008). Such information is of major importance for weed control in papaya production.

Beneficial effect of mulching on soil humidity maintenance and weed control in Banana was reported by Oliveira *et al.* (2003). According to Gomes-Filho *et al*. (2007), mulching treatments reduced the incidence of skin freckles and produced higher yield in cv. Golden. Studies on soil management practices for papaya revealed that mulching improves soil biological activity, retards soil erosion and increases the absorptive capacity of the soil (Yamanishi *et al*., 2010).

2.7.1. Organic Mulching

Elder *et al.* (2002) reported an increase yield of papaya by the use of coarse grass hay mulch. The use of straw mulch decreased soil loss and improved soil moisture and soil organic matter content in papaya orchards (Walsh and Ragupathy, 2007). Grass-hay mulch is very effective in papaya in controlling weeds, conserving soil moisture and protecting the soil from erosion during sudden heavy tropical rains (Zimmerman, 2008).

Singh and Singh (2005) observed highest fruit yield in Guava cv. L-49 with paddy straw mulching followed by black polythene. Singh *et al.* (2007) noticed significant reduction in soil temperature, maximum soil moisture conservation and highest yield per tree under paddy straw mulching in Aonla. A similar study was conducted by Maji and Das (2008) reported that Guava cv. Allahabad Safeda mulched with banana leaves gave highest yield followed by paddy straw.

Coir pith is a byproduct of the coir industry, which is having a good water holding capacity (Manickam and Subramanian, 2006). Pineapple plants mulched with a 5 cm thick layer of coir pith produced higher yield (Uthaiah *et al*., 1990). Coir pith contains 0.7 to 1.20 per cent K. Being acidic, its application enhances the release of fixed and mineral K in soil for crop use (Savithri *et al*., 1993).

Incorporation of coir pith and paddy waste increased the number of fruits per plant of oriental pickling melon (Veeraputhiran and Joseph, 1997). Coir pith compost improved the structure and physical properties of the soil and the studies in banana revealed that fertilizer dose could be reduced to half by the addition of coir pith compost at 15 kg per plant (Geetha *et al*., 2005).

Sonawane *et al.* (1996) observed that 31.6 per cent of nitrogen in residues of glyricidia was mineralised within eight days (compared with 92.3 % for urea), with a slow release of N over the next 45 days. Baiju *et al.* (2010) reported that by the application of green mulch of mixed species, a steady and intermediate rate of nutrient release can be assured which is important for soil fertility management and plant uptake.

Shashidhar *et al.* (2008) found more number of bacterial, fungal and actinomycetes colonies in plots mulched with *Cassia sericea* (32 cfu x 10^5/g), paddy straw (53 cfu x 10^4/g) and sunnhemp (53 cfu x 10^3/g).

2.7.2. Plastic Mulching

Balerdi (1976) reported good tree growth and excellent weed control with plastic mulch in tropical fruits like papaya, avocado and mango. Increased yield and water use efficiency were obtained when mulching (with 25 µm thick black plastic mulch) was supplemented with drip irrigation in papaya (Agrawal *et al*., 2002). Mulching with transparent polyethylene mulch (25 µm) produced maximum soil temperature of 47.3^0 C at 10 cm depth in papaya orchard, which was 14.6 per cent higher than control (Singh *et al*., 2004c).

Soil covers of 2 m wide plastic mulch and organic mulch in combination with 0.75 m mounds and on flat ground reduced the incidence of root rot and resulted in higher yield in papaya (Vawdrey *et al.,* 2004a; Vawdrey *et al.,* 2004b). Singh and Singh (2005) reported 100 per cent weed control and 70 per cent soil moisture retention with maximum water savings (45 %) in polythene mulched papaya plots. According to Pandey *et al*. (2005), drip irrigation with black plastic mulch (25 µm thick) enhanced the yield and yield attributing characters of papaya.

Considerable reduction in water requirement in plastic mulched fruit trees was reported by Singh *et al*. (2005). Aswathi *et al.* (2006) reported maximum soil moisture retention with synthetic mulches. Soil moisture content was higher by 10.6 to 14.2 per cent to a depth of 60 cm in polythene mulched plot over control in oriental pickling melon (Anoop, 2009).

Mulching and maintaining higher available soil moisture shortened the root penetration depth and crop duration and increased the shoot-root ratio in dwarf cavendish banana cv. Giant Governor. An available soil moisture depletion level of 20 per cent + black polyethylene mulch gave better results (Jana, 2001). Maximum vegetative growth and fruit yield were reported in pineapple with black polythene mulch (Hazarika and Das, 2000 ; Tiwari *et al.*, 2005). Murali *et al*. (2006) observed an increase in plant height, pseudostem girth, leaf number and leaf area of banana cv. Elakki with black polyethylene mulch, compared to no-mulch treatment.

Nutrient uptake and yield of banana were highest under black polythene mulch (Babu and Sharma, 2003). Application of plastic mulch with drip irrigation resulted in maximum yield in banana (Agrawal and Agrawal, 2005).

2.8. PLANT GROWTH PROMOTING MICROORGANISMS

Aryantha *et al*. (2000) demonstrated the ability of microorganisms isolated from animal manures (including fungi, actinomycetes and bacteria) to antagonise and parasitise *P. cinnamomi* in vitro and the potential for chicken manure to control *Phytophthora* diseases in the field. Aseri *et al*. (2005) investigated the effect of different bioinoculants on soil microbial diversity in rhizosphere soils of fruit plants. Shing *et al.* (2008) reported a positive correlation between organic matter content and microbial diversity in the soil, under papaya cultivation.

Kumar and Marimuthu (1994) reported that *T. viride* was most antagonistic with *R. solani*, followed by *T. harzianum* and *T. longibrachiatum*. Application of *T. harzianum* at 50 g per square meter of the nursery bed and soil treatment with neem cake at 100 g were effective for the control of damping off of papaya seedlings (Nethravati, 2001). Soil inoculation with

Trichoderma gave 70 per cent germination and best seedling growth in papaya cv. Maradol Roja (Santana *et al.*, 2002). According to Vawdrey *et al*. (2002), addition of Trichodry (1.0 kg/m3), Trichoflow (5.0 kg/ha) and chicken manure failed to reduce root rot of papaya caused by *Phytophthora palmivora*.

Application of 75 and 100 per cent of recommended dose of 300:300:300 g of NPK in six splits along with Azospirillum + VAM (50 g/plant) + PSB + *P. fluorescens* (2.5 g/plant) + *T. viride* (50 g/plant) has proved to enhance fruit number and yield of papaya cv. CO 7 (Nandhini, 2004). Application of *Trichoderma* spp. in the potting media reduced *Fusarium* infection in papaya seedlings (Cardenas *et al.,* 2005). Amiri *et al.* (2008) observed an improvement in seed germination of papaya cv. Solo, when *Trichoderma* and Endo Root Soluble were applied in the potting media and produced healthy and disease free seedlings.

Application of effective microorganism (EM) resulted in vigorous plants with higher yield and increased fruit quality of papaya cv. Solo (Desoky *et al.,* 2001). Application of *Trichoderma* along with VAM, PSB, Azospirillum and 100 per cent RDF resulted in higher stem girth, lower fruit bearing height, highest number of fruits per tree, fruit weight and yield per tree per year (Nalina *et al.*, 2008).

According to Khade and Rodrigues (2010), thirteen species of AM fungi belonging to the genera *Acaulospora*, *Glomus*, *Gigaspora* and *Destiscutata* were found colonized in papaya roots in tropical agrobased ecosystem of Goa. They also recorded a significant positive correlation of organic carbon, available phosphorus and total nitrogen with root colonization of AM fungi.

Banos *et al*. (2004) evaluated the isolates of antagonistic bacteria *P. fluorescens* and *Bacillus firmus* and found that only strains of *B. firmus* reduced the growth of *Colletotrichum gloeosporioides* in papaya. According to Lopez-Moctezuma *et al.* (2005), *Bacillus pumilus* and *Bacillus macerans* promoted growth and flowering of papaya. Rahman *et al*. (2007) isolated 27 antagonistic bacteria from the fructosphere of papaya and reported the biocontrol activities of *Pseudomonas aeruginosa* and *Burkholderia cepacia* on *C. gloeosporioides* in papaya.

Seed and soil treatments with the formulations of *Pseudomonas fluorescens* and *Trichoderma harzianum*, each at 5 g per kg soil, produced vigorous seedlings of papaya with significant increase in growth (Rao, 2007). Samiayappan (2008) reported that soil application of *Pseudomonas fluorescens* (5 kg/ha) and *Trichoderma viridae* (15 g/plant) mixed in well decomposed FYM, around the root zone reduces the foot rot of papaya. Application of *Trichoderma harzianum* or *Paecilomyces lilacinus* (0.5 g and 1.0 g/plant) improved growth of papaya and reduced the number of galls (Jonathan *et al.,* 2008).

Treatment with *Trichoderma* improved plant height, shoot weight and root length and weight and reduced nematode population in tomato (Devi and Richa-Sharma, 2002).

2.9. ECONOMICS OF CULTIVATION

Application of 400 g each of NPK per plant at monthly interval resulted in highest return in cv. CO 2 (Ravitchandirane, 1999 ; Ravitchandirane *et al*., 2002). Carvalho *et al.* (2003) reported a greater net income of 31.2 per cent by the use of legumes as inter row crop for weed control compared to mechanical control in cv. Sunrise Solo. The drip irrigation with black polythene mulch in papaya produced higher net income with a beneficit:cost ratio of 1:3.85 (Pandey *et al*., 2005).

According to Kirad *et al*. (2010) the treatment of 75 per cent RDF + 25 per cent vermicompost + rhizosphere bacteria culture was found superior and economically viable for cv. Surya. Lower yield and increased cost of production with organic manures resulted in lower beneficit:cost ratios in papaya cv. Pusa Delicious (Ray *et al*., 2008). Sharma *et al*. (2010) reported a beneficit:cost ratio of 2.86 from papaya cultivation , based on the financial viability study conducted in Maharashtra.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Response of papaya to organic manures, plant growth promoting microorganisms and mulching" was carried out in the Department of Pomology and Floriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2008 - 2010.

3.1. SITE, SOIL AND CLIMATE

The experiment was laid out in the research field of the Department of Pomology and Floriculture, College of Horticulture. The area is located at an elevation of 22.5 m above mean sea level and between $10^0 32^1$ N latitude and $76^0 16^1$ E longitude and it enjoys a warm humid tropical climate.

The soil of the experimental site is sandy loam in texture and acidic in reaction. The area lies in a tropical monsoon climate with more than 80 per cent of the rainfall getting distributed through south-west and north-east monsoon showers.

3.2. EXPERIMENTAL MATERIAL

Papaya variety CO 7 released from Tamil Nadu Agricultural University, Coimbatore was used for the study. It is a gynodioecious variety suited for fresh consumption with attractive and firm red flesh.

3.3. MANURES AND FERTILIZERS

Farmyard manure, vermicompost, biovermi and poultry manure were used as organic source of nitrogen. Bone meal and wood ash were used as organic source of phosphorous and potassium respectively. Biovermi is the enriched vermicompost with *Trichoderma viridae* and *Pseudomonas fluorescens.* Urea, single super phosphate and muriate of potash were used as inorganic source of nutrients. Nutrient composition of the organic manures and inorganic fertilizers used in the study is given in the Appendix II.

3.4. EXPERIMENTAL DETAILS

The study was undertaken as two field experiments as detailed below:

3.4.1. Experiment I – Effect of Organic Manures and Growth Promoting Microorganisms on Plant Growth, Yield and Quality of Papaya.

Plant growth, flowering and yield of papaya as influenced by organic and inorganic nutrients and plant growth promoting microorganisms were studied in this experiment.

Design: Randomised Block Design

Replications: 3

Number of treatments: 12

Number of plants per treatment: 4

Spacing: 2×2 m

Treatments

T_1 - Absolute control

T_2 - 240:240:480 g of NPK + 20 kg FYM/plant/year (As per POP recommendation, KAU, 2007)

T_3 - NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*

T_4 - NPK (POP) + Vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*

T_5 - NPK (POP) + Poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*

T_6 - NPK (POP) + Biovermi (N equivalent to 20 kg FYM)

T_7 - ½ NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*

T_8 - ½ NPK (POP) + Vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*

T_9 - ½ NPK (POP) + Poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*

T_{10} - ½ NPK (POP) + Biovermi (N equivalent to 20 kg FYM)

T_{11} - Fully organic (FYM + bone meal + wood ash equivalent to NPK of POP)

T_{12} - Fully organic (FYM + bone meal + wood ash equivalent to NPK of POP) + *Trichoderma* + *Pseudomonas*

Seedlings were raised in polybags and 45 days old seedlings were transplanted to the main field (Plate 1). Manures and fertilizers were applied as per treatment in six equal split doses at bimonthly intervals. *Trichoderma viridae* (5 g per plant) and *Pseudomonas fluorescens* (10 g per plant) were given as soil application at the time of planting.

3.4.2. Experiment II – Effect of Mulching on Water Retention, Weed Control and Growth of Papaya.

Experiment II was designed to study the effect of various mulching materials on soil moisture retention, weed control and growth of papaya.

Design: Randomised Block Design

Replications: 3

Number of treatments: 7

Number of plants per treatment: 4

Spacing: 2×2 m

Treatments

T_1 - Control (No mulch)

T_2 - Paddy straw (10 kg/plant)

T_3 - Coconut coir pith (5 kg/plant)

T_4 - Coconut leaf (10 kg/plant)

T_5 - Glyricidia (10 kg/plant)

T_6 - Biodegradable polythene (30 µg density)

T_7 - Black polythene (120 µg density)

Plate 1. General view of the field

Basins were mulched with various mulching materials at the time of planting. Manures and fertilizers were applied according to POP recommendation (KAU, 2007) for papaya *i.e.* NPK 240:240:480 g along with 20 kg farmyard manure per plant per year, in four equal split doses at once in three months intervals. Treatment without any mulch was kept as control (Plate 2).

Pre-planting irrigation was given uniformly to all pits. After transplanting light irrigation was given for 10 days. Differential irrigation according to the treatment was started when the plants were well established.

3.5. OBSERVATIONS

3.5.1. Plant Characters

Following biometric parameters were recorded at monthly interval in both the experiments, for a period of one year.

3.5.1.1. Plant height

Plant height was measured from the ground level to the growing point using a graduated pole and expressed in cm.

3.5.1.2. Collar girth

Collar girth at 10 cm above ground level was taken using a measuring tape and expressed in cm.

3.5.1.3. Number of leaves

Total number of functional leaves present at each observation was counted.

3.5.1.4. Internodal length

Internodal length, the mean distance between adjacent nodes, was estimated from the mean of 15 nodes in the middle region of the stem and expressed in cm.

T_1 (Control)

T_2 (Paddy straw mulch)

T_3 (Coir pith mulch)

T_4 (Coconut leaf mulch)

Plate 2. Plants mulched with different mulches

T_5 (Glyricidia mulch)

T_6 (Biodegradable polythene mulch)

T_7 (Black polythene mulch)

Plate 2. Plants mulched with different mulches

3.5.2. Floral characters

3.5.2.1. Days to flowering

Number of days taken from transplanting till the opening of first female/hermaphrodite flower was recorded and average was worked out.

3.5.2.2. Height at flowering

Height of the plant from ground level to the node where first flower appeared was recorded in cm.

3.5.2.3. Number of flowers per node

Number of flowers produced per node in each plant was recorded for three months, starting from first flowering and the average was worked out.

3.5.2.4. Sex of flowers

Total number of female and hermaphrodite plants in each treatment was recorded and ratio of hermaphrodite to female plants was calculated.

3.5.2.5. Fruit set (%)

Total number of female/hermaphrodite flowers produced and fruit set were recorded upto five months, from which the percentage of fruit set was calculated in each plant.

$$\text{Percentage of fruit set} = \frac{\text{Number of fruit set}}{\text{Total number of flowers}} \times 100$$

3.5.3. Yield Attributes

Fruits were harvested when yellow colour appeared along the furrows of the fruits and fruit characters were recorded.

3.5.3.1. Fruit size

Fruit length was measured from the stylar end to the pedicel end of the selected fruits using a thread and expressed in cm. Girth at the broadest portion of the fruit was measured and expressed in cm. Five fruits were selected randomly from each treatment plant and the fruit characters were recorded.

3.5.3.2. Fruit weight

Four fruits were taken randomly from each plant and the average fruit weight was worked out and expressed in g.

3.5.3.3. Fruit volume

Volume of selected fruit were found by water displacement method using glass volumetric jar, average was worked out and expressed in ml.

3.5.3.4. Number of fruits per plant

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

3.5.3.5. Number of seeds per fruit

Seeds were extracted randomly from five ripe fruits in each treatment, dried, number counted and their average was recorded.

3.5.3.6. Yield per plant

Average weight of fruit calculated was multiplied with total number of fruits to get the fruit yield per plant and expressed in kg.

3.5.3.7.Days taken for maturity

Flowers were tagged on the day of anthesis and the days taken from fruit set to reach harvest maturity was noted.

3.5.4. Quality Attributes of Fruits

3.5.4.1. Total soluble solids (TSS)

TSS of a ripe fruit was found out by a hand refractometer and expressed in degree brix.

3.5.4.2. Acidity

Titrable acidity of the fruit pulp was estimated as per A.O.A.C. method (1975) and expressed as percent anhydrous citric acid.

3.5.4.3. Reducing, non reducing and total sugars

Reducing and total sugars were determined as per the method described by A.O.A.C. (1975). Non reducing sugars were obtained by subtracting the percent of reducing sugars from total sugars.

3.5.4.4. Shelf life of fruits

The shelf life was calculated as number of days from harvest to till the fruits remained marketable with the retention of edible qualities at normal atmospheric conditions. Fruits were declared as unmarketable when it shows symptoms of decay or mould growth or shriveling to the tune of 25 per cent or more.

3.5.4.5. Organoleptic evaluation of fruits

A score chart was prepared based on nine point hedonic scale, where zero denoted poor and nine represented excellent quality. Quality attributes included in the score chart were taste, flavor, colour and texture. Organoleptic evaluation of ripe fruits was done by a panel of 15 judges. The score card used for the evaluation of fruits is given in the Appendix IV.

3.5.5. Soil Analysis

Soil samples were collected from the experimental area to assess the initial nutrients status. It was done before transplanting. Then the soil samples were collected one year after transplanting and chemically analysed to estimate the status of organic matter, major nutrients and pH by following the methods indicated in Table 1. In this way nutrient analysis was carried out in both the experiments.

Table 1. Methods followed for soil analysis

SL. No.	Nutrient estimated (kg/ha)	Method followed	Reference
1	Organic matter (%)	Organic carbon x 1.724	Jackson (1958)
2	Available N	Alkaline permanganate	Subbiah and Asija, (1956)
3	Available P	Bray-1 Extractant Ascorbic acid reductant-Spectrophotometry	Bray and Kurtz (1945)
4	Available K	Neutral Normal ammonium acetate extract using Flame Photometer	Jackson (1958)
5	pH	1:25 soil water ratio	Jackson (1958)

3.5.6. Incidence of pest and Diseases

Incidence of major pests and diseases were observed and recorded.

3.5.7. Cost of Cultivation

Cost of cultivation of each treatment was worked out and total cost per hectare was calculated.

Apart from the above parameters, following observations were also recorded in Experiment I and Experiment II separately.

Experiment I

3.5.8. Microbial Population in Soil

Enumeration of microorganisms in the soil was carried out at pre-planting and one year after planting stages by Serial Dilution Plate Technique (Johnson and Curl, 1972) using different media as detailed in Table 2.

Table 2. Media used for enumeration of soil micro organisms

SL. No.	Microbes	Dilution for plating	Medium	Reference
1	Bacteria	10^{-5}	Nutrient Agar	Rao, 1986
2	Fungus	10^{-4}	Martin's Rose Bengal Agar	Martin, 1950
3	Actinomycetes	10^{-4}	Kenknight & Munaier's Medium	Rao, 1986
4	*Trichoderma* spp.	10^{-3}	Trichoderma selective medium	Dhingra and Sinclair (1995)
5	*Pseudomonas fluorescens*	10^{-2}	King's Medium B Base	Dhingra and Sinclair (1995)

100 µl of the suspension was pore plated on corresponding medium. Plates were incubated at 28 ± 2^0C for a period of seven days. Observations were taken as and when the colonies appeared.

Experiment II

3.5.9. Soil Moisture Content

Moisture content in the soil was recorded using a soil moisture meter at a depth of 30 cm and expressed in percentage. Observations were recorded for a period of six months starting from December to May.

3.5.10. Weed Intensity

Total weed count in the plant basins in one m^2 quadrant was noted at three months intervals for a period of one year.

3.5.11. Dry Mater Production of Weeds

All the weeds enclosed by one m^2 size quadrant were uprooted. After removing the adhering soil, it was oven dried at 80 ± 5^0C to a constant weight and dry matter content was expressed in g/m^2.

3.6. STATISTICAL ANALYSIS

Data were statistically analysed using the MSTAT.C package. Treatment means were compared using DMRT.

Results

4. RESULTS

The trials were conducted at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during 2008-2010 with an objective of studying the response of papaya to organic manures, plant growth promoting microorganisms and mulching. The results of the studies are presented below.

4.1. EXPERIMENT I - Effect of organic manures and growth promoting microorganisms on plant growth, yield and quality of papaya.

4.1.1. Plant Characters

Plant characters, *viz*; height, collar girth, number of leaves and internodal length were recorded at monthly interval for 12 months and presented in Table 3 to 6.

4.1.1.1. Plant Height

Plant height as influenced by different organic manures and plant growth promoting microorganisms at different stages of growth is presented in Table 3. T_4 (NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas*) and T_5 (NPK (POP) + poultry manure + *Trichoderma* + *Pseudomonas*) were statically superior in terms of plant height throughout the growth period. The lowest value was registered by plants in control plots (T_1) and T_7 plants (½ NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*) which differed significantly from the rest of the treatments. At 12 months after planting (MAP) T_4 recorded significantly high value for plant height (245.8 cm) followed by T_5 (225.80 cm) and the minimum value (179.80 cm) was recorded by T_1.

4.1.1.2. Collar Girth

Collar girth of the plants was found non-significant during the early stages of growth (Table 4). However significant difference was observed between treatments

Table 3. Effect of organic manures and microbial inoculants on plant height, cm

Treatments \ MAP	1	2	3	4	5	6	7	8	9	10	11	12
T1	28.83^{a}	46.50^{a}	63.00^{a}	76.33^{bc}	90.50^{d}	112.7^{c}	122.5^{e}	132.7^{e}	143.7^{f}	157.0^{e}	168.5^{f}	179.8^{f}
T2	28.50^{a}	45.00^{a}	65.83^{a}	81.50^{bc}	99.50^{bcd}	121.7^{bc}	138.2^{bcde}	150.0^{cde}	163.2^{cdef}	178.8^{bc}	191.3^{bcd}	203.2^{cde}
T3	31.50^{a}	48.17^{a}	66.33^{a}	87.50^{bc}	110.3^{bc}	141.5^{ab}	154.7^{b}	170.3^{b}	186.3^{b}	196.0^{b}	207.3^{a}	216.7^{bc}
T4	26.50^{a}	52.00^{a}	71.50^{a}	106.50^{a}	128.3^{a}	153.5^{a}	176.3^{a}	194.5^{a}	212.8^{a}	224.0^{a}	234.8^{b}	245.8^{a}
T5	30.83^{a}	46.57^{a}	64.73^{a}	85.73^{bc}	107.4^{bcd}	129.6^{bc}	146.4^{bcd}	163.9^{bc}	179.9^{bc}	195.3^{b}	210.3^{b}	225.8^{b}
T6	37.50^{a}	46.83^{a}	58.33^{a}	74.50^{c}	91.67^{d}	116.5^{c}	135.0^{cde}	148.5^{cde}	161.5^{cdef}	175.3^{cd}	187.5^{cdef}	201.0^{cde}
T7	34.17^{a}	45.50^{a}	58.67^{a}	75.33^{bc}	93.17^{cd}	112.7^{c}	127.5^{de}	137.0^{de}	147.3^{ef}	158.7^{de}	171.0^{ef}	186.0^{ef}
T8	34.17^{a}	48.50^{a}	65.00^{a}	82.83^{bc}	99.67^{bcd}	124.8^{bc}	139.7^{bcde}	155.2^{bcd}	168.0^{bcd}	179.2^{bc}	194.7^{bcd}	209.8^{bcd}
T9	36.83^{a}	50.50^{a}	66.00^{a}	88.17^{b}	111.2^{b}	139.3^{ab}	152.5^{bc}	165.3^{bc}	178.2^{bc}	187.5^{bc}	200.2^{bcd}	219.7^{bc}
T10	36.83^{a}	47.00^{a}	63.50^{a}	78.50^{bc}	95.17^{bcd}	115.3^{c}	127.5^{de}	142.3^{de}	157.3^{def}	170.7^{cde}	183.0^{def}	195.3^{def}
T11	29.17^{a}	42.67^{a}	60.83^{a}	79.17^{bc}	97.50^{bcd}	123.0^{bc}	137.8^{bcde}	154.0^{bcd}	170.7^{bcd}	179.5^{bc}	189.8^{cde}	197.5^{def}
T12	32.50^{a}	46.33^{a}	67.83^{a}	84.33^{bc}	101.2^{bcd}	124.3^{bc}	139.8^{bcde}	152.2^{bcd}	164.5^{cde}	179.2^{bc}	191.0^{bcd}	202.2^{cde}

Treatment means having similar alphabets in superscript, do not differ significantly

Table 4. Effect of organic manures and microbial inoculants on collar girth, cm

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	4.17^{a}	4.67^{a}	9.66^{a}	10.83^{f}	12.67^{e}	15.00^{d}	16.67^{f}	18.00^{e}	19.00^{e}	20.33^{f}	21.33^{f}	22.67^{f}
T2	6.33^{a}	7.67^{a}	11.17^{a}	14.00^{bcde}	16.67^{bcd}	18.67^{bcd}	21.33^{bcdef}	23.33^{cde}	25.33^{cd}	27.00^{cde}	28.67^{cde}	30.33^{cde}
T3	4.67^{a}	7.33^{a}	11.50^{a}	15.00^{abcd}	17.33^{abcd}	20.00^{bc}	22.00^{abcde}	24.00^{bcd}	26.33^{bcd}	28.67^{bcde}	30.33^{bcde}	32.33^{bcde}
T4	4.50^{a}	7.33^{a}	11.67^{a}	16.33^{ab}	21.00^{a}	24.67^{a}	27.00^{a}	29.83^{a}	32.83^{a}	35.83^{a}	38.83^{a}	41.17^{a}
T5	5.17^{a}	6.33^{a}	10.83^{a}	15.83^{abc}	19.67^{ab}	23.00^{ab}	26.17^{ab}	29.17^{ab}	31.67^{ab}	33.67^{ab}	36.33^{ab}	38.17^{ab}
T6	5.00^{a}	6.67^{a}	9.50^{a}	13.17^{def}	16.50^{bcd}	18.50^{bcd}	20.33^{def}	23.17^{cde}	26.50^{bcd}	29.17^{bcd}	31.50^{bcd}	34.00^{abcd}
T7	4.83^{a}	6.67^{a}	10.50^{a}	12.67^{def}	14.00^{de}	15.33^{cd}	17.00^{ef}	19.33^{de}	20.83^{de}	22.50^{ef}	23.83^{ef}	25.50^{ef}
T8	5.50^{a}	6.33^{a}	11.20^{a}	14.67^{abcde}	18.33^{abc}	22.00^{ab}	25.67^{abc}	29.00ab	31.00^{abc}	33.17^{abc}	35.00^{abc}	37.00^{abc}
T9	5.37^{a}	8.67^{a}	13.00^{a}	16.67^{a}	19.33^{ab}	22.33^{ab}	25.33^{abcd}	28.33^{abc}	30.67^{abc}	33.17^{abc}	35.00^{abc}	36.83^{abc}
T10	4.67^{a}	5.43^{a}	10.50^{a}	12.33^{ef}	14.00^{de}	16.83^{cd}	20.67^{cdef}	24.00^{bcd}	26.33^{bcd}	28.50^{bced}	30.33^{bcde}	32.17^{bcde}
T11	5.17^{a}	6.60^{a}	11.33^{a}	13.33^{de}	14.67^{cde}	16.00^{cd}	17.33^{ef}	18.83^{de}	20.83^{de}	22.83^{def}	24.50^{ef}	26.17^{ef}
T12	5.17^{a}	6.10^{a}	11.83^{a}	13.67^{cde}	16.33^{bcde}	17.33^{cd}	18.67^{ef}	20.17^{de}	21.67^{de}	23.50^{def}	25.50^{def}	27.17^{def}

Treatment means having similar alphabets in superscript, do not differ significantly

from fourth month onwards and the same trend was continued up to 12 months. During the observation period, T_4 (RDF+ vermicompost + *Trichoderma* + *Pseudomonas*) showed maximum collar girth followed by T_5 (RDF+ poultry manure + *Trichoderma* + *Pseudomonas*), T_8 (½ NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas*) and T_9 (½ NPK (POP) + poultry manure + *Trichoderma* + *Pseudomonas*) plants. At 12 MAP T_4 recorded highest stem girth (41.17 cm) followed by T_5 (38.17 cm), T_8 (37.00cm) and T_9 (36.83 cm). The lowest value for collar girth was recorded by T_1 (22.67 cm).

