ORGANIC NUTRIENT MANAGEMENT IN CHETHIKKODUVELI (*Plumbago rosea* L.)

NIHAD, K.

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Department of Plantation Crops and Spices
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522

DECLARATION

I hereby declare that this thesis entitled **"Organic nutrient management in chethikkoduveli (*Plumbago rosea* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
6-9-2005

NIHAD, K.
(2003-12-14)

CERTIFICATE

Certified that this thesis entitled **"Organic nutrient management in chethikkoduveli (*Plumbago rosea* L.)"** is a record of research work done independently by **Mrs. Nihad, K. (2003-12-14)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani,
6-9 -2005

Dr. P.C. JESSYKUTTY
(Chairperson, Advisory Committee)
Assistant Professor,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

APPROVED BY

CHAIRPERSON

Dr. P.C. JESSYKUTTY
Assistant Professor,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522

2/2/06

MEMBERS

Dr. B. K. JAYACHANDRAN
Associate Professor and Head,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522

2/2/2006

Dr. B.R. REGHUNATH
Associate Professor,
Department of Plantation Crops and Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

2-2-06

Dr. P. SIVAPRASAD
Associate Professor (Microbiology),
Department of Plant Pathology,
College of Agriculture, Vellayani,
Thiruvananthapuram-695 522.

2-2-06

EXTERNAL EXAMINER

2.2.2006

Dr. P. Selvaraj, Ph.D
Professor and Head
Dept. of Horticulture
Pandit Jawaharlal Nehru College of
Agriculture and Research Institute
Karaikal - 609 603

Dedicated to my husband

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LIST OF ABBREVIATIONS

°C	–	Degree Celsius
@	–	At the rate of
AMF	–	Arbuscular Mycorrhizal fungi
B	–	Boron
b	–	Breadth
BCR	–	Benefit cost ratio
Ca	–	Calcium
CD	–	Critical difference
CGR	–	Crop growth Rate
cm	–	Centimetre
Cu	–	Copper
DMP	–	Dry matter production
et al.	–	And others
Fe	–	Iron
FW	–	Fresh weight
FYM	–	Farm yard manure
g	–	Gram
GA_3	–	Gibberellic acid
ha	–	Hectare
HI	–	Harvest Index
IAA	–	Indole acetic acid
K	–	Potassium
KAU	–	Kerala Agricultural University
kg	–	Kilogram
l	–	Length
LAI	–	Leaf area index
m	–	Metre
MAP	–	Months After Planting
Mg	–	Magnesium
mi	–	Microbial inoculants
min	–	Minute

LIST OF ABBREVIATIONS CONTINUED

ml	–	Millilitre
mm	–	Millimetre
Mn	–	Manganese
Mo	–	Molybdenum
MSL	–	Mean Sea Level
N	–	Nitrogen
NAR	–	Net assimilation rate
NC	–	Neem cake
nm	–	Nanometer
NUE	–	Nitrogen use efficiency
P	–	Phosphorus
POP	–	Package of practice
RGR	–	Relative growth rate
S	–	Sulphur
SE	–	Standard Error
t	–	Tonnes
TDM	–	Total dry matter production
TNAU	–	Tamil Nadu Agricultural University
TSS	–	Total Soluble salts
VAM	–	Vescicular Arbuscular Mycorrhizal
VC	–	Vermicompost
Zn	–	Zinc

Introduction

1. INTRODUCTION

Medicinal plants are one among the very important national resources of India. India has one of the richest plant based ethno-medical traditions in the world. Ninety per cent of the drugs used in indigenous system of medicine are based on plant material as it is considered to be safe, cost-effective and with minimal side effects, when genuine ingredients are used (Rawat and Uniyat, 2003). Proper assessment of the drugs and their safety and efficacy for health improvement warrants scientific study in these areas. The plants that are used for medicinal purposes should be free from any residues of pesticides or fertilizers or else, they become more a poison than a medicine. Growing medicinal plants using chemical fertilizers and pesticides may alter their active ingredients and cause deterioration in their quality (Sharma, 2003). In India, the single most important factor, which is standing in the way of wider acceptance of drugs of plant origin, is the non-availability of quality raw material. So the cultivation of medicinal plants should be done near to nature or what is popularly known as organic farming. By adopting such a farming system we can also enhance the export of drug plants, as the risk of their rejection by the importing countries may become less.

Chethikkoduveli (*Plumbago rosea* L., Family: Plumbaginaceae), known as Rosy flowered lead wort or fire plant in English, is an important medicinal plant, the root of which is used in more than 100 ayurvedic formulations such as Chitrakasava, Dasamoolarishta, Gulgguluthiktaka, Ayaskriti etc. The roots are acrid, astringent, thermogenic, anthelmintic, digestive, gastric, sudorific and are useful in fever, cough, ring worms, leucoderma, dyspepsia, skin diseases, scabies and anaemia. They are also narotic, carminative, antiperiodic, nervine tonic and rejuvenating (Nambiar *et al.*, 2003). The root bark contains an orange-yellow pigmented alkaloid, plumbagin (2-methyl-5-hydroxy 1, 4 naphthoquinone, $C_{11}H_8O_3$) which has anti-cancerous, antifungal and anti-bacterial activity (Krishnaswamy and Purushothaman, 1980). The roots also contain sitosterol glycoside ($C_{33}H_{56}O_6$), sitosterol, fatty alcohol probably arachidyl alcohol, tannin and one amorphous brown pigment. The flowers contain three rhamnosides of pelargonidin, cyanidin and delphinidin.

The average annual requirement of plumbago roots during last decade was around 400 t (Nair *et al.*, 1992). Plumbago cultivation is highly profitable under Kerala condition (Swapna, 2005). Eventhough the crop is cultivated in isolated pockets in the state; the domestic production is quite insufficient to meet the ever increasing demand. In Kerala, the cropping intensity is high and there is limited scope for monocropping of *Plumbago rosea.* However, there is ample scope for introducing it as intercrop in coconut and rubber plantations. *Plumbago rosea* has already been identified as a potential intercrop in young rubber and coconut plantations (RRII, 1989; Nair *et al.*, 1991; Kurien *et al.*, 2000). Agro technology for the cultivation of chethikoduveli as an intercrop in coconut garden has been developed which includes the use of both organic and chemical fertilizers (KAU, 2002).

The use of organic manures improves the physical properties of the soil and balances the nutrient availability to plants. Microbial inoculants like *Azospirillum, Phosphobacteria* and AMF are capable of enhancing the fertilizer use efficiency, soil fertility status and thus help in improving the yield and quality of crops. Mycorrhizal infection enhances plant growth by increasing the absorbing surface and mobilizing sparingly available nutrient sources or by secretion of ectoenzymes (Rhodes, 1980; Bolan *et al.*, 1987).

Detailed investigations regarding the combined effect of organics and microbial inoculants on the yield and quality is lacking in the case of

Plumbago rosea. Hence, the present study is taken up with the following objectives.

- To study the combined effect of organic manures and microbial inoculants in the growth, yield and plumbagin content of *Plumbago rosea.*
- To formulate an organic manurial schedule for *Plumbago rosea* in a coconut based cropping system
- To assess the relative efficiency of organic manures and microbial inoculants as substitutes for inorganic fertilizers
- To work out the economics of various combinations of manures and microbial inoculants.

Review of Literature

2. REVIEW OF LITERATURE

Among the three species of Plumbago recorded in India, *Plumbago rosea* (chethikkoduveli) is the accepted source of drug in Kerala. *P. rosea* is considered to be therapeutically more active.

Different species of Plumbago (Sivarajan and Balachandran, 2002)

Species	Flower colour	Medicinal use
Plumbago rosea	Red flower	Accepted source of drug in Kerala
P. zeylanica	White flower	Source of drug in North India
P. capensis	Blue flower	Not known as a source of drug

Vernacular names of *P. rosea*

Hindi – Lalcitra, Raktacitra

Kannada – Kempucitramula

Malayalam – Chethikoduveli, Chuvannakoduveli

Sanskrit – Citrakah, Dahanah

Tamil – Cenkotiveli, Cittiramulam

Telugu – Yerracitramulam (Varier, 2003)

The aim of the present project is to study the effectiveness of different organic manures and microbial inoculants on growth, yield and quality improvement in chethikkoduveli, grown as an intercrop in coconut plantations. The relevant works pertaining to the study are reviewed here.

2.1 ORGANIC MANURE

Soils with high diversity of flora and fauna can continuously support the growth of healthy crops and are termed 'living soils', which is the basis of organic farming (Nampoothiri, 2001). Organic farming enhances the quality of produce, as, in addition to major nutrients, almost all the essential plant nutrients, enzymes, hormones, growth regulators etc are supplied (Kumaraswamy, 2004). Moreover, the usage of organic manures reduces environmental contamination and also pesticide residue in food (Jothimani and Vanangamudi, 2004).

Farmyard manure (FYM), the most common and readily available traditional organic manure is a mixture of animal shed wastes containing dung, urine and some straw (Gaur, 1994).

Vermicomposting is the bioconversion of organic waste materials through earthworm consumption. Vermicompost is rich in N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu, Co, Mo, and B. It also has a high bacterial count of 10^{10} consisting of phosphate solublisers, nitrobacter, actinomycetes, fungi, *rhizobium* etc. and is free from all pathogens. Vermicompost is a good source of GA_3, IAA and cytokinin (Gaur and Sadasivam, 1993).

Neem cake is a non-edible oil cake. Among the oil cakes, neem cake isolates resulted in increased nitrogen use efficiency (NUE) as well as agronomic use efficiency (Kumar and Ali, 2003).

2.1.1 Effect of Organic Manures on Plant Growth Characters

Organically grown tomato plants were taller with more number of branches than inorganically grown ones (Thamburaj, 1994). Addition of organic manure enhanced the growth and biomass of pepper vines (Sivakumar and Wahid, 1994). The beneficial effect of organic amendments in increasing the growth parameters were reported in tomato (Pushpa, 1996) and chilli (Anitha, 1997).

2.1.1.1 FYM

In *Plumbago zeylanica* the growth parameters such as number of branches per plant, plant height, fresh and dry weight per plant were better in FYM @ 10 t ha^{-1} + NPK @ 60 : 40 : 30 kg ha^{-1} over control (Shah *et al.*, 2000). Vidyadharan (2000) reported increased plant height, number of leaves per plant, sucker number per hill and dry matter production by highest level of FYM (20 t ha^{-1}) in arrowroot. According to Arunkumar (2000) highest level of FYM and vermicompost applied plants maintained their superiority in plant height, number of leaves and number of branches of amaranthus at all growth stages. A study on the effect of FYM and N on growth and yield of wheat in Hissar revealed higher plant height with the application of FYM @ 20 t ha^{-1} over the control (Singh and Agarwal, 2001). FYM applied turmeric showed higher initial growth (Rakhee, 2002). Ginger plants received FYM recorded maximum height at all growth stages (Sreekala, 2004).

2.1.1.2 Vermicompost

Vadiraj *et al.* (1996) observed 30 per cent increase in plant height and 70 per cent in leaf area in vermicompost applied plants over control in ginger varieties Armour and Suroma. Pushpa (1996) observed that in tomato biometric observation *viz.*, height of the plant, number of leaves and number of flowers was greatly influenced by the application of vermicompost. Better growth was recorded in cowpea plants supplied with vermicompost and FYM (Sailajakumari and Ushakumari, 2001)

2.1.1.3 Neem Cake

Arunkumar (2000) reported that when neem cake was used as organic manure in amaranthus, an increase in number of leaves was observed and growth characters such as plant height, number of branches, dry matter production and LAI were found to be on par with the Package of Practises (POP) recommendation. of Kerala Agricultural University.

According to Sharu (2000) in chilli, the growth characters such as plant height, number of branches and dry matter accumulation as a result of neem cake application was found to be on par with plants received manuring as per POP recommendation of Kerala Agricultural University. Neem cake was found to be effective in improving the biometric characters in *Plumbago rosea* (Santhoshkumar, 2004).

2.1.2 Effect of Organic Manures on Physiological Characters

The physiological characters of plants are greatly influenced by organic manures. The influence of organic manures on leaf number, LAI and DMP in brinjal was superior over inorganic fertilizer application (Subbarao and Ravisankar, 2001). In galangal, grown as intercrop in coconut garden, an increase in dry matter accumulation in the rhizomes at harvest was noticed in FYM and vermicompost applied plots (Maheswarappa *et al.*, 2001). DMP and LAI was the highest for FYM and coir pith compost treated plants in turmeric (Rakhee, 2002).

The integrated nutrient management studies in chilli revealed that RGR, CGR and NAR were the highest in vermicompost applied plants (Sharu, 2000). In turmeric, NAR was the highest for treatments such as vermicompost, green leaves and NPK alone (Rakhee, 2002).

2.1.3 Effect of Organic Manures on Yield and Yield Components

2.1.3.1 FYM

The results of a long term fertilizer experiment conducted at TNAU, Coimbatore, in a mixed red and medium black soil for a period of sixteen years revealed significant differences in the yield of finger millet, maize and cowpea due to FYM application (Muthuswamy *et al.*, 1990). Maheswarappa *et al.* (1997) found that application of FYM resulted in higher HI, number and length of rhizomes of arrowroot raised as an intercrop in coconut garden. The rhizome yield of kacholam was more in FYM (30 t ha^{-1}) treated plots over control (KAU, 1997). According to

Joseph (1998) in snakegourd, yield attributing characters like length, weight and number of fruits per plant was the highest in plants applied with FYM and FYM to substitute NPK. According to Rakhee (2002) the rhizome spread of turmeric was influenced by organic manures only at 8 MAP and was the highest for coir pith compost treatment which was on par with FYM. A study on the effect of organics and inorganics in betel vine (Arulmozhiyan *et al.*, 2002) revealed highest yield attribute by the application of FYM @ 200 kg ha^{-1}.

Application of FYM alone resulted in higher yield in yam (Mohankumar and Nair, 1979), amorphophallus (Patel and Mehta, 1987), turmeric (Balashanmugam *et al.*, 1989), arrowroot (Vidhyadharan, 2000) and ginger (Sreekala, 2004).

2.1.3.2 Vermicompost

Vadiraj *et al.* (1996) reported increased yield in turmeric plants treated with vermicompost alone or in combination with inorganic fertilizers. Arunkumar (2000) reported higher yield and quality of amaranthus than POP recommendation in vermicompost treated plots. Enhanced yield was recorded in treatments supplied with vermicompost in cowpea (Sailajakumari and Ushakumari, 2001) and chilli (Ankarao and Haripriya, 2003).

2.1.3.3 Neem Cake

Application of NC @ 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). In betelvine, application of N through NC produced significant response in increasing the yield (Kadam *et al.*, 1993). A study conducted at Kerala Agricultural University, revealed that the best source of organic manure for banana was neemcake followed by FYM (KAU, 1993).

2.1.4 Effect of Organic Manure on Quality Aspects

World over, the demand for medicinal plants and herbal drugs is increasing. As far as medicinal plants are concerned, quality is more important than quantity. Organic produces are free from pesticide residues (Sharma, 2002) attributing to better quality.

2.1.4.1 FYM

FYM enhanced the ascorbic acid content in spinach leaves (Kanşal *et al.*, 1987). According to Vidhyadharan (2000), highest protein content in arrowroot was recorded at highest level of FYM.

2.1.4.2 Vermicompost

Vermicompost has a definite advantage over other organic manures in respect to quality of cowpea (Sailajakumari and Ushakumari, 2001).

2.1.4.3 Neem Cake

According to Sadanandan and Hamza (1996) neemcake application was found to be superior with regard to curcumin recovery in turmeric.

2.1.5 Effect of Organic Manure on Soil Dynamics

Srivastava (1985) observed that the application of organic manures resulted in increased organic carbon content, total N and available P and K status of soil. Kabeerathumma *et al.* (1990) and Susan *et al.* (1998) in a long term manurial experiment, after thirteen years of continuous cropping observed increased nutrient status in organic treated plots compared to inorganic treatment. Use of organic matter enhances the soil productivity (Sangeetha, 2004).

2.1.5.1 FYM

Increased availability of potassium due to the combined application of FYM with 100 percent recommended quantity of NPK in a long term fertilizer experiment was reported by Aravind (1987). FYM has higher efficiency in producing better yield and improving chemical properties of soil compared to castor oil cake and urea (Gomes *et al.*, 1983). More (1994) reported that addition of farm waste and organic manures increased the status of available nitrogen and phosphorus of the soil. Available P content in post harvest soil was highest in rock phosphate + FYM treatment (Venkatesh *et al.*, 2003).

2.1.5.2 Vermicompost

An increased availability of K was observed in soils with earth worm activity (Rao *et al.*, 1996). Available P, K, Mg, Ca and organic carbon content of the rhizosphere soil almost doubled when it was supplied with vermicompost for over two years (Hegde *et al.*, 1998). Vermicompost contains beneficial microbes, various amino acids and minerals, which humidify the organic matter and surrounding soil and act as a biofertilizer for plants (Shanbhag, 1999).

2.1.5.3 Neem Cake

In addition to nutrients, neemcake contains the alkaloids, nimbin, nimbidin and certain S compounds which effectively inhibit the nitrification process (Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). Sathiananthan (1982) found that neem cake and mahua cake reduced leaching loss and extended the period of availability of N to the crop from applied N. The application of neem cake added organic carbon and potash to the soil and increased ginger yield (Sadanandan and Iyer, 1986). Neem cake can aid in metered supply of nitrogen over a stipulated period of crop growth (Hulagur, 1993).

2.1.6 Plant Uptake

Increased uptake of nutrients and higher yield in tomato (Pushpa, 1996) and chilli (Rajalekshmi, 1996) were reported by the application of vermicompost. Deiz (1989) reported that nitrogen uptake by wheat was much higher in organic manured plots than in the inorganic control. There was significant increase in N, P and K uptake by ginger rhizome due to application of rock phosphate, SSP and FYM (Venkatesh *et al.*, 2003).

2.1.7 Pest and Disease Incidence

Alam and Khan (1974) observed that neem cake, mahua cake and mustard cake controlled phytonematodes in the field almost as effective as DD and nemagon. Rajani (1998) investigated the effectiveness of neem cake @ 200 g m^{-2} for managing root-knot nematode in kacholam. Sheela and Rajani (1999) reported that crop loss in *Piper nigrum*, *Plumbago rosea* and *Kaempferia galanga* due to root-knot nematode was 20-36 per cent (in terms of weight of root) which can be effectively controlled by neem cake (Santhoshkumar, 2004). Several other authors also reported the effectiveness of organic amendments (oil seed cakes) for the management of nematodes in various crops (Abid *et al.*, 1995; Sheela *et al.*, 1995; Rajani *et al.*, 1998). The experiment conducted at Kerala Agricultural University reported that the nematode population in soil and root mat was found to be minimum in neem cake treatment and maximum in treatment with nitrogen alone (KAU, 1997 and KAU, 2003).