4.1.1.3. Number of Leaves

Data on the effect of various treatments on number of leaves at monthly interval is given in Table 5. At three MAP treatments T_4 (RDF + vermicompost) recorded maximum number of leaves (14) followed by T_5 (RDF + poultry manure) and the minimum (10.67) was recorded in control plots (T_1). From fourth month onwards treatment T_5 recorded significantly higher values. The lowest value was recorded by T_1 at all stages of growth. At 12 MAP T_5 recorded the highest number of leaves (35.33) which significantly differed with T_8 (33.33) where as T_1 plants produced the lowest number of leaves (21.33).

4.1.1.4. Internodal Length

Internodal length of the plants was found non-significant at all stages of growth (Table 6). At first month, the values ranged from 3.03 cm (T_2) to 3.67 cm (T_9). A decrease in internodal length was found while the growth progresses and the value ranged from 0.80 cm to 1.27cm, at 12 MAP.

4.1.2. Floral Characters

Data pertaining to various floral characters are presented in Table 7 and Plate 3.

Table 5. Effect of organic manures and microbial inoculants on number of leaves per plant

Treatments \ MAP	1	2	3	4	5	6	7	8	9	10	11	12
T1	8.00^{d}	8.667^{d}	10.67^{c}	12.67^{d}	13.00^{d}	14.00^{c}	15.00^{d}	15.67^{e}	17.00^{f}	18.33^{d}	20.00^{d}	21.33^{g}
T2	10.33^{abc}	11.00^{abc}	13.00^{ab}	15.67^{ab}	17.33^{ab}	19.33^{ab}	21.33^{bc}	23.00^{bc}	24.67^{bc}	26.33^{b}	28.33^{b}	30.67^{bc}
T3	9.00^{bcd}	9.667^{cd}	11.33^{bc}	13.00^{cd}	14.00^{cd}	18.33^{b}	20.67^{bc}	23.00^{bc}	25.00^{abc}	27.67^{ab}	30.00^{ab}	32.00^{abc}
T4	11.00^{a}	12.00^{a}	14.00^{a}	15.00^{abc}	16.67^{b}	18.00^{b}	20.33^{bc}	22.67^{bc}	24.33^{bc}	27.33^{ab}	30.00^{ab}	32.00^{abc}
T5	10.33^{abc}	11.00^{abc}	13.33^{ab}	16.33^{a}	19.33^{a}	22.00^{a}	25.00^{a}	26.33^{a}	28.00^{a}	30.67^{a}	33.33^{a}	35.33^{a}
T6	10.67^{ab}	11.33^{abc}	12.00^{bc}	13.00^{cd}	13.33^{cd}	16.00^{bc}	19.33^{bc}	21.00^{bcd}	22.67^{cde}	25.67^{bc}	29.00^{b}	32.00^{abc}
T7	9.00^{bcd}	10.00^{bcd}	13.00^{ab}	14.33^{abcd}	15.33^{bcd}	16.33^{bc}	18.00^{cd}	19.33^{d}	20.33^{e}	22.33^{c}	24.00^{c}	25.33^{efg}
T8	9.33^{abcd}	10.00^{bcd}	12.33^{abc}	14.00^{bcd}	15.67^{bcd}	18.33^{b}	22.00^{ab}	23.67^{ab}	26.00^{ab}	28.33^{ab}	30.33^{ab}	33.33^{ab}
T9	10.33^{abc}	11.00^{abc}	11.67^{bc}	14.33^{abcd}	16.00^{bc}	19.00^{ab}	21.00^{bc}	22.33^{bcd}	24.00^{bcd}	26.00^{bc}	28.00^{b}	29.67^{bcd}
T10	8.67^{cd}	9.667^{cd}	11.67^{bc}	12.67^{d}	13.67^{cd}	16.00^{bc}	19.00^{bc}	20.67^{bcd}	22.00^{cde}	24.67^{bc}	26.67^{bc}	28.67^{cde}
T11	10.67^{ab}	11.67^{ab}	13.00^{ab}	14.00^{bcd}	15.33^{bcd}	17.33^{bc}	19.33^{bc}	20.00^{cd}	21.00^{de}	22.33^{c}	23.67^{c}	24.33^{fg}
T12	10.00^{abc}	10.67^{abc}	12.00^{bc}	12.67^{d}	13.67^{cd}	16.33^{bc}	18.00^{cd}	19.33^{d}	20.33^{e}	22.33^{c}	24.00^{c}	26.00^{def}

Treatment means having similar alphabets in superscript, do not differ significan

Table 6. Effect of organic manures and microbial inoculants on internodal length, cm

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	3.47[a]	3.03[a]	2.50[a]	1.60[a]	1.67[a]	1.70[a]	1.60[a]	1.50[a]	1.13[a]	0.93[a]	0.90[a]	0.87[a]
T2	3.03[a]	2.67[a]	2.23[a]	2.20[a]	2.00[a]	1.67[a]	1.67[a]	1.60[a]	1.57[a]	1.50[a]	1.37[a]	1.20[a]
T3	3.30[a]	3.00[a]	2.70[a]	2.63[a]	2.33[a]	2.10[a]	2.00[a]	1.93[a]	1.63[a]	1.10[a]	1.10[a]	0.97[a]
T4	3.13[a]	2.93[a]	2.63[a]	2.47[a]	2.27[a]	2.07[a]	1.93[a]	1.67[a]	1.47[a]	1.50[a]	1.23[a]	0.97[a]
T5	3.17[a]	2.83[a]	2.63[a]	2.33[a]	2.10[a]	1.77[a]	1.70[a]	1.60[a]	1.50[a]	1.27[a]	1.00[a]	0.80[a]
T6	3.13[a]	2.90[a]	2.43[a]	2.30[a]	2.20[a]	2.10[a]	1.80[a]	1.50[a]	1.37[a]	1.3[a]	1.50[a]	1.27[a]
T7	3.40[a]	3.00[a]	2.53[a]	2.50[a]	2.40[a]	2.20[a]	1.87[a]	1.67[a]	1.60[a]	1.57[a]	1.17[a]	1.10[a]
T8	3.43[a]	3.30[a]	3.07[a]	2.87[a]	2.3[a]	1.97[a]	1.83[a]	1.67[a]	1.57[a]	1.47[a]	1.00[a]	0.90[a]
T9	3.67[a]	3.43[a]	3.23[a]	2.93[a]	2.77[a]	2.23[a]	2.13[a]	2.00[a]	1.77[a]	1.50[a]	0.87[a]	0.80[a]
T10	3.10[a]	2.80[a]	2.57[a]	2.27[a]	2.07[a]	1.73[a]	1.67[a]	1.50[a]	1.50[a]	1.43[a]	1.17[a]	1.03[a]
T11	3.23[a]	3.13[a]	2.93[a]	2.67[a]	2.57[a]	2.17[a]	1.93[a]	1.60[a]	1.47[a]	1.40[a]	1.00[a]	0.83[a]
T12	3.27[a]	3.10[a]	2.97[a]	2.40[a]	2.13[a]	2.17[a]	1.93[a]	1.73[a]	1.60[a]	1.50[a]	1.17[a]	0.93[a]

Treatment means having similar alphabets in superscript, do not differ significantly

Table 7. Effect of organic manures and microbial inoculants on floral characters

Treatments	Days to flowering	Height at flowering (cm)	Number of flowers/node	Fruit set (%)
T1	184.87^{a}	103.33^{ab}	1.03^{c}	75.33^{i}
T2	161.95^{d}	89.34^{de}	1.13^{ab}	78.97^{ef}
T3	162.32^{d}	92.00^{de}	1.17^{a}	80.27^{bc}
T4	136.52^{h}	86.67^{e}	1.18^{a}	79.40^{de}
T5	143.26^{g}	94.00^{cd}	1.17^{a}	81.50^{a}
T6	156.92^{de}	85.67^{e}	1.10^{abc}	78.60^{f}
T7	168.33^{c}	100.33^{bc}	1.08^{bc}	76.17^{h}
T8	149.33^{f}	88.67^{de}	1.17^{a}	80.57^{b}
T9	151.33^{ef}	94.00^{cd}	1.17^{a}	79.80^{cd}
T10	156.33^{de}	88.00^{de}	1.10^{abc}	77.90^{g}
T11	175.17^{b}	108.00^{a}	1.17^{a}	76.62^{h}
T12	175.00^{b}	110.33^{a}	1.13^{ab}	76.61^{h}

Treatment means having similar alphabets in superscript, do not differ significantly

Plate 3. Plants in the flowering stage

4.1.2.1. Days to Flowering

Treatments differed significantly in days taken for the emergence of first flower. T_4 took minimum number of days for first flowering (136.52 days) followed by T_5 (143.26), T_8 (149.33 days) and T_9 (151.33 days). All the above treatments were significantly different. Treatments T_{10} (156.33 days) and T_6 (156.92 days) were statistically on par, but differed significantly from other treatments. Plants in the control plots (T_1) took maximum days to first flowering was for T_1 (184.87 days) followed by fully organic treated plants, T_{11} (175.17 days) and T_{12} (175.00 days).

4.1.2.2. Height at Flowering

Lowest height at which first flower appeared was in T_6 (85.67 cm) and T_4 (86.67 cm) plants and both these treatments were statistically on par. This was followed by T_{10} (88.00 cm) which was on par with T_8 (88.67 cm), T_2 (89.34) and T_3 (92.00 cm). Maximum height was recorded in T_{12} (110.33 cm) which was on par with T_{11} (108.00 cm) and these treatments were found to differ significantly from the other treatments.

4.1.2.3. Number of Flowers per Node

The analysis of data on number of flowers per node showed significant difference among the treatments. The treatments T_3, T_5, T_8, T_9 and T_{11} had highest number of flowers per cluster (1.17) followed by T_4 (1.18). These treatments were found to be statistically on par. The lowest number of flowers per node was found in T_1 (1.03) and T_7 (1.08) and these treatments were found to differ significantly from the other treatments.

4.1.2.4. Sex of Flowers

In general a sex ratio of 2.1 hermaphrodite:1female plant was noted in the present study. The treatments did not differ significantly with respect to the sex ratio.

4.1.2.5. Fruit set (%)

The treatments differed significantly with respect to the percentage of fruit set. It was highest in T_5 (81.50 %) followed by T_8 (80.57 %) and T_3 (80.27 %). The lowest fruit set was noted in control plants (75.33 %).

4.1.3. Yield Attributes

Data related to yield attributes are furnished in Table 8.

4.1.3.1. Fruit Size

Treatments differed significantly in terms of fruit length and girth. The highest value for fruit length was observed in T_4 (19.50 cm) which differed significantly from other treatments. This was followed by T_8 (19.33 cm), T_9 (19.33 cm) and T_3 (19.17 cm). The lowest value was given by T_1 (15.50 cm) followed by T_7 (17.00 cm) and T_{11} (17.50 cm).

Regarding fruit girth, T_4 was superior to all other treatments (43.00 cm). This was followed by T_5 (42.17 cm) and T_6 (41.33 cm). The lowest value was registered by T_1 (23.67 cm) i.e. plants in the control plots followed by T_7 (31.50 cm) and T_2 (33.50 cm).

4.1.3.2. Fruit Weight

The data on the weight of fruits revealed significant difference among the 12 treatments studied. Weight of the fruit was highest in T_4 (1.25 kg), which was significantly superior to all other treatments. T_5 (1.13 kg) and T_6 (1.12 kg) were the next best treatments and were statically on par. The treatments T_8 (1.08 kg), T_{10} (1.03 kg), T_9 (0.99 kg), T_3 (0.99 kg) and T_2 (0.98 kg) did not differ significantly from one another. The lowest weight of fruits was recorded in T_1 (0.51 kg) and T_7 (0.76 kg), which differed significantly from all other treatments.

Table 8. Effect of organic manures and microbial inoculants on yield attributes

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (kg)	Fruit volume (ml)	Days taken for maturity	No. of fruits/plant	No. of seeds/fruit	Fruit yield (kg/plant)
T1	15.50^{e}	23.67^{h}	0.51^{f}	445.67^{e}	142.67^{a}	19.58^{f}	63.67^{j}	9.90^{f}
T2	18.33^{abc}	33.50^{f}	0.98^{c}	756.33^{d}	130.33^{cd}	32.73^{cd}	525.00^{c}	32.13^{d}
T3	19.17^{ab}	34.33^{ef}	0.99^{c}	781.66^{cd}	129.33^{cd}	35.37^{abc}	526.33^{c}	34.87^{bcd}
T4	19.50^{a}	43.00^{a}	1.25^{a}	1176.67^{a}	116.33^{g}	34.15^{abcd}	644.67^{a}	42.59^{a}
T5	18.50^{abc}	42.17^{ab}	1.13^{b}	1172.00^{a}	120.33^{g}	36.21^{a}	418.67^{d}	40.93^{a}
T6	18.50^{abc}	41.33^{b}	1.12^{b}	1143.67^{a}	118.00^{fg}	32.89^{bcd}	604.00^{b}	36.82^{b}
T7	17.00^{d}	31.50^{g}	0.76^{e}	743.00^{d}	134.33^{bc}	27.00^{e}	128.00^{i}	20.50^{e}
T8	19.33^{ab}	36.33^{c}	1.08^{c}	952.67^{cd}	123.33^{ef}	36.00^{ab}	313.00^{f}	36.82^{b}
T9	19.33^{ab}	35.00^{de}	0.99^{c}	796.67^{cd}	126.33^{de}	34.67^{abcd}	155.00^{h}	34.39^{bcd}
T10	18.16^{bc}	36.00^{cd}	1.03^{c}	953.33^{b}	121.00^{efg}	32.17^{d}	325.00^{e}	33.11^{cd}
T11	17.50^{cd}	35.83^{cd}	0.86^{d}	848.67^{c}	138.00^{ab}	24.00^{e}	179.67^{g}	20.52^{e}
T12	18.17^{bc}	36.00^{cd}	0.87^{d}	857.67^{c}	137.33^{ab}	24.67^{e}	177.00^{g}	21.41^{e}

Treatment means having similar alphabets in superscript, do not differ significantly

4.1.3.3. Fruit Volume

The data regarding the volume of fruits indicated that treatment T_4 (1176.67 ml) followed by T_5 (1172.00 ml) and T_6 (1143.67 ml) were on par and statically superior to all other treatments. Volume of fruits was lowest in T_1 (445.67 ml). Treatments T_7 (743.00 ml) and T_2 (756.33 ml) also showed lower volume of fruits.

4.1.3.4. Number of Fruits per Plant

Analysis of data on the number of fruits per plant showed significant difference among the treatments. The treatment T_5 (36.21) produced highest number of fruits per plant followed by T_8 (36.00) and T_3 (35.37). Treatments T_9 (34.67) and T_4 (34.15) were statistically on par. The lowest number of fruits per plant was observed in T_1 (19.58). This was followed by T_{11} (24.00), T_{12} (24.67) and T_7 (27.00); all these treatments were statistically on par and produced lower number of fruits.

4.1.3.5. Number of Seeds per Fruit

The data on seed content of fruits are presented in Table 8. Number of seeds was highest in the treatment T_4 (644.67) followed by T_6 (604.00) which differ significantly from each other and found superior to all other treatments. The lowest number of seeds was recorded in T_1 (63.67) followed by T_7 (128.00) and T_9 (155.00) which were significantly different.

4.1.3.6. Yield per Plant

The data on fruit yield per plant, presented in Table 8 showed significant difference among treatments. The highest fruit yield was recorded in T_4 (42.59 kg/plant) followed by T_5 (40.93 kg/plant), which were statistically on par and superior to all other treatments (Plate 4). These plants were manured with NPK (POP), biocontrol agents, *viz; Trichoderma* and *Pseudomonas* along with either vermicompost (T_4) or poultry manure (T_5). The lowest yield was recorded in control

T_4 (RDF+ vermicompost + *Trichoderma* + *Pseudomonas*)

T_5 (RDF + poultry manure + *Trichoderma* + *Pseudomonas*)

Plate 4. Effect of organic manures and microbial inoculants on fruit yield

plots (9.90 kg/plant) followed by T_7 (20.50 kg/plant). Treatments receiving organic manure alone also registered lower yield (T_{11} - 20.52 and T_{12} - 21.41 kg/plant).

4.1.3.7. Days Taken for Maturity

Days taken from fruit set to harvest as influenced by various treatments are presented in Table 8. Different treatments had significant influence on the days required to reach harvest maturity. The lowest time for harvest was recorded in T_4 (116.33 days) which was significantly superior to all other treatments. This was followed by T_6 (118.00 days) and T_5 (120.33 days); both being statistically on par with T_4. Treatment T_1 (142.67 days) recorded the highest period for harvest followed by T_{11} (138.00 days) and T_{12} (137.33 days).

4.1.4. Quality Attributes of Fruits

Data depicting the effect of various treatments on quality attributes of fruits are presented in Table 9.

4.1.4.1. Total Soluble Solids (TSS)

Statistical analysis of the data revealed that the treatments varied significantly with regard to TSS. T_{12} recorded maximum TSS (14.47 ^{0}B) followed by T_{11} (13.67 ^{0}B). Treatments T_2 (9.10 ^{0}B) recorded significantly lower TSS.

4.1.4.2. Acidity

The treatments differed significantly in the case of acidity of fruits. The highest acidity of 0.36 per cent was recorded by T_1. This was followed by T_7 (0.26 %), T_{12} (0.26 %), T_2 (0.24 %), T_3 (0.24 %), T_6 (0.24 %), T_5 (0.23 %), T_{11} (0.22 %) and T_9 (0.21 %); all these treatments being statistically on par. The lowest value was recorded by T_4 and T_{10} (0.13 %) which was found to be statistically on par with T_8 (0.16 %).

Table 9. Effect of organic manures and microbial inoculants on quality attributes of fruits

Treatments	TSS (^{0}B)	Acidity (%)	Reducing sugars (%)	Non reducing sugars (%)	Total sugar (%)	Shelf life (days)
T1	11.97^{e}	0.36^{a}	12.00^{b}	1.60^{f}	13.60^{b}	8.00^{b}
T2	9.10^{j}	0.24^{b}	4.43^{g}	1.35^{g}	5.78^{g}	6.00^{f}
T3	9.57^{i}	0.24^{b}	6.37^{f}	2.36^{a}	8.76^{f}	6.10^{ef}
T4	11.53^{f}	0.13^{c}	8.77^{d}	2.07^{cd}	10.84^{c}	6.47^{de}
T5	11.10^{g}	0.23^{b}	7.80^{e}	2.21^{b}	10.01^{e}	6.83^{d}
T6	11.10^{g}	0.24^{b}	7.60^{e}	2.39^{a}	9.99^{e}	6.57^{d}
T7	10.03^{h}	0.26^{b}	8.57^{d}	2.10^{c}	10.67^{cd}	7.30^{c}
T8	13.00^{c}	0.16^{c}	11.70^{bc}	1.78^{e}	13.48^{b}	7.80^{b}
T9	12.50^{d}	0.21^{b}	8.57^{d}	1.83^{e}	10.40^{d}	7.80^{b}
T10	11.60^{f}	0.13^{c}	11.50^{c}	1.97^{d}	13.47^{b}	7.90^{b}
T11	13.67^{b}	0.22^{b}	12.56^{a}	1.61^{f}	14.18^{a}	8.43^{a}
T12	14.47^{a}	0.26^{b}	12.70^{a}	1.62f	14.32^{a}	8.47^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

4.1.4.3. Reducing, Non Reducing and Total Sugars

Significant difference was noticed for reducing sugar content of fruits among the treatments. Maximum reducing sugar was observed in the treatment T_{12} (12.70 %) followed by T_{11} (12.56 %); both being statistically on par. The lowest value was recorded in T_2 (4.43 %) followed by T_3 (6.37 %).

Statistical analysis of data revealed that the treatments varied significantly with regard to non reducing sugar content of fruits. Maximum value was recorded in T_6 (2.39 %) which was on par with T_3 (2.36 %). T_2 recorded significantly lowest value of 1.35 per cent followed by T_1 (1.60 %), T_{11} (1.61 %) and T_{12} (1.62 %).

The treatments showed significant difference in the total sugar content of fruits. The treatment T_{12} recorded maximum total sugar content of 14.32 per cent and it was on par with T_{11} (14.18 %). T_2 recorded the least value of 5.78 per cent. T_3 (8.76 %), T_6 (9.99 %) and T_5 (10.01 %) also showed lower amount of total sugar.

4.1.4.4. Shelf Life of Fruits

The shelf life of the fruits kept at room temperature varied significantly in various treatments. The highest mean value for shelf life was noted in T_{12} (8.47 days) followed by T_{11} (8.43 days). The treatments T_{10} (7.9 days), T_8 and T_9 (7.8 days) were statistically on par. The lowest shelf life of the fruits was observed in T_2 (6.0 days) and T_3 (6.1 days).

4.1.4.5. Organoleptic Evaluation of Fruits

Organoleptic characters, *viz;* taste, flavour, colour, texture and overall acceptability of the fruits among the treatments are evaluated and presented in Table 10. The mean score obtained for taste ranged from 5.00 to 8.27. The treatment T_{12} recorded highest score (8.27) followed by T_{11} (8.13); both being statistically on par. Treatment T_2 recorded the lowest score (5.00) followed by T_3 (5.07).

Table 10. Organoleptic evaluation of fruits

Quality attributes / Treatments	Taste	Flavour	Colour	Texture	Overall acceptability
T1	6.00^{e}	4.30^{g}	4.03^{f}	4.60^{e}	18.93^{h}
T2	5.00^{f}	4.20^{g}	4.93^{e}	4.13^{f}	18.26^{i}
T3	5.07^{f}	4.50^{g}	5.17^{e}	4.27^{f}	19.00^{h}
T4	6.07^{e}	5.23^{f}	6.77^{c}	6.27^{c}	24.33^{g}
T5	6.67^{d}	5.30^{f}	6.90^{bc}	6.17^{cd}	25.03^{f}
T6	6.16^{e}	6.07^{e}	6.97^{bc}	6.03^{d}	25.23^{f}
T7	7.10^{c}	6.83^{d}	6.03^{d}	6.93^{b}	26.90^{e}
T8	7.57^{b}	7.17^{c}	7.00^{bc}	7.03^{b}	28.77^{c}
T9	7.13^{c}	7.77^{b}	7.10^{b}	7.10^{b}	29.10^{c}
T10	7.17^{c}	7.03^{cd}	6.97^{bc}	7.00^{b}	28.17^{d}
T11	8.13^{a}	7.80^{b}	8.07^{a}	7.73^{a}	31.73^{b}
T12	8.27^{a}	8.23^{a}	8.10^{a}	7.80^{a}	32.40^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

Results of the quality attribute flavour showed that the treatment T_{12} registered highest score (8.23) followed by T_{11} (7.80) and T_9 (7.77). The lowest score was recorded in T_2 (4.20).

Mean score obtained for colour ranged from 4.03 to 8.10. Treatment T_{12} scored highest value (8.10) which was on par with T_{11} (8.07). The lowest score for colour was obtained for T_1.

With regard to the texture of the pulp, it was observed that treatment T_{12} scored the maximum value (7.80) followed by T_{11} (7.73) and T_9 (7.10), while the minimum score was recorded by T_2 (4.13).

A detailed assessment of the organoleptic quality of the fruits obtained from different treatments indicated that those harvested from fully organically manured plants (T_{12}) was most acceptable with a score of 32.40. Treatments T_{11} (31.73), T_9 (29.10) and T_8 (28.77) also showed better acceptability. The least mean score for overall acceptability was obtained for the treatment T_2 (18.26) followed by T_1 (18.93), T_3 (19.00) and T_4 (24.33).

4.1.5. Soil Analysis

The data on nutrient status of soil are presented in Table 11.

4.1.5.1. Organic Matter

There was no significant difference in soil organic matter content among various treatments, even though a considerable increase in organic matter content was noticed one year after planting. From the initial value of 1.59 per cent it increased up to 2.45 per cent. The highest value was recorded in T_4 where as the least value was recorded in T_1 (1.89 %).

Table 11. Nutrient status of the soil as influenced by different treatments

Treatments	Organic matter (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH
T0	1.59^{b}	397.2^{fg}	23.0^{i}	110.6^{fg}	4.6^{bcd}
T1	1.89^{ab}	402.6^{fg}	24.1^{i}	110.5^{fg}	4.9^{abcd}
T2	2.43^{a}	412.9^{de}	32.0^{g}	125.6^{ef}	4.9^{abcd}
T3	2.42^{a}	413.2^{de}	35.0^{h}	136.8^{e}	5.3^{ab}
T4	2.45^{a}	481.0^{a}	54.3^{b}	175.7^{b}	5.5^{a}
T5	2.42^{a}	464.0^{ab}	61.0^{a}	172.9^{bc}	4.3^{bcd}
T6	2.43^{a}	475.0^{a}	56.0^{c}	185.1^{a}	5.5^{a}
T7	2.42^{a}	437.9^{ef}	37.0^{k}	143.4^{d}	4.1^{d}
T8	2.41^{a}	457.7^{ab}	48.3^{e}	166.5^{bc}	5.0^{abcd}
T9	2.43^{a}	448.7^{abc}	51.0^{d}	151.1^{cd}	5.1^{abc}
T10	2.42^{a}	449.3^{abc}	45.0^{f}	159.8^{bcd}	4.5^{bcd}
T11	2.44^{a}	427.0^{g}	40.5^{j}	135.0^{e}	4.5^{bcd}
T12	2.44^{a}	427.2^{g}	41.0^{j}	131.6^{fg}	4.5^{bcd}

Treatment means having similar alphabets in superscript, do not differ significantly

4.1.5.2. Available N

Significant variation existed among the different treatments, with regard to the available nitrogen status of soil. At the pre planting stage, it was 397.20 kg per ha. One year after the study, highest value was recorded in T_4 (481.0 kg/ha) though it was on par with T_6 (475.0 kg/ha). The treatment T_1 recorded lowest value of 402.6 kg per ha.