2.2 EFFECT OF MICROBIAL INOCULANTS

2.2.1 Plant Growth Characters

Application of VAM alone or together with *Azospirillum* has been found to benefit crop growth and yield in bajra (Rajput, 1990), chilli, bellary onion (Subbiah, 1994) and grain legumes (Rao and Rao, 1998). Biofertilizers have pronounced positive effect on plant height, number of tillers and leaves per plant in ginger (Nath and Korla, 2000). Seed inoculation of *Azospirillum brasillience* in wheat plants increased the leaf area, chlorophyll content and total biomass production (Panwar and Singh, 2000). According to Anith and Manomohandas (2001) application of biocontrol agents are found to have profound effect on the growth parameters of black pepper cuttings. Significant increase in height, root length, dry weight of shoot and root were obtained with *Azospirillum* treated chilli plants (Kavitha, 2001). *Azospirillum* has nitrogen fixing ability and are also known to produce growth promoting substances, which favour better growth in turmeric (Subramanian *et al.*, 2003). Dual inoculation of fenugreek seed with rhizobium + PSB was found significantly superior in increasing the plant height, dry matter accumulation, number of pods/plant, shelling per cent over single inoculation or uninoculated control (Purbey *et al.*, 2003). Use of biofertilizers gave increased LAI, chlorophyll content, plant height, dry matter accumulation, grain yield and protein content in sorghum (Patidar and Mali, 2004). Plant growth promoting rhizobacteria significantly increased growth parameters like number of leaves, seedling height etc. (Gupta *et al.*, 2004) in plants intercropped in coconut garden.

2.2.2 Physiological Characters

Dual inoculation of *Azospirillum* and AMF with higher dose of chemical fertilizer positively influenced the physiological parameters in amaranthus (Niranjana, 1998). Biofertilizers significantly and favourably influenced LAI, NAR, RGR and harvest index in peas (Vimala and Natarajan, 2002).

2.2.3 Yield and Yield Components

The root colonization of VAM – fungi (*Glomus* spp.) have significantly increased the growth, number of branches and fresh biomass yield of periwinkle in comparison to non-inoculated control plants (Gupta *et al.*, 2003).

2.2.4 Quality Aspects

The quality attributes of tomato *viz.*, vitamin C content and TSS significantly increased over control by AMF inoculation (Sundaram and Arangarasan, 1995). A study conducted in blackgram and greengram fixing bacteria. Sharma *et al.* (2002) studied the effect of VAM and P on soil and leaf nutrient status and observed higher P in inoculated plants.

2.2.7 Pests and Disease Incidence

The positive effect of AMF against pest and diseases was reported in grain legumes (Ray and Dalei, 1998) pepper (Sivaprasad *et al.*, 2000) and Kacholam (KAU, 2003).

2.3 COMBINED EFFECT OF ORGANIC MANURES AND MICROBIAL INOCULANTS

2.3.1 Plant Growth Characters

The maximum plant height, leaf area per plant, dry matter production per plant and yield were recorded in chilli plants supplied with 75 per cent N, P and 100 per cent K in addition to the inoculation of Azotobacter, *Azospirillum*, PSB and VAM (Sajan *et al.*, 2002). Seed treated with Azotobacter and *Azospirillum* + 75 per cent N and also with 50 per cent N significantly increased plant height, branches per plant and seed yield of coriander (Hooda and Tehlan, 2003).

2.3.2 Physiological Characters

The physiological changes in plant are due to the action of growth promoting substances like auxin and gibberellins synthesized by inoculated microorganisms (Thimman, 1974). Biofertilizers significantly and favourably influenced the parameters LAI, NAR, RGR and HI in peas (Vimala and Natarajan, 2002). According to Sreekala (2004), in ginger physiological parameters like DMP, CGR, LAI and HI were higher in plots treated with FYM + AMF and FYM + NC + AMF + *Trichoderma.*

2.3.3 Yield and Yield Components

The combined application of neem cake along with seed treatment using *Trichoderma viride* recorded maximum yield in fenugreek (IISR, 1998). The plot treated with 5 t of FYM + 50 per cent N + *Azospirillum*

(5 kg ha^{-1}) showed highest yield in turmeric (Subramanian *et al.*, 2003). Seed yield of coriander was the highest in plants treated with 50 per cent N + *Azospirillum* (Subramanian *et al.*, 2003). Parthiban and Easwaran (2003) reported maximum number of fruits per vine, bean length, bean girth, single bean weight and bean weight per vine in vanilla plants treated with VAM, *Azospirillum* and phosphobacteria + 100 g NPK per vine per year.

2.3.4 Quality Aspects

AMF inoculated *Cymbopogon martini* var. *motia* produced more oil than control plants (Ratti and Janardhan, 1996). In ginger fifteen per cent increase in essential oil content was observed in plots where 25 per cent N was substituted through *Azospirillum* and was on par with FYM alone treatment. In geranium the cumulative herbage yield and essential oil yield were significantly higher under fertigation with 80 per cent NPK + Azotobacter + *Azospirillum* + VAM biofertilizers in all the three seasons (Pasha *et al.*, 2003).

2.3.5 Soil Dynamics

Subbiah (1990) reported that when adequate amount of FYM was added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of the soil. VAM converts unavailable nutrient content of the rhizosphere soil to available forms.

2.3.6 Plant Uptake

Integrated nutrient management studies in betelvine by Mozhiyan and Thamburaj (1998) revealed highest uptake of N, P, K, Ca and Mg with the application of *Azospirillum* along with FYM and nitrogen through inorganic way. The experiment conducted in Kerala Agricultural University (KAU, 1999) showed that in ginger, the treatment involving FYM alone at 48 t ha^{-1} substituting 50 per cent N and 25 per cent N revealed that mycorrhizal plants showed greater leaf chlorophyll and TSS than non-mycorrhizal plants (Rao and Rao, 1998).

2.2.5 Soil Dynamics

Mycorrhiza are known to produce amino acids, vitamins and growth promoting substances such as IAA and GA which help in better growth of plants (Barea and Azcon, 1982). Many bacterial, fungal and actinomycete species are capable of solubilizing sparingly soluble P in soil and rhizosphere and they increase the availability of P to plants (Kucey *et al.*, 1989). Microbial inoculants or bioinoculants are beneficial microorganisms domesticated in suitable carriers which on application to soil augment crop growth and yield (Verma, 1993). Phosphate solubilising bacteria produces organic acid which makes unavailable P more available (Sharma, 2002). In soil, P solubilising bacteria constitute 1-50 per cent and fungi 0.5-1 per cent of the total respective population (Gyaneswar *et al.*, 2002). Microbial inoculants are the products containing living cells of different microorganisms, which have an ability to mobilize nutritionally important elements from non-usable to usable form through biological processes (Arora and Dan, 2003). According to Zhahir *et al.* (2004), mycorrhizosphere interaction between bacteria and fungi affect P-cycling, thus promoting a sustainable nutrient supply to plants.

2.2.6 Plant Uptake

A study conducted in blackgram and greengram revealed that mycorrhizal plants showed greater concentration of P and N than non-mycorrhizal plants (Rao and Rao, 1998). Combined inoculation of Rhizobium and VAM enhanced plant uptake of NPK in green gram (Ray and Dalei, 1998). Mycorrhiza inoculated plants show better growth due to enhanced uptake of P, Zn and copper (Krishna and Bhagyaraj, 1999). Ashithraj (2001) reported that N and P content increased significantly in pepper cuttings with the application of biofertilizer such as AMF and N through *Azospirillum* recorded higher total uptake of N, P and K at 180 DAP.

2.4 ECONOMICS

The benefit cost ratio was highest for plots supplied with FYM+ *Azospirillum* over POP recommendations of Kerala Agricultural University (KAU, 1996). An experiment conducted at Kerala Agricultural University (KAU, 1999) in ginger revealed the positive influence of different organic manures and *Azospirillum* on growth, yield and quality. Raj (1999) found that in okra, FYM + neem cake application recorded the maximum profit and highest BC ratio. According to Arunkumar (2000) vermicompost application at highest dose gave the maximum BC ratio in amaranthus. Maximum yield and monthly returns per rupee investment was obtained from 60 g N +300 g P_2O_5 +300 gK_2O +15 g neem cake/plant/year in acid lime (Ingle *et al.*, 2001).

Asha (1999) standardized the organic nutrient schedule for bhindi using five organic nitrogen sources, and the study revealed maximum profit at N_3 level of nitrogen (150 kg ha^{-1}) and *Azospirillum* inoculation. Nath and Korla (2000) studied the effect of biofertilizers on growth, yield and economics of ginger cultivation. The results revealed maximum net returns and BC ratio for plots treated with Azofert. In Rose Mary, three levels of N (50, 75, 100 kg ha^{-1}) and phosphorus (20, 30 and 40 kg ha^{-1}) with a constant level of potash at 40 kg ha^{-1} along with three biofertilizers (*Azotobacter*, *Azospirillum* and AMF) recorded higher BC ratio and essential oil production (Anuradha *et al.*, 2003).

As a cost effective supplement to chemical fertilizers and as a renewable energy source, microbial inoculants can economize the high investment needed for fertilizer usage of N and P (Pandey and Kumar, 2002). These microbial inoculants can save N/P requirement upto 50 per cent in most of the vegetable crops and increase the yield by 18 to 50 per cent in them (Kanuja and Narayanan, 2003). The effect of *Azospirillum* and graded level of nitrogenous fertilizers on the growth and yield of turmeric indicated that the application of *Azospirillum* reduced 50 per cent of recommended nitrogenous fertilizers besides increasing the fresh rhizome weight (Subramanian *et al.*, 2003).

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was to study the combined effect of organic manures and microbial inoculants on the growth, yield and plumbagin content of chethikkoduveli (*Plumbago rosea* L.). The study carried out in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani during 2004-2005, was to formulate an organic manurial schedule for chethikkoduveli in a coconut based cropping system. The study also aims at assessing the relative efficiency of organic manures and microbial inoculants as substitutes for inorganic fertilizers and comparing the economics of cultivation of various treatment combinations.

3.1 EXPERIMENTAL SITE

3.1.1 Location

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani. The area is situated at 8° 30' North latitude and 76° 54' East longitude, at an altitude of 29 m above MSL.

3.1.2 Soil

The soil of the experimental site is red loam, which belonged to the Vellayani series under the order oxisol. Texturally the soil is classified as clay loam. The pH of the soil was 5.2 and was low in available N and K but high in available P as per the soil sample analysis.

3.1.3 Nature and Cropping History of the Site

Coconut garden with palms above forty years of age, spaced at about 8 m was selected for the study. The shade intensity of the field was estimated as 25 per cent using Model LI-250 Light meter. Tapioca was the previous intercrop in the field.

3.2 SEASON

The field experiment was conducted from June 2004 to May 2005.

3.3 WEATHER

The climate of the experimental site is humid tropical. The mean annual rainfall during the period was 140mm. The mean annual maximum and minimum temperatures were 31.77 and 21.9° C. The mean annual evaporation during the cropping period was 3.49cm. Data on weather conditions such as temperature, rainfall and evaporation were obtained from the Meteorological Observatory, College of Agriculture, Vellayani and Coconut Research Station, Balaramapuram and is given in Appendix I and graphically depicted in Fig. 1

3.4 MATERIALS

3.4.1 Planting Material

Uniform sized good quality cuttings raised in polybags collected from the Instructional Farm, Vellayani were used for the study.

3.4.2 Manures and Biofertilizers

Three organic manures and three biofertilizers were used in the experiment. The analytical report of the major nutrients contained in the organic manures used for the experiment is given in Table 1.

Doses of farmyard manure, vermicompost and neem cake were fixed on nitrogen equivalent basis and applied in beds prior to planting. Quantity of major nutrients added through manures and fertilizers are given in Appendix II.

For the control treatment, urea (46 % N), rock phosphate (16 % P_2O_5) and muriate of potash (60 % K_2O) were used as chemical sources of nitrogen, phosphorus and potassium respectively.

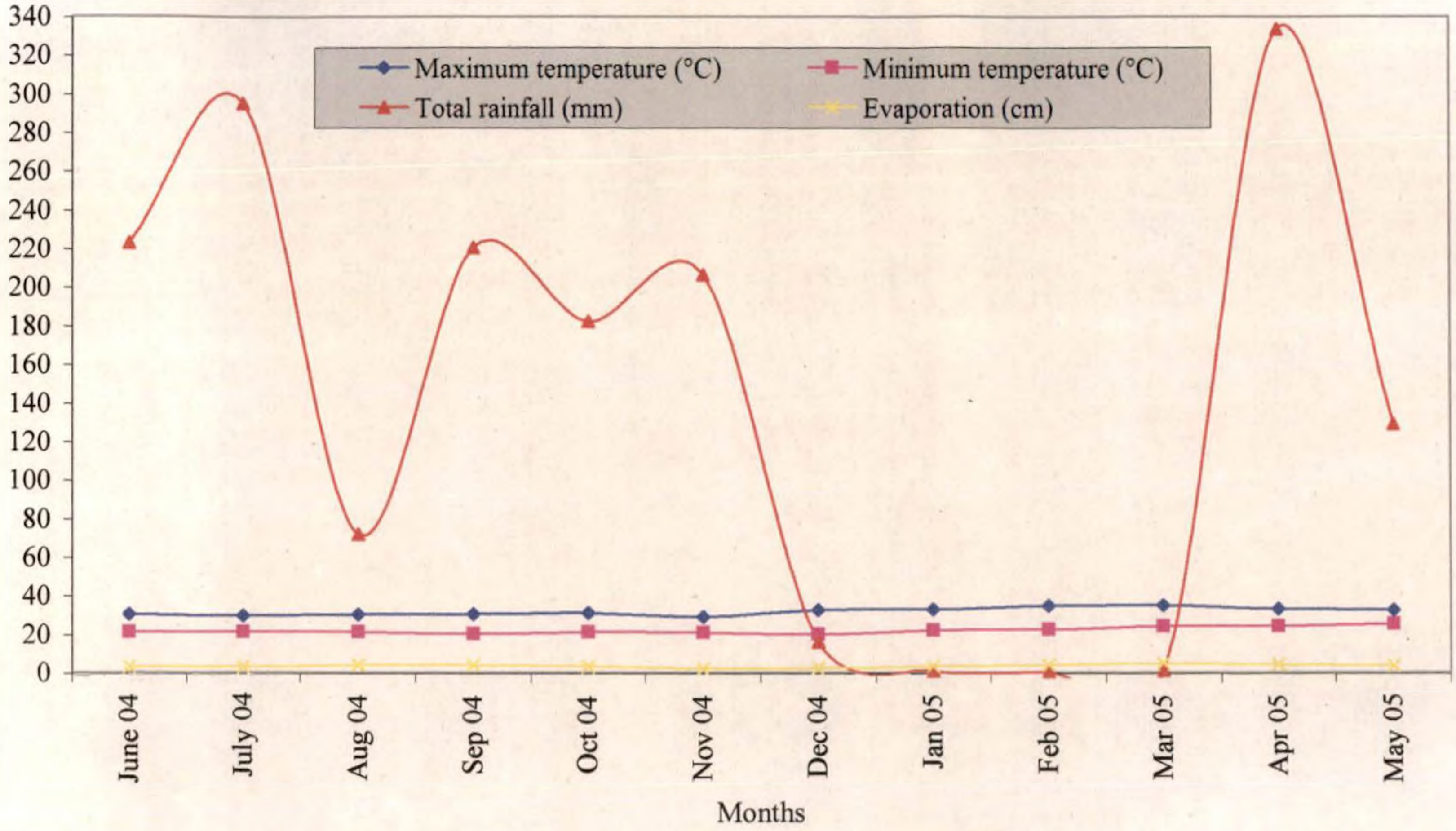


Fig. 1. Weather parameters during the cropping period (June 2004 - May 2005)

Table 1. Nutrient content of organic manures used for the experiment

Sl. No.	Organic manures	Nutrient content (%)		
		N	P	K
1	FYM	0.9	0.4	1.2
2	Vermicompost	0.6	0.5	1.2
3	Neem cake	1.7	0.2	2.0
4	Wood ash	-	-	2.3
5	Rock phosphate	-	16	-

Microbial inoculants

Commercial formulations of *Azospirillum*, AMF and Phosphobacteria obtained from the Department of Plant Pathology, College of Agriculture, Vellayani were used.

Treatment Combination Details

Farmyard manure was applied @ 10 t ha^{-1} uniformly to all the plots. Quantity of neem cake and vermicompost was so fixed as to supply 25 per cent of the N requirement of the respective treatment and the remaining quantity through FYM. Additional quantity of P and K requirement was supplied as rock phosphate and wood ash. Nutrients were applied on N equivalent basis

3.5 METHODS

3.5.1 Design and Layout of the Experiment

Design	:	RBD
Treatments	:	13
Replication	:	3
Spacing	:	50 cm x 15 cm
Plot size	:	2.5 m x 0.75 m
Number of plants per pot	:	25

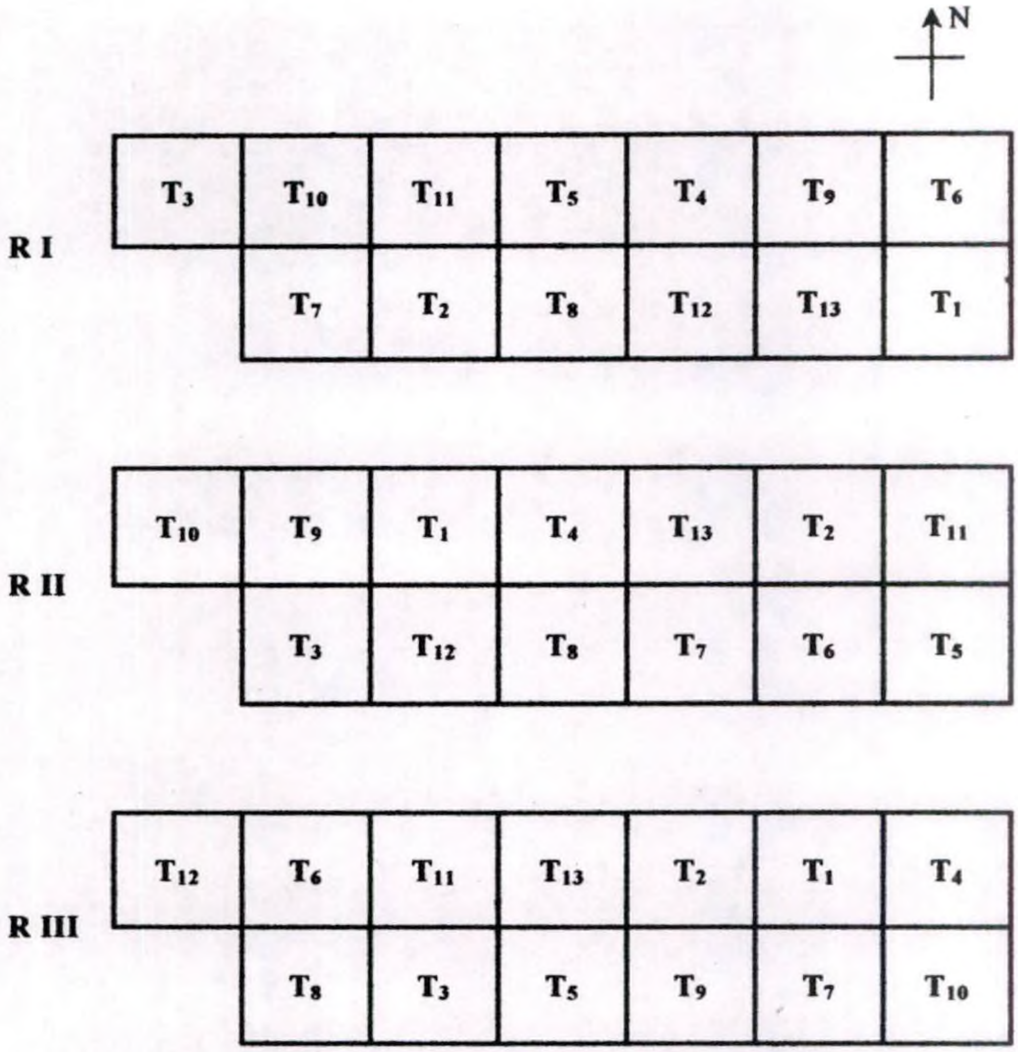


Fig.1. Layout of the field experiment

3.5.1.1 Treatments

FYM @ 10 t ha^{-1} will be applied uniformly to all plots.

T_1	:	50 : 50 : 50 NPK kg ha^{-1} ; POP recommendation.(KAU,2002)
T_2	:	FYM alone (100 % N of POP)
T_3	:	FYM (75 % N of POP) + microbial inoculants
T_4	:	FYM (50 % N of POP)+ microbial inoculants
T_5	:	FYM + neem cake (100 % N of POP)
T_6	:	FYM + neem cake (75 % N of POP)+ microbial inoculants
T_7	:	FYM + neem cake (50 % N of POP)+ microbial inoculants
T_8	:	FYM + vermicompost (100 % N of POP)
T_9	:	FYM + vermicompost(75 % N of POP) + microbial inoculants
T_{10}	:	FYM + vermicompost(50 % N of POP) + microbial inoculants
T_{11}	:	FYM + neem cake + vermicompost (100 % N of POP)
T_{12}	:	FYM + neem cake + vermicompost (75 % N of POP)+ microbial inoculants
T_{13}	:	FYM + neem cake + vermicompost (50 % N of POP)+ microbial inoculants

Treatment combination details are given in Table 2.

3.5.2 Land Preparation and Planting

The field was ploughed to a fine tilth and plots of size 2.5 m x 0.75 m were taken in the interspaces of coconut garden leaving an area of 2.0m radius from the base of the palms. Between plots a spacing of 30 cm was maintained. Lime was applied @ 600 kg ha^{-1} and was well incorporated. After four weeks organic manures were applied to respective plots as per the treatments. Microbial inoculants such as AMF, *Azospirillum* and phosphate solubilizers were also added to these plots as per the treatment. Rooted cuttings were planted two weeks after the addition of organic and biofertilizers at a spacing of 50 x 15 cm.

Table 2. Treatment combinations

Notation	Treatments	Details
T_1 (Control – POP recommendation)	50 : 50 : 50 kg NPK ha^{-1}	FYM @ 10 t ha^{-1} + Urea + Rock phosphate + MOP
T_2	FYM alone (100 % N of POP)	FYM @ 10 t ha^{-1} + FYM (100 % N) + Rock phosphate
T_3	FYM (75 % N of POP)+ microbial inoculants	FYM @ 10 t ha^{-1} + FYM (75 % N) + Rock phosphate + microbial inoculants
T_4	FYM (50 % N of POP)+ microbial inoculants	FYM @ 10 t ha^{-1} + FYM (50 % N) + Rock phosphate + Wood ash + microbial inoculants
T_5	FYM + Neem cake (100 % N of POP)	FYM @ 10 t ha^{-1} + FYM (75 % N)* + Neem cake (25 % N) + Rock phosphate
T_6	FYM + Neem cake (75 % N of POP)+ microbial inoculants	FYM @ 10 t ha^{-1} + FYM (50 % N) + Neem cake (25 % N) + Rock phosphate + Wood ash + microbial inoculants
T_7	FYM + Neem cake (50 % N of POP) + microbial inoculants	FYM @ 10 t ha^{-1} + FYM (25 % N) + Neem cake (25 % N) + Rock phosphate + Wood ash + microbial inoculants
T_8	FYM + Vermicompost (100 % N of POP)	FYM @ 10 t ha^{-1} + FYM (75 % N) + Vermicompost (25 % N) + Rock phosphate
T_9	FYM + Vermicompost + microbial inoculants (75 % N of POP)	FYM @ 10 t ha^{-1} + FYM (50 % N) + Vermicompost (25 % N) + Rock phosphate + microbial inoculants
T_{10}	FYM + Vermicompost (50 % N of POP)+ microbial inoculants	FYM @ 10 t ha^{-1} + FYM (25 % N) + Vermicompost (25 % N) + Rock phosphate + wood ash + microbial inoculants
T_{11}	FYM + Neem cake + Vermicompost (100 % N of POP)	FYM @ 10 t ha^{-1} + FYM (75 % N) + Neem cake + Vermicompost (25 % N) + Rock phosphate
T_{12}	FYM + Neem cake + Vermicompost (75 % N of POP) + microbial inoculants	FYM @ 10 t ha^{-1} + FYM (50 % N) + Neem cake + Vermicompost (25 % N) + Rock phosphate + microbial inoculants
T_{13}	FYM + Neem cake + Vermicompost (50 % N of POP) + microbial inoculants	FYM @ 10 t ha^{-1} + FYM (25 % N) + neem cake + Vermicompost (25 % N) + Rock phosphate + wood ash + microbial inoculants

Plate 1. General view of the experimental field

Plate 2. Closer view of experimental plot

Plate 3. *Plumbago rosea*

3.5.3 Application of Manures and Fertilizers

Full dose of organic manures as per the treatments was applied as basal dose before planting. Commercial inoculum of AMF containing a mixture of *Glomus fasciculatum*, *Glomus etunicatum* and *Glomus* sp. maintained in pots using sorghum as host was used. The inoculum consisted of root bits, mycelial fragments, and rhizosphere soil or vermiculite-perlite substrate carrying chlamydospores of AMF. The vermiculite-perlite inoculum containing 400 propagules per gram was used for the study. It was well mixed with top soil @ 200 g m^{-2}. *Azospirillum* and phosphate solublizers (*Bacillus megatherium*) applied as soil drench (2 kg ha^{-1} in 60 l water).

In the control plot (T_1) fertilizers and FYM were applied as per POP recommendation (KAU, 2002). Nitrogen was applied in the form of urea, potash as muriate of potash and phosphorus as rock phosphate. N and K were applied in two equal splits *i.e.,* 2 MAP and 4 MAP. FYM and full dose of P were applied as basal dose.

3.5.4 After Cultivation

The crop was grown as a rain fed crop. However, life saving irrigation was given. Periodical hand weeding was done depending upon the intensity of weed growth.

3.5.5 Plant Protection

The plants were observed frequently for any pest /disease occurrence.

3.5.6 Harvesting

The crop was harvested 12 MAP for calculating yield.

3.6 OBSERVATIONS

For each treatment combination three replications were maintained. Leaving the border rows there were nine observation plants. Three of these plants in each replication and treatment were tagged for taking biometric observation and the remaining six were selected randomly for destructive sampling at bimonthly interval from the sixth month after planting till harvesting. The observations on yield and yield components and plant analyses were made only at the final harvest.

3.6.1 Plant Characters

3.6.1.1 Growth Characters

The observations on growth characters were taken from three sample plants selected at random at bimonthly interval after six months of planting and the mean values were worked out.

3.6.1.2 Plant height

The height of the plant was measured from the base of the plant to the tip and the mean was recorded in cm.

3.6.1.3 Number of Branches

The number of aerial shoots were counted and the mean was recorded.

3.6.1.4 Number of Leaves

The number of fully opened leaves were counted and the mean was recorded.

3.6.1.5 Leaf Area

The leaf area constant was worked out statistically from the leaf area measurement of 100 sample leaves obtained by graphical method. This constant was multiplied with the length and breadth of respective leaves to get the leaf area and expressed in cm^2.

$$\text{Leaf area} = 8.4312 + 0.1803\ (l \times b)$$

where, l and b is the length and breadth of the sample leaves.

3.6.2 Physiological Characters

Leaf area index, total dry matter production, specific leaf weight, crop growth rate, net assimilation rate and harvest index were computed at bimonthly intervals from 6 MAP till final harvest.

3.6.2.1 Leaf Area Index (LAI)

Leaf area constant of chethikkoduveli (*Plumbago rosea* L.)

Length (l) and breadth (b) of one hundred leaves at flowering stage were recorded. The corresponding leaf area of each of these leaves was calculated graphically. Based on the relationship between the above parameters, the following regression equation was computed statistically to estimate the leaf area of the sample plants.

$$\text{Leaf area} = 8.4312 + 0.1803\ (l \times b)$$

where, l and b is the length and breadth of the sample leaves.

$$(t = 20.82^{**} \quad t = 10.9^{**})$$

$$F_{1,98} = 118.79^{**}$$

$$R^2 = 0.54$$

The LAI is computed by using the equation

$$LAI = \frac{\text{Leaf area (cm}^2)}{\text{Land area (cm}^2)} = \frac{\text{Leaf area (cm}^2)}{\text{Spacing (cm}^2)}$$

3.6.2.2 Total Dry Matter Production

Whole plants from the treatments were uprooted and dried to a constant weight at 70° C in a hot air oven. The dry weights of plants were converted to kg ha^{-1} to get the total dry matter production (kg ha^{-1}).

TDM (kg ha^{-1}) = Number of plants ha^{-1} x Dry weight of plant in kg

3.6.2.3 Specific Leaf Weight

The specific leaf weight was calculated using the following formula of Watson (1958) and expressed as mg cm^{-2}.

$$\text{Specific leaf weight} = \frac{\text{Leaf dry weight}}{\text{Leaf area}}$$

3.6.2.4 Net Assimilation Rate

Net assimilation rate (NAR) was calculated as per the procedure given by Watson (1958) as modified by Buttery (1970). The following formula was used to derive NAR and expressed in mg day^{-1} cm^{-2}.

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)\,(A_1 + A_2)/2}$$

where, W_2 is the total dry weight of the plant in g at time t_2

W_1 is the total dry weight of the plant in g at time t_1

t_2-t_1 = time interval in days.

A_2= Leaf area (m^2) at time t_2

A_1= Leaf area (m^2) at time t_1

3.6.2.5 Crop Growth Rate

Crop growth rate (CGR) was calculated using the formula of Watson (1958) and expressed as mg day^{-1} cm^{-2}.

CGR = NAR x LAI

3.6.2.6 Harvest Index

Harvest index was calculated at bimonthly interval from six months after planting. The pooled mean of the three replications was taken for each treatment.

$$HI = \frac{Y\ econ}{Y\ biol}$$ where,

Y econ – total fresh weight of roots, Y biol – total fresh weight of plant

3.6.3 Yield and Yield Components

3.6.3.1 Fresh Weight of Roots

The fresh weight of roots was recorded at final harvest and expressed in g $plant^{-1}$.

3.6.3.2 Dry Weight of Roots

The roots after final harvest were washed and dried under shade for one week. It was then kept in hot air oven at 70° C till constant weight obtained. The dry root yield was expressed as g $plant^{-1}$.

3.6.3.3 Number of Roots

The number of healthy roots of sample plants was counted and their mean worked out and expressed on per plant basis.

3.6.3.4 Length of Roots

The length of three randomly selected roots per plant was measured. The mean root length was expressed in cm.

3.6.3.5 Girth of Roots

The girth of roots was measured randomly using a thread and the mean girth was recorded in cm.

3.6.4 Plant Analysis

3.6.4.1 Alcohol Soluble Extracts

Five gram of powdered root sample was extracted in a 250 ml capacity Soxhlet extractor using methanol as the extractant. The solvent was removed by distillation and the quantity of extracts was determined gravimetrically. It was converted to gram kg^{-1} of dried root powder.

3.6.4.2 Plumbagin Content

Plumbagin content was estimated as per the procedure by Gupta *et al.* (1993).

Preparation of extract

One gram dried and powdered root material of each treatment was taken in stoppered test tubes. Ten ml of acetone was added to each tube, shaken well and kept for 48 hours with intermittent shaking. The tubes were washed repeatedly with acetone, filtered and quantitatively transferred to 50 ml standard flasks.

Estimation of plumbagin in the extract

The extraction was by a high pressure liquid chromatograph of Shimadzu Instrument Corporation, Japan make, Model LC8A. The detector used was spectrophotometer detector model SPD10A (wavelength 415 nm). SHIM-PAK-CLC-SIL 250 x 48 mm column was used for detection. Solvent system used was 4 per cent propanol in n-hexane with a flow rate of 1 ml/min.

One ml extract of each sample was injected into the column and the peak area at 415 nm was measured and the plumbagin content was estimated from the standard curve prepared by using different concentrations of standard plumbagin and recorded as percentage.

3.6.4.3 Plant Uptake of NPK

The plant samples were analysed for nitrogen, phosphorus and potassium content. The whole plant was chopped and dried in hot air oven at 70° C till constant weights were obtained. It was then powdered and the composite sample for each treatment was taken for analysis. The methods adopted were:

a) Total N

Modified Microkjeldhal Method (Jackson, 1973).

b) Total P

Vanadomolybdophosphoric yellow colour method and read in spectrophotometer at wavelength 470 nm (Jackson, 1973).

c) Total K

Flame photometric method in Systronics Flame Photometer (Piper, 1967).

Uptake of nutrients by the whole plant at harvest was calculated from the values of dry matter production and per cent nutrient content of plant and was expressed as kg ha^{-1}.

3.6.4.4 Total Chlorophyll Content

The leaf chlorophyll content was estimated by using DMSO method (Sadasivam and Manickam, 1991).

Leaf samples each weighing 250 mg were taken and cut into small pieces. They were put in test tubes and incubated overnight in room temperature in 5 ml DMSO. The extracts were then decanted into volumetric flasks and the volume made up to 25 ml with DMSO. Absorbance @ 652 nm were recorded and total chlorophyll was estimated using the formula:

Total chlorophyll = (A_{652} x V) / (34.5 x FW), where V is the volume of extract.

3.6.5 Nutrient Status of Organic Manures

The NPK content of organic manures was estimated before the experiment. The methods adopted were:

a) Available N

Alkaline permanganate method (Subbiah and Asija, 1956).

b) Available P_2O_5

Bray colorimetric method (Jackson, 1973).

c) Available K_2O

Ammonium acetate method (Jackson, 1973).

3.6.6 Soil Nutrient Status

The soil samples were grouped into three based on the dry root yield of *P. rosea*. Group A consisting of T_7, T_{10} T_{12} and T_3 (high yield), Group B consisting of T_4, T_{11} T_{13} and T_5 (medium yield) and Group C with T_7, T_{10} T_{12} and T_3 (low yield). The soil samples from the plots belonging to each group were mixed separately and composite samples were prepared. These samples were analysed for NPK and microbial inoculants and compared with the soil sample values before the experiment

a) Available N

Alkaline permanganate method (Subbiah and Asija, 1956).

b) Available P_2O_5

Bray colorimetric method (Jackson, 1973).

c) Available K_2O

Ammonium acetate method (Jackson, 1973).

d) Soil pH

The soil was dried in the shade, sieved and pH was measured at 1: 2.5 soil–water ratio using a pH meter with glass electrode.

3.6.7 Soil Microbial Population

The soil microbial population (fungi, bacteria and actinomycetes) was estimated before the experiment. These values were compared with that of the composite soil samples taken from the different treatment plots after the crop harvest.

The microbial population in the rhizosphere soil was estimated by the serial dilution plate technique (Johnson and Curl, 1972).

One gram of rhizosphere soil was taken along with the roots and transferred to 100 ml sterile water and shaken for 5-10 minutes on a shaker. From this stock suspension, different dilution of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8} and 10^{-9} were prepared. The population of fungi was estimated at 10^{-5} and 10^{-7} dilutions, actinomycetes population at 10^{-3} and 10^{-5} and bacterial population at 10^{-7} and 10^{-9}. The dilution giving better results was selected for final analysis.

The media used were:

Bacteria	:	Nutrient Agar Medium
Fungi	:	Potato Dextrose Agar Medium
Actinomycetes	:	Kenknight's Agar

The composition of media used was as follows:

a) Nutrient agar

Peptone	-	5 g
NaCl	-	5g
Beef extract	-	3 g
Agar	-	20 g
Distilled water	-	1000 ml
pH	-	7.0

b) Potato Dextrose Agar

Potato	-	200 g
Dextrose	-	20 g
Agar	-	20 g
Distilled water	-	1000 ml

c) Kenknight's Agar

Dextrose	-	1 g
KH_2PO_4	-	0.1 g
$NaNO_3$	-	0.1 g
KCl	-	0.1 g
$MgSO_4 . 7H_2O$	-	0.1 g

Agar	-	15 g
Distilled water	-	1000 ml

3.6.8 Benefit Cost Ratio

The total income, total cost, net return and benefit : cost ratio (BCR) of various treatments were worked out considering the cost of cultivation and the income derived from each treatment. The norms and rates prevalent at Instructional Farm, College of Agriculture, Vellayani during 2004-2005 were followed for estimation. The price of plumbago roots was taken as Rs. 70 kg^{-1} (Swapna, 2005). BCR was analysed statistically.

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

$$BCR = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.6.9 Statistical Analysis

The experimental data were analysed statistically by applying the techniques of analysis of variance as per the layout of the experiment (Panse and Sukhatme, 1985).

Results

4. RESULTS

The results of the experiment conducted at the Instructional Farm, Vellayani during 2004-2005 to study the effect of organic manures and microbial inoculants on growth, yield and quality of chethikkoduveli (*P. rosea*) are presented below.

4.1 GROWTH CHARACTERS

4.1.1 Height of the Plant, cm

The height of the plants was significantly different under different treatments throughout the growth period (Table 1). Plants supplied with FYM (75 %) + mi; T3 showed significantly higher heights at all stages of observation. At the time of harvest T_5 and T_{10} recorded highest height of 56.3 cm which was on par with T_7, T_2, T_3 and T_8 (54.5, 53.5, 52.8 and 52.7 respectively). T_1 showed the lowest height of 41.5 cm which was on par with T_6 (41.9). T_{10} had significantly highest height at all stages of crop growth except 6 MAP.