4.1.5.3. Available P

Regarding the available phosphorous content in soil, initial value was 23.0 kg per ha. At the post experiment stage, significant variation was observed among the treatments and it ranged from 24.15 (T_1) to 61.0 kg per ha (T_5).

4.1.5.4. Available K

As in the case of available nitrogen and phosphorous, available potassium status of the soil also increased from the initial value of 110.6 kg per ha. It was highest in T_6 (185.1 kg/ha) followed by T_4 (175.7 kg/ha). The lowest value of 110.5 kg per ha was recorded in T_1.

4.1.5.5. pH

Significantly higher pH value was recorded in T_4 (5.5) and T_6 (5.5) followed by T_3 (5.3) and the least value was observed in T_7 (4.1).

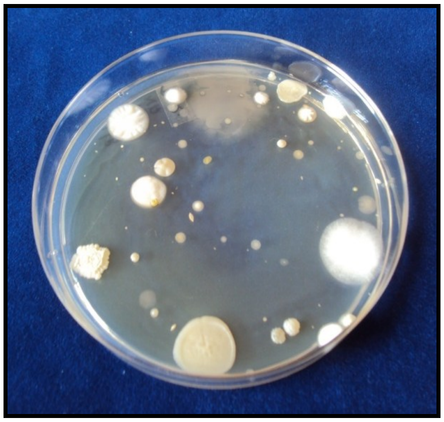
4.1.6. Microbial Population in Soil

Data showing the microbial population in the soil at one year after planting and at the pre-treatment stages are presented in Table 12. Enumeration of micro organisms showed a significant increase in the total count of bacteria, fungi and actinomycetes (Plate 5).

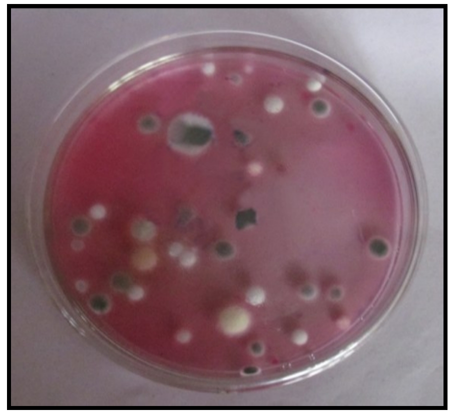
Table 12. Effect of organic manures and microbial inoculants on soil microbial population

Treatments	Bacteria ($x10^6$ cfu/g)	Fungi ($x10^5$ cfu/g)	Actinomycetes ($x10^5$ cfu/g)
T0	6.50^{f}	3.17^{g}	1.83^{f}
T1	8.16^{f}	4.13^{g}	2.50^{hi}
T2	9.67^{ef}	5.67^{fg}	2.67^{ghi}
T3	14.00^{e}	7.83^{defg}	3.83^{fghi}
T4	19.33^{d}	6.50^{efg}	7.5^{cde}
T5	21.00^{d}	9.0^{cdefg}	8.17^{bcd}
T6	22.00^{d}	15.00^{ab}	6.50^{def}
T7	21.33^{d}	12.50^{abcde}	5.67^{ef}
T8	29.00^{c}	14.17^{abc}	11.78^{ab}
T9	26.67^{c}	14.29^{abc}	4.83^{efgh}
T10	31.00^{c}	17.17^{a}	5.50^{efg}
T11	36.16^{b}	11.33^{bcdef}	10.00^{abc}
T12	43.67^{a}	12.83^{abcd}	12.17^{a}

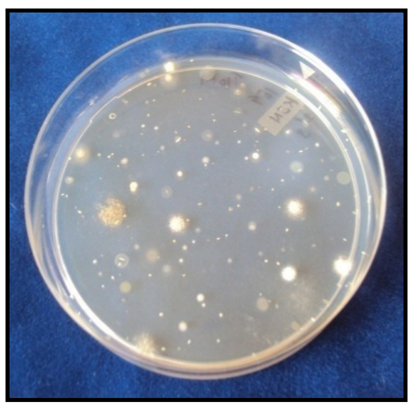
Treatment means having similar alphabets in superscript, do not differ significantly



Bacteria (T12)



Fungi (T10)



Actinomycetes (T12)

Plate 5. Effect of organic manures and microbial inoculants on soil microbial population

Regarding the bacterial population in the soil, treatments T_{12} (organic manures + bioinoculants) and T_{11} (organic manures alone) recorded significantly higher values of 43.67×10^{6} cfu/g and 36.16×10^{6} cfu/g respectively. The lowest value was recorded in pre-treatment sample (T_0-6.50×10^{6} cfu/g) and it was on par with absolute control (T_1-8.16×10^{6} cfu/g).

Results showed a similar increase in the fungal population in soil compared to the initial value. Treatment with RDF + biovermi (T_{10}-17.17×10^{5} cfu/g) recorded highest value followed by treatment receiving ½ RDF + biovermi (T_6-15.0×10^{5} cfu/g) and the least value was recorded in T_0 (3.17×10^{5}cfu/g).

Enumeration of actinomycetes population in the soil also showed a similar trend. Treatment with organic manures + bioinoculants (T_{12}) gave highest value (12.17×10^{5} cfu/g) followed by T_8 (½ RDF+ vermicompost-11.78×10^{5} cfu/g) and T_{11} (10.0×10^{5} cfu/g). The least value was recorded in T_0 (1.83×10^{5} cfu/g) followed by T_1 (2.5×10^{5} cfu/g).

There was a significant increase in the population of *Trichoderma* spp. and *Pseudomonas fluorescens* in the soil (Table 13 and Plate 6). The population of *Trichoderma* spp. in the soil was found to be highest in treatment with ½ RDF + biovermi (T_{10}-7.5 x10^{5} cfu/g) followed by treatment receiving RDF + biovermi (T_6-6.33 x10^{5} cfu/g) and T_{12} (5.03 x10^{5} cfu/g) where as population of *P. fluorescens* was highest in T_{10} (½ RDF + biovermi) and T_{12} (fully organic + biocontrol agents) (3.83 x10^{3} cfu/g) followed by T_6 (3.67 x10^{3} cfu/g) and T_3 (3.5 x10^{3} cfu/g). In both the cases initial samples recorded significantly lower values.

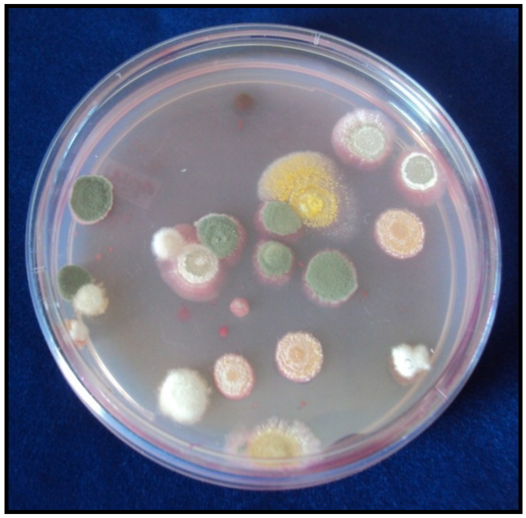
4.1.7. Incidence of Pest and Diseases

No serious pest and diseases were noticed during the observation period. There was a miner incidence of papaya mosaic virus, even though the treatments did not differ significantly.

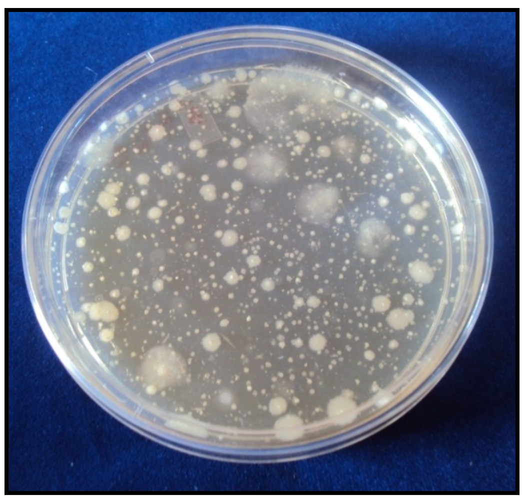
Table 13. Effect of organic manures and microbial inoculants on *Trichoderma* spp. and *Pseudomonas fluorescens* population in soil

Treatments	*Trichoderma* spp. ($x10^4$ cfu/g)	*Pseudomonas fluorescens* ($x10^3$ cfu/g)
T0	1.83^{e}	1.33^{b}
T1	2.00^{de}	2.00^{ab}
T2	2.17^{de}	2.17^{ab}
T3	4.17^{bcd}	3.50^{a}
T4	2.50^{de}	2.50^{ab}
T5	2.67^{de}	2.33^{ab}
T6	6.33^{b}	3.67^{a}
T7	2.17^{de}	2.50^{ab}
T8	2.67^{de}	3.00^{ab}
T9	2.78^{de}	2.33^{ab}
T10	7.50^{a}	3.83^{a}
T11	3.67^{cde}	2.67^{ab}
T12	5.03^{bc}	3.83^{a}

Treatment means having similar alphabets in superscript, do not differ significantly



Trichoderma spp. (T_{10})



Pseudomonas fluorescens (T_{10})

Plate 6. Effect of organic manures and microbial inoculants on *Trichoderma* spp. and *Pseudomonas fluorescens* population in soil

Table 14 . Cost of cultivation per hectare

Treatments	Total cost (Rs./ha)
T1	32,100.00
T2	1,12,767.50
T3	1,15,642.50
T4	2,65,592.50
T5	1,90,642.50
T6	3,96,017.50
T7	1,00,303.00
T8	2,50,253.00
T9	1,75,303.00
T10	3,80,678.00
T11	1,50,750.00
T12	1,53,625.00

4.1.8. Cost of Cultivation

As far as cost of cultivation if concerned, application of RDF + biovermi incurred highest cost per hectare (Rs. 3,96,017.50/ha) followed by ½ RDF + biovermi (Rs. 3,80,678.00/ha) (Table 14 and Appendix I). Cost of cultivation was least in absolute control (Rs. 32,100.00/ha).

4.2. EXPERIMENT II - Effect of mulching on water retention, weed control and growth of papaya.

4.2.1. Plant Characters

4.2.1.1. Plant Height

Plant height as influenced by various mulches studied, at the different stages of growth is presented in Table 15. The treatments did not differ significantly at any stages of growth. The treatment T_4 - coconut leaf mulch (59.83 cm) recorded the lowest plant height at three MAP followed by T_5 (64.00 cm) and T_6 (65.50 cm). The highest value for height of the plant at this stage of growth was recorded in T_3 (68.00 cm) followed by T_7 (67.00 cm). Up to sixth MAP T_4 recorded the lowest plant height (109.50 cm). At this stage the highest value was recorded in T_2 (131.00 cm) followed by T_7 (120.83 cm). Plants in the control plots (T_1) recorded the lowest plant height (181.17 cm) at 12 MAP and highest value was recorded in T_2 (189.17 cm) followed by T3 (187.33 cm).

4.2.1.2. Collar Girth

Collar girth of the plants was found to be non-significant at all stages of growth (Table 16). At three MAP, the values ranged from 11.17 cm (T_1) to 13.50 cm (T_7). During the six MAP T_7 (24.50 cm) recorded the highest value and lowest value was recorded in T_1 (18.50 cm). At nine MAP and 12 MAP also T_7 (black polythene mulch) recorded the highest value (33.00 cm and 39.67 cm respectively) followed by T_6

Table 15. Effect of mulching on plant height, cm

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	33.83[a]	44.33[a]	66.00[a]	85.00[a]	98.83[a]	118.50[a]	130.17[a]	138.17[a]	151.17[a]	163.00[a]	172.00[a]	181.17[a]
T2	35.00[a]	43.83[a]	67.00[a]	90.17[a]	106.67[a]	131.00[a]	141.17[a]	153.33[a]	158.67[a]	165.83[a]	175.67[a]	189.17[a]
T3	43.50[a]	54.67[a]	68.00[a]	81.17[a]	97.67[a]	117.33[a]	131.50[a]	141.83[a]	151.50[a]	161.17[a]	176.17[a]	187.33[a]
T4	40.17[a]	50.17[a]	59.83[a]	76.67[a]	92.67[a]	109.50[a]	120.50[a]	132.00[a]	150.00[a]	167.33[a]	177.33[a]	187.00[a]
T5	39.50[a]	51.33[a]	64.00[a]	86.17[a]	100.50[a]	120.50[a]	130.67[a]	140.67[a]	151.67[a]	162.33[a]	174.00[a]	185.83[a]
T6	40.83[a]	52.33[a]	65.50[a]	83.83[a]	97.50[a]	115.50[a]	133.83[a]	145.00[a]	154.00[a]	163.67[a]	173.83[a]	183.00[a]
T7	45.00[a]	57.17[a]	66.83[a]	84.67[a]	100.8[a]	120.83[a]	131.33[a]	141.83[a]	152.83[a]	162.83[a]	173.50[a]	184.17[a]

Treatment means having similar alphabets in superscript, do not differ significantly

Table 16. Effect of mulching on collar girth, cm

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	6.33[a]	7.67[a]	11.17[a]	13.17[a]	16.50[a]	18.50[a]	21.33[a]	23.33[a]	25.33[a]	27.00[a]	30.67[a]	33.33[a]
T2	6.00[a]	6.67[a]	12.50[a]	14.00[a]	16.67[a]	18.67[a]	20.33[a]	23.17[a]	26.00[a]	29.17[a]	31.50[a]	34.00[a]
T3	7.33[a]	9.20[a]	11.50[a]	14.17[a]	17.17[a]	21.00[a]	24.17[a]	27.00[a]	29.83[a]	32.33[a]	34.67[a]	38.83[a]
T4	6.67[a]	8.50[a]	11.50[a]	14.67[a]	17.17[a]	20.50[a]	22.50[a]	24.83[a]	27.83[a]	30.67[a]	34.50[a]	37.67[a]
T5	6.13[a]	7.80[a]	11.50[a]	15.17[a]	19.00[a]	22.33[a]	24.33[a]	27.00[a]	29.67[a]	32.00[a]	34.00[a]	36.17[a]
T6	6.03[a]	8.00[a]	11.67[a]	15.00[a]	18.83[a]	22.00[a]	24.67[a]	27.67[a]	30.83[a]	33.50[a]	36.16[a]	39.17[a]
T7	6.73[a]	9.33[a]	13.50[a]	16.83[a]	21.33[a]	24.50[a]	27.50[a]	30.00[a]	33.00 [a]	35.50[a]	36.17[a]	39.67[a]

Treatment means having similar alphabets in superscript, do not differ significantly

(30.83cm and 39.17 cm respectively) and the lowest value was recorded in T_1 (25.33 cm and 33.33 cm respectively).

4.2.1.3 Number of Leaves

Data on the effect of treatments on the number of leaves at monthly intervals is given in Table 17. The treatments differed significantly from eight MAP onwards. At three MAP treatments T_7 recorded maximum number of leaves (13) followed by T_6 (12.67). The minimum number of leaves (11.33) was recorded in T_1. At sixth MAP onwards, T_7 produced maximum number of leaves. At six MAP treatment T_7 recorded maximum number of leaves (19.00) and the minimum was (17.33) was recorded by T_1. At nine MAP treatment T_7 recorded maximum number of leaves (25.00) and the minimum was (20.00) was recorded by T_1. At 12 MAP also treatment T_7 recorded maximum number of leaves (33.00) and the minimum was (24.67) was recorded by T_1.

4.2.1.4. Internodal Length

Internodal length of the plants was found non-significant at all stages of growth (Table 18). At first month, the values ranged from 2.77 cm (T_1) to 3.17cm (T_2). As in experiment I, a decrease in internodal length was found when growth progressed and the value ranged from 1.03 cm (T_6) to 1.50 cm (T_2), at 12 MAP.

4.2.2. Floral Characters

Data pertaining to variation in floral characters are presented in Table 19.

4.2.2.1. Days to Flowering

The lowest time taken for first flowering was observed in T_6 and T_7 (145.50 days). This was followed by T_2 (149.50 days) and T_3 (150.50 days). The plants in T_1

Table 17. Effect of mulching on number of leaves per plant

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	9.33^{a}	10.33^{a}	11.33^{a}	13.67^{a}	15.33^{a}	17.33^{a}	18.33^{a}	19.33^{a}	20.00^{c}	20.33^{b}	22.33^{b}	24.67^{d}
T2	9.00^{a}	11.33^{a}	12.40^{a}	14.33^{a}	16.33^{a}	18.33^{a}	19.67^{a}	20.67^{a}	21.33^{bc}	22.00^{b}	23.33^{b}	25.33^{d}
T3	10.33^{a}	11.00^{a}	11.67^{a}	14.33^{a}	16.00^{a}	18.33^{a}	21.00^{a}	22.33^{a}	24.00^{ab}	26.00^{a}	28.00^{a}	29.67^{bc}
T4	9.67^{a}	11.00^{a}	12.00^{a}	13.67^{a}	15.33^{a}	18.33^{a}	19.33^{a}	20.33^{a}	21.33^{bc}	22.33^{b}	24.33^{b}	27.00^{cd}
T5	8.67^{a}	11.00^{a}	12.00^{a}	13.33^{a}	14.33^{a}	17.63^{a}	18.33^{a}	19.00^{a}	20.33^{c}	21.67^{b}	23.00^{b}	25.67^{d}
T6	9.00^{a}	9.67^{a}	12.67^{a}	13.00^{a}	14.00^{a}	18.67^{a}	20.67^{a}	23.00^{a}	24.67^{ab}	27.67^{a}	30.00^{a}	32.00^{ab}
T7	10.33^{a}	10.67^{a}	13.00^{a}	14.67^{a}	16.00^{a}	19.00^{a}	21.33^{a}	23.00^{a}	25.00^{a}	27.33^{a}	30.00^{a}	33.00^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

Table 18. Effect of mulching on inter nodal length, cm

MAP / Treatments	1	2	3	4	5	6	7	8	9	10	11	12
T1	2.77^{a}	2.73^{a}	2.66^{a}	2.35^{a}	2.25^{a}	2.13^{a}	2.00^{a}	1.80^{a}	1.60^{a}	1.60^{a}	1.13^{a}	1.13^{a}
T2	3.17^{a}	2.97	2.90^{a}	2.83^{a}	2.70^{a}	2.40^{a}	2.40^{a}	2.20^{a}	1.93^{a}	1.83^{a}	1.66^{a}	1.50^{a}
T3	2.90^{a}	2.87^{a}	2.63^{a}	2.50^{a}	2.40^{a}	2.37^{a}	2.23^{a}	2.10^{a}	1.83^{a}	1.60^{a}	1.40^{a}	1.26^{a}
T4	3.03^{a}	2.77^{a}	2.50^{a}	2.46^{a}	2.36^{a}	2.27^{a}	2.27^{a}	2.07^{a}	1.87^{a}	1.77^{a}	1.57^{a}	1.43^{a}
T5	3.03	2.83^{a}	2.76^{a}	2.63^{a}	2.57^{a}	2.50^{a}	2.37^{a}	2.17^{a}	1.90^{a}	1.77^{a}	1.50	1.43^{a}
T6	3.00^{a}	2.80^{a}	2.60^{a}	2.43^{a}	2.33^{a}	2.30^{a}	2.03^{a}	1.93^{a}	1.80^{a}	1.63^{a}	1.30^{a}	1.03^{a}
T7	2.90^{a}	2.83^{a}	2.53^{a}	2.43	2.33^{a}	2.27^{a}	2.07^{a}	1.87^{a}	1.67^{a}	1.67^{a}	1.30^{a}	1.06^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

Table 19. Effect of mulching on floral characters

Treatments	Days to flowering	Height at flowering (cm)	Number of flowers/node	Fruit set (%)
T1	156.67[a]	87.50[a]	1.13[a]	75.37[c]
T2	149.50[c]	89.50[a]	1.16[a]	76.23[ab]
T3	150.50[bc]	85.83[a]	1.17[a]	75.90[b]
T4	152.00[b]	82.33[a]	1.15[a]	76.53[a]
T5	155.67[a]	86.83[a]	1.17[a]	76.10[b]
T6	145.50[d]	83.50[a]	1.18[a]	75.83[b]
T7	145.50[d]	86.83[a]	1.18[a]	75.87[b]

Treatment means having similar alphabets in superscript, do not differ significantly

Table 20. Effect of mulching on yield attributes

Treatments	Fruit length (cm)	Fruit girth (cm)	Fruit weight (kg)	Fruit volume (ml)	Days taken for maturity	No. of fruits/plant	No. of seeds/fruit	Fruit yield (kg/plant)
T1	17.17[c]	32.33[d]	0.97[b]	756.33[d]	129.50[a]	31.50[d]	516.33[c]	30.55[e]
T2	18.50[b]	32.50[d]	0.98[b]	763.00[d]	127.83[b]	33.83[bc]	525.00[bc]	33.15[d]
T3	20.17[a]	34.17[c]	1.07[b]	952.67[c]	123.83[c]	35.33[ab]	535.00[b]	37.80[ab]
T4	16.83[c]	32.33[d]	1.06[b]	753.00[d]	122.17[cd]	32.67[cd]	521.00[c]	34.66[cd]
T5	18.50[b]	32.50[d]	1.08[b]	763.00[d]	123.17[cd]	33.17[cd]	525.00[bc]	36.08[bc]
T6	18.83[b]	39.50[b]	1.12[a]	1137.00[b]	120.50[e]	36.80[a]	559.67[a]	40.99[a]
T7	18.83[b]	41.83[a]	1.12[a]	1168.67[a]	120.50[e]	36.50[a]	565.00[a]	40.76[a]

Treatment means having similar alphabets in superscript, do not differ significantly

plots took maximum number of days to flowering (156.67 das) followed by T_5 (155.67 days) and both these treatments were statistically on par.

4.2.2.2. Height at Flowering

The treatments did not differ significantly with respect to height at first flowering. T_4 recorded lowest value of 82.33 cm and maximum height at which first flower occurred was in T_2 (89.50 cm).

4.2.2.3. Number of Flowers per Node

The data on the number of flowers per node showed no significant variation among the treatments. The treatment with polythene mulches (T_6 and T_7) had highest number of flowers per node (1.18) followed by T_3 and T_5 (1.17) plants. The lowest value was observed in T_1 (1.13).

4.2.2.4. Sex Ratio of Flowers

The treatments did not differ significantly with respect to the sex ratio and a sex ratio of 2.1 hermaphrodite: 1female plant was observed.

4.2.2.5. Fruit Set (%)

The highest fruit set percentage was noticed in T_4 (76.53 %) followed by T_5 (76.10 %). The lowest fruit set was noted in control plants (75.37 %).

4.2.3. Yield Attributes

Data related to yield attributes are furnished in Table 20.

4.2.3.1. Fruit Size

The highest value for fruit length was observed in T_3 (20.17 cm) which differed significantly from other treatments. The lowest value was given by T_4 (16.83 cm) followed by T_1 (17.17 cm). Regarding fruit girth, T_7 was superior to all other treatments (41.83 cm) followed by T_6 (39.50 cm). The lowest value was registered by T_1 and T_4 (32.33 cm) followed by T_2 and T_5 (32.50 cm); all these treatments being statistically on par.

4.2.3.2. Fruit Weight

Average weight of the fruit was highest in T_6 and T_7 (1.12 kg). The lowest average weight of fruits was recorded in T_1 (0.97 kg) followed by T_2 (0.98 kg), T_4 (1.06 kg) and T_3 (1.07 kg); all these treatments being statistically on par.

4.2.3.3. Fruit Volume

Analysis of data on fruit volume showed significant difference among the treatments. Treatment T_7 (1168.67 ml) registered maximum value for fruit volume followed by T_6 (1137.00 ml). The lowest value of 753.00 ml was recorded in T_4 which was on par with T_1 (756.33 ml), T_2 and T_5 (763.00 ml).

4.2.3.4. Days Taken for Maturity

The treatment T_6 and T_7 took significantly lesser number of days from fruit set to reach harvest maturity (120.50 days). Treatment T_1 (129.50 days) took the longest time for harvest followed by T_2 (127.83 days).

4.2.3.5. Number of Fruits per Plant

The treatment T_6 and T_7 *i.e.* plants mulched with polythene sheets produced significantly higher number of fruits per plant (36.80 and 36.50 respectively) followed by coir pith mulched plants (T_3-35.33). The minimum number of fruits per plant was observed in control plots (T_1-31.50).

4.2.3.6. Number of Seeds per Fruit

Significant difference was observed among the treatments with respect to number of seeds per fruit. Seed number was highest in the treatment T_7 (565.00) followed by T_6 (559.67) but they did not differ significantly. The lowest seed content was recorded in T_1 (516.33) followed by T_4 (521.00) which were statistically on par.

4.2.3.7. Yield per Plant

Yield per plant showed significant difference between treatments. The highest fruit yield was recorded in T_6 (40.99 kg/plant) and T_7 (40.76 kg/plant) *i.e.* plants mulched with biodegradable polythene and black polythene respectively (Plate 7). These treatments were statistically on par. The lowest fruit yield of 30.55 kg per plant was recorded in control plots.

4.2.4. Quality Attributes of Fruits

Effect of treatments on fruit quality parameters such as TSS, acidity, total, reducing and non-reducing sugars of the fruit pulp and shelf life of fruits are presented in Table 21.

4.2.4.1. Total Soluble Solids (TSS)

TSS exhibited significant difference among the treatments. Treatment T_7 recorded maximum TSS (11.67 ^{0}B) and it was on par with T6 (11.56 ^{0}B). The lowest TSS was recorded in fruits from control plots (10.50 ^{0}B) and paddy straw mulch plots (10.63 ^{0}B).