4.1.2 Number of Branches

There was no significant difference in the number of branches of the plants from various treatments, at different stages of growth (Table 4).

4.1.3 Number of Leaves

All treatments differed significantly in the number of leaves of all stages of observation (Table 5). Plants supplied with FYM (50 %) + mi; T_4 showed highest number of leaves throughout the crop growth. T_7 had the highest leaf count at 10 MAP (66.3) and 12 MAP (95). At the time of harvest T_4 recorded the highest number of leaves (101.3) which was on par with T_7 (95) and T_{10} (89). T_1 showed the least (47.67) which was on par with T_3, T_{12}, T_{11} (58, 53,67 and 53 respectively).

Table 3. Effect of organic manures and microbial inoculants on the plant height of *P. rosea* at different growth stages (mean of three replications), cm

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	27.3	30.7	40.3	41.5.
T_2	21.2	37.0	51.8	53.5
T_3	26.2	37.6	53.9	52.8
T_4	25.9	37.3	51.5	48.3
T_5	25.9	31.3	57.5	56.3
T_6	23.5	26.9	45.3	41.9
T_7	19.4	35.3	58.7	54.5
T_8	20.7	40.2	55.1	52.7
T_9	24.8	31.8	46.3	45.4
T_{10}	14.7	43.0	58.1	56.3
T_{11}	23.8	32.3	49.3	49.6
T_{12}	28.2	37.7	52.3	49.4
T_{13}	25.6	39.8	49.0	51.2
SE	2.94	2.84	1.85	1.82
CD	8.58	8.29	5.39	5.32

CD-Significant @ 5% level of significance
NS-Not significant

Table 4. Effect of organic manures and microbial inoculants on the number of branches of *P. rosea* at different growth stages (mean of three replications)

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	3.00	4.33	6.00	7.00
T_2	3.00	5.00	6.00	8.33
T_3	3.67	5.00	6.00	9.00
T_4	3.33	5.00	7.00	10.67
T_5	2.67	4.33	6.33	9.33
T_6	3.33	5.00	6.33	8.00
T_7	2.33	4.33	7.00	10.33
T_8	3.00	4.67	6.67	9.00
T_9	2.67	4.33	6.33	8.00
T_{10}	2.67	4.67	7.67	12.00
T_{11}	2.67	4.67	5.00	8.33
T_{12}	2.33	4.00	6.33	8.33
T_{13}	3.67	5.33	7.00	7.67
SE	0.46	0.54	0.59	1.16
CD	NS	NS	NS	NS

CD-Significant @ 5% level of significance
NS-Not significant

Table 5. Effect of organic manures and microbial inoculants on the number of leaves of *P. rosea* at different growth stages (mean of three replications)

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	18.33	30.67	39.67	47.67
T_2	18.67	33.33	41.33	54.33
T_3	19.00	30.00	40.67	58.00
T_4	29.00	44.30	64.00	101.30
T_5	21.67	37.67	51.00	73.30
T_6	23.33	35.33	44.00	60.60
T_7	13.67	31.00	66.30	95.00
T_8	21.33	33.33	44.00	59.00
T_9	22.33	34.67	45.00	67.67
T_{10}	13.00	22.67	37.30	89.00
T_{11}	22.67	35.33	43.67	53.00
T_{12}	23.67	32.00	41.00	53.67
T_{13}	22.67	35.00	46.33	64.33
SE	2.09	3.16	2.88	4.29
CD	6.12	9.21	8.39	12.53

CD-Significant @ 5% level of significance
NS-Not significant

4.1.4 Leaf Area (cm^2)

There was significant difference among the various treatment combinations in the leaf area of the plants (Table 6). T_3 plants recorded significantly highest leaf area throughout the crop growth. T_9 and T_2 plants also showed significantly highest leaf area at all stages of crop growth except 8 MAP. At the time of harvest T_{12} recorded the highest leaf area (23.38) which was found to be on par with T_{13}, T_3, T_4, T_9, T_6 and T_2 (23.16, 21.22, 20.62, 19.67, 19.19 and 19.06). T_{11} plants recorded the lowest leaf area (14.85) which was on par with T_1 (15.07).

4.1.5 Fresh Weight of Plants (g $plant^{-1}$)

The fresh weight of plants was found to be significantly different for various treatment combinations at all stages of observations (Table 7). T_7 plants recorded the highest fresh weight throughout the crop growth. At harvest T_7 plants recorded the highest fresh weight of 115.3 g and T_2 plants the lowest (56.23 g). The highest fresh weight was recorded by T_3 plants (41.6) at 6 MAP, T_{12} plants (59.4) at 8 MAP and T_7 plants (95.8) at 10 MAP.

4.2 PHYSIOLOGICAL CHARACTERS

4.2.1 Leaf Area Index

Leaf area index (LAI) was significantly different for various treatment combinations at all stages of observation except 10 MAP (Table 8). T_3 plants recorded the highest LAI at all stages of crop growth. At the time of harvest T_3 plants recorded the highest value (0.028) which was on par with T_4, T_{12}, T_{13}, T_9, T_6, T_7, T_2, T_{10}, T_8 and T_5 (0.027, 0.027, 0.026, 0.026, 0.025, 0.025, 0.025, 0.023, 0.023 and 0.021 respectively). T_{11} recorded the least (0.019) which was on par with T_1 and T_5 (0.02 and 0.021 respectively).

Table 6. Effect of organic manures and microbial inoculants on the leaf area of *P. rosea* at different growth stages (mean of three replications), cm^2

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	14.18	23.69	12.16	15.07
T_2	18.10	15.01	19.05	19.06
T_3	18.83	22.09	19.61	21.22
T_4	9.09	22.89	18.64	20.62
T_5	15.21	15.83	13.87	15.59
T_6	20.34	16.35	16.34	19.19
T_7	17.17	15.05	17.59	18.88
T_8	14.88	16.58	18.49	17.01
T_9	18.33	12.24	22.08	19.67
T_{10}	19.19	14.87	10.93	17.42
T_{11}	13.70	13.59	13.69	14.85
T_{12}	15.14	18.23	20.61	23.38
T_{13}	13.91	18.90	21.26	23.16
SE	2.15	2.00	1.89	1.52
CD	6.28	5.84	5.53	4.43

CD-Significant @ 5% level of significance
NS-Not significant

Table 7. Effect of organic manures and microbial inoculants on the fresh weight of *P. rosea* at different growth stages (mean of three replications), g plant^{-1}

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	20.80	36.50	48.80	66.67
T_2	36.50	46.23	51.20	56.23
T_3	41.60	54.63	72.30	88.30
T_4	25.60	38.57	55.70	84.20
T_5	25.40	52.80	65.90	77.40
T_6	40.00	51.40	61.10	74.60
T_7	37.40	55.60	95.80	115.30
T_8	36.87	55.70	62.10	66.40
T_9	27.27	43.40	52.20	81.30
T_{10}	32.03	45.80	55.20	84.03
T_{11}	27.60	48.80	61.20	74.37
T_{12}	23.30	59.40	75.80	90.70
T_{13}	32.81	51.80	75.70	91.97
SE	1.94	2.03	2.35	2.33
CD	5.65	5.94	6.85	6.81

CD-Significant @ 5% level of significance
NS-Not significant

Table 8. Effect of organic manures and microbial inoculants on LAI of *P. rosea* at different growth stages (mean of three replications)

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	0.014	0.027	0.019	0.020
T_2	0.024	0.020	0.021	0.025
T_3	0.025	0.003	0.026	0.028
T_4	0.012	0.033	0.024	0.027
T_5	0.021	0.021	0.019	0.021
T_6	0.027	0.022	0.019	0.025
T_7	0.023	0.019	0.024	0.025
T_8	0.0197	0.022	0.020	0.023
T_9	0.024	0.016	0.025	0.026
T_{10}	0.027	0.020	0.017	0.023
T_{11}	0.014	0.018	0.018	0.019
T_{12}	0.020	0.022	0.023	0.027
T_{13}	0.014	0.022	0.024	0.026
SE	0.0034	0.0030	0.0036	0.0028
CD	0.01	0.009	NS	0.008

CD-Significant @ 5% level of significance
NS-Not significant

4.2.2 Total Dry Matter Production (kg ha^{-1})

The various treatment combinations varied significantly in total dry matter (TDM) production at all stages of crop growth (Table 9). T_7 plants recorded the highest TDM at 10 MAP (4807.97) and 12 MAP (5999.97). T_1 plants showed the least TDM production throughout the crop growth. At the time of harvest T_2 plants had the lowest TDM production (3491.97) which was on par with T_1 and T_8 (3773.3 and 3493.3 respectively).

4.2.3 Specific Leaf Weight (mg cm^{-2})

The specific leaf weight was found to be significantly different for the various treatments at all stages of crop growth (Table 10). T_6 plants recorded the least values at all stages of observation. At the time of harvest T_3 plants recorded the highest value of 17.73 mg cm^{-2}and T_4 plants recorded the least (2.43) which was on par with T_6, T_2 and T_4 (2.6, 2.83 and 2.43 respectively) plants.

4.2.4 Net Assimilation Rate (mg day^{-1} cm^{-2})

Significant difference among the treatments was noticed in net assimilation rate (NAR) throughout the growth phase (Table 11). At 8 MAP T_{12} and T_{13} plants recorded the highest NAR of 14.43 and 12.33 which was lowered to 2.00 and 4.5 respectively at 10 MAP. The treatment T_{11} recorded the highest value at 10 MAP (7.83) which was 7.07 at 8 MAP and 4.57 at 12 MAP. At the time of harvest T_9 plants recorded the highest NAR (14.2) which was on par with T_{10}, T_1 and T_4 (12.67, 12.5 and 10.37 respectively) plants. T_8 plants had the least NAR (1.73) which was on par with T_{12} (2.77).

4.2.5 Crop Growth Rate (mg day^{-1} cm^{-2})

Crop growth rate (CGR) was significantly different for various treatments at the three stages of observation (Table 12). At 8 MAP T_{12} plants recorded highest CGR of 0.32 which was reduced to 0.049 and 0.069 at 10 MAP and 12 MAP respectively. The other treatments which

Table 9. Effect of organic manures and microbial inoculants on total dry matter production of *P. rosea* at different growth stages (mean of three replications), kg ha^{-1}

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	1302.23	1946.63	2316.87	3773.30
T_2	2271.07	2430.50	2591.10	3491.97
T_3	2183.93	3217.30	3629.30	4806.20
T_4	1247.07	1683.90	2482.60	4172.30
T_5	1630.63	2910.20	3259.50	3866.60
T_6	2231.00	3119.97	3431.10	3959.97
T_7	1640.00	2275.57	4807.97	5999.97
T_8	1975.07	2695.50	3257.30	3493.30
T_9	1217.73	2110.20	2256.87	5248.90
T_{10}	1539.07	2670.63	3062.20	4902.20
T_{11}	1663.10	2600.87	3764.40	4282.67
T_{12}	1262.63	3410.67	3746.57	4266.67
T_{13}	1531.97	3391.10	4176.90	5008.90
SE	120.10	111.89	115.75	159.60
CD	350.58	326.59	337.87	465.88

CD-Significant @ 5% level of significance
NS-Not significant

Table 10. Effect of organic manures and microbial inoculants on specific leaf weight of *P. rosea* at different growth stages (mean of three replications), mg cm^{-2}

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	1.47	1.67	4.20	3.40
T_2	1.10	2.43	1.73	2.83
T_3	1.67	2.00	3.13	17.73
T_4	4.07	2.17	3.00	2.43
T_5	1.60	2.07	3.47	3.27
T_6	1.80	2.50	2.90	2.60
T_7	1.97	1.53	3.87	3.37
T_8	4.00	7.37	9.53	8.17
T_9	5.87	14.00	5.13	7.33
T_{10}	2.10	5.07	10.67	3.67
T_{11}	5.80	2.77	10.67	4.57
T_{12}	4.13	4.73	1.43	5.40
T_{13}	3.36	3.23	5.07	7.07
SE	0.48	0.63	1.12	0.57
CD	1.40	1.83	3.20	1.67

CD-Significant @ 5% level of significance
NS-Not significant

Table 11. Effect of organic manures and microbial inoculants on NAR of *P. rosea* at different growth stages (mean of three replications), mg day^{-1} cm^{-2}

Treatments	8 MAP	10 MAP	12 MAP
T_1	3.37	3.67	12.50
T_2	1.33	1.06	5.87
T_3	3.23	2.80	6.50
T_4	2.40	5.57	10.37
T_5	1.09	2.50	5.30
T_6	6.73	3.50	3.50
T_7	5.57	1.80	8.17
T_8	5.30	4.67	1.73
T_9	5.23	0.77	14.20
T_{10}	9.47	4.77	12.67
T_{11}	7.07	7.83	4.57
T_{12}	14.43	2.00	2.77
T_{13}	12.33	4.63	4.50
SE	1.18	1.10	1.75
CD	3.45	3.22	5.11

CD-Significant @ 5% level of significance
NS-Not significant

Table 12. Effect of organic manures and microbial inoculants on CGR of *P. rosea* at different growth stages (mean of three replications), mg day^{-1} cm^{-2}

Treatments	8 MAP	10 MAP	12 MAP
T_1	0.092	0.074	0.243
T_2	0.026	0.022	0.145
T_3	0.105	0.076	0.185
T_4	0.079	0.128	0.282
T_5	0.023	0.049	0.104
T_6	0.151	0.067	0.086
T_7	0.117	0.037	0.196
T_8	0.118	0.085	0.039
T_9	0.091	0.020	0.355
T_{10}	0.187	0.079	0.291
T_{11}	0.125	0.136	0.376
T_{12}	0.320	0.049	0.069
T_{13}	0.269	0.102	0.122
SE	0.034	0.020	0.086
CD	0.098	0.059	0.252

CD-Significant @ 5% level of significance
NS-Not significant

recorded highest value were T_{13}, T_{10} and T_{11} (0.269, 0.187 and 0.125 respectively). At the time of harvest T_{11} plants recorded the highest CGR (0.376) which was on par with T_9, T_{10}, T_4, T_1, T_7 and T_3 (0.355, 0.291, 0.282, 0.243, 0.196 and 0.185 respectively) plants. The treatment T_8 showed the lowest CGR (0.039) which was on par with T_{12}, T_6, T_5, T_{13} and T_2 (0.069, 0.086, 0.104, 0.122 and 0.145) plants. At all the stages of observation the CGR of T_2 plants was found to be significantly lowest.

4.2.6 Harvest Index (HI)

Through out the crop growth of *P.rosea*, significant difference in the harvest index (HI) was noticed for the various treatments. T_6, T_{11}, T_3, T_4 and T_7 plants showed significantly highest HI at all stages of observation (Table 13) and T_1 and T_9 plants recorded the least HI. At the time of harvest (12 MAP), T_6 recorded maximum HI (0.81) which was on par with T_{11}, T_3, T_4, T_7 and T_5 (0.78, 0.77, 0.76, 0.75 and 0.74 respectively) and T_9 recorded the least HI (0.48) which was on par with T_{13} and T_1 (0.53 and 0.49 respectively).

4.3 YIELD AND YIELD COMPONENTS

4.3.1 Fresh Weight of Roots (g plant^{-1})

There was significant difference in the fresh root weight of *P.rosea* under different treatments (Table 14). Treatment combination containing FYM + NC (50 % N of POP) + microbial inoculants (T_7) had the highest fresh weight of roots (86.33) and the control (POP recommendation KAU, 2002) recorded the lowest (32.47). T_3 plants also recorded a higher fresh weight of roots (68.17) which was on par with T_4 (63.83). Other treatments which produced better root yields were T_6, T_{10}, T_{11} and T_{12} (60.57, 60.1, 58.23 and 57.57 respectively).

4.3.2 Dry Weight of Roots (g plant^{-1})

Statistically the treatment combinations can be categorized into three based on dry weight of roots (Table 14). The highest dry weight was

Table 13. Effect of organic manures and microbial inoculants on harvest index of *P. rosea* at different growth stages (mean of three replications)

Treatments	6 MAP	8 MAP	10 MAP	12 MAP
T_1	0.44	0.49	0.48	0.49
T_2	0.71	0.73	0.71	0.72
T_3	0.77	0.77	0.77	0.77
T_4	0.76	0.76	0.76	0.76
T_5	0.74	0.74	0.74	0.74
T_6	0.82	0.82	0.81	0.81
T_7	0.75	0.76	0.75	0.75
T_8	0.72	0.72	0.71	0.71
T_9	0.48	0.49	0.49	0.48
T_{10}	0.71	0.70	0.71	0.71
T_{11}	0.77	0.76	0.77	0.78
T_{12}	0.64	0.64	0.63	0.63
T_{13}	0.53	0.53	0.53	0.53
SE	0.023	0.028	0.027	0.028
CD	0.068	0.082	0.079	0.081

CD-Significant @ 5% level of significance
NS-Not significant

recorded by T_7 plants (33.03) which was on par with T_{10}, T_3 and T_{12} (30.63, 27.8 and 27.7 respectively). The treatment, T_9 had the lowest dry weight of roots (17.73) which was on par with T_5, T_2, T_6 and T_1 (22.47, 19.73, 19.5 and 17.83 respectively). The rest of treatments recorded a medium dry weight of roots (T_4, T_8, T_{11} and T_{13}).

4.3.3 Yield ha^{-1} as an Intercrop (kg ha^{-1})

Significant difference in the fresh root yield of *P. rosea* was noticed under different treatments (Table 14). Treatment consisting of FYM + neem cake (50 % N of POP) + mi (T_7) recorded the highest fresh root yield (7597.3 kg ha^{-1}). Yield of T_3 plants (FYM (75 % N of POP) + mi) plants (5998.67) was on par with T_4 (FYM *i. e*, 50 % N of POP+ mi) plants (5677.3). Other treatments which recorded higher yields were T_6, T_{10}, T_{11} and T_{12} (5229.87, 5288.8, 5124.5 and 5065.87 respectively). The control (T_1) recorded the lowest yield of 2857.07 kg ha^{-1} which was on par with T_8 (3446.67).

4.3.4 Number of Roots

The root number of *P. rosea* varied significantly with the treatments (Table 15). T_9 recorded the highest root number (23.3) which was on par with T_6 plants (22). T_2 plants recorded the least value (7.3) which was on par with T_5, T_1, T_8 and T_{12} plants (9.3, 8.0, 8.0 and 7.3 respectively).

4.3.5 Length of Roots

All the treatment combinations varied significantly with regard to the root length of plants (Table 15). T_7 plants recorded highest root length (80.1 cm) which was followed by T_{10} (69.8 cm). T_9 plants recorded the lowest root length of 29.1 cm.

4.3.6 Girth of Roots

There was significant difference in the root girth of plants under different treatments (Table 15). T_3 (FYM supplying 75 % N of POP + mi)

Table 14. Effect of organic manures and microbial inoculants on fresh weight of roots per plant (g), dry weight of roots per plant (g) and fresh root yield (kg ha^{-1}) of *P. rosea* as intercrop in coconut garden (mean of three replications)

Treatments	Fresh weight of roots (g plant^{-1})	Dry weight of roots (g plant^{-1})	Yield (kg ha^{-1}) (FW basis)
T_1	32.47	17.83	2857.07
T_2	40.80	19.73	3590.40
T_3	68.17	27.80	5998.67
T_4	63.83	27.00	5617.30
T_5	56.97	22.47	5013.07
T_6	60.57	19.50	5229.87
T_7	86.33	33.03	7597.30
T_8	39.17	26.77	3446.67
T_9	47.17	17.73	4150.70
T_{10}	60.10	30.63	5288.80
T_{11}	58.23	25.33	5124.50
T_{12}	57.57	27.70	5065.87
T_{13}	49.30	23.73	4338.40
SE	2.17	1.98	193.17
CD	6.34	5.79	563.86

CD-Significant @ 5% level of significance
NS-Not significant

Table 15. Effect of organic manures and microbial inoculants on number of roots per plant, length of roots (cm) and girth of roots (cm) of *P. rosea* as intercrop in coconut garden (mean of three replications)

Treatments	Number of roots	Length of roots (cm)	Girth of roots (cm)
T_1	8.00	45.67	2.60
T_2	7.30	36.43	1.80
T_3	10.30	35.00	3.10
T_4	10.70	64.03	2.73
T_5	9.30	46.40	2.87
T_6	22.00	47.67	2.53
T_7	11.30	80.10	3.03
T_8	8.00	59.37	2.23
T_9	23.30	29.10	2.07
T_{10}	10.70	69.80	3.03
T_{11}	14.30	40.80	2.90
T_{12}	7.30	36.73	3.00
T_{13}	16.00	43.50	2.73
SE	0.82	1.46	0.047
CD	2.40	4.25	0.138

CD-Significant @ 5% level of significance
NS-Not significant

had the highest root girth (3.1 cm) which was on par with T_8, T_{10} and T_{12} (2.23, 3.03 and 3.00 respectively). The lowest value was recorded by T_2 plants (1.8 cm) where 100 per cent N of POP was given through FYM alone.

4.4 PLANT ANALYSIS

Analysis of the plant samples were done at the final harvest (12 MAP).

4.4.1 Total Chlorophyll Content

All the treatments varied significantly in the total chlorophyll content of the leaves (Table 16). T_7 had maximum chlorophyll content of 1.25 per cent and T_{10} the minimum (0.265 %). T_{13} and T_{11} had slightly lower total chlorophyll content (0.879 and 0.874 respectively) than T_7 plants.

4.4.2 Plant Uptake of NPK

Significant difference in the NPK uptake of plants was noticed among the treatments (Table 17).

4.4.2.1 Plant Uptake of N (kg ha^{-1})

T_7 recorded highest N uptake of 285.6 kg ha^{-1} which was followed by T_9 (235.13) and T_{13} (224.4). T_{10} and T_3 plants also had higher N uptake. The lowest N uptake was for T_8 plants (97.57) which was on par with T_2 and T_5 (107.53 and 108.23 respectively) plants. T_4 (151.77), T_1 (126.83) and T_6 (121.93) were the other treatments with inferior N uptake.

4.4.2.2 Plant Uptake of P (kg ha^{-1})

T_7 (FYM + NC (50 % N of POP) + mi) and T_3 (FYM *i.e.*, 75 % N of POP + mi) plants recorded highest uptake of 16.1 and 15.33 respectively. T_{13} (14.57), T_9 (13.1) and T_{11} (11.67) were the other treatments with higher P uptake. T_1 (POP recommendation) recorded the

Table 16. Effect of organic manures and microbial inoculants on total chlorophyll content of *P. rosea* at the time of harvest, per cent (mean of three replications)

Treatments	Total chlorophyll
T_1	0.652
T_2	0.500
T_3	0.699
T_4	0.745
T_5	0.854
T_6	0.485
T_7	1.250
T_8	0.622
T_9	0.634
T_{10}	0.265
T_{11}	0.874
T_{12}	0.424
T_{13}	0.879
SE	0.003
CD	0.00898

CD-Significant @ 5% level of significance
NS-Not significant

lowest P uptake of 6.73. T_8, T_{10} and T_5 were the other treatments with lower P uptake of 9.39, 8.73 and 8.17 respectively.

4.4.2.3 Plant Uptake of K (kg ha^{-1})

T_7 plants recorded highest K uptake of 197.97 kg ha^{-1}. T_{12}, T_4 and T_8 were the other treatments with higher K uptake of 149.3, 141.2 and 126.27 respectively. T_1 plants recorded the lowest uptake of 90.54 which was on par with T_{10} (98.04). The other treatments with lesser K uptake were T_{13}, T_6 and T_9 (110.2, 102.93 and 99.73 ^{1} respectively).

4.4.3 Alcohol Soluble Extracts (g kg^{-1} of dried roots)

The treatments varied significantly with regard to the quantity of alcohol soluble extracts in the roots (Table 18). T_3 plants recorded the highest concentration of extracts (464.67) and T_8 plants the minimum (226.67), Other treatments with highest concentration were T_9 (449.0) and T_6 (446). T_7 recorded 432.67 g kg^{-1} of extracts which was on par with T_5 (433) and T_2 (426.3).

4.4.4 Plumbagin Content

Root plumbagin content was found to have significant difference among the various treatment combinations (Table 19). T_3 plants (FYM *i.e.* 75 % N of POP + mi) recorded the highest plumbagin content of 0.32 per cent. T_8 (FYM + vermicompost) gave the lowest plumbagin content of 0.087 per cent which was on par with T_4, T_{12} and T_{13} (0.113, 0.096 and 0.088 per cent respectively).

Based on the dry root yield of *Plumbago rosea* under different treatment combinations, the treatments were grouped into three: Group A consisting of T_7, T_{10} T_{12} and T_3 (high yield), Group B consisting of T_4, T_{11} T_{13} and T_5 (medium yield) and Group C with T_7, T_{10} T_{12} and T_3 (low yield).

The soil samples from the plots belonging to each group were mixed separately and composite samples were prepared. These samples

Table 17. Effect of organic manures and microbial inoculants on N, P and K uptake of *P. rosea* at the time of harvest (mean of three replications), kg ha^{-1}

Treatments	N	P	K
T_1	126.83	6.73	90.54
T_2	107.53	10.47	125.70
T_3	188.37	15.33	125.00
T_4	151.77	9.59	141.20
T_5	108.23	8.17	112.13
T_6	121.93	9.43	102.93
T_7	285.60	16.10	197.97
T_8	97.57	9.39	126.27
T_9	235.13	13.10	99.73
T_{10}	205.87	8.73	98.04
T_{11}	167.80	11.67	111.33
T_{12}	167.23	9.87	149.30
T_{13}	224.40	14.57	110.20
SE	5.99	0.43	5.55
CD	17.48	1.26	16.19

CD-Significant @ 5% level of significance
NS-Not significant

Table 18. Effect of organic manures and microbial inoculants on alcohol soluble extracts of roots of *P. rosea* at the time of harvest (mean of three replications), g kg^{-1} of dried roots

Treatments	Alcohol soluble extracts
T_1	364.00
T_2	426.30
T_3	464.67
T_4	277.67
T_5	433.00
T_6	446.00
T_7	432.67
T_8	226.67
T_9	449.00
T_{10}	305.33
T_{11}	410.00
T_{12}	288.33
T_{13}	256.67
SE	4.27
CD	12.45

CD-Significant @ 5% level of significance
NS-Not significant

Table 19. Effect of organic manures and microbial inoculants on plumbagin content of roots of *P. rosea* at the time of harvest (mean of three replications), per cent

Treatments	Plumbagin content
T_1	0.158
T_2	0.233
T_3	0.320
T_4	0.113
T_5	0.275
T_6	0.275
T_7	0.243
T_8	0.087
T_9	0.260
T_{10}	0.140
T_{11}	0.265
T_{12}	0.096
T_{13}	0.088
SE	0.0014
CD	0.0043

CD-Significant @ 5% level of significance
NS-Not significant

were analysed for NPK and microbial inoculants and compared with the soil sample values before the experiment.

4.5 SOIL NPK ANALYSIS BEFORE AND AFTER THE EXPERIMENT

4.5.1 Soil N (kg ha^{-1})

Noticeable increase in soil N content was noticed after the experiment (Table 20). Soil N content of Group A soils was 288.5, Group B and C had 244.6 and 208 respectively. Soil N before the experiment was 188.16.

4.5.2 Soil P (kg ha^{-1})

There was not much difference in the soil P content before and after the experiment (Table 20). The P content of Group A and B soils were found to be 44 kg ha^{-1}. The P content of soils of Group C was 42.3 and the soil before experiment had a P content of 41.4 kg ha^{-1}.

4.5.3 Soil K (kg ha^{-1})

A slight decrease in the soil K content was noticed after the experiment (Table 20). Soil K before the experiment was 138.08 kg ha^{-1}. Group B had 135.8 kg ha^{-1}, Group C and A soils recorded 134.8 and 131.36 kg ha^{-1} respectively.

4.6 SOIL MICROBIAL POPULATION BEFORE AND AFTER THE EXPERIMENT

Marked increase in the soil microbial population was noticed after the experiment (Table 21).

4.6.1 Soil Bacterial Population

Soil bacterial count was found to be directly proportional to the dry root yield of plants. Group A soils which recorded high root yield had a count of 216 x 10^7, Group B and Group C had 148 x 10^7 and 21 x 10^7 bacterial count respectively. The soil bacterial count before experiment was much low (9 x 10^7).

4.6.2 Soil Fungal Population

Soil fungal count was also directly proportional to the dry root yield. Group A soil (high root yield) had a fungal population of 6 x 10^5 followed by Group B (medium yield) of 4 x 10^5 and Group C (low yield) of 3 x 10^5. The fungal count before experiment was 1 x 10^5 which has increased significantly by addition of organic manures (Table 21).

4.6.3 Soil Actinomycete Population

The actinomycetes population of Group A and B soils (high and medium yield) was found to be 3 x 10^5. Group C soil had a count of 2 x 10^5 which was more than that of the soil before experiment (1 x 10^5) (Table 21).

4.7 PEST AND DISEASE INCIDENCE

No major attack of pests or diseases were noticed in the field. During initial months of planting (4 MAP) there was minor attack of mealy bugs and jassids. As the infection was below economic threshold level control measures were not adopted.

4.8 BENEFIT – COST RATIO (BCR)

All the treatments varied significantly in the BCR (Table 22). The treatment supplied with FYM + NC (50 % N of POP) + mi (T_7), recorded the highest BCR (2.73) which was significantly different from the rest of the treatments. T_3 and T_4 were the other treatments with higher BCR of 2.2 and 2.05 respectively. The control plot (T_1) had the lowest BCR (1.14) which was on par with T_8, T_2 and T_9 (1.2, 1.37 and 1.47 respectively).

Table 20. Effect of organic manures and microbial inoculants on soil N, P and K content before and after the experiment (mean of three replications), kg ha^{-1}

Soil nutrients	Before experiment	After experiment		
		A	B	C
N	188.16	288.50	244.60	208.60
P	41.40	44.00	44.00	42.30
K	138.08	131.36	135.84	134.80

* Not statistically analysed

Table 21. Effect of organic manures and microbial inoculants on soil microbial population before and after the experiment (mean of three replications), kg ha^{-1}

Soil microbes	Before experiment	After experiment		
		A	B	C
Bacteria	9×10^7	216×10^7	148×10^7	21×10^7
Fungi	1×10^5	6×10^5	4×10^5	3×10^5
Actinomycetes	1×10^5	3×10^5	3×10^5	2×10^5

* Not statistically analysed

Table 22. Effect of organic manures and microbial inoculants on BCR of *P. rosea* (mean of three replications)

Treatments	Benefit cost ratio
T_1	1.14
T_2	1.37
T_3	2.20
T_4	2.05
T_5	1.88
T_6	1.83
T_7	2.73
T_8	1.20
T_9	1.47
T_{10}	1.93
T_{11}	2.00
T_{12}	1.80
T_{13}	1.53
SE	0.089
CD	0.262

CD-Significant @ 5% level of significance
NS-Not significant

Table 23. Effect of organic manures and microbial inoculants on the economics of cultivation of *P. rosea* (mean of three replications), Rs. ha^{-1}

Treatments	Benefit (Gross income)	Cost	Profit (Net income)
T_1	199995.2	179480.4	20514.8
T_2	251326.5	179741.1	233385.4
T_3	419907.2	190463.3	229443.9
T_4	393212.8	191818.3	201394.5
T_5	350915.2	186706.2	164209
T_6	373091.2	195538.60	177552.6
T_7	531818.82	193976.40	337836.4
T_8	290547.2	194843.9	95703.3
T_9	241264.9	199346.4	41918.5
T_{10}	370216.0	193461.8	176754.2
T_{11}	358706.0	179547.0	179159.0
T_{12}	354595.80	195283.9	159311.9
T_{13}	303688.00	194353.7	109334.3

* Not statistically analysed

Discussion

5. DISCUSSION

The effect of different combinations of organic manures and microbial inoculants (mi) on growth, yield and quality of *Plumbago rosea* is discussed here based on the field experiment conducted during the year 2004-2005.

5.1 GROWTH CHARACTERS

The results of the present study indicated that morphological parameters of *Plumbago rosea* were significantly influenced by the application of different combinations of organic manures and microbial inoculants.

5.1.1 Plant height

Throughout the crop period, T_3 (FYM (75 % N of POP) + mi) plants recorded higher plant heights. The positive effect of FYM on plant height was noticed by many workers such as Shah *et al.* (2000) in *P. zeylanica*, Vidyadharan (2000) in arrowroot, Singh and Agarwal (2001) in wheat, Rakhee (2002) in turmeric and Sreekala (2004) in ginger. The effects of neem cake and vermicompost on plant height were also significant at the time of harvest. According to Arunkumar (2000), highest level of FYM and vermicompost maintained superiority in plant height of amaranthus. Significant positive effect of vermicompost on plant height was also recorded in tomato (Pushpa, 1996), ginger (Vadiraj *et al.*, 1996), amaranthus (Arunkumar, 2000), chilli (Sharu, 2000) and chethikkoduveli (Santhoshkumar, 2004).

Application of microbial inoculants also significantly influenced the plant height. The treatments T_3, T_{10} and T_7, containing Azospirillum, AMF and phosphate solubilising bacteria recorded significantly higher plant heights. The combined effect of microbial inoculants for enhancing plant height was recorded in ginger (Nath and Korla, 2000; Sreekala, 2004), black pepper (Anith and Manomohandas, 2001), chilli (Sajan *et al.*, 2002) and sorghum (Patidar and Mali, 2004). The effect of *Azospirillum* in increasing plant height was also reported in chilli plants by Kavitha (2001).

The combination of organic manures (T_2, T_5 and T_8) significantly influenced the plant height over the inorganic fertilizer supplemented treatment (T_1). Similar effects of organic farming were reported in tomato (Thamburaj, 1994), pepper (Sivakumar and Wahid, 1994) and chilli (Anitha, 1997).

The increased height of plants in all the superior treatment combinations except T_2 (FYM alone), T_5 (FYM + NC) and T_8 (FYM + VC) might be due to the combined effect of organic manures and microbial inoculants. The height of the inorganic fertilizer supplemented treatment (T_1) was superior during initial stages of growth *i.e.*, up to 6 MAP, after which organically produced plants showed better heights. This might be due to the capability of organic manures to act as nutrient reservoirs which can supply nutrients on a long term basis, when compared to inorganic fertilizers.

5.1.2 Number of Branches

In the present study, the various treatment combinations did not have any significant influence on the number of branches of the plants. Subbiah *et al.* (1983) reported that incorporation of organic residues did not influence the number of tillers in rice.

5.1.3 Number of Leaves

The study showed the significant influence of FYM and microbial inoculants in increasing the number of leaves of *P. rosea* at all stages of crop growth (Fig. 3). The effect of FYM in increasing the number of leaves was reported in tomato (Pushpa, 1996), arrowroot (Vidhyadharan, 2000) and ginger (Sreekala, 2004). At the time of harvest the treatment

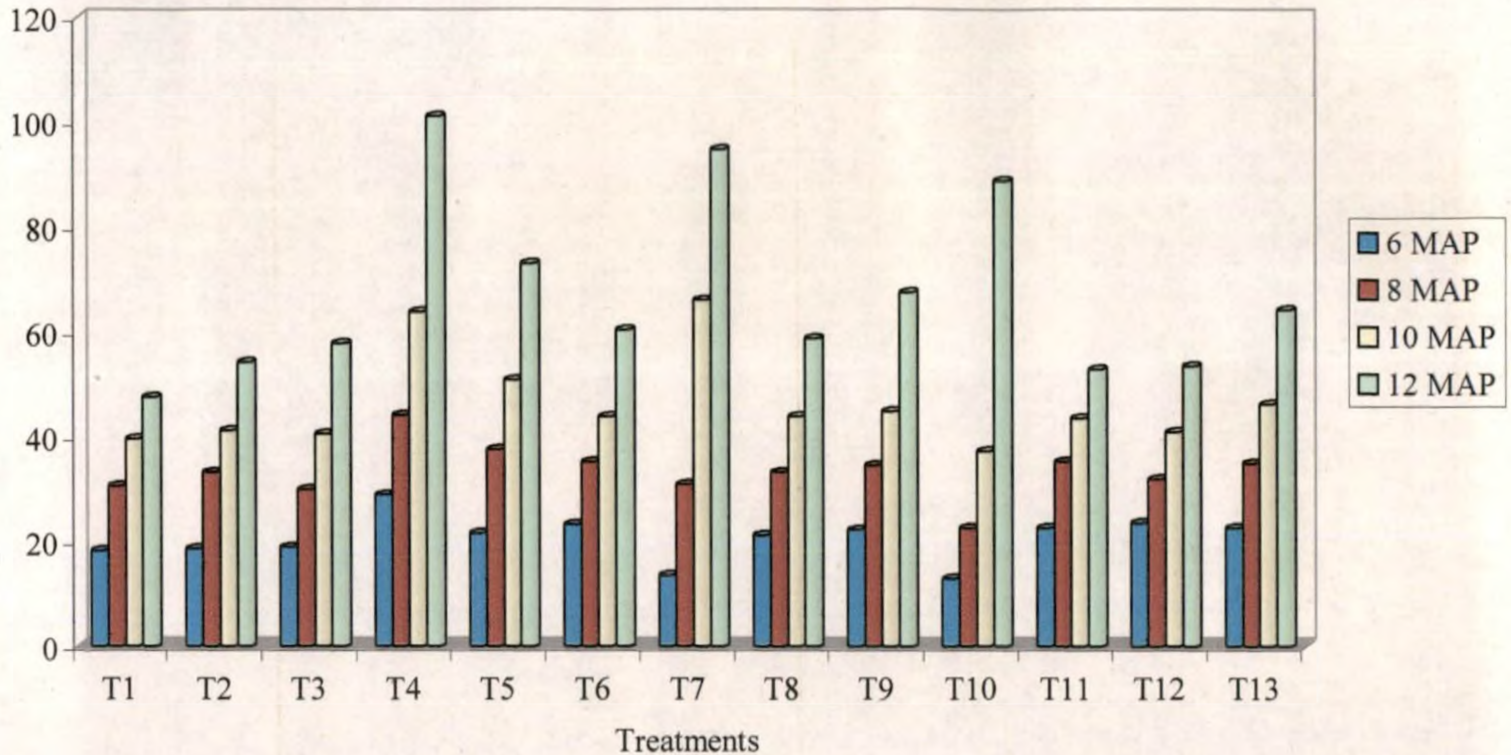


Fig. 3. Effect of organic manures and microbial inoculants on the number of leaves of *P. rosea* at different growth stages

combinations with FYM + NC + mi (T_7) and FYM + VC + mi (T_{10}) also recorded highest number of leaves apart from T_4 which consisted of FYM and mi only. FYM, NC and VC treated amaranthus plants recorded highest leaf number (Arunkumar, 2000). Santhoshkumar (2004) also reported an increased number of leaves in neem cake treated *P. rosea* plants.