Table 21. Effect of mulching on quality attributes of fruits

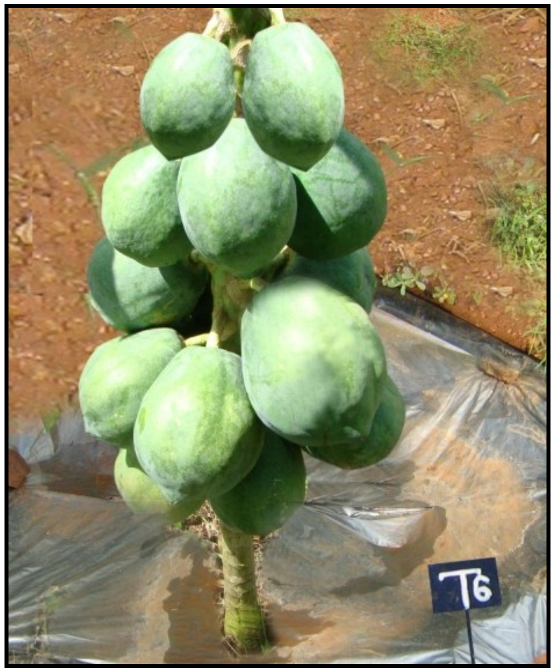
Treatments	TSS (^{0}B)	Reducing sugars (%)	Non reducing sugars (%)	Total sugar (%)	Acidity (%)	Shelf life (in days)
T1	10.50^{d}	7.25^{d}	1.48^{d}	8.73^{d}	0.23^{ab}	7.00^{b}
T2	10.63^{d}	7.68^{c}	2.15^{ab}	9.83^{c}	0.26^{a}	7.13^{ab}
T3	11.03^{b}	8.53^{b}	2.07^{bc}	10.60^{b}	0.23^{ab}	7.23^{a}
T4	10.83^{c}	7.70^{c}	2.39^{a}	10.09^{bc}	0.20^{ab}	7.14^{ab}
T5	10.93^{bc}	7.40^{cd}	1.69^{cd}	9.09^{d}	0.26^{a}	7.15^{ab}
T6	11.56^{a}	9.96^{a}	1.48^{d}	11.44^{a}	0.21^{ab}	7.33^{a}
T7	11.67^{a}	9.40^{a}	2.09^{ab}	11.49^{a}	0.20^{ab}	7.32^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

Table 22. Organoleptic evaluation of fruits

Treatments	Taste	Flavour	Colour	Texture	Overall acceptability
T1	7.56^{b}	7.33^{b}	7.63^{a}	7.77^{a}	30.30^{b}
T2	7.56^{b}	7.33^{b}	7.83^{a}	7.83^{a}	30.57^{b}
T3	7.67^{b}	7.50^{b}	7.90^{a}	7.80^{a}	30.87^{b}
T4	7.87^{b}	7.57^{b}	7.63^{a}	7.53^{a}	30.60^{b}
T5	7.80^{b}	7.70^{b}	7.73^{a}	7.50^{a}	30.73^{b}
T6	8.27^{a}	8.23^{a}	8.10^{a}	7.80^{a}	32.40^{a}
T7	8.27^{a}	8.23^{a}	8.10^{a}	7.80^{a}	32.40^{a}

Treatment means having similar alphabets in superscript, do not differ significantly



T_6 (Biodegradable polythene mulch)

T_7 (Black polythene mulch)

Plate 7. Effect of mulching on fruit yield

4.2.4.2. Acidity

Acidity of the fruits showed significant variation among treatments. The highest acidity of 0.26 per cent was recorded by T_2 and T_5. The lowest value was recorded by T_4 and T_7 (0.20 %).

4.2.4.3. Reducing, Non Reducing and Total Sugars

Significant variation was noticed with respect to total, reducing and non reducing sugar contents among the treatments. The highest value for reducing sugar content was observed in the treatment T_6 (9.96 %) and T_7 (9.40 %). The lowest value was recorded in T_1 (7.25 %).

The maximum value for non-reducing sugar content was recorded by T_4 (2.39 %). T_1 and T_6 recorded significantly lowest value of 1.48 per cent. The treatments T_7 and T_6 recorded maximum total sugar content of 11.49 and 11.44 per cent respectively and T_1 (8.73 %) and T_5 (9.09 %) recorded the least values.

4.2.4.4. Shelf Life of Fruits

Storage life of the fruits exhibited significant difference between the treatments. The highest mean value for shelf life was noted in T_6 (7.33 days), T_7 (7.32 days) and T_3 (7.23 days). The lowest value was observed in T_1 (7.0 days).

4.2.4.5. Organoleptic Evaluation of Fruits

As indicated in the Table 22 there was no significant difference among treatments for colour. However, treatments T_7 and T_6 recorded the highest value of 8.10. The lowest value was recorded by T_4 and T_1 (7.63).

While considering the quality attribute flavour, the highest score was obtained for treatment T_7 (8.23) and T_6 (8.23). The lowest score was recorded in T_1 and T_2

(7.33) followed by T_3 (7.50), T_4 (7.57) and T_5 (7.70); all these treatments were statistically on par.

Various treatments did not show significant difference with regard to the texture of the pulp. Treatment T_2 scored the maximum score (7.83) followed by T_3 (7.80), T_7 (7.80) and T_6 (7.80) while the minimum score was recorded by T_5 (7.50).

The mean score obtained for taste ranged from 7.56 to 8.27. The treatment T_6 and T_7 recorded the highest score (8.27). Treatments T_1 and T_2 recorded the lowest score (7.56) followed by T_3 (7.67), T_5 (7.80) and T_4 (7.87).

A detailed assessment of the organoleptic quality of the treatments indicated that the treatment T_7 and T_6 were most acceptable with a score of 32.40. The least mean score for overall acceptability was obtained for the treatment T_1 (30.30) followed by T_2 (30.57), T_4 (30.60), T_5 (30.73) and T_3 (30.87).

4.2.5. Soil Analysis

The data on nutrient status of soil are presented in Table 23.

4.2.5.1. Organic Matter

Results showed that from the initial value (1.59 %) content of organic matter doubled in all the treatments one year after the experiment period. But there was no significant difference in soil organic matter content among treatments at the final stage and the value ranged from 4.98 per cent (T_2) to 4.82 per cent (T_6).

4.2.5.2. Available N

Available nitrogen content increased in all the treatments with in a period of one year. Significant difference was noted among the treatments. It was highest in T_3

Table 23. Nutrient status of the soil as influenced by different treatments

Treatments	Organic matter (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	pH
T0	1.59[b]	396.7[e]	23.10[h]	110.6[c]	4.5[a]
T1	2.42[a]	411.2[d]	27.05[g]	112.0[c]	4.5[a]
T2	2.48[a]	442.0[a]	30.00[f]	151.0[a]	5.0[a]
T3	2.46[a]	446.0[a]	53.06[a]	161.3[a]	5.0[a]
T4	2.44[a]	429.0[bc]	39.50[d]	143.3[ab]	5.0[a]
T5	2.42[a]	436.0[b]	34.12[e]	151.0[a]	4.4[a]
T6	2.41[a]	421.6[c]	44.32[c]	121.7[bc]	4.3[a]
T7	2.45[a]	412.5[d]	49.03[b]	132.4[abc]	4.3[a]

Treatment means having similar alphabets in superscript, do not differ significantly

(496.0 kg/ha) though it was on par with T_2 (482.0 kg/ha). The treatment T_1 recorded the lowest value of 397.2 kg per ha.

4.2.5.3. Available P

Regarding the available phosphorous content, significantly higher values were observed in all the treatments from the initial stage. T_3 showed the highest value (53.06 kg/ha) followed by T_7 (49.03 kg/ha) were as lowest value was observed in T_1 (27.05 kg/ha) followed by T_2 (30.00 kg/ha).

4.2.5.4. Available K

A significant difference among treatments was seen in the content of available K. It was highest in T_3 (161.3 kg/ha) followed by T_2 and T_5 (151.0 kg/ha). The lowest value of 112.0 kg per hectare was recorded in T_1.

4.2.5.5. pH

There was no significant difference in soil pH among treatments and the values ranged from 4.3 (T_6 and T_7) to 5.0 (T_2 and T_3).

4.2.6. Soil Moisture Content

The soil moisture content at 30 cm depth in papaya plant basin as influenced by various mulch materials is presented in Table 24. Soil moisture content was higher in mulched plots as compared to unmulched (control) plots. The treatments T_6 and T_7 recorded significantly higher soil moisture percentage throughout the growth period. During the first month, significantly higher moisture content was registered by T_7 (16.19 %) followed by T_6 (15.97 %) and T_3 (15.20 %), at three days after irrigation. The lowest value was recorded by T_1 (8.0 %) followed by T_5 (10.85 %).

Table 24. Effect of mulching on soil moisture content, percentage

Treatments	1MAP					2MAP					3MAP				
	1DAI	2DAI	3DAI	4 DAI	5DAI	1DAI	2DAI	3DAI	4 DAI	5DAI	1DAI	2DAI	3DAI	4 DAI	5DAI
T_1	15.75^{e}	12.53^{d}	8.00^{d}	-	-	15.31^{d}	12.75^{e}	7.67^{e}	4.63^{f}	-	15.82^{d}	12.80^{e}	7.63^{d}	4.37^{e}	-
T_2	21.83^{c}	19.15^{b}	13.24^{b}	10.06^{b}	8.00^{b}	21.00^{c}	19.15^{b}	13.53^{c}	10.23^{c}	6.79^{c}	20.66^{c}	17.91^{b}	12.68^{b}	10.30^{b}	6.56^{c}
T_3	23.25^{b}	21.28^{a}	15.20^{a}	11.56^{a}	8.88^{b}	23.37^{b}	21.40^{a}	15.48^{b}	11.19^{b}	8.88^{b}	22.80^{b}	20.85^{a}	15.02^{a}	11.01^{b}	8.63^{b}
T_4	19.93^{d}	16.23^{c}	12.18^{b}	8.63^{c}	4.63^{c}	20.21^{c}	16.50^{c}	12.40^{c}	8.88^{d}	4.63^{d}	20.39^{c}	16.33^{c}	12.17^{b}	8.37^{c}	4.93^{d}
T_5	19.92^{d}	16.21^{c}	10.85^{c}	6.79^{d}	3.63^{d}	19.67^{c}	15.25^{d}	10.77^{d}	6.56^{e}	3.60^{e}	16.62^{d}	14.67^{d}	9.67^{c}	5.67^{d}	-
T_6	26.08^{a}	21.60^{a}	15.97^{a}	12.09^{a}	9.00^{a}	25.81^{a}	21.13^{a}	16.25^{ab}	12.00^{a}	9.37^{a}	25.86^{a}	20.10^{a}	16.50^{a}	12.00^{a}	9.17^{a}
T_7	27.23^{a}	21.12^{a}	16.19^{a}	12.17^{a}	9.00^{a}	26.50^{a}	21.12^{a}	17.13^{a}	12.55^{a}	9.88^{a}	26.95^{a}	20.68^{a}	15.92^{a}	12.18^{a}	9.38^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

DAI – Days after irrigation

Table 24. Effect of mulching on soil moisture content, percentage (continued)

Treatments	4MAP					5MAP					6MAP				
	1DAI	2DAI	3DAI	4DAI	5 DAI	1DAI	2DAI	3DAI	4DAI	5 DAI	1DAI	2DAI	3DAI	4DAI	5 DAI
T_1	15.50^{e}	12.35^{e}	8.05^{d}	3.97^{e}	-	14.95^{e}	12.53^{d}	7.98^{d}	4.17^{c}	-	15.13^{e}	12.30^{e}	7.73^{d}	3.97^{c}	-
T_2	18.92^{d}	15.48^{c}	12.65^{c}	9.90^{b}	5.68^{b}	18.04^{d}	13.57^{d}	11.50^{c}	7.28^{b}	3.24^{d}	16.20^{d}	12.33^{e}	7.95^{d}	4.68^{c}	-
T_3	23.16^{c}	20.95^{b}	14.83^{b}	11.68^{a}	8.44^{a}	22.70^{c}	19.80^{b}	14.17^{b}	11.32^{a}	7.25^{b}	21.69^{b}	19.42^{c}	13.18^{b}	11.34^{a}	7.25^{b}
T_4	19.55^{d}	16.25^{c}	11.81^{c}	8.25^{c}	4.00^{c}	18.68^{d}	15.92^{c}	12.08^{c}	7.92^{b}	4.18^{c}	17.93^{c}	15.77^{d}	11.80^{c}	7.08^{b}	-
T_5	15.21^{e}	13.76^{d}	8.71^{d}	5.18^{d}	-	14.21^{e}	13.17^{d}	8.44^{d}	4.50^{c}	-	15.81^{e}	12.76^{e}	7.80^{d}	4.00^{c}	-
T_6	25.53^{b}	21.80^{a}	16.79^{a}	11.80^{a}	8.91^{a}	25.41^{a}	21.29^{a}	16.32^{a}	12.10^{a}	9.57^{a}	25.89^{a}	21.20^{a}	15.76^{a}	12.12^{a}	9.15^{a}
T_7	26.74^{a}	20.95^{b}	16.93^{a}	11.83^{a}	8.72^{a}	26.59^{b}	21.32^{a}	16.47^{a}	11.94^{a}	9.37^{a}	26.13^{a}	20.47^{b}	15.63^{a}	12.10^{a}	9.37^{a}

Treatment means having similar alphabets in superscript, do not differ significantly

DAI – Days after irrigation

At two MAP T_7 recorded a soil moisture content of 17.13 per cent followed by T_6 (16.25 %), at three days after irrigation. The lowest value was recorded by T_1 (7.67 %). During the third month of planting, T_6 recorded the highest moisture content of 16.5 per cent followed by T_7 (15.92 %), at three days after irrigation. The lowest value was recorded by T_1 (7.63 %).

At four MAP T_7 recorded 16.93 per cent of soil moisture followed by T_6 (16.79 %), at three days after irrigation. The lowest value was recorded by T_1 (8.05%) which was on par with T_5 (8.71 %). During fifth month after planting, the highest moisture content of 16.47 and 16.32 per cent were recorded by T_7 and T_6 respectively, at three days after irrigation. The lowest value was recorded by T_1 (7.98 %) followed by T_5 (8.44 %). At six MAP, there was no significant difference among the treatments T_2 (7.95 %), T_5 (7.80 %) and T_1 (7.73 %). Treatments T_6 and T_7 recorded significantly higher values of 15.76 and 15.63 per cent respectively, at three days after irrigation. On fifth day of irrigation, treatments T_6 and T_7 retained significantly higher soil moisture content throughout the observation period.

4.2.7. Weed Growth

4.2.7.1. Weed Intensity

At all stages of growth treatment T1 (with out any mulch) recorded significantly higher values for weed intensity (Table 25). At three MAP T_1 recorded a mean value of 18.68 per m^2 followed by T_5 (16.16 g/m^2) and both these treatments were statistically different. The lowest value was recorded by T_3 (9.87/m^2). In the polythene mulched plots, weed growth was checked by 100 per cent (Plate 8). So it is not included in analysis of variance.

At six MAP T_1 recorded a weed count of 20.91 per square meter and significantly lower value was recorded by T_3 (12.67/m^2). At nine MAP treatments T_4 (21.57/m^2), T_1 and T_5 (21.50/m^2) were statistically on par and the lowest weed count

Table 25. Effect of mulching on intensity of weeds

Treatments \ MAP	Number of weeds/m^2			
	3	6	9	12
T_1	18.68^a	20.91^a	21.50^a	21.80^a
T_2	13.73^c	19.72^b	21.47^a	21.57^a
T_3	9.87^d	12.67^c	20.63^b	21.07^a
T_4	13.71^c	19.40^b	21.57^a	21.50^a
T_5	16.16^b	19.85^b	21.50^a	21.54^a

Treatment means having similar alphabets in superscript, do not differ significantly

Table 26. Effect of mulching on dry matter production of weeds

Treatments \ MAP	Dry weight of weeds (g/m^2)			
	3	6	9	12
T_1	20.50^a	22.50^a	23.65^a	24.47^a
T_2	15.43^c	20.25^b	23.16^b	24.37^a
T_3	10.90^e	13.89^c	22.51^c	24.26^a
T_4	14.65^d	20.48^b	23.28^b	24.39^a
T_5	17.29^b	20.60^b	23.64^a	24.37^a

Treatment means having similar alphabets in superscript, do not differ significantly

T_6 (Biodegradable polythene mulch)

T_7 (Black polythene mulch)

T_1 (Control)

Plate 8. Effect of mulching on intensity of weeds

was recorded in T_3 (20.63/m^2). A weed count of 21.80 per m^2 was recorded by T_1 at 12 MAP and the lowest value was recorded by T_3 (21.07/m^2) and all the treatments were statistically on par.

4.2.7.2. Dry Matter Production of Weeds

The treatments showed significant difference with respect to the dry weight of weeds at all stages of growth as shown in Table 26. Significantly higher weed dry weight was recorded in treatment T1 (with out any mulch) at all stages of growth.

The weed dry weights of 20.50, 22.50, 23.65 and 24.47 g per m^2 were recorded by T_1 at 3, 6, 9 and 12 MAP respectively. At three MAP T_5 recorded a dry weight of 17.29 g per m^2 followed by T_2 (15.43 g/m^2) and both these treatments were statistically different. The lowest value was recorded by T_3 (10.90 g/m^2) followed by T_4 (14.65 g/m^2).

At six MAP treatments T_5 (20.60 g/m^2), T_4 (20.48 g/m^2) and T_2 (20.25 g/m^2) were statistically on par. T_3 recorded a lowest weed dry weight of 13.89 g per m^2. At nine MAP T_5 recorded a dry weight of 23.64 g per m^2 followed by T_4 (23.28 g/m2), T_2 (23.16 g/m^2) and the lowest value was recorded by T_3 (22.51 g/m^2). At 12 MAP treatments T_4 (24.39 g/m^2), T_2 and T_5 (23.37 g/m^2) and T_3 (23.26 g/m^2) were statistically on par.

4.2.8. Incidence of Pest and Diseases

No major pest and diseases were noticed during the observation period.

4.2.9. Cost of Cultivation

The data presented in the Table 27 and Annexure 1, clearly indicate that among the various mulching treatments, total cost of cultivation was highest in plots mulched with paddy straw (T_2) (Rs. 1,50,267.50/ha). Treatment T_7 incurred a cost of

Rs. 1,31,338.65 per ha whereas it was Rs. 1,27,767.50 per ha in T_6 and T_1 (control) had least cost of cultivation (Rs. 1,12,767.50 /ha).

Table 27. Cost of cultivation per hectare

Treatments	Total cost (Rs./ha)
T_1	1,12,767.50
T_2	1,50,267.50
T_3	1,37,767.50
T_4	1,13,767.50
T_5	1,13,767.50
T_1	1,27,767.50
T_2	1,31,338.65

Discussion

5. DISCUSSION

Papaya *(Carica papaya* L.) is considered as one of the most important and nutritious fruits that has gained commercial importance over the years because of its varied uses. It is easily cultivable, has a short pre bearing period, gives quick returns and adapts itself to diverse soil and climatic conditions. Balanced nutrition combined with sound soil management practices plays a vital role on plant growth, yield and fruit quality. Papaya is a heavy yielder under proper water and nutrient management systems but exposure of the plants to peak summer months affect the growth significantly. Integrated nutrient management can be envisaged which involves inorganic fertilizers, organic manures and plant growth promoting microorganisms. Hence the present study was conducted with the objective of studying the response of organic manures, plant growth promoting microorganisms on growth, yield and quality of papaya (cv. CO 7). Selection of ecofriendly mulch for papaya is also aimed as it saves water and reduces weed growth. The results of the present study with the above objectives are discussed here under:

5.1. EXPERIMENT

5.1.1. Plant Characters

Papaya being a crop with high yield potential due to its precocious bearing and indeterminate growth habit, the assessment of tree growth characters is vital. In this investigation, the plant growth was assessed in terms of plant height, stem girth, number of leaves per plant and internodal length.

The data presented in Table 3 and Figure 1 depicts that there was significant difference among the treatments at all the stages from fourth month onwards with respect to plant height. Recommended dose of fertilizers (NPK-240:240:480 g/plant) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* recorded maximum plant height (245.8 cm) at 12 MAP followed by NPK (POP) +

Fig.1. Effect of organic manures and microbial inoculants on plant height

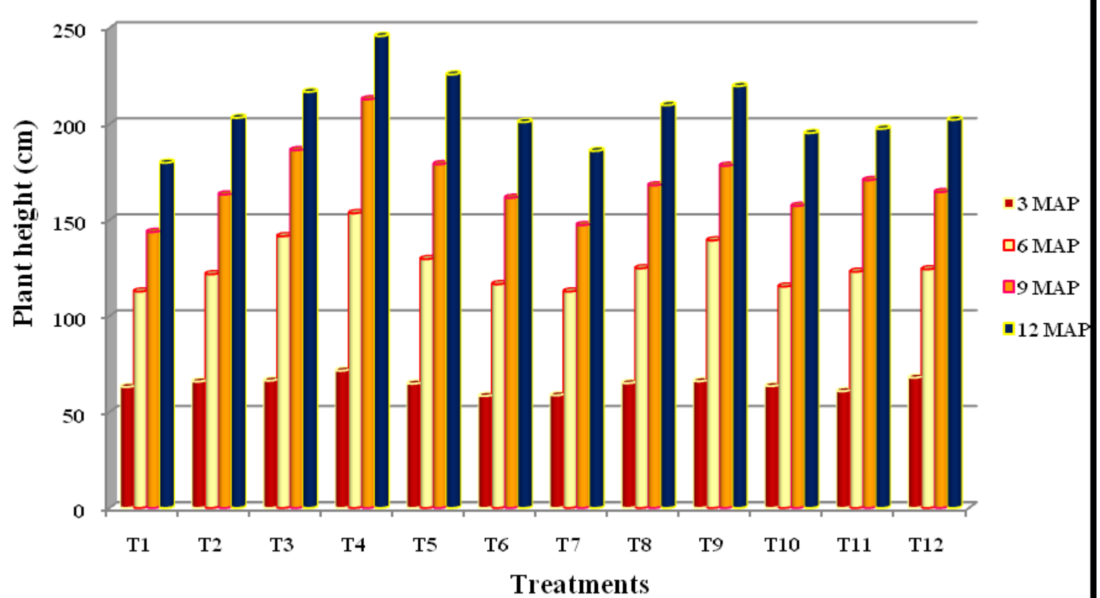
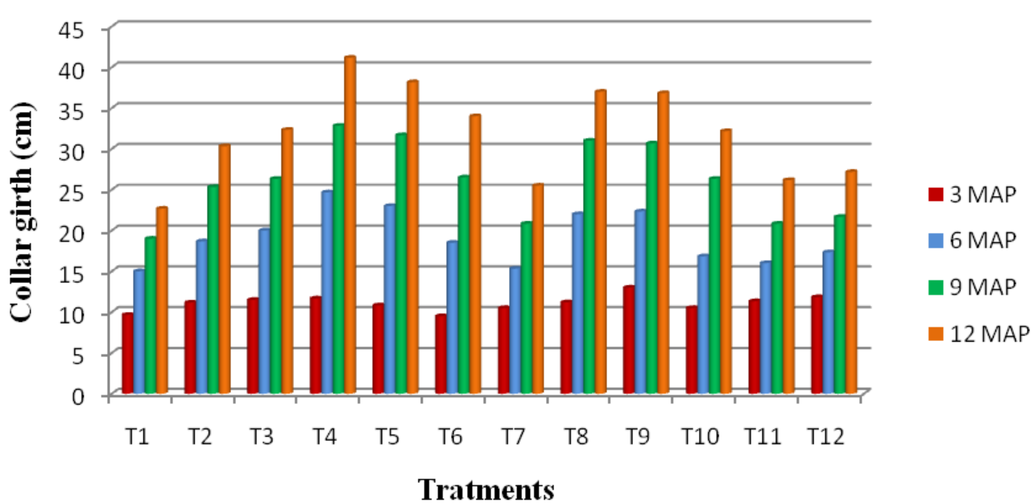


Fig.2. Effect of organic manures and microbial inoculants on collar girth

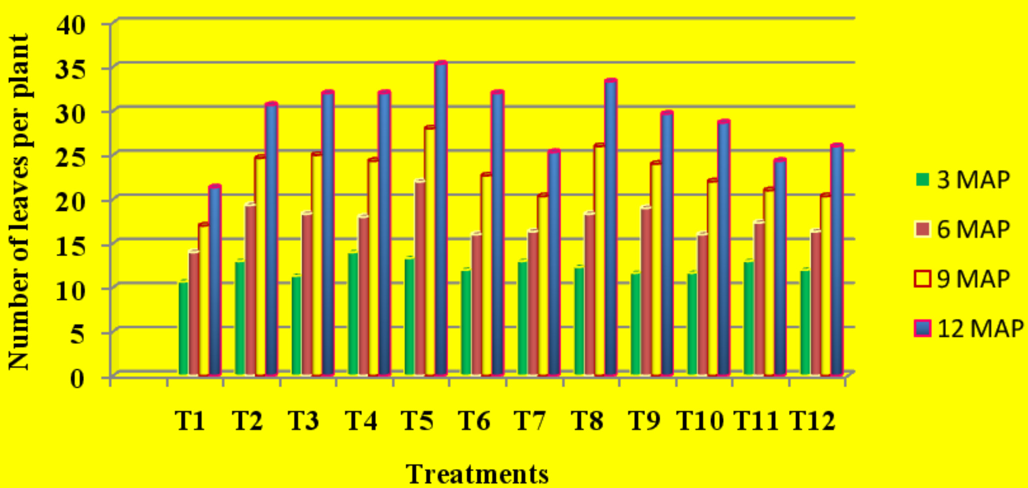


poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* (225.0 cm), which differ significantly from each other. Increased plant height may be due to better uptake and utilisation of major nutrients. Increased plant height with increasing level of nutrients in papaya was also reported by Ravishankar and Karunakaran (2008). Application of organic inputs showed highest response to plant height in papaya which is attributed to the humus content ensuring more release of nitrogen by microbes, regulations of nitrogen supply to the plant and production of plant growth promoters (Babu, 2003).

The beneficial effect of vermicompost was evident in respect of trunk diameter also. The collar girth was significantly higher in the treatment of RDF + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* (41.17 cm) (Figure 2). The increase in stem diameter was due to more uptake and accumulation of nutrients in leaf tissue which in turn ensured the photosynthetic efficiency, causing greater synthesis, translocation and accumulation of carbohydrate (Ghanta *et al*., 1995). Acevedo and Pire (2004) also reported similar increase in stem girth of papaya with vermicompost and N fertilizer. The increase in vegetative growth with increasing levels of nitrogen was because nitrogen is an important constituent of chlorophyll and amino acids. Similar observation has been reported by Jayasundara and Huruggamuwa (2005) and Akinyemi and Akande (2008).

Number of leaves per plant was significantly increased by the treatment of NPK (POP) + poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* and it was 35.33. This was followed by treatment with ½ NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* (33.33) (Figure 3). Increased number of leaves might have produced more photosynthates in plants. It is evident that organic sources of nutrients have beneficial effect on growth and development of papaya (Babu *et al*., 1989). Addition of organic manures to the soil in conjunction with chemical fertilizers and bioinoculants

Fig.3. Effect of organic manures and microbial inoculants on number of leaves per plant



increases the availability of nutrients on long term basis, resulting in favorable effect on plant growth. Amiri *et al.* (2008; 2010) reported about the probiotic effect of microbial inoculants (*viz*; *Trichoderma*, Mycoplex and Mycorrhiza roots) in improving the plant growth parameters at the seedling stage in papaya. Increase in the vegetative growth may be either due to better root growth and root spread or improved nutrient availability to plants.

Internodal length of the plants was found to be positively associated with tree height. In the present study internodal length was non-significant at all stages of growth and the variation in plant height observed might be due to the variation in number of nodes produced. Lim and Hawa (2007) also reported similar results.

5.1.2. Floral Characters

Precocity of flowering and low first flowering height are most desirable traits in papaya. Flowering at lower height facilitates easy harvest of fruits and the total fruit yield is directly correlated with height (Ghanta *et al.,* 1995). Height of the plant at which the first flower appeared was lowest in treatment receiving NPK (POP) + biovermi (85.67cm).

Treatment with NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas* took minimum number of days for first flowering. Rajamanickam *et al.*, (2008) also reported similar results of early flowering with minimum plant height with vermicompost. Early flowering could be attributed to higher availability and uptake of nitrogen, phosphorus and potassium in proper ratio (Rao and Rao, 1978 in CO 1 papaya; Purohit *et al*., 1979 in Coorg Honey Dew papaya; Reddy and Kohli, 1989). Shivaputra *et al.* (2004c) also reported early reproductive phase in papaya with vermicompost + inorganic fertilizers. This was contradictory to the findings of Rajbhar *et al*. (2010), who suggested that lesser nutrient level enhances early flowering in papaya at a lower node.

The present study indicated that the number of flowers per node was more in treatment receiving NPK (POP) + vermicompost (N equivalent to 20 kg FYM) and it was on par with T3, T5, T8, T9 and T11. Earlier reports on the number of flowers per cluster in papaya are very scanty. Singh (1990) has reported that in papaya, the female flowers are borne either solitary or in racemose of five to six. Generally in papaya, only one fruit develops and reaches harvest stage which gives satisfactory yield per plant. It is observed in the present study that percentage of fruit set was highest in plants receiving RDF + poultry manure. It may be due to more number of flower producing leaf axils indicating the relationship between productive leaf axils and number of fruits per plant. It was seen that the treatments which had higher number of leaves had more number of fruits per plant also.

The number of days from flowering to fruit maturity should be less so that total crop duration is not extended unduly. In the present study the lowest time for harvest was recorded in NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* where as maximum number of days to reach harvest maturity was noticed in control treatment.

5.1.3. Yield Attributes

With regard to yield and yield components also, significant differences were noticed due to application of different types of nutrients and biocontrol agents. The number of fruits per plant varied significantly due to the treatments and it ranged from 19.55 to 36.21. The highest number of fruits per plant was recorded in treatment receiving NPK (POP) + poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*, followed by ½ NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*.

Application of organic manures alone registered significantly lesser number of fruits per plant even though it was superior to control. Ray *et al.* (2008) also reported similar results with organic manures in papaya. Present study also suggests the necessity of inorganic fertilizers along with organic nutrients for enhancing the number of fruits in papaya. Fruit length and girth were higher in treatment with NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas.* The volume of fruit which indicates the external size of fruit was also highest with NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* followed by NPK (POP) + poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* (1176.67 ml and1172.00 ml respectively).

The number of seeds per fruit, which may increase with the overall weight of fruit, was found to be affected by various treatments. In the present study highest number of seeds per fruit (644.67) was recorded in NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas.* The seed content was lowest (63.67) in control plots followed by the treatment receiving ½ NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*. This was in agreement with the findings of Sulladmath *et al.* (1981), where combined application of cattle manure with chemical fertilizer reduced the weight of the seeds in most of the fruits.

Significantly higher yield was recorded in NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas* (42.59 kg/plant), which was at par with NPK (POP) + poultry manure + *Trichoderma* + *Pseudomonas* (40.93 kg/plant) (Figure 4). The yield response in this regard was mainly due to the higher average weight of fruits in NPK (POP) + vermicompost + *Trichoderma* + *Pseudomonas*, whereas in NPK (POP) + poultry manure + *Trichoderma* + *Pseudomonas,* it was due to the higher number of fruits per plant. Shivaputra *et al.* (2004c) also got higher yield in papaya with vermicompost + inorganic fertilizers. Similar results were reported in many other fruit crops (Bandyopadhyay, 2009). Zabedah (2001) and Falcao and Borges (2006) obtained higher yield in papaya when poultry manure was used along with inorganic fertilizers.

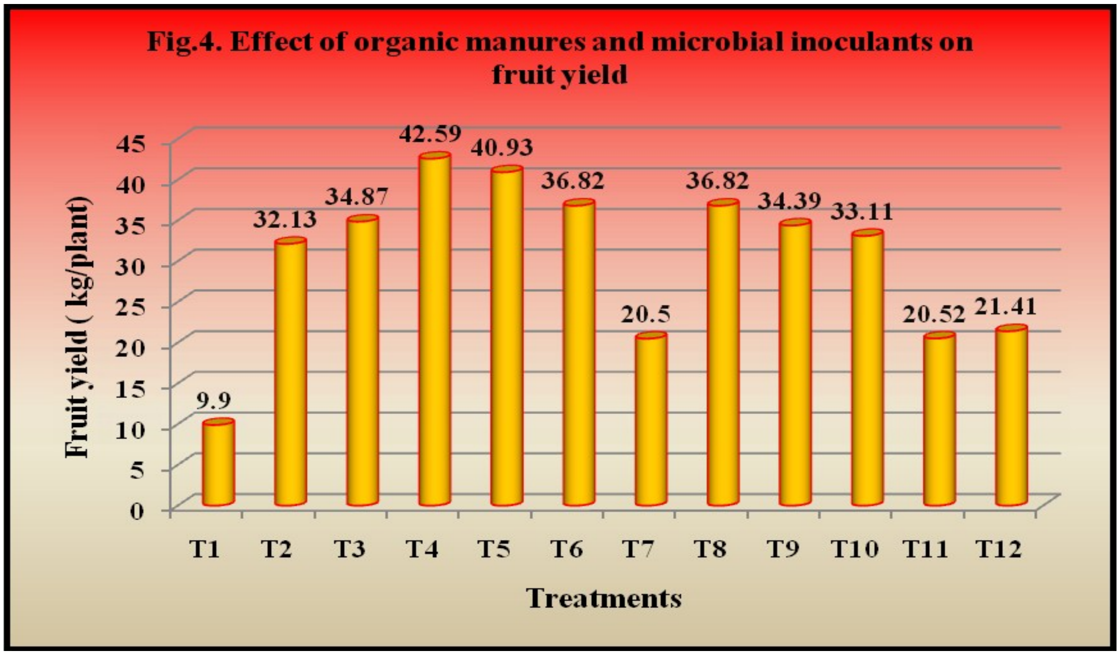


Fig.4. Effect of organic manures and microbial inoculants on fruit yield
Fruit yield (kg/plant)
45
40
35
30
25
20
15
10
5
0
9.9
32.13
34.87
42.59
40.93
36.82
20.5
36.82
34.39
33.11
20.52
21.41
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Treatments

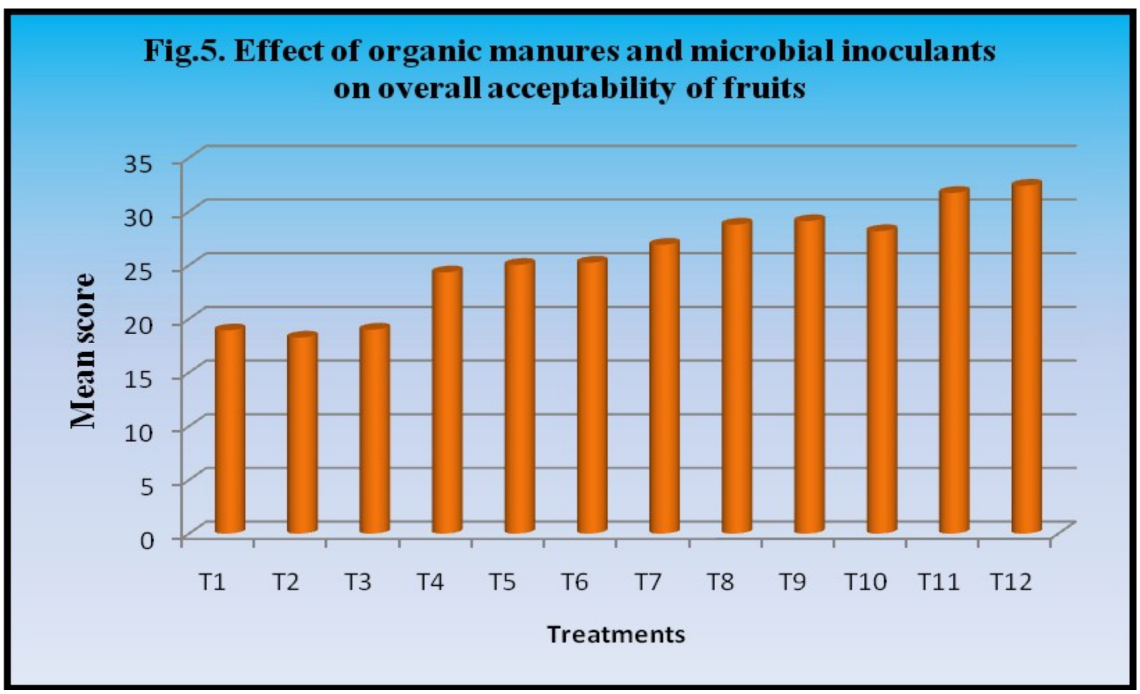


Fig.5. Effect of organic manures and microbial inoculants on overall acceptability of fruits
Mean score
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
Treatments

Increase in these parameters may be attributed to improved growth characters leading to improved yield components. Similar observations were also recorded by Jayasundara and Huruggamuwa (2005) and Jacquiline (2008). The lowest yield was recorded in absolute control (9.9 kg/plant) where no nutrients were applied. Earlier workers reported that in plants receiving no nitrogen, most of the biomass accumulation was in vegetative parts, where as in those receiving nitrogen biomass accumulation in fruits was increased (Reddy and Kohli, 1989).

Awada and Long (1978) and Xianghong *et al*. (2006) reported that higher yield was achievable when organic manure was combined with inorganic NPK fertilizers. This may be due to slow and consisted release of plant nutrients from applied organic manures and thereby ensuring continuous supply of nutrients for better plant growth. Results generated from present study supports these findings. Ochse *et al*. (1961) opined that the productiveness of a papaya plant depended upon its constant growth for which higher rates of fertilizers and organic matter should be applied at frequent intervals. Application of bioinoculants, *viz*; *Trichoderma* and *Pseudomonas* showed positive effects on the growth and yield of plants. Rao (2010) reported that bioinoculants improved soil fertility and helped plant growth by increasing the availability of nutrients and hormones.

The number of days from flowering to fruit maturity should be less so that total crop duration is not extended unduly. In the present study the lowest time for harvest was recorded in NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* where as maximum number of days to reach harvest maturity was noticed in control treatment.

5.1.3. Quality Attributes of Fruits

Significant differences were noticed with regard to quality traits (TSS, total sugar and acidity). Quality parameters of the fruits were found to increase with decreasing level of chemical fertilizers. Fully organic treatments recorded significantly higher values for quality parameters implying its role in improving fruit quality which may be attributed to balanced availability of nutrients leading to enhanced metabolic activities (Patil *et al*., 1995; 1997). The highest percentage of TSS of the fruit pulp was recorded with fully organic (FYM + bone meal + wood ash (equivalent to NPK of POP) + *Trichoderma* + *Pseudomonas* followed by FYM + bone meal + wood ash (equivalent to NPK of POP) alone. This is in conformity with the findings of earlier workers (Rajput and Ram, 1998; Singh and Sharma, 2006). In contrast, total acidity of the fruit pulp decreased with organic manures alone. Similar result was reported by Alexandrescu *et al.* (1978) and Jayasundara and Huruggamuwa (2005).

Reducing sugar and total sugar contents were also highest in treatments with oraganic manures. Non reducing content was highest in NPK (POP) + biovermi (N equivalent to 20 kg FYM) and NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas.* Xianghong *et al*., (2006) also reported similar improvement in the quality of fruits in papaya cv. Eksotika.

Balanced nutrient supply is necessary not only for obtaining higher and regular yields of better quality fruits but also for increasing shelf life of fruits. Increasing shelf life and minimising post harvest losses will go a long way in increasing fruit production indirectly. Shelf life was highest in fully organic treatments. This might be due to higher Ca content in fruits under organic treatments (Garcia *et al.,* 2003; Rajkumar *et al*., 2005; Kirad *et al*., 2010).

The evaluation of organoleptic characters *viz;* colour, flavour, texture, taste and overall acceptability also proved that fruits under fully organic treatments were superior, as explained in Figure 5.

5.1.4. Soil Analysis

Papaya being an exhaustive crop, the soil fertility status as influenced by nutrient application should be considered. Soil properties were also improved by adding organic manures in combination with inorganic fertilizers.

In the present study, the organic matter content of the soil increased significantly following addition of different organic manures and inorganic fertilizers. Different treatments were at par with each other. This implied that application of organic sources of nutrients contributed to the improvement of organic carbon in the soil. This is in conformity with the findings of Yin-Po and Ching (1995) and Ravishankar *et al.* (2008).

Available N content of the soil (Table 10) was highest under NPK (POP) + vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* and NPK (POP) + biovermi (N equivalent to 20 kg FYM). Organic N in natural organic materials is mostly of unstable forms and readily mineralisable but also include stable forms that are resistant to mineralisation *e.g.*, lignin. Composting however stabilizes organic matter in the substrate. A similar increase in organic matter and exchangeable K content in soil were reported by Seripong (1993). Fruit yield is correlated with available N content of soil (Hossain *et al.*, 1990). The lack of response to application of NPK (POP) + FYM (20 kg) and NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas* in the present study is possibly explained by the factor of slow release of N from FYM (Kumar and Goh, 2003).

Application of NPK (POP) + poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas* recorded highest available P content in soil. Similar results have been reported by Jacquiline (2008) and observed a significant correlation between papaya yield and soil available P content (Reddy *et al.*, 1989; Munoz *et al.*, 2004). Available K content of the soil was highest in NPK (POP) + biovermi (N equivalent to 20 kg FYM). Bandyopadhyay, (2009) also reported an improvement in the physico-chemical properties of soil with the application vermicompost along with chemical fertilizers in many crops.

5.1.5. Microbial Population in Soil

In general, microbial population in soil was significantly enhanced (Table 12) due to application of organic manures and bioinoculants over pretreatments samples (T0). Highest population of bacteria and actinomycetes in the soil was observed in treatments with organic manures + bioinoculants where as fungal population was highest in treatment with ½ RDF + biovermi (Figure 6). Treatment with organic manures alone also showed superiority over other treatments. This was in agreement with the findings of earlier workers (Krishnakumar *et al*., 2005; Hangarge *et al*., 2004). Ravishankar *et al.* (2008) recorded a significant positive association between organic matter status and microbial populations (bacteria, fungi and actinomycetes) in the soil.

Lower populations of soil microbes recorded in the present study in pre-treatment samples might be due to limited access to substrates (Killham *et al*., 1993). The results of the present study indicated that the application of organic manures significantly influenced the soil microbial activities which could improve soil health and attain sustainability in papaya production.

Among the various groups of microorganisms studied, bacteria were the most abundant followed by fungi and actinomycetes.

Application of ½ RDF + biovermi and RDF + biovermi recorded higher population *Trichoderma* spp. in the soil (Figure 7). Application of organic manures + bioinoculants and RDF + FYM (with bioinoculants) also showed superiority over other treatments. Fully organic treatments (with bioinoculants) resulted in maximum population of *P. fluorescens* which was at par with ½ RDF + biovermi, RDF +

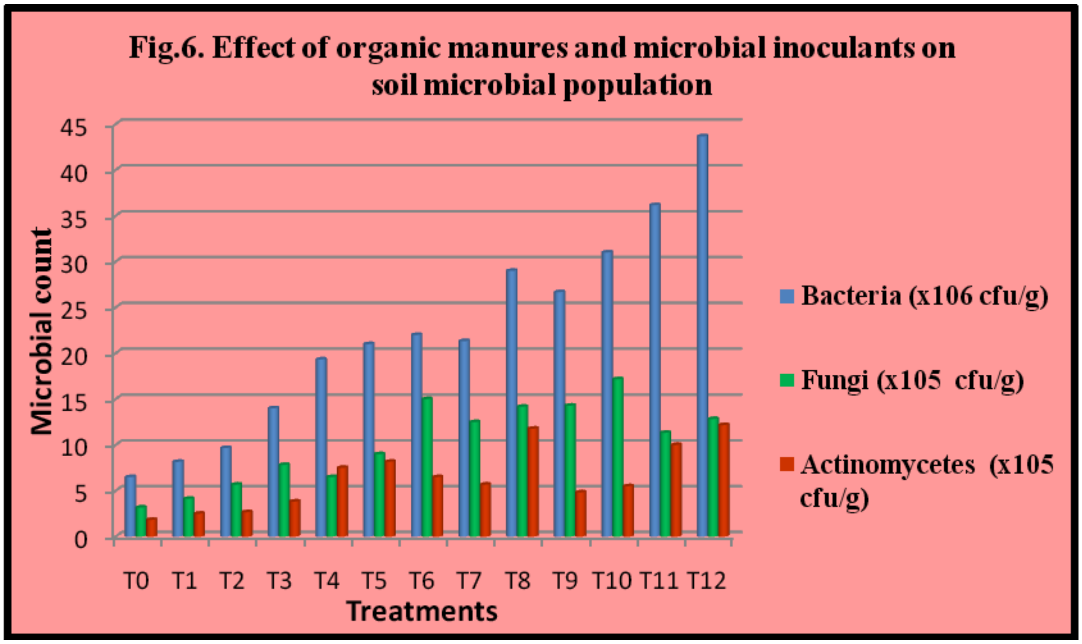


Fig.6. Effect of organic manures and microbial inoculants on soil microbial population
Microbial count
45
40
35
30
25
20
15
10
5
0
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12
Treatments
Bacteria (x106 cfu/g)
Fungi (x105 cfu/g)
Actinomycetes (x105 cfu/g)

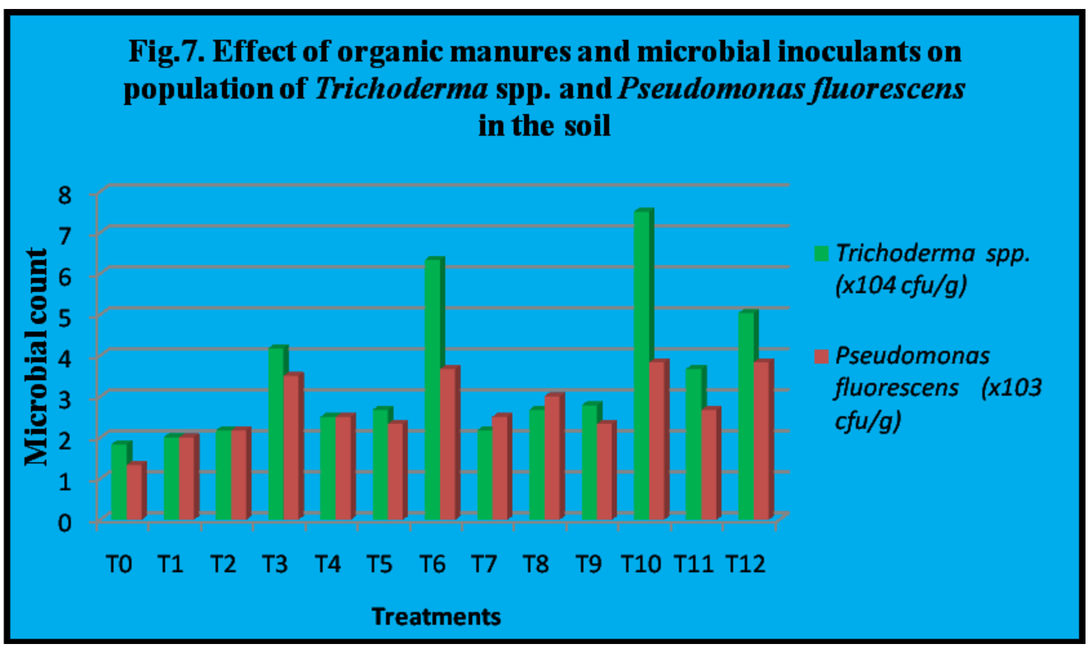


Fig.7. Effect of organic manures and microbial inoculants on population of *Trichoderma* spp. and *Pseudomonas fluorescens* in the soil
Microbial count
8
7
6
5
4
3
2
1
0
T0 T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12
Treatments
Trichoderma spp. (x104 cfu/g)
Pseudomonas fluorescens (x103 cfu/g)

biovermi and RDF + FYM + bioinoculants. The data clearly indicated the positive and favourable effects of application of *Trichoderma* and *Pseudomonas* along with organic manures on soil micro flora. There are reports that these bio-agents did not affect each other's colonisation at the same time organic manures encourage their colonization (Rao, 2010). The present studies support these findings and indicate their competency in the soil.

5.1.6. Incidence of Pest and Diseases

No major pests were observed throughout the period of observation. Incidence of disease like mosaic was noticed, which was very negligible.

5.1.7. Cost of Cultivation

Among the various organic manures tried, unit cost of biovermi (Rs. 10.00/kg) was highest and the treatment with RDF + biovermi registered highest cost per hectare followed by ½ RDF + biovermi. Treatments with vermicompost incurred higher cost next to the above treatments followed by treatments having poultry manure.

5.2. EXPERIMENT II

Papaya is sensitive to growing environment and the changes in the environmental factors severely affect the productivity and quality of fruits. Prolonged moisture stress will slow down the growth and encourage the production of male or sterile flowers which lead to poor fruit set. The crop needs more irrigation during dry periods to maintain its growth and fruit production (Malo and Campbell, 1986). Frequent manuring and irrigation leads to the occurrence of heavy weed population in the plots which will hinder the production potential of papaya plants. With this background, the present study was undertaken to study the effect of mulches on growth, yield and quality of papaya. The selection of ecofriendly mulch for papaya may help the farmers to improve or at least sustain the productivity of papaya.

5.2.1. Plant Characters

The data pertaining to the growth characteristics of papaya presented in the Table 15 to 18 indicate that these parameters were significantly influenced by various mulching treatments over control. The increase in plant height as well as stem girth was recorded highest in black polythene and biodegradable polythene mulch. Polythene mulches maintained a constant growth and vigour of plants and retained their superiority over other mulches and control plants throughout the growth period due to their better efficiency in weed control and moisture conservation. Balerdi (1976) also reported similar increase in growth of papaya with plastic mulch. Similar trend in height and girth of banana by using black polythene was reported by Battacharyya and Rao (1985).

It is evident from Table 14 that mulching increased the number of leaves. Amongst the treatments, black polythene as well as biodegradable polythene registered maximum number of leaves as compared to control. This may be due to the fact that polythene mulch is more efficient in controlling weeds and thus accumulating more amount of nutrient for better growth of plants.

Tree height of papaya, as a single erect-stemmed plant, is influenced by the rate of node production and internodal length. In the present study it was found that there was no significant difference among the treatments with respect to the internodal length. Hence increase in plant might be due to an increase in the number of nodes produced. Similar observations have been reported by Lim and Hawa (2007) in papaya.

The higher soil moisture availability, addition of nutrients and less weed growth associated with polythene mulches can be attributed to higher growth under mulching treatments. Similar result has been reported by Borathkur and Bhattacharya (1992).

5.2.2. Floral Characters

The days taken for first flowering and ripening were significantly earlier in treatments with black polythene as well as biodegradable polythene mulch compared to organic mulches and control. This may be due to the better soil conditions during the early stage resulting to earliness in flowering and fruiting. Aiyelaagbe *et al.* (1986) reported that moisture stress will retard the plant growth and reproductive development in papaya. The present study indicated that various mulching trials had no significant influence on number of flowers per node, even though it was found lowest in control plots. Aiyelaagbe *et al.* (1986) and Masri *et al.* (1990) reported similar results in papaya under moisture deficit condition. There was no significant difference noticed with regard to the height at first flowering. Fruit set (%) was found to be the highest in coconut leaf mulched plots. This may be due to the release of maximum available K in the soil as reported under section 4.2.5.4.

5.2.3. Yield Attributes

Fruit length and diameter was observed to be maximum under coconut coir pith and black polythene mulch respectively which was superior over other treatments and control (without mulch). Increased uptake of nutrients and moisture from conducive soil environment might have produced enough carbohydrate in the leaves for translocation to sink for better filling of fruits which resulted in increased size of fruits. The maximum fruit volume was recorded due to black polythene mulch followed by biodegradable polythene mulch.

Treatments with polythene mulches produced more number of fruits per plants. Lowest number of fruits was recorded in unmulched plots. This may be due to the reduction in the number of flowers produced under water stress condition

(Masri *et al.*, 1990). Average fruit weight was higher in treatments with biodegradable polythene and black polythene and produced significantly higher yield over control. The increase in fruit weight may be due to the higher absorption of nutrients and moisture from the soil by the increasing number of superficial roots, leading to movement of nutrients to sink. Average fruit weight was lowest in control which is attributed to retarded growth and development of papaya fruits under water stress condition (Masri *et al.*, 1990). Number of seeds per fruits was highest in polythene mulched plots which will also contribute to average fruit weight.

Marked increase in fruit yield was also noted due to mulch treatments. Among the organic mulches, fruit yield per plant was highest in plots mulched with coconut coir pith followed by coconut leaf. Other organic mulches studied, *viz;* paddy straw and glyricidia although played a significant role in increasing soil moisture availability, fruit yield per plant was less, but superior to control. This might be due to the fact that during later part of growth, weeds emerged in plots with organic mulch which might have competed with the crop. Biodegradable polythene as well as black polythene mulch exhibited the higher fruit yield (Figure 8) where as lowest fruit yield was observed in control. Similar results with black polythene mulch were reported in papaya (Agrawal *et al*., 2002) and banana (Babu and Sharma, 2003).

5.2.3. Quality Attributes of Fruits

The fruit quality parameters were also influenced by different mulching. Higher TSS and shelf life of fruits were observed in treatment with black polythene mulch followed by biodegradable polythene mulch. Singh and Singh (2005) also reported similar results in papaya. Reducing sugar and total sugar content were highest in treatments with biodegradable polythene mulch. Non reducing sugar content was highest in coconut leaf mulch. Higher value for acidity noted in treatments with paddy straw and glyricidia mulch might be due to the improvement of organic matter content of the soil.