The application of different microbial inoculants also influenced production of leaves. In the present study, higher number of leaves was observed in treatments with microbial inoculants. Similar results were reported in ginger (Nath and Korla, 2000;Sreekala, 2004). Gupta *et al.* (2004) reported that plant growth promoting rhizobacteria significantly increased the number of leaves in plants intercropped in coconut garden.

Another observation noticed was that the number of leaves produced by the different treatment plants varied significantly from the control (T_1) at all stages of growth. T_1 recorded the least number of leaves. The higher leaf production in FYM treated plants might be due to the action of FYM as nutrient reservoir which upon decomposition produces organic acids, thereby adsorbed ions are released slowly from the soil for the entire growth period (Nimje and Jagdishseth, 1988). Vermicompost supplies all major and minor nutrients, microbes and growth hormones, for enhanced crop growth (Gaur and Sadasivam, 1993). Neem cake treated plants recorded higher leaf number because of its increased nitrogen use efficiency (Kumar and Ali, 2003).

5.1.4 Leaf Area

The study showed the positive influence of organic manures and mi in the leaf area of *P. rosea* (Fig. 4). The treatment supplied with FYM and mi (T_3) recorded significantly higher leaf area throughout the crop growth. At the time of harvest, neem cake and vermicompost supplied plants also showed significantly higher leaf area than control (T_1). Similar results

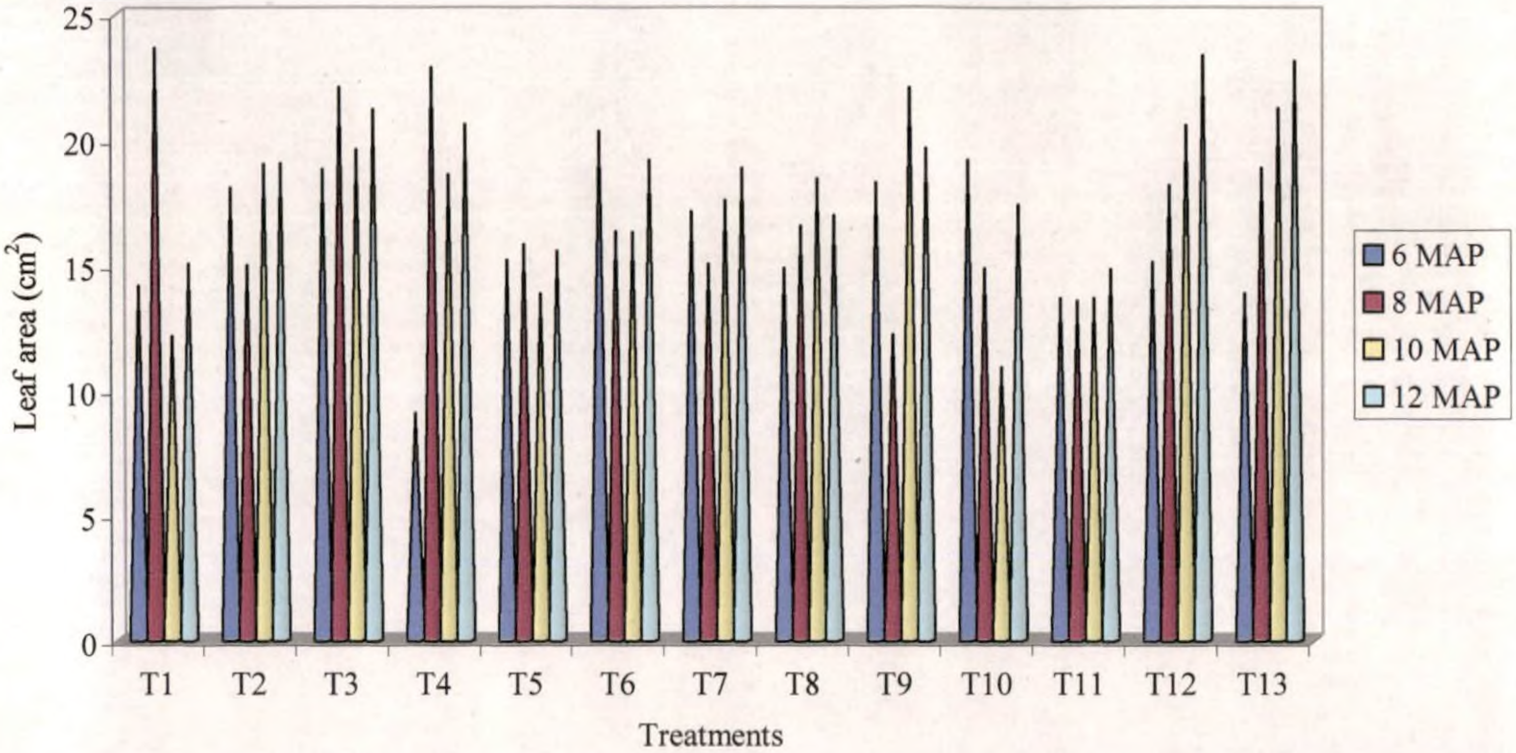


Fig. 4. Effect of organic manures and microbial inoculants on the leaf area of *P. rosea* at different growth stages, cm^2

were recorded in chilli (Sajan *et al.*, 2002) and wheat (Panwar and Singh, 2002).

5.1.5 Fresh Weight of Plants (g)

In the present study, the plants supplied with FYM + neem cake + mi were found to have significantly highest fresh weight throughout crop growth (Fig. 5). Such increased fresh weight might be due to better vegetative growth of the organic manured and microbial inoculants applied plants .The effect of FYM in enhancing the fresh weight was reported in *P. zeylanica* (Shah *et al.*, 2000), arrowroot (Vidhyadharan, 2000) and amaranthus (Arunkumar, 2000). Neem cake was effective in enhancing the biometric characters in *Plumbago rosea* (Santhoshkumar, 2004).

Microbial inoculants also influenced the crop growth. This is due to the production of growth promoting substances by AMF favouring better crop growth (Barea and Azcon, 1982). Similar results were recorded in wheat (Panwar and Singh, 2000). The beneficial effect of VAM alone or together with *Azospirillum* in crop growth was recorded in bajra (Rajput, 1990 chilli, bellary onion (Subbiah,1994) and grain legumes (Rao *et al.*, 1998)

5.2 PHYSIOLOGICAL CHARACTERS

The present study indicated that application of different combinations of organic manures and mi greatly influenced the physiology of *P. rosea*.

5.2.1 Leaf Area Index (LAI)

The effect of organic manures and/or microbial inoculants on LAI was significant at all stages of crop growth except at 10 MAP (Fig. 6). The treatment supplied with FYM (75% N of POP) + mi recorded the highest LAI. The superiority of FYM in enhancing LAI in amaranthus

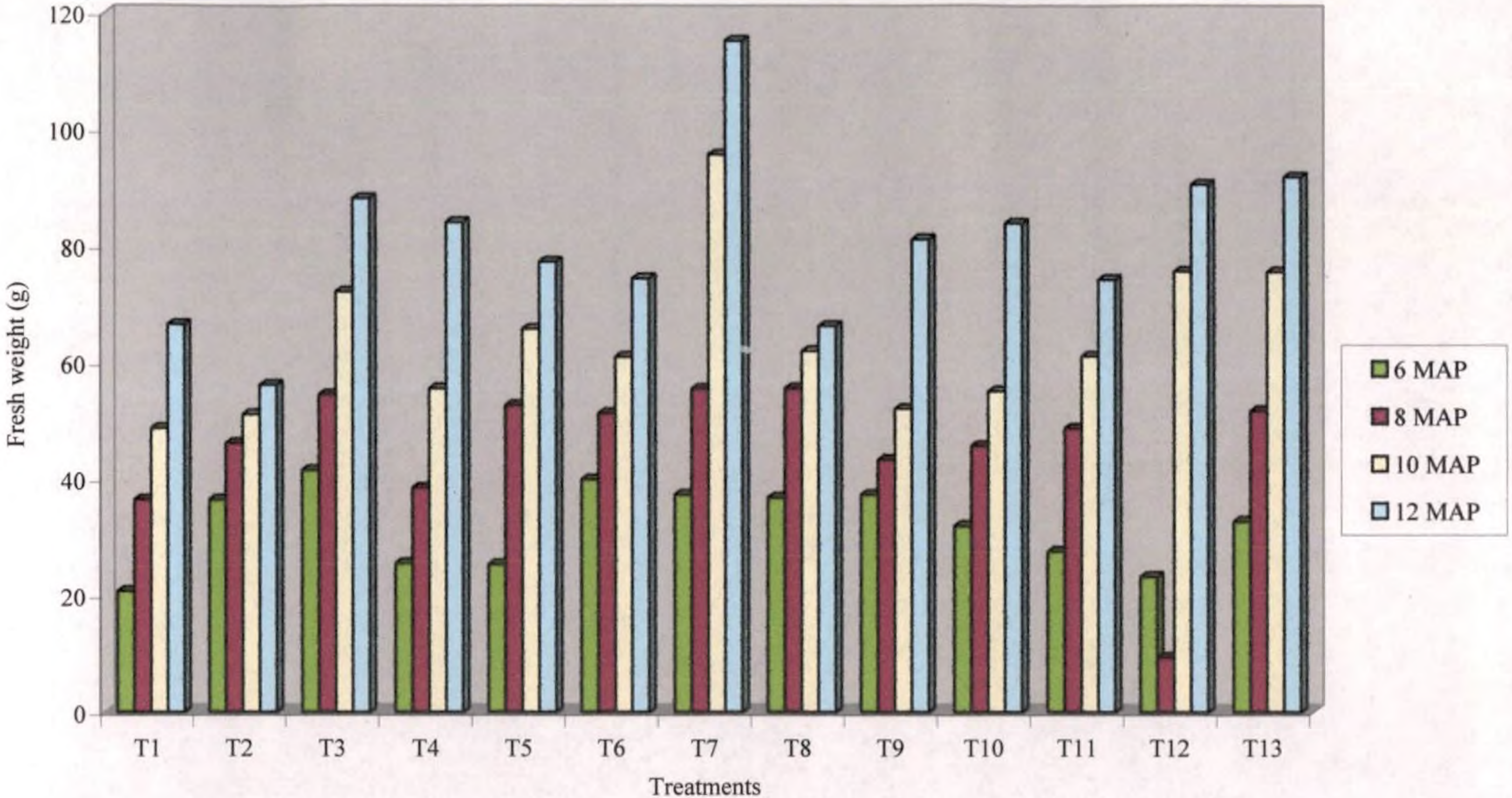


Fig. 5. Effect of organic manures and microbial inoculants on the fresh weight of *P. rosea* at different growth stages, g plant^{-1}

was reported by Arunkumar (2000). The positive influence of biofertilizers in the LAI in peas was described by Vimala and Natrajan (2002). The effect of combined application of microbial inoculants in enhancing LAI was reported in amaranthus (Niranjana, 1998) and ginger (Sreekala, 2004).

The larger leaf size of T_3 plants might have resulted in higher LAI. The superiority of organic manure over inorganic fertilizers in increasing the LAI was reported by many workers (Sharma and Mitra, 1990; Kuppuswamy *et al.*, 1992; Subbarao and Ravisankar, 2001).

5.2.2 Total Dry Matter Production (TDM)

The treatment supplied with FYM (50% N of POP) + NC + mi (T_7) recorded highest TDM. In general, total dry matter production was significantly higher in organic manure treated plants than inorganic fertilizers applied plants (T_1). The positive influence of FYM + NC + mi in increasing the plant height, number of leaves and fresh weight of plants might have resulted in high TDM production also. The effect of FYM in enhancing TDM production was reported in bhindi (Senthilkumar and Sekar, 1998), arrowroot (Vidyadharan, 2000), P. *zeylanica* (Shah *et al.*, 2000), galangal (Maheswarappa *et al.*, 2000) and turmeric (Rakhee, 2002). The superior effect of NC in TDM production in chilli was reported by Sharu (2000). The influence of microbial inoculants in enhancing dry matter production was reported in amaranthus (Niranjana, 1998) and fenugreek (Purbey *et al.*, 2003). The influence of *Azospirillum* in enhancing TDM production was reported in wheat (Panwar and Singh, 2000), chilli (Kavitha, 2001) and sorghum (Patidar and Mali, 2004). Sreekala (2004) reported that in ginger, plants supplied with FYM + NC + AMF + *Trichoderma* recorded better dry matter production, which strongly supports the above result.

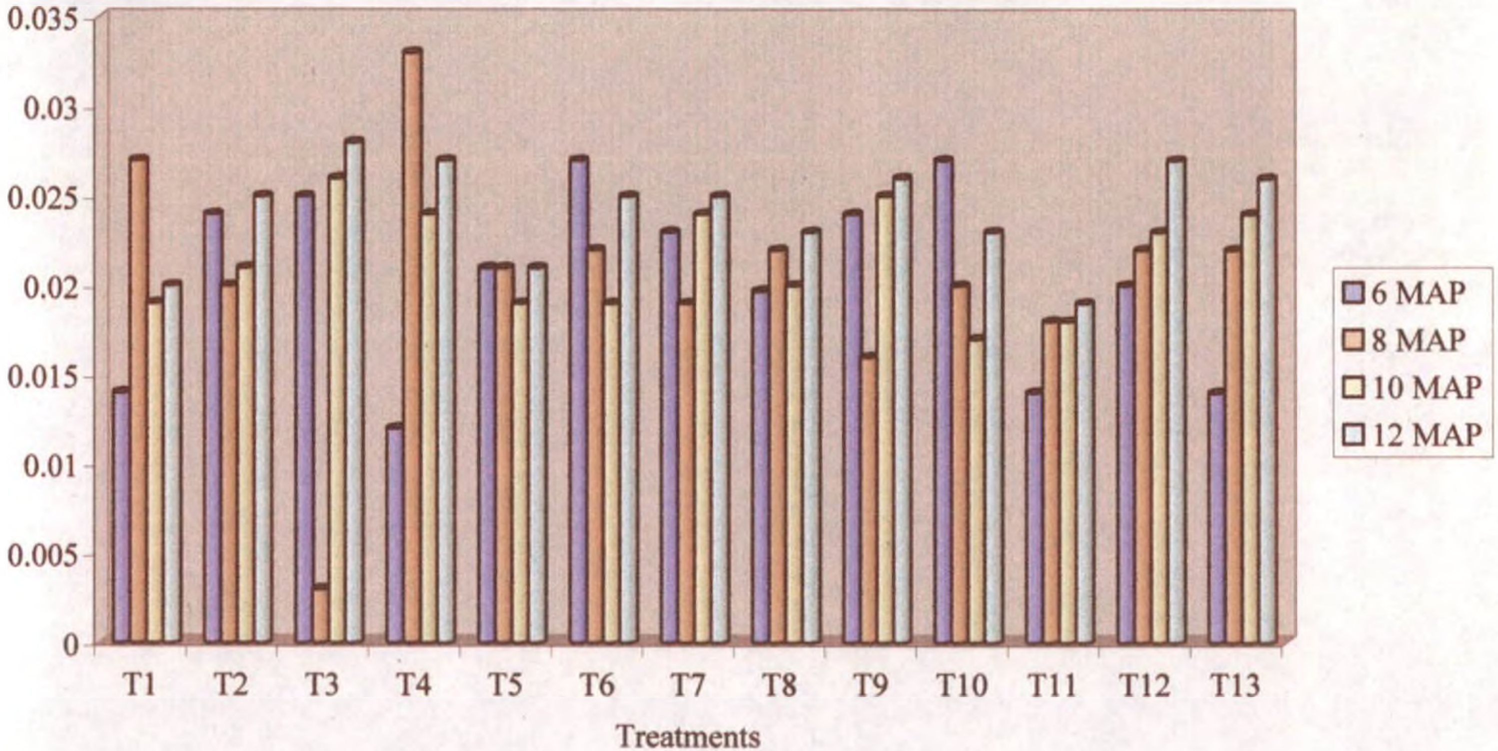


Fig. 6. Effect of organic manures and microbial inoculants on LAI of *P. rosea* at different growth stages

5.2.3 Specific Leaf Weight

In the study, the treatment containing FYM + mi (T_3) recorded highest specific leaf weight. This could be attributed to the physiological changes in plant on exposure to the action of growth promoting substances like auxin and gibberellins synthesized by inoculated microorganisms (Thimman, 1974). The larger leaf area recorded by these plants also might have resulted in higher specific leaf weight in T_3. Plants supplied with FYM+VC (T_8 and T_9) also recorded superior specific leaf weight which can be due to the positive influence of vermicompost and FYM in enhancing crop growth. Similar results were recorded in cowpea (Sailajakumari and Ushakumari, 2001).