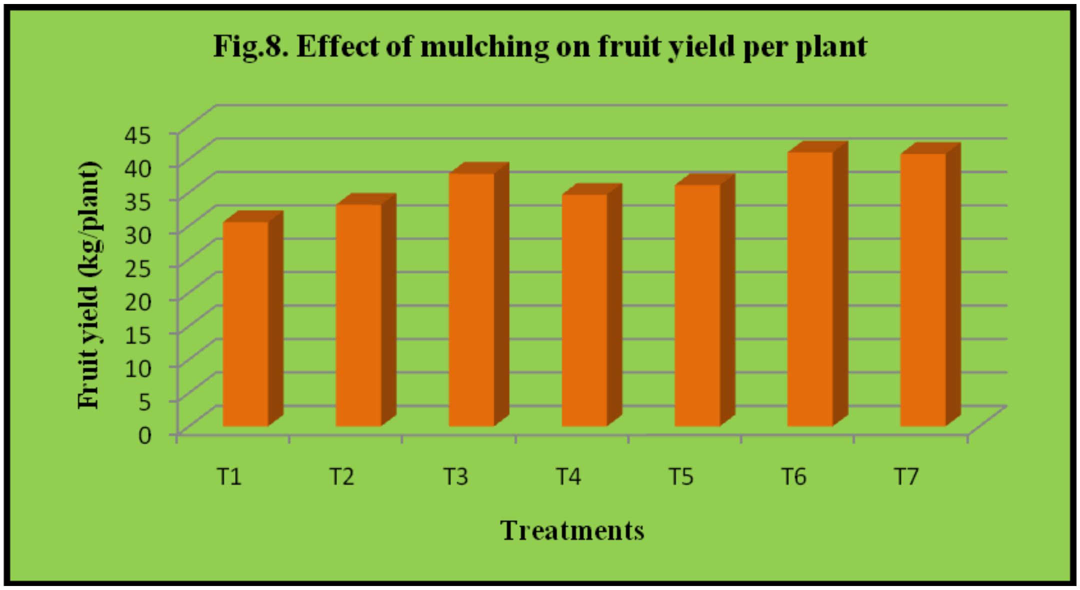


Fig.8. Effect of mulching on fruit yield per plant
Fruit yield (kg/plant)
45
40
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
Treatments

Shelf life of the fruits was highest in polythene mulched plots. Oragnoleptic evaluation of fruits indicated that the treatments with polythene mulches were superior in all the parameters studied *viz;* colour, flavour, taste and texture and overall acceptability and there was no significant difference among organic mulches for these characters.

5.2.4. Soil Analysis

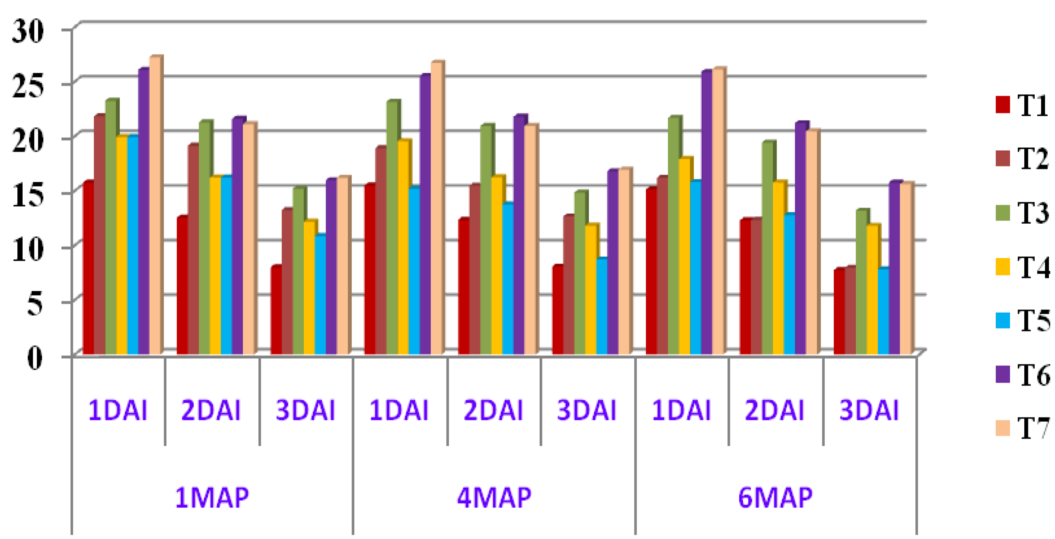
The data on nutritional properties of soil revealed that there was no significant difference in soil organic matter content and pH of soil between treatments. This was in conformity with the findings of Singh *et al*. (2005). Walsh and Ragupathy (2007) reported higher soil organic matter content in papaya orchard with paddy straw mulch. The highest available N content was observed in coir pith mulch which was on par with paddy straw mulch. Available P content in soil was high in treatment with coir pith mulch. Highest value for available k content in soil was observed in treatment with coir pith mulch followed by paddy straw mulch and glyricidia mulch. Savithri *et al*. (1993) reported that application coir pith enhances the release of fixed and mineral K in soil.

5.2.5. Soil Moisture Content

All the treatments enhanced the soil moisture significantly as compared to control. Maximum soil moisture content was recorded with polythene mulches (Figure 9). Minimum soil moisture content was recorded in the basins of control plants. Increased soil moisture content in the polyethylene mulch treatments may be due to increased infiltration capacity and reduced evaporation losses from soil surface.

Higher soil moisture content in these treatments might be due to reduction in soil surface evaporation from mulched basins of plants and the minimum soil

Fig. 9. Effect of mulching on soil moisture content, percentage



moisture in control plot due to higher evaporation from the bare soil surface. Similar observation with black polythene has been reported by Singh and Singh (2005).

The five days irrigation interval was best followed by polythene mulch in respect of vegetative growth of papaya. Beneficial effect of organic mulches in reducing evaporation as reflected by increased moisture storage in soil has been reported by various workers (Sterk and Spaan, 1997; Singh *et al*., 2005; Aswathi *et al.* 2006).

5.2.6. Weed Intensity and Dry Matter Production

Maximum weed intensity and weed dry weight were observed in control (without mulch) (Figure 10; 11). Black polyethylene and biodegradable polythene mulch were most effective in suppressing the weeds. Balerdi (1976) and Singh and Singh (2005) also reported similar results of 100 per cent weed control in papaya with polythene mulch. The low transmittance of visible light, especially photosynthetically active radiation results in the inhibition of weed growth (Singh *et al.,* 2008).

5.2.7. Incidence of pest and diseases

No major pest and diseases were observed throughout the observation period.

5.2.7. Cost of Cultivation

Cost of cultivation was lowest in treatments T_6 and T_7 compared to paddy straw and coir pith mulches.

Fig.10. Effect of mulching on intensity of weeds

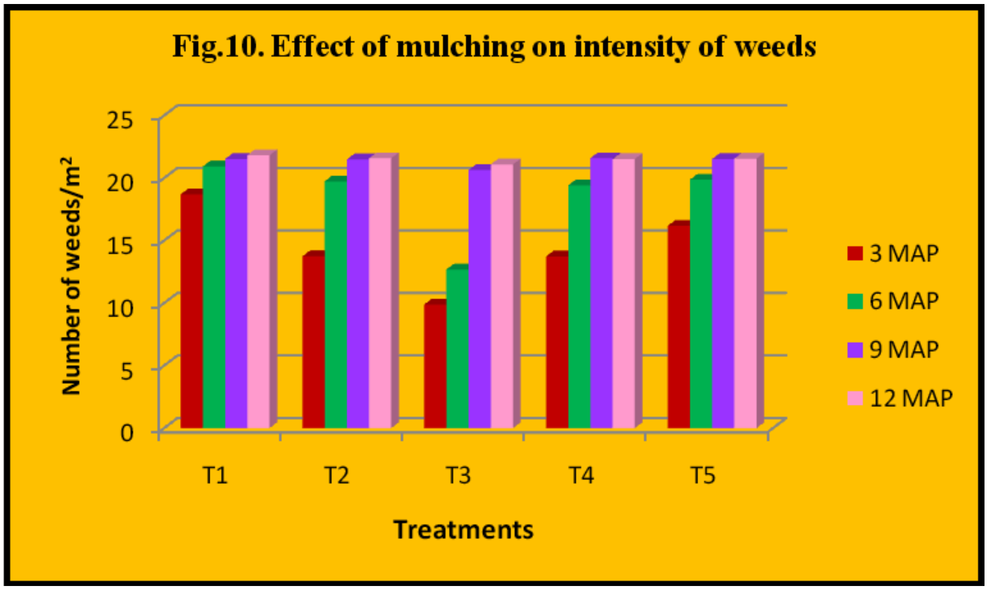
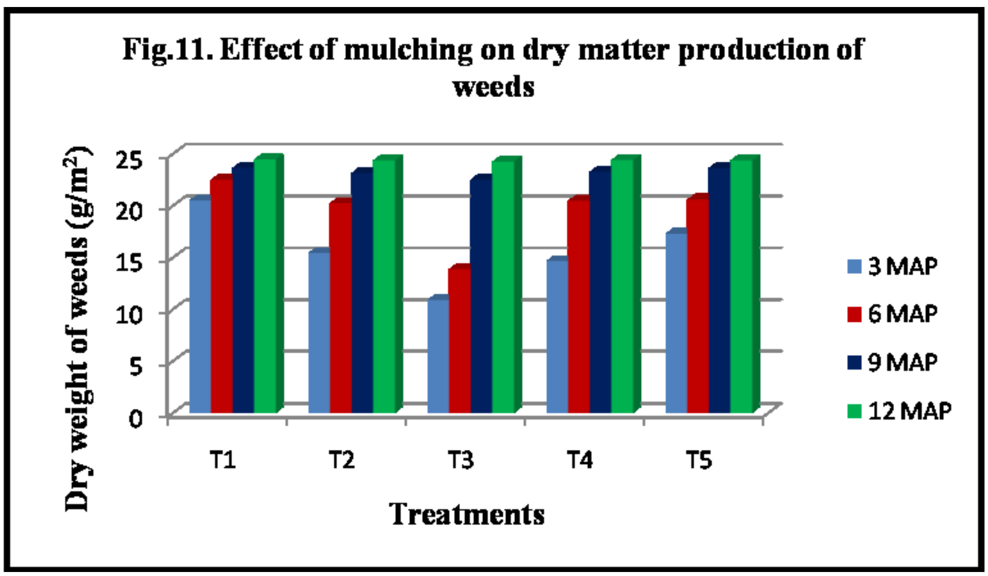


Fig.11. Effect of mulching on dry matter production of weeds



Summary

SUMMARY

The present investigations on “Response of papaya to organic manures, plant growth promoting microorganisms and mulching” was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Thrissur during 2008 – 2010, to study the effect of organic manures, plant growth promoting microorganisms and mulching on growth, yield and quality of papaya cv. CO 7, under Kerala conditions. The study also aimed at standardisation of optimum nutrient combination and selection of ecofriendly mulch suitable for papaya. During the course of the study, plant growth, yield and quality of the produce under different treatments were critically observed. The salient findings of the study are summarized below:

Experiment I consisted of 12 treatments which were the combinations of organic manures, growth promoting microorganisms along with inorganic fertilizers and without inorganic fertilizers.

- Vegetative parameters like plant height and stem girth were found to be significantly improved in T_4 (RDF + vermicompost + *Trichoderma* + *Pseudomonas*) followed by T_5 (RDF + poultry manure + *Trichoderma* + *Pseudomonas*). Treatments T_8 (½ NPK + vermicompost + *Trichoderma* + *Pseudomonas*) and T_9 (½ NPK + poultry manure + *Trichoderma* + *Pseudomonas*) also exhibited superiority in terms of stem girth.

- Treatment T_5 (RDF + poultry manure + *Trichoderma* + *Pseudomonas*) recorded highest number of leaves per plant. No significant variation was noticed with respect to the internodal length.

- Plants manured with RDF, vermicompost and biocontorl agents (T_4) took minimum number of days for first flowering where as the lowest height at which first flowering occurred was in T_6 (RDF + biovermi) followed by T_4. Treatments T_3, T_4, T_5, T_8, T_9 and T_{11} had highest number of flowers per node.

- Among the yield attributes, fruit size, fruit weight, fruit volume and number of seeds per fruit were highest in plants receiving RDF, vermicompost and biocontrol agents (T_4). In all these parameters T5 (RDF + poultry manure + *Trichoderma* + *Pseudomonas*) also recorded superiority next to T_4. The treatment T_5 produced highest number of fruits per plant followed by T_8 where as total fruit yield per plant was highest in T_4 followed by T_5. The lowest time to reach harvest maturity was recorded in T_4.

- Regarding the quality attributes, TSS, total and reducing sugar content and shelf life were highest in fully organic treatments (T_{12} and T_{11}). Non reducing sugar content was highest in T6 (RDF + biovermi). The highest acidity was recorded by T_1 (Absolute control).

- Colour, flavor, texture, taste and overall acceptability were highest for T_{12} followed by T_{11}.

- There was a significant increase in the soil organic matter content irrespective of the treatments. Soil analysis revealed the superiority of T_4 and T_6 in terms of available N. Available P contents in soil was highest in T_5 followed by T_4 where as available K content and soil pH was highest in T_6 followed by T_4.

- Population of bacteria and actinomycetes in the soil was highest in T_{12} (organic manures + bioinoculants) where as highest fungal population was recorded in T_{10} (½ NPK + biovermi).

- Highest population of *Trichoderma* spp. and *Pseudomonas fluorescens* was recorded in T_{10} (1/2 RDF + biovermi)

- Regarding the cost of cultivation, application of biovermi incurred highest cost per ha.

Experiment II consisted of seven treatments with various mulching materials.

- A marked improvement in vegetative characters like plant height, number of leaves and stem girth were observed in T_7 (black polythene) and T_6 (biodegradable polythene). Internodal length was also lowest in T_6 and T_7.

- The treatments T_6 and T_7 took minimum number of days for first flowering and recorded maximum number of flowers per node. Lowest height at which first flowering occurred was in plants mulched with coconut leaves (T_4) followed by T_6.

- Regarding the yield attributes, fruit length was highest in T_3 (coir pith mulch). T_6 and T_7 also exhibited superiority in terms of fruit length. Significantly higher values for fruit girth, average fruit weight, fruit volume and number of seeds per fruit and lowest time to reach harvest maturity were observed in T_7 followed by T_6. The treatment T_6 produced highest number of fruits per plant and the highest fruit yield followed by T_7.

- Quality attributes like TSS, total sugar and reducing sugar contents and shelf life were significantly improved by T_7 and T_6. The highest acidity was recorded by T_2 and T_5. Maximum value for non-reducing sugar content was observed in T_4.

- As far as organoleptic qualities are concerned, T_7 and T_6 had positive influence on colour, flavour, taste and overall acceptability of ripe fruits. T_2 scored the maximum score for texture.

- There was a significant increase in the soil organic matter content irrespective of the treatments. Available N and K content in the soil were highest in T_3 and T_2 where as available P in soil was highest in T_3.

- Soil moisture retention was highest in T_7 and T_6 throughout the study period and irrigation was scheduled at five days interval.

- There was no weed growth in T_6 and T_7 throughout the study period. Hence the weed intensity and dry weight of weeds were least in these treatments.

- With respect to cost of cultivation also treatments T_6 and T_7 were superior.

References

REFERENCES

Acevedo, I.C. and Pire, R. 2004. Effects of vermicompost added to a substrate on the growth of pawpaw (*Carica papaya* L.). *Interciencia.* 29(5): 274-279

Agrawal, N. and Agrawal, S. 2005. Effect of drip irrigation and mulch on the growth and yield of banana cv. Dwarf Cavendish. *Indian J. Hort*. 62(3): 238-240

Agrawal, N., Dubey, P., Sharma, H.G. and Dixit, A. 2002. Effect of irrigation and mulches on the growth and yield of papaya. *Pl. Archives*. 2(2): 197-202

Aiyelaagbe, I.O.O., Fawusi, M.O.A. and Babalola, O. 1986. Growth, development and yield of papaw (*Carica papaya* L.) 'Homestead Selection' in response to soil moisture stress. *Pl. Soil.* 93(3): 427-435

Akinyemi, S.O.S. and Akande, M.O. 2008. Effect of organic and inorganic fertilizers on growth and yield of papaya (*Carica papaya* L.). In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.96

Akinyemi, S.O.S., Makinde, J.O., Aiyelaagbe, I.O.O., Tairu, F.M. and Falohun, O.O. 2006. Growth, yield and productivity response of 'Sunrise Solo' papaya to weed management strategies. *Biological Agric. Hort*. 23(4): 383-392

Alexandrescu, I., Popa, C. and Baciu, M. 1978. Effect of organic and chemical fertilizer on growth, yield and quality of selected fruits. *Riv. Hort. Vitic*. 4: 295-307

Allan, P. 2002. *Carica papaya* Responses under Cool Subtropical Growth Conditions. In: Drew, R. (ed.), *Proceedings of the International Symposium on Tropical and Subtropical Fruits.* pp.757-763

Allan, P. 2007. Phenology and Production of *Carica papaya* 'Honey Gold' under cool subtropical conditions. *Acta Hort*. 740: 217-224

Allan, P., Taylor, N.J. and Dicks, H.M. 2000. Fetilization of 'Solo' papayas with nitrogen, phosphorous and potassium. *Acta Hort*. 511: 27-34

Almida, F.T., Bernado, S., De-Sousa, E.F., Marin, S.L.D. and Grippa, S. 2003. Growth and yield of papaya under irrigation. *Scientia Agricola.* 60(3): 419-424

Amiri, A.W., Shyamalamma, S. and Gowda, V.N. 2008. Effect of bio-inoculants on growth and performance of papaya (cv.Solo) seedlings in the nursery. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.95

Amiri, A.W., Shyamalamma, S. and Gowda, V.N. 2010. Effect of bio-inoculants on growth and performance of papaya (cv. Solo) seedlings in the nursery. *Acta Hort*. 851: 389-394

Andrade-Rodriguez, M., Ayala-Hernandez, J.J., Alia-Tejacal, I., Rodriguez-Mendoza, H., Acosta-Duran, C.M. and Lopez-Martinez, V. 2008. Effect of germination promoters and substrates in the development of papaya seedlings. *Revista de la Facultad de Agronomia, Universidad del Zulia*. 25(4): 617-635

Anilkumar, A.S., Nair, K.H. and Sherief, A.K. 2007. Utilization of enriched coir pith-vermicompost in organic mediculture. *Pl. Archives*. 7(2): 617-620

[Anonymous]. 2008. *Annual Report* 2008-2009. *Technical Doc. No. 94.* AICRP and ICAR-Hoc Schemes on tropical fruits. IIHR, Banglore. 102p.

Anoop, N.C. 2009. Micro irrigation and polythene mulching in oriental pickling melon (*Cucumis melo* var. *conomon* (L.) Makino). MSc.(Agri.) thesis, Kerala Agricultural University, Thrissur. 96p.

A.O.A.C. 1975. *Official and Tentative Methods of Analysis.* (12th ed). Association of Official Analytical Chemists. Washington, D.C., USA. pp.76

Araujo, W.B.M., de Alencar, R.D., Mendonca, V., Medeiros, E.V., de Andrade, R.C. and Araujo, R.R. 2010. Goat manure used in substrate composition for formation of papaya seedlings. *Ciencia e Agrotecnologia*. 34(1): 68-73

Aryantha, I.N.P., Cross, R. and Guest, D.I. 2000. Suppression of *Phytophthora cinnamomi* in potting mixes amended with uncomposted and composted animal manures. *Phytopathol.* 90: 775-782

Aseri, G.K., Rao, A.V. and Meghwal, P.R. 2005. Rhizosphere enzymes: an index to detect changes in the microbial functioning in soil around fruit plants as affected by bio-inoculants. *Indian J. Hort*. 62(4): 398-401

Aswathi, O.P., Singh, I.S. and Sharma, B.D. 2006. Effect of mulch on soil-hydrothermal regimes, growth and fruit yield of brinjal under arid conditions. *Indian J. Hort*. 63(2): 192-194

Athani, S.I., Revanappa and Dharmatti, P.R. 2009. Influence of organic fertilizer doses and vermicompost on growth and yield of banana. *Karnataka J. Agric. Sci*. 22(1): 147- 150

Auxcilia, J., Balamohan, T.N., Nalina, L., Manoranjitham, S.K. and Jeyakumar, P. 2008a. Standardisation of stagewise nutrient requirement for papaya var. CO 2. In:Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.99

Auxcilia, J. and Sathiamoorthy, S. 1999. Effect of nitrogen, paclobutrazole (PP 333) and human hair-derived aminoacid on fruit yield and yield attributing characters in papaya var. CO 2. *S. Indian. Hort*. 47(1-6): 12-16

Auxcilia, J. and Sathiamoorthy, S. 2001. Human hair derived amino acid as an organic substitute for nitrogen in papaya. *S. Indian Hort.* 49(Special): 214-215

Awada, M. and Long, C. 1978. Relation of nitrogen and phosphorous fertilization to fruiting and petiole composition of Solo papaya. *J. Amer. Soc. Hort. Sci.* 103: 217-219

Awada, M. and Long, C. 1980. Nitrogen and potassium fertilization effects on fruiting and petiole composition of 24-to 48- month old papaya plants. *J. Amer. Soc. Hort. Sci.* 105(4): 505- 507

Babu, N. 2003. Effect of organic inputs and potassium on growth and yield of CO 5 papaya (*Carica papaya*). *Indian J. Agric. Sci*. 73(4): 212-214

Babu, N. and Sharma, A. 2003. Effect of weed management practices on the nutrient uptake of banana and its associated weeds under foot hills of Nagaland. *Ann. Agric. Res*. 24(1): 35-36

Babu, R.L., Mohandas, S., Veerannah, L. and Nagarajan, M. 1989. Leaf area in relation to petiole length in papaya. *S. Indian Hort*. 26: 103-107

Baiju, E.C., Chandrasekhara, U.M., Sabu, R. and Sujatha, M.P. 2010. Decomposition and nutrient release pattern in a traditional system of mulching in Kerala. In: (eds.), *Proceedings of the 22nd Kerala Science Congress*; 28-31 January, 2010, Peechi, Kerala State Committee on Science, Technology and Environment, Government of Kerala. pp.39-40

Balamohan, T.N., Auxcilia, J. and Jeyakumar, P. 2008. Planting and aftercare in papaya. In: Souvenir*, Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.35-37

Balasubramaniam, S. and Rao, V.N.M. 1988. Water requirement of Co.2 papaya in sandy loam soils. *S. Indian Hort*. 36(3): 141-142

Balerdi, C.F. 1976. Plastic and hay mulches for tropical fruit crops: observations and economics. *Proc. Fla. St. Hort. Soc*. 89: 234-236

Bandyopadhyay, P.K.S.K.A.G.K.B., 2009. Soil health management by applying vermicompost prepared from organic waste. *J. Interacademicia*. 13(4): 412-417

Banos-Guevara, P.E., Zavaleta-Mejia, E., Teresa-Colinas-Leon, M., Luna-Romero, I. and Gutierrez-Alonso, J.G. 2004. Biological control of *Colletotrichum gloeosporioides* ((Penz.) Penz. and Sacc.) on papaya Maradol Roja (*Carica papaya* L.) and postharvest physiology of infected fruits. *Revista Mexicana-de-Fitopatologia.* 22(2): 198-205

Basso-Figuere, C., Sachaffer, B., Crane, J.H., Colls, A.M. and Bryan, H.H. 1994. Effect of municipal solid waste compost and trench depth on papaya (*Carica papaya* L.) yield and fruit quality. *Proc. Fla. St. Hort. Soc*. 107: 334-337

Battacharyya, R.K. and Rao, V.N.M. 1985. Soil cover increases banana production. *Indian Hort*. 30: 58

Bertuzzi, S.M., Rodriguez, V.A. and Mazza-de-Gaiad, S.M. 1996. Response of pawpaw (*Carica papaya*) to application of nitrogen, phosphorus and potassium on a sandy soil in north-western Corrientes. *Horticultura Argentina.* 15(38): 62-66

Bindu, B. 2003. Response of papaya (Carica papaya L.) to major mineral nutrients. MSc(Hort.) thesis, Kerala Agricultural University, Thrissur. 153p.

Biswas, B., Sen, S.K. and Maiti, S.C. 1981. Effect of different levels of N, P and K on growth, yield and fruit quality in papaya. In: *National Symposium on Tropical and Subtropical fruit crops*, Banglore. pp.54

Biswas, B., Sen, S.K. and Maiti, S.C. 1989. Effect of different levels of nitrogen and potassium on growth, yield and quality of papaya var. Ranchi. *Haryana J. Hort. Sci*. 18(3-4): 197-203

Biswas, R.K., Rana, S.K. and Mallick, S. 1999. Performance of drip irrigation in papaya cultivation in new alluvium agro-climatic zone of West Bengal. *Ann. Agric. Res*. 20(1): 116-117

Borathkur, P.K. and Bhattacharya, R.K. 1992. Organic mulches in guava orchards. *Indian Hort.* 37: 43-44

Borges-Gomez, L., Soria-Fregoso, M. and Ruz-Febles, N. 2003. Macronutrient content in sisal and pig manure substrates and their effects on development of papaya seedlings in nursery. *Revista Chapingo Serie Horticultura*. 9(2): 291-304

Bougnom, B.P., Mair, J., Etoa, F.X. and Insam, H. 2009. Composts with wood ash : a risk or a chance for ameliorating acid tropical soils? *Geoderma*. 153(3/4): 402-407

Bray, K.H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorous in soils. *Soil Sci.* 59: 39-45

Buenzo-Jaquez, J.E., Alonso-Lopez, A., Volke-Haller, V., Gallardo-Lopez, F., Ojeda-Ramierz, M.M. and Mozquada-Vazquez, R. 2005. Response of papaya tree to nitrogen, phosphorous and potassium fertilization in a Luvisol. *Hort. Sci. Abtsr*. 75(9): 1213

Canesin, Simao, R.C.F. and Correa. 2006. The use of manure associated with mineral fertilization in papaya (*Carica papaya* L.) seedling production. *Rev. Bras-Fruitic*. [on line]. 28(3): 481-486. Available: http://www.scielo.br/scielo.php?pid=S010029452006000300031&script=sci_abstract. ISSN. 0100-2945. [22 April 2010]

Cardenas, J.C.G., Garcia, J.M.M. and Acosta, A.G. 2005. Antagonistic comparison of *Trichoderma* spp. against *Fusarium oxysporum*, causal agent of damping off of seedlings in papaya in Tuxpan, Veracruz, Mexico. *Revista Cientifica Agricola*. 5(1): 45-47

Carvalho, J.E.B., Lopes, L.C., Araujo, A.M.D., Souza, L.S. and Caldas, R.C. 2003. Integrated control of weeds of papaya and their effect on the physical properties of soils of the coastal plateau. *ComunicadoTecnico Embrapa Mandioca-e-Fruticultura.* 83: 4

Chagas, P.R.R., Tokeshi, H. and Alves, M.C. 2000. Diagnosis of flowers and fruits dehiscence in papaya Formosa and Hawaii. In: *IFOAM: the world grows organic.* Proceedings 13th International IFOAM Scientific Conference, 28-31 August, 2000; Basel, Switzerland. pp.276

Chundwat, B.S. 1979. *Nutrient Management in Fruit Crops*. Agrotech Publishing Academy, Udaipur. 312p.

CIMMYT [International Maize and Wheat Improvement Centre]. 2006. *Food security in Bangladesh: Improving wheat, maize and papaya production and impact of arsenic contamination*. October- December, 2006; Fifth quarterly activity report No.2. 15p.