5.2.4 Net Assimilation Rate (mg day^{-1} cm^{-2})

During the entire crop growth, highest NAR was recorded by plants supplied with FYM + VC+ mi (T_9). At the time of harvest the treatments supplied with 50: 50: 50 kg NPK ha^{-1} (T_1), FYM (50% N of POP) + mi (T_4) and T_{10} {FYM+VC (50% N of POP) + mi} also recorded superior NAR (Fig. 7). A decreasing trend in NAR was noticed at 10 MAP in T_2, T_3, T_7, T_8, T_9, T_{10}, T_{12} and T_{13} and a decrease was noticed at 12 MAP in the treatments T_8, T_{11} and T_{13}. Such decreasing trend in NAR with age has been reported by Sreekala (2004) in ginger. As leaf area ratio falls with advancing age, the rate of respiration per unit leaf area tends to increase and hence NAR decreases, independently of any change in the rate of photosynthesis or respiration per unit dry weight (Watson, 1958). The positive effect of vermicompost on NAR was reported in chilli (Sharu, 2000). Vimala and Natarajan (2002) reported the favourable influence of microbial inoculants in NAR in peas. The higher NAR recorded by T_9 and T_{10} might be due to the combined action of vermicompost and microbial inoculants. Vermicompost is composted manure where N, P, K and other micronutrients are easily available to plants. It also has a good count of

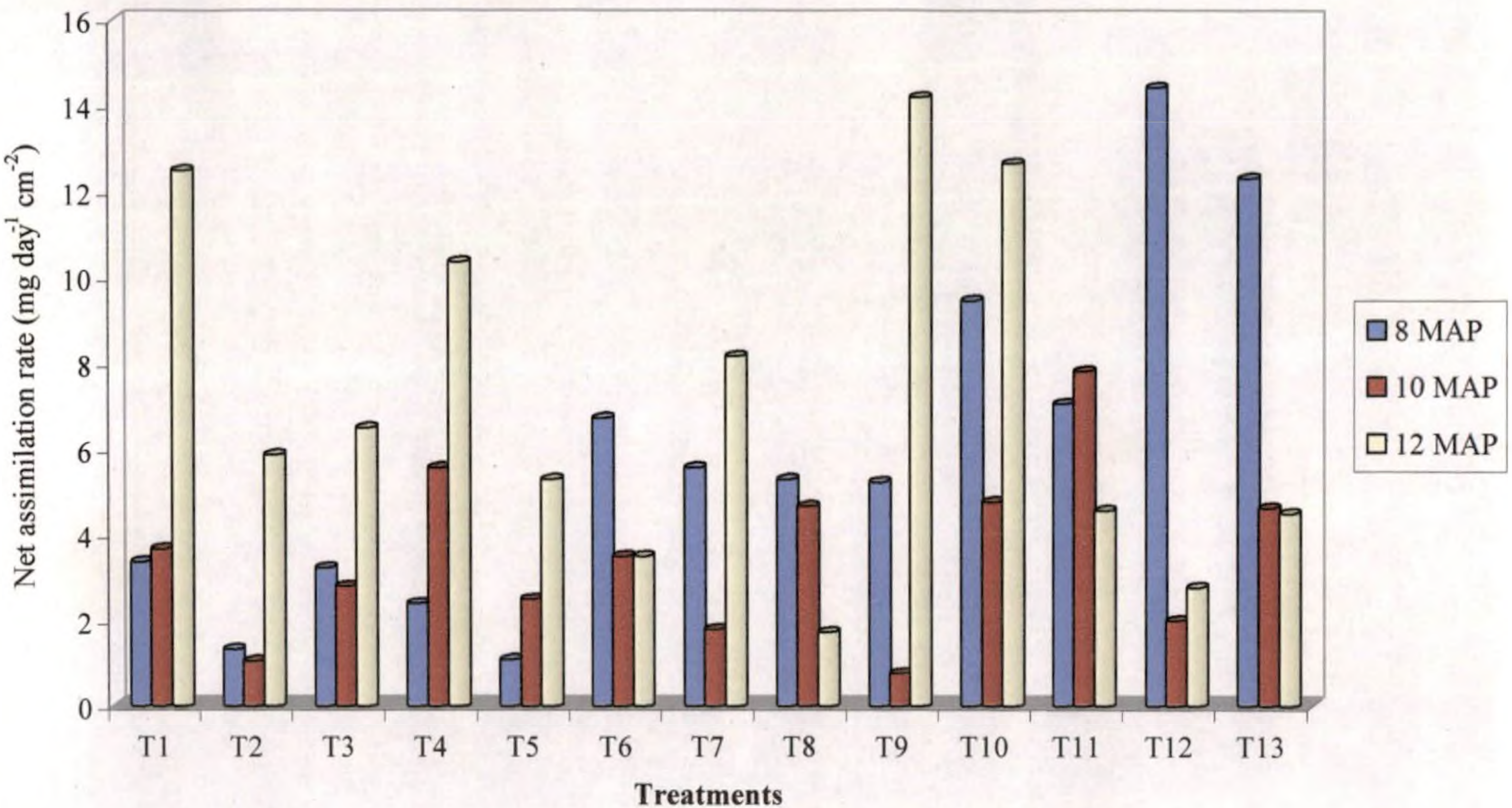


Fig. 7. Effect of organic manures and microbial inoculants on NAR of *P. rosea* at different growth stages, mg day^{-1} cm^{-2}

microbes and growth promoting substances (Gaur and Sadavasivam, 1993).

5.2.5 Crop Growth Rate

The treatments (T_{11}, T_9, T_{10}, T_4, T_7 and T_3) supplied with microbial inoculants recorded highest CGR in addition to T_1 (50: 50: 50 kg NPK ha^{-1}). The higher CGR recorded in these treatments might be due to higher LAI which resulted in greater rate of dry matter production per unit ground area (CGR). The higher CGR recorded by T_1 plants might be due to the higher net assimilation rate. The positive influence of NC might have resulted in the better CGR for T_{11}. The different organic manures produced similar effects on CGR and there was significant influence by the interaction of microbial inoculants (Fig. 8). Organic manures and their interaction with microbial inoculants generally result in better crop growth rate of plants (Sreekala, 2004). Sharu (2000) reported the positive influence of VC on CGR in chilli. Sreekala (2004) reported higher CGR in ginger plants treated with FYM + AMF and FYM + NC + AMF + Trichoderma.

5.2.6 Harvest Index

Harvest index is the ratio of fresh root yield to the biological yield. In the present study, the treatments supplied with FYM + NC + mi (T_7 and T_6), FYM + NC + VC (T_{11}) and FYM + mi (T_4 and T_3) recorded highest HI throughout the crop growth. Though T_1 recorded better CGR and NAR, the HI was lower. This might be due to the poor efficiency of these plants in translocation of assimilates to the economic part. Different organic manures also have similar effect in the assimilate translocation whereas microbial inoculants have significant effects. Maheswarappa *et al*. (2000) reported that in galangal intercropped in coconut garden, FYM and vermicompost applied plants recorded higher HI which can be attributed to the better translocation of assimilates into roots. The positive influence of microbial inoculants in HI was also reported in peas (Vimala and

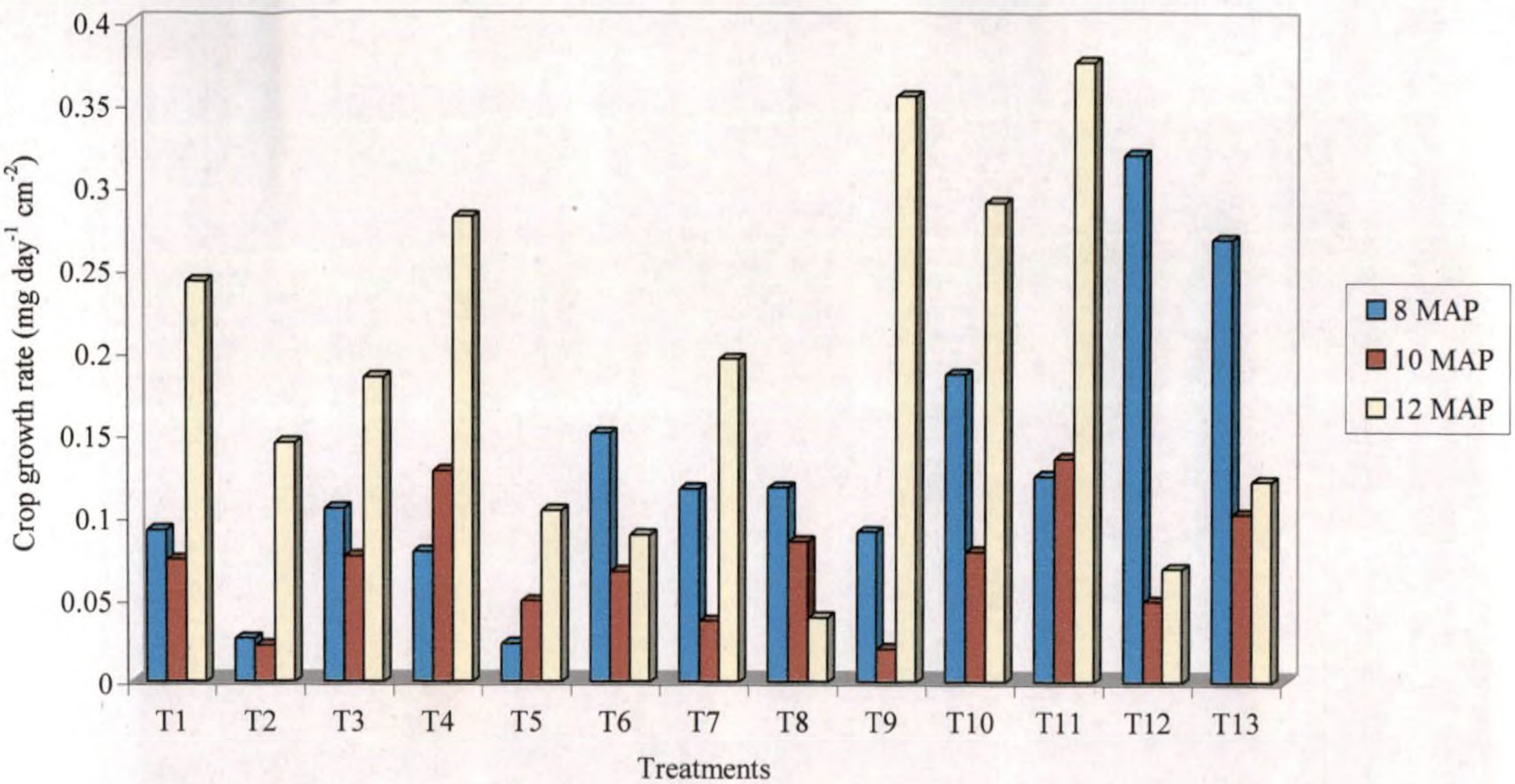


Fig. 8. Effect of organic manures and microbial inoculants on CGR of *P. rosea* at different growth stages, mg day^{-1} cm^{-2}

Natarajan, 2002). Sreekala (2004) reported the positive effect of FYM + mi and FYM + NC + mi in increasing the HI in ginger.

5.3 YIELD AND YIELD COMPONENTS

The results of the present study showed that application of organic manures and mi at different combinations could significantly increase the yield of *P. rosea* over the control plants, where chemical fertilizers were used as the source of nutrients.

5.3.1 Fresh Weight of Roots (g $plant^{-1}$)

The fresh weight of roots was better for organic manured plants. The plants supplied with FYM + NC + mi (T_7) gave significantly higher fresh root yield. The treatments T_3 and T_4 (FYM + mi) also recorded superior fresh root yield (Fig. 9). According to Suja (2001) and Sreekala (2004) application of different organic manures significantly increased the yield of white yam and green ginger respectively. Reduction in the leaching loss coupled with increased absorption of nutrients might be the reason for the highest yield in the plants treated with neem cake and mi. Similar result was reported by Sreekala (2004) in ginger. According to her, FYM + AMF, FYM + NC + AMF + *Trichoderma* recorded superior yield. The increased length and girth of roots in organic manured plants (T_7 and T_3) also contributed to the better fresh root yield. Another factor noticed was the better NPK uptake and the resultant higher chlorophyll of T_7 plants. These factors might have led to production of more photosynthates and their further efficient translocation to the roots contributing to better yield. Among the organic manure applied plots T_8 (FYM + VC) recorded the lowest yield. The N and P uptake was lower in these plants. As vermicompost is already composted manure, the net loss of nutrients was the highest in this treatment. Reduction in fresh yield in vermicompost alone treated plants were also reported in ginger (Sreekala, 2004).

The influence of microbial inoculants in increasing yield was recorded in chilli by Sajan *et al.* (2002) and in periwinkle by Gupta *et al.* (2003).

The favourable effect of FYM on fresh yield was recorded in amorphophallus (Patel and Mehta, 1987), snake gourd (Joseph, 1998) and betel vine (Arulmozhiyan *et al.*, 2002). The significance of neem cake in enhancing yield was reported in banana (KAU, 1993) and betel vine (Kadam *et al.*, 1993). From the results of this study it can be concluded that, it was the nitrogen use efficiency that determined the root yield of plants.

5.3.2 Dry Weight of Roots

The treatments can be clearly grouped into three based on the dry root weight of plants. The treatments supplied with organic manures and microbial inoculants recorded better dry root yield plant $^{-1}$(Fig. 9). The effect of FYM in increasing yield was reported in many crops such as yam (Mohankumar and Nair, 1979), turmeric (Balashanmugham *et al.*, 1989), kacholam (KAU, 1997) and ginger (Sreekala, 2004).

The influence of vermicompost in enhancing rhizome yield was reported by Vadiraj *et al.* (1996) in turmeric. For the treatment , FYM + VC + mi (T_{10}) the combined action of FYM as nutrient reservoir, vermicompost as an easily available nutrient source and the microbial inoculants as the solubilisers might have resulted in better yield.

Neem cake is a potent organic manure which contains the alkaloids that inhibit nitrification process (Rajkumar and Sekhon, 1981; Reddy and Prasad, 1985). In the present study neem cake application along with FYM and mi improved the yield (T_7). Similar results were reported in ginger (KAU, 1990; Sreekala, 2004). The N, P, K uptake of plants was also highest in T_7 plants. The higher nutrient uptake combined with higher chlorophyll content might have resulted in the better performance of T_7

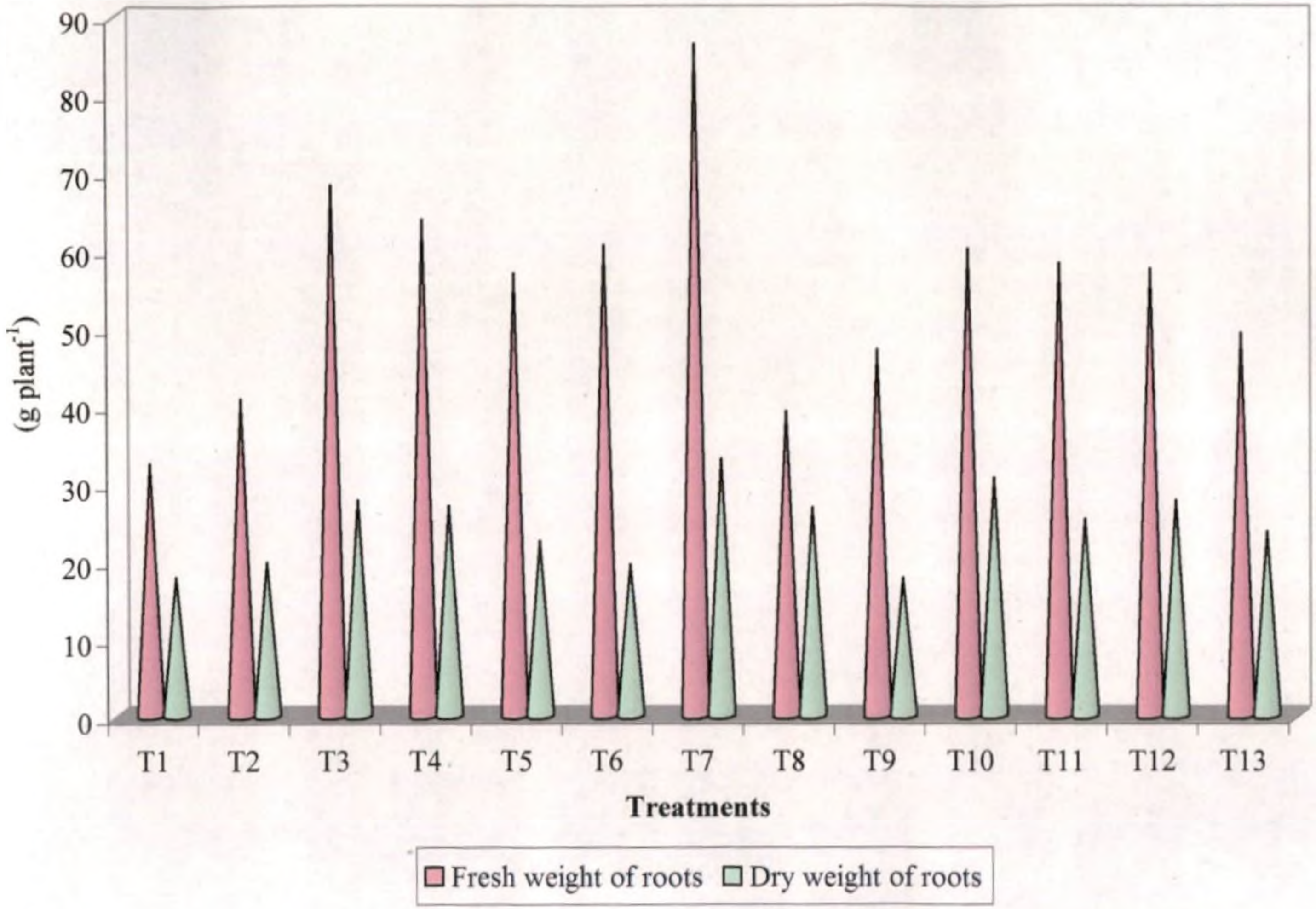


Fig. 9. Effect of organic manures and microbial inoculants on fresh weight of roots per plant (g) and dry weight of roots per plant (g) of *P. rosea* as intercrop in coconut garden

plants. Soil analysis based on the dry weight yield of roots, indicated that soils rich in microorganisms and nitrogen gave better results. It was not the soil P and K, but the nutrient uptake, that determined the yield. The more the microbial count the more was the nutrient uptake leading to better yield.

The influence of microbial inoculants was highly significant at the time of harvest. The role of biofertilizers in enhancing yield was reported in fenugreek (IISR, 1998), chilli (Kavitha 2001 and Sajan *et al.*, 2002), turmeric (Subramanian *et al.*, 2003), periwinkle (Gupta *et al.*, 2003), coriander (Hooda and Tehlan, 2003 and Subramanian *et al.*, 2003) and vanilla (Partibhan and Easwaran, 2003). The influence of anatomical and morphological changes in the root system such as increased lignification, root branching, the meristmatic and nuclear activities of root cells due to AMF (Sivaprasad *et al.*, 2000) might have helped in the better nutrient absorption and translocation which resulted in better yield. The application of organic manure alone resulted in lower yield compared to combined application of organic manure and microbial inoculants indicating the importance of microbial inoculants.