Conway, K.E., McCraw, B.D., Motes, J.E. and Sherwood, J.L. 1989. Evaluation of mulches and row covers to delay virus diseases and their effects on yield of yellow squash. *Appl. Agric. Res.* 4(3): 201-207

Cripps, R. and Allan, P. 1997. Effects of N, P and K on 'Honey Gold' papaws. *J. Southern Afr. S. Hort. Sci*. 7(2): 62-64

Cruz, J.L., Coelho, E.F., Pelacani, C.R., Coelho-Filho, M.A., Dias, A.T. and Santos, M.T. 2004. Growth and dry matter and carbon partition in papaya plants in response to nitrogen nutrition. *Bragantia*. 63(3): 351-361

Cruz, J.L., Pelacani, C.R., Carvalho, J.E.B.de, Souza-Filho, L.F.S. and Queiroz, D.C. 2007. Nitrogen levels and photosynthetic rate of papaya 'Golden'. *Ciencia Rural*. 37(1): 64-71

Desoky, I.M., Riad, M. and Belatus, E.L. 2001. Influence of Effective microorganisms on growth and fruit characteristics of papaya in Egypt. Sixth International Conference on Kyusei Nature Farming. In: *Proceedings of the conference on greater productivity and a cleaner environment through Kyusei Nature Farming,* 28-31 October, 2001, University of Pretoria, Pretoria, South Africa. pp.312-316

Devi, L.S. and Richa-Sharma, 2002. Effect of *Trichoderma* spp. against root-knot nematode *Meloidogyne incognita* on tomato. *Indian J. Nematology*. 32(2): 227-228

Dhingra and Sinclair, 1995. *Basic Plant Pathology Methods* (2nd ed.) CRC press, Florida, 435p.

Dutta, P., Kundu, S. and Chatterjee, S. 2008. Effect of biofertilizers on homestead fruit production of papaya cv. Ranchi. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*; 9-12 December, 2008, TNAU, Coimbatore, India. pp.94

Elder, R.J., Reid, D.J., Macload, W.N.B. and Gillespie, R.L. 2002. Post-ratoon growth and yield of three hybrid papayas (*Carica papaya* L.) under mulched and bare ground conditions. *J. Exp. Agric*. 42(1): 71-81

Eswaran, A. and Manivannan, K. 2007. Effect of foliar application of lignite fly ash on the management of papaya leaf curl disease. *Acta Hort*. 740: 271-275

Falcao, N.P.S. and Borges, L.F. 2006. Effect of Amazonian dark earth fertility on nutritional status and fruit production of papaya (*Carica papaya* L.) in Central Amazonia. *Acta Amazonica*. 36(4): 401-406

Garcia, E.J.L., Saucedo-Veloz, C., Martinez-Damian, M.T., Martinez-Garza, A., Sanchez-Garcia, P. and Soto-Hernandez, R.M. 2003. Organic, mineral and foliar fertilization on development and production of papaya cv. Maradol. *Terra.* 21(2): 157-166

Garcia, F.C.H., Bezerra, F.M.L. and Freitas, C.A.S. 2007. Effect of irrigation levels on the yield of papaya (group Formosa) in the Plateau of Apodi, CE. *Revista Ciencia Agronomica.* 38(2): 136-141

Geetha, D., Suharban, M., Vijayan, M. and Pramod, R. 2005. Coir pith compost for increasing banana crop production efficiency. *Indian Cocon. J*. 35(9): 7-9

Ghanta, P.K., Dhua, R.S. and Mitra, S.K. 1995. Effect of varying levels of nitrogen, phosphorus and potassium on growth, yield and quality of papaya (*Carica papaya* L.). *Ann. Agric. Res.* 16(4): 405-408

Ghosh, S.N. and Tarai, R.K. 2007. Effect of NPK on yield and quality of papaya in laterite soils. *Indian J. Fertil.* 3(5): 47-49

Goenaga, R., Rivera, E. and Almodovar, C. 2004. Yield of papaya irrigated with fractions of Class A pan evaporation in a semi-arid environment. *J. Agric. Univ. Puerto Rico*. 88(1/2): 1-10

Gomes-Filho, A., Oliveira, J.G., Viana, A.P. and Pereira, M.G. 2007. Irrigation dosages and soil coverings in the incidence of skin freckles and yield components of papaya 'Golden'. *Ciencia Rural.* 37(6): 1654-1660

Hafle, O.M., Santos, V.A., Ramos, J.D., Cruz, M.C.M. and Melo, P.C. 2009. Production of seedlings of papaya tree using bokashi and lithothamnium. *Revista Brasileira de Fruticultura.* 31(1): 245-251

Hangarge, D.S., Raut, R.S., Hanwate, G.R., Gaikwad, G.K. and Dixit, R.S. 2004. Influence of coir pith compost and vermicompost application on the microbial population in vertisols. *J. Soils Crops.* 14(2): 447-49

Harjadi, Pribadi, F. and Koswara, S. 1995. The effect of K levels on the yield and quality of fruit and crude papain from 3 papaya cultivars. *Acta Hort.* 379: 83-88

Hazarika, B. and Das, P.K. 2000. Comparative performance of black polythene and paddy husk mulches in pineapple. *The Hort. J.* 13(1): 29-36

Hossain, M.M., Khan, L.A., Paul, N.K., Hossain, M. and Joarder, O.I. 1990. Morphological, biochemical and yield responses of papaya (*Carica papaya* L.) to different sources of nitrogen. *Crop Res. Hisar*. 3(2): 222-233

Jackson, M.L. 1958. *Soil Chemical Analysis.* Indian Reprint 1967. Prentice Hall of India Private Ltd., New Delhi. 498p.

Jacquiline, K.D. 2008. *Impact of nutrient management, planting date and location on papaya yield and quality in Bangldesh* [on line]. Available: http://hdl.handle.net/1813/11666. [22 April 2010]

Jana, A.H.S.B.A. 2001. Influence of different soil moisture regimes and mulching on phyllochron, root penetration, crop cycle and harvest index of Dwarf Cavendish banana (*Musa* AAA). *Haryana J. Hort*. Sci. 30(3/4): 154

Jauhuri, O.S. and Singh, D.V. 1971. Effect of N, P and K on growth, yield and quality of papaya (*Carica papaya* L.) var. Honey Dew. *Prog. Hort*. 2(4): 81-89

Jayaprakash, R., Bojappa, K.M., Seenappa, K. and Ramanjini, P.H. 1992. The effect of irrigation and fertilizers on yield and quality of Solo papaya (*Carica papaya* L.). *Progressive Hort*. 21(3-4): 239-243

Jayasundara, J.M.P.B. and Huruggamuwa, H.M.N.K. 2005. Effect of organic and chemical fertilizers on growth, yield and fruit quality of papaw. *Ann. Srilanka Dep. Agric*. 7: 103-110

Jeyakumar, P., Amutha, R., Balamohan, T.N., Auxcilia, J. and Nalina, L. 2008. Fetigation improves yield and quality of papaya. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.91

Jeyakumar, P., Kavino, M., Kumar, N. and soorianathasundaram, K. 2007. Physiological performance of papaya cultivars under abiotic stress conditions. *Acta Hort.* 740: 209-211

Jeyakumar, P., Kumar, N. and Soorianathasundaram, K. 2001. Fertigation studies in papaya (*Carica papaya* L.). *S. Indian Hort*. 49(Special): 71-75

Johnson, L.F. and Curl, E.A. 1972. *Methods on Research on the Ecology of Soil Borne Plant Pathogen.* Burgas. Publication Company, New York. 33p.

Jonathan, E.I., Prabhu, S. and Bagam, M.Z. 2008. Integrated management of nematodes in papaya. In: Souvenir*, Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.35-37

KAU [Kerala Agricultural University]. 2007. *Package of Practices Recommendations: Crops* (12th ed.). Kerala Agricultural University, Thrissur, 334p.

Khade, S.W. and Rodrigues, B.F. 2010. Arbuscular mycorrhizal fungi associated with varieties of *Carica papaya* L. in tropical agro-based ecosystem of Goa, India. *Trop. Subtropical Agroecosystems.* 10(3) 369-381

Khan, T.A. and Khan, S.T. 1995. Effect of NPK on disease complex of papaya caused by *Meloidogyne incognita* and *Fusarium solani*. *Pakist. J. Nematology*. 13(1): 29-34

Khondaker, N.A. and Ozava, K. 2007. Papaya plant growth as affected by soil air oxygen deficiency. *Acta Hort*. 740: 225-232

Killham, K., Amato, A. and Ladd, J.N. 1993. Effect of substrate location in soil and soil pore-water regime on carbon turnover. *Soil Biol. Biochem.* 25: 57-62

Kirad, K.S., Barche, S. and Singh, D.B. 2010. Integrated nutrient management in papaya (*Carica papaya* L.) cv. Surya. *Acta Hort*. 851: 377-379

Krishnakumar, S., Saravanan, A., Natarajan, S.K., Veerabadran, V. and Mani, S. 2005. Microbial population and enzymatic activity as influenced by organic farming. *J. Agri. Biological Sci.* 1(1): 85-88

Kudada, N. and Prasad, S.M. 2006. Effect of planting season and manuring on incidence of papaya ringspot disease and fruit yield. *Indian J. Virol*. 17(1): 47-49

Kumar, A. and Marimuthu, T. 1994. Biological control of damping-off of *Eucalyptus camaldulensis* caused by *Rhizoctonia solani* with *Trichoderma viride* and decomposed coconut coir pith. *Pl. Dis. Res*. 9(2): 116-121

Kumar, D. and Prasad, J. 1998. Mineral nutrient content in petiole of papaya leaf cv. Pusa Dwarf as affected by growth regulators and chemicals. *The Orissa J. Hort*. 26(1): 58-60

Kumar, K. and Goh, K.M. 2003. Nitrogen release from crop residues and organic amendments as affected by biochemical composition. *Commun. Soil Sci. Pl. Anal.* 34: 2441-2460

Kumar, N., Jeyakumar, P. and Manivannan, M.I. 2008a. Balanced fertilization for sustainable yield and quality in tropical fruit crops. *Bangldesh J. Agric. Environ*. 4: 69-79

Kumar, N., Jeyakumar, P. Soorianathasundaram, K., Meenakshi, N. and Auxcilia, J. 2008b. Nutrient management in papaya. In: Souvenir*, Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.35-37

Kumar, N., Meenakshi, N., Suresh, J. and Nosov, V. 2006a. Effect of potassium nutrition on growth, yield and quality of papaya (*Carica papaya* L.). In: Mukhopadhyay, S.S., Brar, M.S. and Sharma, P. (eds.), *Proceedings of the International Symposium on Balanced Fertilization.* 22-25 November, 2006, Punjab Agricultural University, Ludhiana. pp.489-490

Kumar, N., Meenakshi, N., Suresh, J. and Nosov, V. 2006b. Effect of potassium nutrition on growth, yield and quality of papaya (*Carica papaya* L.). *Indian J. Fertil*. 2(4): 43-47

Kumar, N., Soorianathasundaram, K., Meenakshi, N., Manivannan, M.I., Suresh, J. and Nosov, V. 2008c. Balanced fertilization in papaya (Carica papaya L.) for higher yield and quality. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.89

Kumar, S., Swaminathan, V. and Sathiamoorthy, S. 2000. Effect of spacing, nutrition and intercrops on yield and quality of papaya (*Carica papaya* L.). *Res. Crops*. 1(1): 58-62

Kusdra, J.F., Moreira, D.F., Silva, S.S., Araujo-Neto, S.E. and Silva, R.G. 2008. Use of earthworm casting in the production of papaya seedlings. *Revista Brasileira-de-Fruticultura.* 30(2): 492-497

Lavania, M.L. and Jain, S.K. 1995. Studies on the effects of different doses of N, P and K on yield and quality of papaya (*Carica papaya* L.). *Haryana J. Hort. Sci*. 24(2): 79-84

Lim, L.S. and Hawa, J.S. 2007. Earliness in flowering and dwarfism in relation to internode length and tree height in papaya (*Carica papaya* L.). *Acta Hort*. 740: 103-108

Li-Mingfu and Yang-Shaocong, 2006. Influence of potassium on the resistance of *Carica papaya* L. to leaf blight. *J. Trop. Subtropical Bot*. 14(2): 141-145

Lokhande, N.M. and Moghe, P.G.1991. Nutrients and hormonal effect on growth promotion and productivity in ringspot infected papaya crop. *S. Indian Hort*. 39(1): 23-26

Lopez-Moctezuma, H., Ferrera-Cerrato, R., Farias-Larios, J., Aguilar-Espinosa, S., Bello, M.R.F. and Lopez-Aguirre, J.G. 2005. Arbuscular mycorrhizae, *Bacillus* and substrate enriched with vermicompost on the development of papaya plants. *Terra*. 23(4): 523-531

Luna, J.V.U. and Caldas. R.C., 1984. Mineral fertilization of papaya (*Carica papaya* L.). *Anais do Vii Congresso Brazileiro de Fruiticultura*. 3: 946-952

Maji, S. and Das, B.C. 2008. Effect of organic and inorganic mulches on vegetative growth and yield of guava cv. L-49. *Environ. Ecol*. 26(3A): 1292-1293

Mahouachi, J., Socorro, A.R. and Talon, M. 2006. Responses of papaya seedlings (*Carica papaya* L.) to water stress and re-hydration: growth, photosynthesis and mineral nutrient imbalance. *Pl. Soil*. 281(1/2): 137-146

Malo, S.E. and Campbell, C.W. 1986. *The Papaya*. Univ. Florida (Gainesville) Coop. Ext. Serv. Fruit Crops. Fact Sheet FC 11

Manickam, I.N. and Subramanian, P. 2006. Study of physical properties of coir pith. *Int. J. Green Energy*. 3(4): 397-406

Manjunatha, V.G., Patil, C.P., Swamy, G.S.K. and Patil, P.B. 2002. Effect of different VAM fungi and phosphorus levels on yield and yield components of papaya. *Karnataka J. Agric. Sci.* 15(2): 336-342

Marinho, C.S., Oliveira, M.A.B., Monnerat, P.H., Vianni, R. and Maldonado, J.F. 2001. Nitrogen sources and rates and the papaya fruit quality. *Scientia Agricola*. 58(2): 345-348

Marte, R. 1993. Production of papaya. In: *Proceedings of papaya and mango seminar,* 10-11 March, 1993, Inter-American Institute for Cooperation on Agriculture, Kingston, Jamaica. pp.19-27

Martelleto, L.A.P., Ribeiro, R.L.D., Sudo-Martelleto, M., Vasconcellos, M.A.S., Marin, S.L.D. and Pereira, M.B. 2008. Cycle development and agronomic performance of organic papaya cultivation in protected environment. *Revista Brasileira de Fruticultura*. 30(3): 662-666

Martin, J.P. 1950. Use of acid, Rose Bengal and Streptomycin in plate method for estimating soil fungi. *Soil Sci*. 69: 215-223

Masri, M., Razak, A.S. and Ghazalli, M.Z. 1990. Response of papaya (*Carica papaya* L.) to limited soil moisture at reproductive stage. *MARDI Res. J.* 18(2): 191-196

Mellado-Vazquez, A., Volke-Haller, V., Tapia-Vargas, M., Sauchez-Garcia, P. and Queredo-Nolasco, A. 2005. Response of papaya to irrigation and N-P-K fertilization in a vertisol. *Hort. Sci. Abstr*. 75(4): 495

Mendonca, V., Abreu, N.A.A.de, Gurgel, R.L.S., Ferreira, E.A., Orbes, M.Y. and Tosta, M.S. 2006b. Growing of papaya cv. Formosa in substrates with organic compost and simple superphosphate. *Ciencia-e-Agrotecnologia*. 30(5): 861-868

Mendonca, V., Martins, P.C.C., Dantas, D.J., Ramos, J.D., Gontijo, T.C.A., Carrijo, E.P. and Pio, R. 2006c. Effects of substrate and osmocote in the production of papaya seedlings. *Revista Cientifica Rural*. 11(1): 21-27

Mendonca, V., Pedrosa, C., Feldberg, N.P., Abreu, N.A.A., Brito, A.P.F. and Ramos, J.D. 2006a. Doses of nitrogen and simple superphosphate on papaya 'Formosa' plant growth. *Ciencia-e-Agrotecnologia.* 30(6): 1065-1070

Mendonca, V., Ramos, J.D., Carrijo, E.P., Pio, R., Dantas, D.J. and Gontijo, T.C.A. 2005. Different environment and substrates in the production of 'Formosa' papaya seedlings. *Revista Cientifica Rural*. 10(1): 18-24

Mendonca, V., Ramos, J.D., Dantas, D.J., Martins, P.C.C., Gontijo, T.C.A. and Pio, R. 2004. Effect of dosages of osmocote and two types of substrate on the growth of papaya 'Formosa' seedlings. *Revista Ceres*. 51(296): 467-476

Mendonca, V., Abreu, N.A.A., Souza, H.A., Ferreira, E.A. and Ramos, J.D. 2007. Different levels of organic compost in substrate constitution for seedlings production of papaya 'Formosa'. *Catinga*. 20(1): 49-53

Menezes-Junior, J.C., Cavalcante, L.F., Mesquita, E.F. Campos, V.B. and Oliveira, A.P. 2008. Micronutrient content in leaf of papaya plants in soil treated with bovine biofertilizer. *Revista Verde de Agroecologia e Desenvolvimento Sustentavel*. 3(2): 56-63

Mesquita, E.F., Cavalcante, L.F., Gondim, S.C., Cavalcante, I.H.L., Araujo, F.A.R. and Beckmann-Cavalcante, M.Z. 2007. Yield and fruit quality of papaya as function of types and levels of biofertilizers. *Semina: Ciencias Agrarias (Londrina)*. 28(4): 589-596

Misra, K.K., Mishra, D.S. and Rajesh-Singh. 2003. Papaya nutrition - a review. *Adv. In Hort. For.* 9: 71-78

Mitra, S. and Tarafdar, J. 2008. Impact of bio-fertilizers on bio chemical characters and nutritional quality of sweet potato grown as inter crop in papaya orchard. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.97

Mitra, S.K. 2007. Sustainable papaya production in West Bengal, India. *Acta Hort*. 740: 31-34

Muller, C.H., Reis, G.G. and Muller, A.A. 1979. Effect of farm yard manure on growth and nutrient accumulation in pawpaw stems and leaves. *Commun. Tech.* 30:14

Munoz, M.A., Rafols, N., O'Hallorans, J.M. 2004. Yield and yield components of papaya grown on coto clay (Typic Eutrutox) and fertilized with chicken manure. *J. Agric. Univ. Puerto-rico.* 88(3&4): 123-124

Murali, K., Kalyanamurthy, K.N. and Rajashekarappa, K.S. 2006. Effect of irrigation and mulching on growth and sucker production of "Elakki" banana (*Musa paradisiaca* L.). *Environ. Ecology.* 24(3): 523-529

Nalina, L., Balamohan, T.N., Auxcilia, J., Jeyakumar, P. and Manoranjitham, S.K. 2008. Effect of bio-fertilizers on growth, yield and quality of papaya. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*; 9-12 December, 2008, TNAU, Coimbatore, India. pp.100

Nandhini., R. 2004. Studies on integrated nutrient management of papaya (*Carica papaya* L.) cv. CO 7. MSc.(Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore. 153p.

Nath, S., Poduval, M., Suresh, C.P. and Sen, S.K. 2008. Studies on the efficiency of phosphate solubilising microbes (PSM) and VAM fungi with graded levels of phosphorous on growth, yield and nutrient uptake of papaya (*Carica papaya* L.) In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.98

Nethravathi, K.S. 2001. Studies on damping off of papaya. MSc.(Agri.) thesis, UAS, Bangalore. 145p.

NHB [National Horticulture Board]. 2010. Area-production statistics 2008-2009. Ministry of Agriculture. Govt. of India, Available: http://nhb.gov.in/statistics/area-production-statistics.html [14 July 2010]

Nkana, J.C.V., Demeyer, A. and Verloo, M.G. 1998. Chemical effects of wood ash on plant growth in tropical acid soils. *Bioresource Technol*. 63(3): 251-260

Ochse, J.J., Soule, M.J., Dijkman, M.J. and Wehlburg, C. 1961. *Tropical and sub-tropical Agriculture.* The Macmillan Company, New York. 213p.

Oliveira, Pinto de, C.A., Sauza and Marciano de, C. 2003. Effect of mulching on humidity, weeds and *Cosmopolites sordidus* on banana (*Musa* spp.) orchard. *Ravista Braseleria de Fruticultura*. 25(2): 345-347

Oliveira, A.M.G. and Caldas, R.C. 2004. Papaya yield under fertilization with nitrogen, phosphorous and potassium. *Rev. Bras. Frutic*. [on line]. 26(1). Available:http://www.scielo.br/scielo.php?pid=S010029452004000100042&script=sci_arttext&tlng=en. ISSN: 0100-2445. [05 April 2010]

Oliveira, A.M.G., Caldas, R.C., Medina, V.M., Oliveira, G.X.S. and Quadros, W.S. 2007. Vegetative development and quality of papaya Sunrise Solo fruits as a result of nitrogen, phosphorus and potassium dosages. *Magistra*. 19(1): 69-75

Oliveira, A.M.G., Souza, L.F.S., and Coelho, E.F. *Papapya* 2004. Available: http://www.ipipotash.org/udocs/8_Papaya.pdf. [05 April 2010]

Pandey, V.K., Sharma, H.G. and Agrawal, N. 2005. Evaluation of drip irrigation and plastic mulching on papaya cultivation. *Drain. Irrig. Wat. Manage*. 136-144

Patil, K.B., Patil, B.B. and Patil, M.T. 1995. Nutritional investigation in papaya var. Washington. *J. Maharashtra Agric. Univ*. 20(3): 364-366

Patil, K.B., Patil, B.B. and Patil, M.T. 1997. Studies on manurial requirement of papaya. *J. Soils Crops*. 7(2): 123-127

Pire, R. and Acevedo, I. 2005. Effects of vermicompost as a substrate amendment on pawpaw (*Carica papaya* L.) nutrition. *Proc. Interamerican Soc. Trop. Hort.* 48: 97-100

Posse, R.P., Bernado, S., De-Sousa, E.F., Pereira, M.G., Monnerall, P.H. and Gottardo, R.D. 2009. Response coefficient of papaya yield to water stress in Northern Riode Janeiro. *Rev.Bras. Eng. Agric. Ambient.* 13(2): 604-605

Prakash, J., Singh, W.P. and Sankaran, M. 2008. Influence of nutrition and VAM on plant growth parameter, physico-chemical composition of fruits and yield of papaya (*Carica papaya* L.) cv. Pusa Deliciosa. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*; 9-12 December, 2008, TNAU, Coimbatore, India. pp.93

Purohit, A.G., Singh, H.P. and Ganapathy, K.M. 1979. Effect of varying levels of N, P and K on growth and yield of papaya (*Carica papaya* L.). *Indian J. Hort.* 36: 131-133

Qiu, Y.X., Nishina, M.S. and Paull, R.E. 1995. Papaya fruit growth, calcium uptake and fruit ripening. *J. Am. Soc. Hort. Sci*. 120(2): 246-253.

Radhakrishnan, B., 2009. Nutrient value and microbial population of vermicompost and vermiwash. Newsletter- UPASI Tea Foundation. 19: 2-3

Rahman, M.A., Kadir, J., Mahmud, T.M.M., Rahman, R.A. and Begum, M.M. 2007. Screening of antagonistic bacteria for biocontrol activities on *Colletotrichum gloeosporioides* in papaya. *Asian J. Pl. Sci*. 6(1): 12-20

Rajamanickam, C., Balasubramanyan, S. and Natarajan, S. 2008. Stuudies on the nursery management in papaya (*Carica papaya* L.) cv. Co.2. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.74

Rajbhar, Y.P., Singh, G. and Lal, M. 2010. Effect of N, P, K and spacing on growth and yield of papaya (*Carica papaya* L.) cv. Pant Papaya-1. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.104

Rajkumar, M., Karuppaiah, P. and Kandasamy, R. 2005. Effect of calcium and gibberellic acid on post-harvest behaviour of papaya cv. CO 2. *Indian J. Hort*. 62(4): 327-331

Rajput, C.B.S. and Sharma, C.D. 1970. *Indian Farmers Digest.* 111: 6-8.

Rajput, M.S. and Ram, R.A. 1998. Effect of organic manures and biofertilizer on growth, yield and fruit quality of mango cv. Dashehari. *Int. J. Mendel.* 15: 49-50

Ram, M. 2005. *Papaya*. Indian Council of Agricultural Research, New Delhi. 189p.

Rani, M.S.A. 1995. Integrated nutrient management of nitrogen and phosphorus in CO 6 papaya (*Carica papaya* L.). M.Sc.(Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore. 123p.

Rao, D.V.S. and Rao, V.N.M. 1978. Effect of NPK on sex, duration and yield of CO 1 papaya (*Carica papaya* L.). *S. Indian Hort*. 26: 103-107

Rao, M.S. 2007. Papaya seedlings colonized by the bio-agents *Trichoderma harzianum* and *Pseudomonas fluorescens* to control root-knot nematodes. *Nematologia Mediterranea*. 35(2): 199-203

Rao, M.S. 2010. Effect of combinations of bio-pesticides on the management of nematodes on *Carica papaya* L. *Acta Hort.* 851: 459-464

Rao, S.N.S. 1986. *Soil Micro Organisms and Plant growth* (2nd ed.). Oxford and IBH Publishing company, Culcutta, India. 286p.

Ravitchandirane, V. 1999. Studies on planting densities and fertilizer management in papaya (*Carica papaya* L.) cv. CO 2. MSc.(Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore. 100p.

Ravitchandirane, V., Kumar, N., Jeyakumar, P., Soorianathasundaram, K. and Vijayakumar, R.M. 2002. Influence of planting density and nutrient levels on growth and yield of papaya cv. Co.2. *S. Indian Hort.* 50: 32-43

Ravishankar, H. and Karunakaran, G. 2008. Perfomance of Coorg Honey Dew papaya under organic farming regimes in the hill zones of Karnataka. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.63

Ravishankar, H., Karunakaran, G. and Hazarika, S. 2008. Nutrient availability and biochemical properties in the soil as influenced by organic farming of papaya under Coorg Region of Karnataka. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.103

Ray, P.K., Kumar, A. and Kumar, S. 2008. Effect of bio-fertilizers on growth and yield of papaya cv. Surya. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.87

Ray, P.K., Singh, S.K. and Kumar, A. 2008. Performance of Pusa Delicious papaya under organic farming. *Indian J. Hort*. 65(1): 100-102

Ray, P.K., Yadav, J.P. and Kumar, A. 1999. Effect of transplanting dates and mineral nutrition on yield and susceptibility of papaya to ringspot virus. *Hort. J*. 12(2): 15-26

Reddy, B.M.C. 2008. Integrated nutrient and water management in papaya. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.85

Reddy, Y.T.N. and Kohli, R.R. 1989. Effect of nitrogen on growth, yield and quality in papaya (*Carica papaya* L.) cv. Coorg Honey Dew. *Narendra Deva J. Agric. Res*. 4(1): 53-56

Reddy, Y.T.N., Kohli, R.R. and Bhargava, B.S. 1989. Yield and petiole nutrient composition of papaya as influenced by different levels of N, P and K. *Porg. Hort*. 21(1-2): 26-31

Reddy, Y.T.N., Kohli, R.R. and Bhargava, B.S. 1990. Growth, yield and petiole nutrient composition of papaya as influenced by different levels of nitrogen. *J. Maharashtra Agric. Univ.* 15(2): 146-148

Ribeiro, O.K. and Linderman, R.G. 1991. Chemical and biological control of phytophthora species in woody plants. In: Lucas, J.A., Shattock, R.C., Shaw, D.S. and Cooke, L.R. (eds.), *Phytophthora*. Cambridge University Press, Sydney, Australia. pp.399-410

Ronchi, C.P., Silva, A.A., Serrano, L.A.L., Cattaneo, L.F., Santana, E.N. and Ferreguetti, G.A. 2008. Weed control in papaya. *Planta Daninha*. 26(4): 937-947

Sadarunnisa, S., Madhumathi, C., Babu, K.H. and Sreenivasulu, B. 2008. Effect of fertigation on growth and yield of papaya cv. Red Lady. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*; 9-12 December, 2008, TNAU, Coimbatore, India. pp.96

Samiyappan, R. 2008. Plant protection in papaya. In: Souvenir*, Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.35-37

Santana, J.L., Sousa, M.J., Rodriguez, M.C. and Suarez, C.L. 2008. Response of the papaya (*Carica papaya* L.) plant to deficit irrigation in the Canary Islands. *Acta Hort*. 792: 559-565

Santana, R.C., Perez, G.G., Santana, M.C.C., Vivos, M.F. and Nararroc, C.P. 2002. Effect of *Trichoderma viridae* and *Azotobactor chroococcum* on germination and seedling development of Carica *papaya* Lin. *Aust. Pl. Path*. 33(1): 103-107

Saraf, R.K., Samaiya, R.K. and Shukla, K.C. 2004. Effect of different sources of nutrients on growth of pomegranate (*Punica granatum* L.). In: *Proceedings of the national conference on biodiversity and sustainable utilization of biological resources.* 16-18 March. 2004, Sagar, Madhya Pradesh, India. pp.203-208

Savithri, P., Muragappan, V. and Nagarajan, R. 1993. Possibility of economising potassium fertilization by composted coir pith application. *Fertil. News*. 38(10): 39-40.

Selvakumari, Muthuvel, P., Subramanian, K.S., Subramanian, P. and Shanmugasundaram, V.S. 1992. Irrigation water requriment of banana under intercrop management. *S. Indian Hort.* 40(1): 5-8

Seripong, S. 1993. Effect of poultry manure on growth of papaya in acid soil. *J. Agric. (Tailand)* 9(3): 248-253

Sharma, S.K., Zote, K.K., Kadam, U.M., Tomar, S.P.S. and Sonawane, A.U. 2010. Economics of papaya cultivation at farmers' fields. *Acta Hort.* 851: 53-60

Shashidhar, K.R., Bhaskar, R.N., Priyadharshini, P. and Chandrakumar, H.L. 2008. Effect of different organic mulches on pH, organic carbon content and microbial status of soil and its influence on leaf yield of M_5 mulberry (*Morus indica* L.) under rainfed condition. *Curr. Biotica*. 2(4): 405-413.

Shing, S.C., Chen, W.C.Y. and Chichu, S.C.L. 2008. Extraction of DNA from soil for analysis of bacterial diversity in transgenic and nontransgenic papaya sites. *J. Agric. Fd. Chem*. 56(24): 11969-11975

Shivaputra, S.S., Patil, C.P., Swamy, G.S.K., Hanamashetti, S.I. and Patil, P.B. 2004a. Influence of VAM fungi and vermiculture on yield and yield attributes of papaya, cv. Sunset solo. *Karnataka J. Agric.Sci.* 17(3): 519-521

Shivaputra, S.S., Patil, C.P., Swamy, G.S.K. and Patil, P.B. 2004b. Cumulative effect of VAM fungi and vermicompost on nitrogen, phosphorus, potassium, and chlorophyll content of papaya leaf. *Mycorrhiza News*. 16(2): 15-16

Shivaputra, S.S., Patil, C.P., Swamy, G.S.K. and Patil, P.B.2004c. Effect of vesicular-arbuscular mycorrhiza fungi and vermicompost on drought tolerance in papaya. *Mycorrhiza News.* 16(3): 12-13

Shukla, A.K., Singh, A.K. and Singh, B.P. 2001. Effect of plant density and nitrogen on papaya (*Carica papaya* L.). *Ann. Agric. Res.* 22(4): 520-522

Shukla, A.K. and Singh, R.P. 2001. Effect of plant density and level of nitrogen on flowering, and yield of papaya (*Carica papaya* L.). *New Botanist*. 28(1/4): 55-58

Silva, J.G.F., Ferreira, P.A., Costa, L.C., Melendes, R.R.V. and Cecom, P.R. 2001. Effects of different depths and frequencies of irrigation on the productivity of pawpaw (*Carica papaya*). *Revista Brasileira de Fruticultura*. 23(3): 597-601

Singh, A.K. and Singh, G. 2003. Approaches and strategies for precision farming in papaya. In: Singh, H.P., Singh, G., Samual, J.C. and Pathak, R.K. (eds.), *Precision Farming in Horticulture*. National Committe on Precision Farming Development Centre, CISH, Lucknow. pp.164-175

Singh, A.K. and Singh, G. 2005. Effect of different mulches on soil moisture content, temperature and production of papaya. In: Choudhary, M. l., Chandra, P., Mishra, P., Prasad, K.V., Patel,V.B., Singh, S.K., Mahur, H. and Lall, R. (eds.); *International Conference on Plasticulture and Precision Farming*; 17-21, November, 2005, New Delhi. National Committee on Plasticulture Applications in Horticulture, New Delhi. pp.496

Singh, A.K., Singh, S., Apparao, V.V., Mashram, D.T. and Bagle, B.G. 2007. Influence of organic mulches on soil temperature, moisture and growth of aonla NA-7 under rainfed condition. *The Hort. J*. 20(2): 71-75

Singh, C., Bhagat, B.K. and Ray, R.N. 1998. Effect of nitrogen, phosphorus and potassium on growth, yield and quality of papaya (*Carica papaya* L.). *Orissa J. Hort*. 26(2): 61-65

Singh, D.K., Paul, P.K. and Ghosh, S.K. 2004b. Growth, yield and fruit quality of papaya as influenced by different levels of N, P and K. *The Hort. J*. 17(3): 199-204

Singh, D.K., Paul, P.K. and Ghosh, S.K. 2006. Leaf and petiole nutrient composition and yield of papaya (*Carica papaya* L.) as influenced by different levels of N, P and K. *Crop Res. Hisar*. 32(1): 60-62

Singh, G., Mishra, R. and Pandey, S. 2008. *Utility of Plastic Mulching in Horticulture.* Extension Folder No. 5. Precision Farming Developing Development Centre, Ministry of Agriculture, Govt. of India, CISH, Lucknow, 4p.

Singh, G. and Singh, G.P. 2005. Guava meadow orchard: effect of mulch material on growth and fruiting pattern. In: Choudhary, M. l., Chandra, P., Mishra, P., Prasad, K.V., Patel,V.B., Singh, S.K., Mahur, H. and Lall, R. (eds.); *International Conference on Plasticulture and Precision Farming*; 17-21, November, 2005, New Delhi. National Committee on Plasticulture Applications in Horticulture, New Delhi. pp.492-493

Singh, G., Singh, G.P. and Soni, M. 2005. Influence of drip irrigation and plastic mulching on crop development and water requirement in fruit crops. In: Choudhary, M. l., Chandra, P., Mishra, P., Prasad, K.V., Patel,V.B., Singh, S.K., Mahur, H. and Lall, R. (eds.); *International Conference on Plasticulture and Precision Farming;* 17-21, November, 2005, New Delhi. National Committee on Plasticulture Applications in Horticulture, New Delhi. pp.491

Singh, H.K., Singh, A.K.P. and Sinha, A.K. 2005a. Effect of fertigation on phenological characteristics of papaya with drip irrigation. *J. Appl. Biol*. 15(1): 85-88

Singh, H.K., Sunil-Kumar and Singh, H.K. 2004c. Soil solarization for the control of damping-off of papaya (*Carica papaya* L.) in the nursery. *Progressive Hort*. 36(1): 177-179

Singh, I.D. 1990. *Papaya.* Oxford and IBH Publishing Co. Ltd., New Delhi. 56p.

Singh, I.P. and Sharma, C.K. 1996. Response of papaya to N and P applications on tilla land in Tripura [India]. *J. Hill Res*. 9(1): 96-98

Singh, N.D., Uniyal, R.P., Arunachalam, K. and Arunachalam, A. 2004a. Physico-chemical properties of soils under guava, papaya and banana plantations at different altitudes of Arunachal Pradesh. *Hort. J*. 17(3): 279-281

Singh, S.K., Singh, S.P. and Singh, B.K. 2007. Effect of vesicular arbuscular mycorrhizae and fertilizer on growth and yield of papaya cv. Honey Dew. *Adv. in Pl. Sci*. 20(2): 431-434

Singh, S.R. and Sharma, M.K. 2006. Effect of different organic nutrient resources on fruit yield, quality, leaf nutrient composition and soil fertility of Red Delicious apple. *J. Asian Hort.* 2: 91-94

Singh, V.K., Bhriguvanshi, S.R., Garg, N., Pathak, S.M. and Singh, D.K. 2005. Effect of mulching on development of softening of tissue and other physiological and biochemical parameters of fruits and soil in mango Dashehari. In: Choudhary, M. l., Chandra, P., Mishra, P., Prasad, K.V., Patel,V.B., Singh, S.K., Mahur, H. and Lall, R. (eds.); *International Conference on Plasticulture and Precision Farming;* 17-21, November, 2005, New Delhi. National Committee on Plasticulture Applications in Horticulture, New Delhi. pp.514

Sinha, R.K., Heart, S., Chauhan, K. and Valani, D. 2009. Earthworms vermicompost: a powerful crop nutrient over the conventional compost and protective soil conditioner against the destructive chemical fertilizers for food safety and security. *Am. Eurasian J. Agric. Environ. Sci*. 5: 14-22

Sonawane, S.S., Patil, A.J., Gaikwad, B.G. and Patil, J.D. 1996. Mineralization of nitrogen in soil mixed with sorghum residue, leucaena and glyricidia loppings. *J. Maharashtra Agric. Univ*. 21(2): 299-300.

Soorianathasundaram, K. 2002. Emerging trends in the productoin technology of papaya. In: Kumar, N., Soorianathasundaram, K. and Azhakiamanavalan, R.S. (eds.), *Emerging trends in production technology of tropical fruit crops*; 3-12, July, 2002, Department of Fruit Crops, Horticultural College and Research Institute, TNAU, Coimbatore. pp.23-28

Souza, E.A., Coelho, E.F. and Paz, V.P.S. 2006. Papaya root distribution under three frequencies of phosphorus application by fertigation. *Magistra*. 18(1): 14-20

Souza, E.A., Coelho, E.F., Paz, V.P.S. and Coelho-Filho, M.A. 2005. Growth and yield of papaya supplied with phosphorous by surface and subsurface drip irrigation. Revista *Brasileira-de-Fruticultura*. 27(3): 495-499

Srinivas, K. 1996. Plant water relations, yield and water use of papaya (*Carica papaya* L.) at different evaporation-replenishment rates under drip irrigation. *Trop. Agric*. 73(4): 264-269

Srinivas, K. 2008. Water management in papaya. In: Souvenir, *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.35-37

Srinivas, K. and Prabhakar, M. 1993. Plant water relations, yield and water use of papaya in relation to irrigation and nitrogen fertilization. *Singapore J. Primary Industries.* 21(1): 1-5

Srivastava, S.S. 2002. Efficacy of organic amendments in the management of root knot nematode (*Meloidogyne incognita*) infecting papaya. *Indian J. Nematology*. 32(2): 183-184

Sterk, G. and Spaan, W.P. 1997. Wind erosion control with crop residues in the Sahel. *Soil Sci. Soc. Amer. J*. 61: 911-916

Subbaiah, B.V. and Asija, C.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci*. 25: 328

Sulladmath, U.V., Gawda, N. and Ravi, S.V. 1981. Influence of increasing application of NPK fertilizer with cattle manure on fruit qualities. *Nat. Symp. Trop. And Sub Trop. Fruit Crops*, Banglore. pp.54-60

Suresh, C.P. and Hasan, M.A. 2001. Studies on the response of Dwarf Cavendish banana (*Musa* AAA) to biofertilizer inoculation. *The Hort. J.* 14(1): 35-41

Suresh, C.P., Nath, S., Poduval, M. and Sen, S.K. 2010. Studies on the efficacy of phosphate solubilizing microbes and VAM fungi with graded levels of phosphorous on growth, yield and nutrient uptake of papaya (Carica papaya L.). *Acta Hort*. 851: 401-406

Suresh, R. and Saha, D.P. 2004. Effect of mulching and drip irrigation on papaya in calcareous soil of North Bihar. *Progressive Hort.* 36(1): 76-81

Tan, K.S.R., O'Gara, E., Guest, D. and Vawdrey, L. 2002. Effects of fertilizer on the susceptibility of durian and papaya to *Phytophthora palmivora*. *Acta Hort.* 575: 457-464

Thomas, M.B., Ferguson, J. and Crane, J. 1995. Identification of N, K, Mg, Mn, Zn deficiency symptoms of carambola, lychee and papaya grown in sand culture. *Proc. State Hort. Soc*. 108: 370-373

Tiwari, K.N., Singh, B.K., Chourasia, S.K. and Mandal, S. 2005. Yield response of pineapple Kew under drip irrigation and plastic mulch. In: Choudhary, M. l., Chandra, P., Mishra, P., Prasad, K.V., Patel,V.B., Singh, S.K., Mahur, H. and Lall, R. (eds.); *International Conference on Plasticulture and Precision Farming;* 17-21, November, 2005, New Delhi. National Committee on Plasticulture Applications in Horticulture, New Delhi. pp.499

Tiwari, S.C. 1996. Effects of organic manure and NPK fertilization on enzyme activities and microbial populations in subtropical Oxisol. *J. Hill Res*. 9(2): 334-340

Tripathi, R.D. 1961. Effect of N, P and K fertilizers on papaya vigour. *A. Rep. Hort. Res. Inst. Saharanpur.* 2: 146-151

Tsai-Yifong, 1996. Study on the localized organic medium for the production of papaya seedlings: Effects on the nutrient contents of papaya seedlings. *Bull. Taichung District Agric. Improv. Stn.* 5(1): 1-7

Ushakumari, K., Prabhakumari, P. and Padmaja, P. 1997. Efficiency of vermicompost on yield and quality of banana (AB) cv. Njalipoovan. *S. Indian Hort*. 45(3&4): 158-160

Uthaiah, B.C., Lingaiah, H.B. and Herle, P.S. 1990. Effect of depth of trench and coir pith mulch on pineapple. *Hort. J*. 3(1-2): 26-30

Vallejo, G.G. 1999. Effects of nitrogen fertilization on papaya (*Carica papaya* L.) yield and the incidence of viruses. *Revista Facultad Nacional-de-Agronomia Medellin*. 52(1): 515-526

Vawdrey, L.L., Grice, K.E. and Peterson, R.A. 2004a. The use of mounds and organic and plastic mulches for the management of phytophthora root rot of papaya in Northern Queensland. *Diversity and Management of Phytophthora in Southern Asia.* pp.167-170

Vawdrey, L.L., Grice, K.E., Peterson, R.A. and Faveri, J.D. 2004b. The use of metalaxyl and potassium phosphonate, mounds and organic and plastic mulches, for the management of Phytophthora root rot of papaya in far northern Queensland. *Aust. Pl. Path.* 33(1): 103-107

Vawdrey, L.L., Martin, T.M. and Faveri, J. 2002. The potential of organic and inorganic soil amendments and a biological control agent (*Trichoderma* sp.) for the management of phytophthora root rot of papaw in far northern Queensland. *Aust. Pl. Path*. 31(4): 391-399

Veerannah, L. and Selvaraj, P. 1984. Studies on growth, dry matter partitioning and pattern of nutrient uptake in papaya. In: *Proceedings of the National Seminar on Papaya and Papain Production*; 26-27 March. 1984. TNAU, Coimbatore. pp.76-78

Veeraputhiran, R. and Joseph, P.A. 1997. Effect of moisture conservation techniques and levels of irrigation on growth and yield attributes of oriental pickling melon (*Cucumis melo* var *conoman* L. makino). *S. Indian Hort*. 45(5/6): 235-239

Viana, T.V.A., Santos, F.S.S. Costa, S.C., Azevedo, B.M. and Sousa, A.E. 2008. Different doses of potassium nitrate applied through fertigation in papaya. *Revista Ciencia Agronomica*. 39(1): 34-38

Viegas, P.R.A., Sobral, L.F. and Carvalho, E.X. 1999a. Growth and accumulation of macro and micronutrients in pawpaw as function of nitrogen doses. *Ensaios-e-Ciencia: Serie Ciencias Biologicas Agrarias-e-da Saude.* 3(2): 39-56

Viegas, P.R.A., Sobral, L.F., Fontes, P.C.R., Cardoso, A.A., Couto, F.A.A. and Carvalho, E.X. 1999b. Effects of nitrogen rates on physical and chemical characteristics of Sunrise Solo papaya. *Revista brasileeira-de-Fruticultura.* 21(2): 182-185

Walsh, K.B. and Ragupathy, S. 2007. Mycorrhizal colonization of three hybrid papayas (*Carica papaya*) under mulched and bare ground conditions. A*ust. J. Exp. Agric*. 47: 81-85

Werner, H. 1993. Response of papaya cv. 'Tainung 2' to different sources, levels and application intervals of nitrogen. *Proc. Interamerican Soc. Trop. Hort.* 37: 94-98

Xianghong, H.M.H.F.L., Chen,T.S.Y. and Xianghe, Y.W. 2006. The high production techniques for Eksotika ' papaw cultivar. *S. China Fruits.* 5: 29-31.

Yamanishi, O.K., Almeida, L.F.P. and Zuffo, V.J. 2010. Sound soil management for papaya: case study of the North of Espirito Santo, Brazil. *Acta Hort*. 851: 249-252

Yamanishi, O.K., Fagundes, G.R., Filho, J.A.M., Altino, J. and Valone, G.V. 2004. Different growth medium and fertilizer effects on papaya seedlings growth. *Revista Brasileira de Fruticultura.* 26(2): 276-279

Yin-Po, W. and Ching, C.C. 1995. The effect of organic farming practices on the chemical, physical and biological properties of soils in Taiwan. In:*Sustainable food production in the Asian and Pacific region*. FETC book series, No. 46. pp.33-39

Zabedah, M. 2001. Effect of bio-organic fertilizer on performance of Eksotika papaya. In: *Project Final Report*. *Development and Testing the Effectiveness of BPA Organic Fertiliser on Selected Horticultural Crops and Rice*. MARDI- Bio-Organic System & Services Sdn. Bhd. (BOSS)

Zang-Xiaoping and Xu-Xuerong, 2002. The nutrition and fertilizing of pawpaw. *S. China Fruits*. 31(1): 34-35

Zimmerman, T.W. 2008. Papaya growth in double row systems established during the dry season in Virgin Icelands. In: Kumar, N., Soorianathasundaram, K. and Jeyakumar, P. (eds.), *Second International Symposium on Papaya*, 9-12 December, 2008, TNAU, Coimbatore, India. pp.64

Appendices

APPENDIX-I

Cost of cultivation per hectare

Sl. No.	Item	Quantity/ Labourers	Unit cost (Rs.)	Total cost (Rs./ha)
1	Labour cost			
	Poly bag filling and sowing of seeds	10 W	150.00	1500.00
	Plouging (Tractor)	15 M	200.00	3000.00
	Lay out, digging pits and transplanting	35 M	200.00	7000.00
	Thinning and gap filling	5 M	200.00	1000.00
2	After care			
	Irrigation	25 W	150.00	3750.00
	Weeding, earthing up and fertilizer application	72 M	200.00	14400.00
	Harvesting	8 W	150.00	1200.00
3	Cost of inputs			
	Seed	250 g	1.00	150.00
	Poly bag	1 kg	100	100.00
	Total			32100.00
	Manures and fertilizers			
A	T1(Absolute control)	-	-	0.00
B	T2 (240:240:480 g of NPK + 20 kg FYM (As per POP recommendation, KAU, 2007)			
	Urea	1302.5 kg	5.25	6838.13
	Superphosphate	3332.5 kg	4.75	15829.38
	MOP	2000 kg	4.00	8000.00
	FYM	50000 kg	1.00	50000.00
	Total			80667.50
C	T3(NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*)			
	Inorganic fertilizers			30667.50
	FYM	50000 kg	1.00	50000.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			83542.50
D	T4 (NPK (POP) + Vermicompost (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*)			
	Inorganic fertilizers			30667.50
	Vermicompost	33325 kg	6.00	199950.00
	*Trichoderm*a	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			233492.50
E	T5 (NPK (POP) + Poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*)			

	Inorganic fertilizers			30667.50
	Poultry manure	25000 kg	5.00	125000.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			158542.50
F	T6 (NPK (POP) + Biovermi (N equivalent to 20 kg FYM))			
	Inorganic fertilizers			30667.50
	Biovermi	33325 kg	10.00	333250.00
	Total			363917.50
G	T7 (½ NPK (POP) + FYM (20 kg) + *Trichoderma* + *Pseudomonas*)			
	Inorganic fertilizers			15328.00
	FYM	50000 kg	1.00	50000.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			68203.00
H	T8 (½ NPK (POP) + Vermicompost (N equivalent to 20 kg FYM) + *Trichoderma*)			
	Inorganic fertilizers			15328.00
	Vermicompost	33325 kg	6.00	199950.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			218153.00
I	T9 (½ NPK (POP) + Poultry manure (N equivalent to 20 kg FYM) + *Trichoderma* + *Pseudomonas*)			
	Inorganic fertilizers			15328.00
	Poultry manure	25000 kg	5.00	125000.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00
	Total			143203.00
J	T10 (½ NPK (POP) + Biovermi (N equivalent to 20 kg FYM))			
	Inorganic fertilizers			15328.00
	Biovermi	33325 kg	10.00	333250.00
	Total			348578.00
K	T11 (Fully organic (FYM + bone meal + wood ash equivalent to NPK of POP))			
	FYM	60000 kg	1.00	60000.00
	Bonemeal	2850 kg	15.00	42750.00
	Wood ash	3975 kg	4.00	15900.00
	Total			118650.00
L	T12 (Fully organic (FYM + bone meal + wood ash equivalent to NPK of POP) + *Trichoderma* + *Pseudomonas*)			
	FYM	60000 kg	1.00	60000.00
	Bonemeal	2850 kg	15.00	42750.00
	Wood ash	3975 kg	4.00	15900.00
	Trichoderma	12.5 kg	70.00	875.00
	Pseudomonas	25 kg	80.00	2000.00

	Total			121525.00
	Cost of mulching materials			
A	T1		-	0.00
B	T2 (Paddy straw)	25000 kg	1.50	37500.00
C	T3 (Coir pith)	12500 kg	2.00	25000.00
D	T4 (Coconut leaf)	25000 kg	0	1000.00
E	T5 (Glyricidia)	25000 kg	0	1000.00
F	T6 (Biodegradable polythene)	2500 m^2	6.00	15000.00
G	T7 (Black polythene)	285.71 kg	65.00	18571.15

W- women; M- men

APPENDIX-II

Nutrient composition of the organic and inorganics used in the experiment

Sl. No.	Item	Nutrient content (%)		
		N	P	K
1	Cowdung	0.80	0.50	0.60
2	Vermicompost	1.6	0.4	1.8
3	Biovermi	1.6	0.4	1.8
4	Poultry manure	1.8	0.31	1.0
5	Bonemeal	1-2	25-30	-
6	Wood ash	0.15	0.8-5.9	1.5-36
7	Urea	46.00	-	-
8	Superphosphate	-	18	-
9	Muriate of potash	-	-	60

APPENDIX-III

Nutrient composition of the organic mulches used in the experiment

Sl. No.	Item	Nutrient content (%)		
		N	P	K
1	Coconut leaves	1.40	0.20	0.62
2	Glyricidia leaves	3.00	0.10	0.70
3	Paddy straw	0.80	0.2	2.0
4	Coir pith	0.35	0.06	0.14

APPENDIX-IV

Score card for the organoleptic evaluation of fruits

Name of the scorer:

Please score the given fruit samples using the 9 point hedonic scale.

Score	Inference
9	Like extremely
8	Like very much
7	Like moderately
6	Like slightly
5	Neither like nor dislike
4	Dislike slightly
3	Dislike moderately
2	Dislike very much
1	Dislike extremely

Treatments	Taste	Flavour	Colour	Texture	Overall acceptability
T_1					
T_2					
T_3					
T_4					
T_5					
T_6					
T_7					
T_8					
T_9					
T_{10}					
T_{11}					
T_{12}					

Remarks:

RESPONSE OF PAPAYA TO ORGANIC MANURES, PLANT GROWTH PROMOTING MICROORGANISMS AND MULCHING

By

SHIJINI E.M.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF POMOLOGY & FLORICULTURE

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2010

ABSTRACT

A research project entitled "Response of papaya to organic manures, plant growth promoting microorganisms and mulching" was conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during 2008-2010. Major objectives were to study the response of organic manures, plant growth promoting microorganisms on growth, yield and quality of papaya, under humid tropical climate. Selection of ecofriendly mulch for papaya was also aimed as it saves water and reduces weed growth. Papaya variety CO 7 was used for the investigation. The study consisted of two field experiments, laid out in RBD with three replications in each experiment. Experiment I included 12 treatments which were combinations of organic manures and plant growth promoting microorganisms along with inorganic fertilizers. In Experiment II effect of different mulches on growth, yield and quality of papaya, soil moisture retention and weed growth was studied. There were seven treatments in experiment II which included six types of mulches.

The study revealed that application of RDF (240:240:480 g NPK/plant/year) + vermicompost (13 kg) + plant growth promoting microorganisms, *viz*; *Trichoderma* and *Pseudomonas* (5 g and 10 g/plant respectively) exhibited superiority in terms of vegetative and floral characters and recorded highest fruit yield (42.59 kg/plant). Application of RDF + poultry manure (10 kg/plant) + plant growth promoting microorganisms were also found superior with respect to growth and yield attributes. Quality of the fruits in terms of TSS, total sugars, acidity, overall acceptability and shelf life was highest in organic treatments where as fruit yield per plant was found lowest in these treatments.

Soil properties like pH, organic matter, available N, P and K were found to be improved by application of organic manures. Application of plant growth promoting microorganisms enhanced the microbial population (bacteria, fungi and actinomycetes) in the soil. Population of *Trichoderma* spp. and *Pseudomonas*

fluorescens was also increased. Regarding the cost of cultivation, application of biovermi incurred highest cost per ha.

In Experiment II, plants mulched with biodegradable polythene and black polythene mulches showed positive response with regard to vegetative and floral characters and recorded highest fruit yield (40.99 and 40.76 kg/plant respectively). Quality attributes of the fruits were also found to improve in these treatments. The polythene mulches showed superiority in terms of soil moisture retention and it reduced the number of irrigation. Significant reduction in weed growth was also noticed in the plots mulched with polythene mulches. Soil nutrient status was improved and was superior in the treatments mulched with organic mulches. With respect to cost of cultivation also treatments T_6 and T_7 were superior.

Over all assessment indicated that application of RDF (240:240:480 g of NPK) + vermicompost (13 kg) + *Trichoderma* (5 g) + *Pseudomonas* (10 g) was highly beneficial for growth, yield and quality improvement in papaya. Similarly mulching with biodegradable polythene was proved to be good as it was effective in weed control, soil moisture retention, thereby improving the growth, yield and quality of papaya and it is also ecofriendly.