5.3.3 Number of Roots

The treatments supplied with FYM + NC + mi (T_6) and FYM + VC + mi (T_9) recorded highest number of roots. The plants treated with FYM + NC + VC + mi (T_{13}) and FYM + NC + VC (T_{11}) also recorded superior values. The influence of FYM in increasing the number of roots was reported by Maheswarappa *et al.* (1997) in arrowroot. In the present study, the yield of chethikkoduveli (P. *rosea*) was related to the thickness and length of the root and not the number. The treatments with better yield ((T_7 and T_3) had lesser number of roots. Singh *et al.* (2000) reported that FYM treated rice plants had higher root density. The growth hormones such as auxins, GA_3 and cytokinins in vermicompost (Gaur and Sadasivam, 1993) coupled with the hormonal action of microbes (Barea and Azcon, 1982) might have resulted in higher root number in T_9 and T_{13} plants. The effect of FYM and VC for enhancing root number might be the reason for higher root number in T_{11} plants. Microbial inoculants were found to have a positive influence on the root number of *P. rosea.*

5.3.4 Length of Roots

Highest root length was recorded by T_7 (FYM + NC + mi) plants, which was followed by T_{10} (FYM + VC + mi) and T_4 (FYM + mi) plants. The microbial inoculants significantly increased root length which might have caused better accumulation of photosynthates and thereby yield. Kavitha (2001) recorded highest root length for chilli plants treated with *Azospirillum brasilience*. The positive influence of FYM in root length was reported in arrowroot by Maheswarappa *et al.* (1997) and turmeric by Rakhee (2002).

5.3.5 Girth of Roots

The girth of roots was significantly high for FYM + mi (T_3), FYM + NC + mi (T_7), FYM + VC + mi (T_{10}) and FYM + NC + VC + mi (T_{12}) applied plants. The combined application of organic manures and microbial inoculants resulted in higher root girth. This might be due to the better mobilization of nutrients, which resulted in better accumulation of photosynthates. In the present study, the root girth was found proportional to the dry weight of roots. The plants which had better dry weight yield recorded higher root girth. Thus root thickness can be taken as an indication of better yield in *P. rosea*. A similar result was reported in ginger (Sreekala, 2004).

5.3.6 Fresh Root Yield ha^{-1} (as intercrop)

In the present study, the highest root yield was recorded in the treatment FYM + NC (50 % N of POP) + mi. The yield from FYM + mi (T_3 and T_4) applied plots were also superior. Microbial inoculants treated plots recorded better root yield than plots treated with organic manure

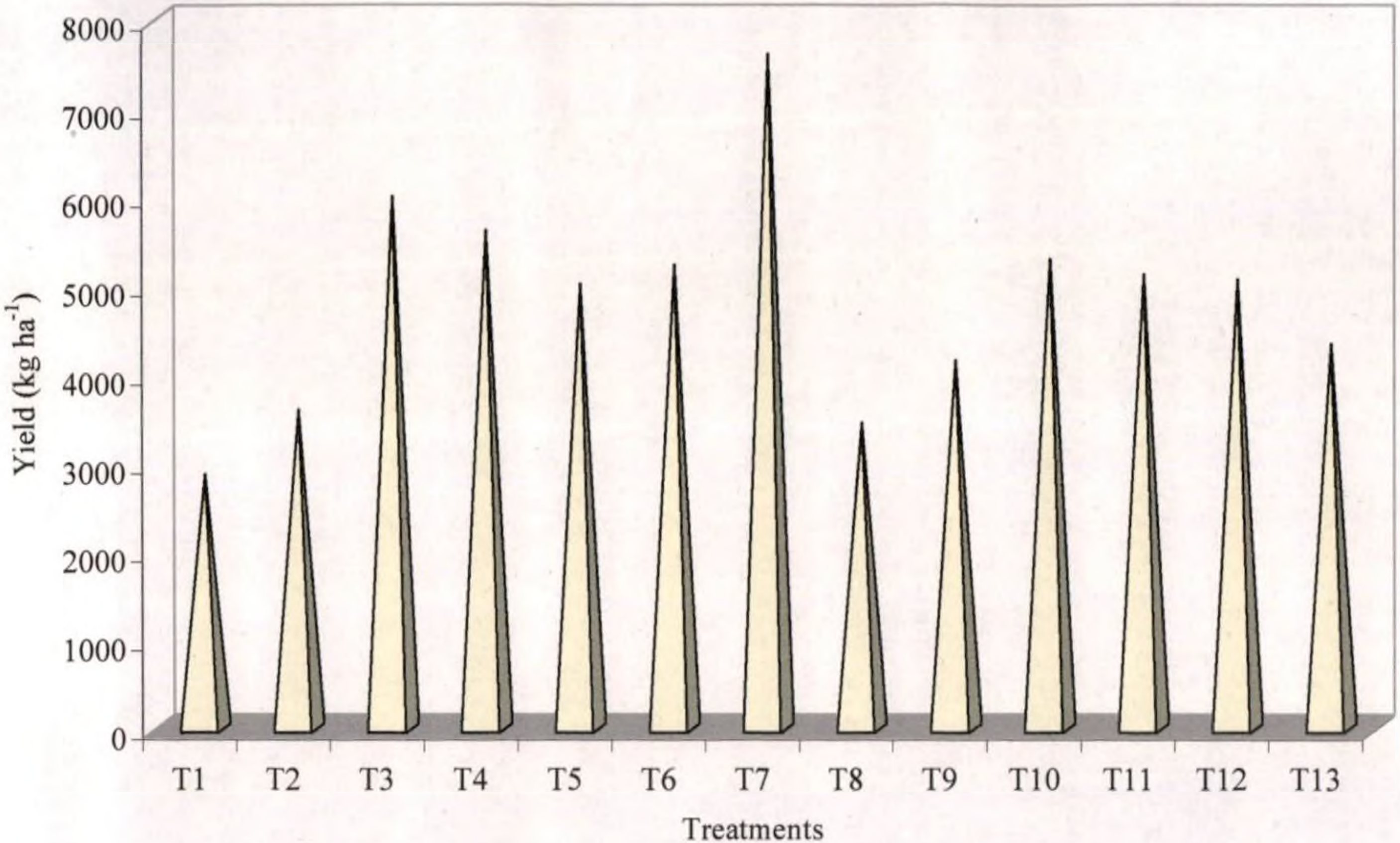


Fig. 10. Effect of organic manures and microbial inoculants on fresh root yield (kg ha^{-1}) of *P. rosea* as intercrop in coconut garden

alone (Fig. 10). The plants treated with inorganic fertilizers (T_1) recorded the least yield which was on par with T_8 (FYM + VC). The lower yield in these treatments might be due to the leaching loss of inorganic nutrients. In the present study, vermicompost was applied as a single basal dose. The inorganic fertilizers and vermicompost are easily soluble nutrient sources which get lost from the soil within a short period. This was evidenced by the decreased NAR and CGR noticed in these plants (Table 11 and 12). This might be the reason for low root yield in T_1 and T_8 plants. The significance of microbial inoculants in yield improvement is evident from various treatments. The high root yield of T_7 plants might be due to better chlorophyll content and NPK uptake. The soil microbial population was also high in the plots which recorded better yield. This might be due to the solubilising effect as well as better penetration of roots to the nutrient source by the action of *Azospirillum*, phosphobacteria and AMF. In addition to this, they are good sources of various growth promoting substances (Krishna and Bhagyaraj, 1991). According to Arora and Dan (2003) biofertilizers can mobilize nutritionally important elements from non-usable to usable form through biological process. The neem cake reduces leaching loss and extends the period of availability of N to the crop from the applied N (Sathianathan, 1982). The combined action of NC, microbial inoculants and FYM in the correct proportion might be the reason for the significantly superior yield in T_7 plants. FYM is effective in increasing crop yield which was supported by many workers in different crops. The influence of FYM for enhancing yield was reported in yam (Mohankumar and Nair, 1979), amorphophallus (Patel and Mehta, 1987), *P. zeylanica* (Shah *et al.*, 2000) arrowroot (Maheswarappa *et al.*, 2000; Vidyadharan, 2000), wheat (Singh and Agarwal, 2001), and turmeric (Rakhee, 2002). The combined effect of FYM + mi in enhancing rhizome yield was reported by Subramanian *et al.* (2003) in turmeric and Sreekala (2004) in ginger

Plate 4. Effect of various treatments on root character of *Plumbago rosea*

5.4 PLANT ANALYSIS

The analysis of the plant samples from the present study indicated that the application of organic manures and mi at different combinations altered the chemistry of *P. rosea*

5.4.1 Total Chlorophyll Content

The treatment consisting of FYM + NC + mi (T_7) recorded highest chlorophyll content (1.25). The treatment FYM + mi (T_3), which recorded the highest plumbagin content, had a chlorophyll content of 0.699. Similar negative correlation of chlorophyll and plumbagin content was reported in *P rosea* by Arya (1999). The positive influence of microbial inoculants in chlorophyll content was reported in green gram (Ray and Dalei, 1998 ; Rao and Rao, 1998), black gram (Rao and Rao, 1998) and sorghum (Patidar and Mali, 2004). Johnston and Onwueme (1998) reported that an increase in leaf chlorophyll content was noticed in root crops grown under shade. The higher plant uptake of NPK coupled with the shade of coconut might have resulted in the high chlorophyll content of T_7 plants. The chlorophyll content was found to be not influenced by the different N treatments. Similar result was reported in blackberry (Naraguma and Clark, 1998).

5.4.2 Plant Uptake of NPK

The analysis of the plant samples from the present study indicated that the application of organic manures and mi at different combinations significantly increased the nutrient uptake of *P. rosea* (Fig. 11).

5.4.2.1 Uptake of N

The influence of microbial inoculants on N uptake was significant in all the treatments. The treatment T_7 {FYM + NC (50 % N of POP) +mi} which gave the highest root yield recorded the highest N uptake also. The nutrient uptake is a function of dry matter production and significantly high TDM was also observed in T_7. Neem cake increases nitrogen use efficiency (Kumar and Ali, 2003). The combined effect of FYM and microbial inoculants in enhancing N uptake was reported in betel vine (Mozhiyan and Thamburaj, 1998) and ginger (KAU, 1999). The effect of AMF in increasing NPK uptake was reported in papaya (Gaddeda *et al.*, 1984). In the present study, the treatments without microbial inoculants were poor in the N uptake. This might be due to inefficient absorption of nutrients. It is not the soil nutrients but the efficiency in plant uptake that determined the yield of the crop. T_7 plants were supplied with only 50 per cent N of POP (KAU, 2002) but had significantly high N uptake (Table 17). Same was the case with T_9 (75 % N) and T_{13} (50 % N). Thus by the addition of microbial inoculants, application of nitrogenous manures / fertilizers can be saved partially without affecting the yield. Similar results were reported in vegetable crops (Kanuja and Narayanan, 2003). The lowest uptake was recorded by T_8 (FYM + VC), T_2 (FYM alone) and T_5 (FYM + NC) treatments. The lower uptake might be due to the lack of microbial inoculants, which have the capacity to solubilise unavailable sources of nutrients to available forms. Organic manures take more time for nutrient decomposition in the absence of microbial inoculants, which might have resulted in poor N uptake. The higher rates of N uptake increased the protein biosynthesis leading to new tissue formation resulting in higher TDM production.

5.4.2.2 Uptake of P

In general, the use of organic manures significantly influenced P uptake. FYM + NC + mi (T_7) application resulted in higher P uptake which was on par with FYM + mi (T_3). Higher uptake of N and K was also noticed in T_7. These treatments produced the highest root yield (Table 14). The beneficial effect of AMF and P solubilisers can be attributed as the reason for enhanced P uptake in microbial inoculant supplied plants. Higher uptake of P by the treatments involving FYM alone @ 48 t ha^{-1}

substituting 59 per cent N and 25 per cent N through *Azospirillum* has been reported (KAU, 1999). The higher root yield of T_3 and T_7 plants might be attributed to the higher P uptake, because P has an important role in root formation. Plants with higher P uptake (T_7) had higher N uptake also *i.e.*, 16.1 kg P ha^{-1} and 285.6 kg N ha^{-1} respectively. Mycorrhiza inoculated plants showed better growth due to enhanced uptake of P (Krishna and Bhagyaraj, 1991; Kennedy and Bhagyaraj, 2001). The increased nutrient uptake in inoculated plants was reported in betel vine (Mozhiyan and Thamburaj, 1998), pepper (Ashithraj, 2001), apple (Sharma *et al.*, 2002) and ginger (Sreekala, 2004),

5.4.2.3 Uptake of K

The organic manured plants showed better K uptake over the inorganically treated plants (T_1). Among the organic manures, FYM + NC + mi (T_7) recorded the highest K uptake. Uptake of N and P was also highest for T_7 plants, so also the growth and yield. The combined effect of organic manures and microbial inoculants also influenced K uptake. The effect of AMF in enhancing K uptake was reported in ginger (Joseph, 1997) and papaya (Kennedy and Rangarajan, 2001). The K uptake was found to be independent of the K supplied to the soil.

5.4.2.4 Alcohol Soluble Extracts

The alcohol soluble extracts give an indication of the concentration of active ingredient of the plants, which differed significantly among the various treatments (Fig. 12). The treatment T_3 { FYM (75 % N of POP) + mi } recorded the highest value. This was on par with T_9 (FYM + VC + mi) and T_6 (FYM + NC + mi). The influence of organic manure in enhancing the quality is reported in kacholam (Kurein *et al.*, 2000) and turmeric (Nampoothiri, 2001). FYM application improved spinach leaf quality (Kansal *et al.*, 1981) and protein content in arrowroot (Vidhyadharan, 2000). The positive influence of FYM+VC in enhancing the quality of cowpea was reported by Sailajakumari and Ushakumari (2001). According

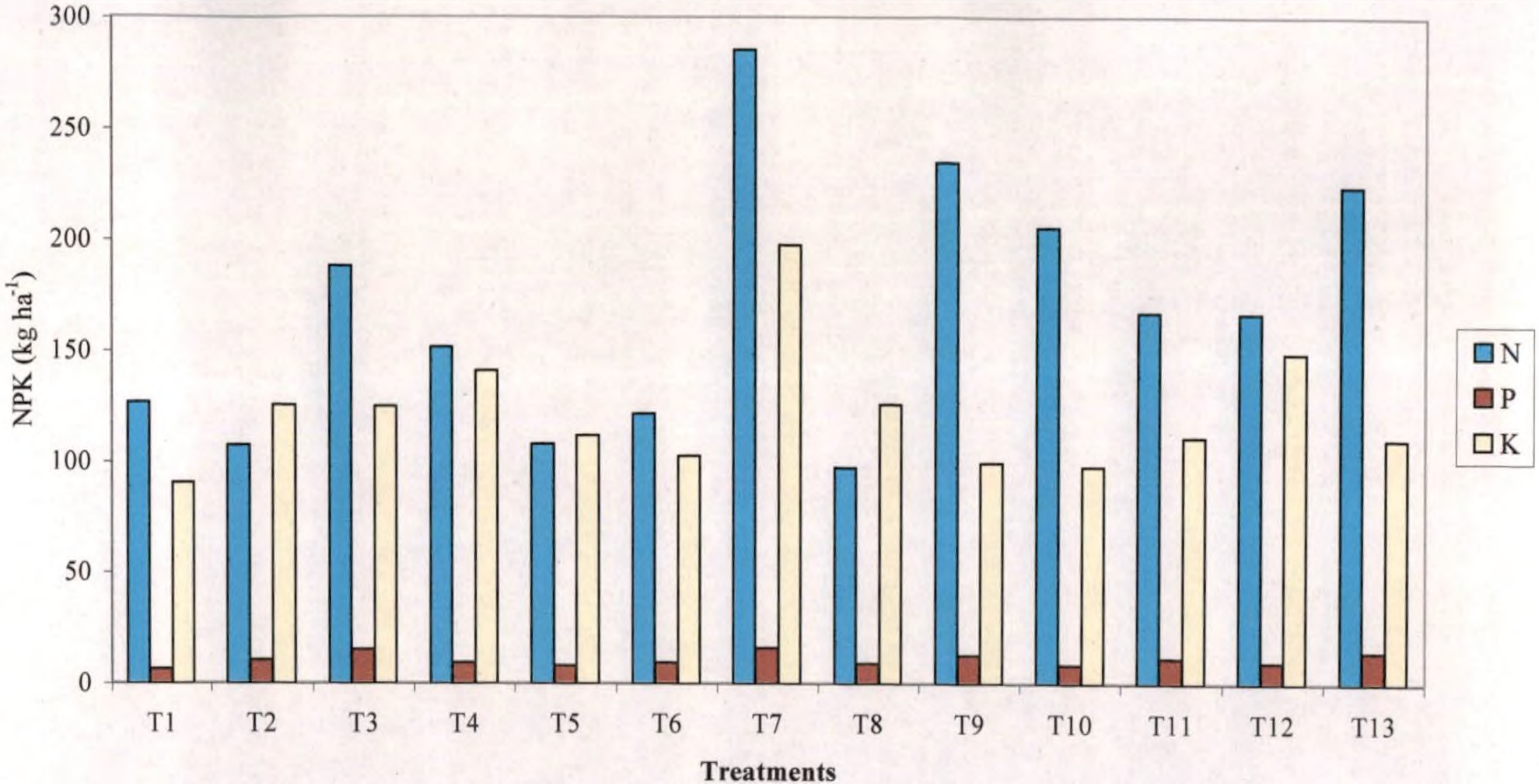


Fig. 11. Effect of organic manures and microbial inoculants on N, P and K uptake of *P. rosea* at the time of harvest, kg ha^{-1}

to Sadanandan and Hamza (1996) NC enhanced curcumin content in turmeric.

The combined effect of organic matter and microbial inoculants might be the reason for higher alcohol soluble extracts in T_7 plants Similar results were reported in tomato (Sundaram and Arangarasan, 1995), *Cymbopogon spp.* (Ratti and Janardhanan, 1996), ginger (KAU, 1999) and geranium (Pasha *et al.*, 2003).

5.4.2.5 Plumbagin Content

Plumbagin is that fraction of the extract which is medicinally important. Generally plumbagin content varies with age of the crop. It increases with age and ranges from 0.38 to 2.72 per cent (Mathew *et al.*, 2005). In the present study, the treatment supplied with FYM + mi (T_3) recorded significantly higher plumbagin content. Organically treated plants such as T_5, T_6, T_{11}, T_9 and T_7 also contained higher amount of plumbagin. The combined effect of FYM and microbial inoculants might have resulted in higher plumbagin content in T_3 plants. The microbial inoculant AMF is known for its endophytic nature in the root and it influences physiology of host plant (Sivaprasad *et al.*, 2000); perhaps the altered physiological and biochemical evaluation favoured higher accumulation of plumbagin content (Fig. 13). The influence of organic manures in enhancing oil yield was reported in kacholam (Kurien *et al*, 2000) and curcumin and oleoresin in turmeric (Nampoothiri, 2001). The plumbagin content in root decreases on drying. Kurien *et al.* (2000) reported a reduction of 68.3 per cent of plumbagin after drying of roots and a further reduction of 87.7 per cent on curing in lime water. Plumbago roots can be used either as fresh or dry depending on the end use.

5.4.3 Soil Analysis

Soil samples from the experimental plots were taken before the experiment for estimating available NPK and soil microbial population.

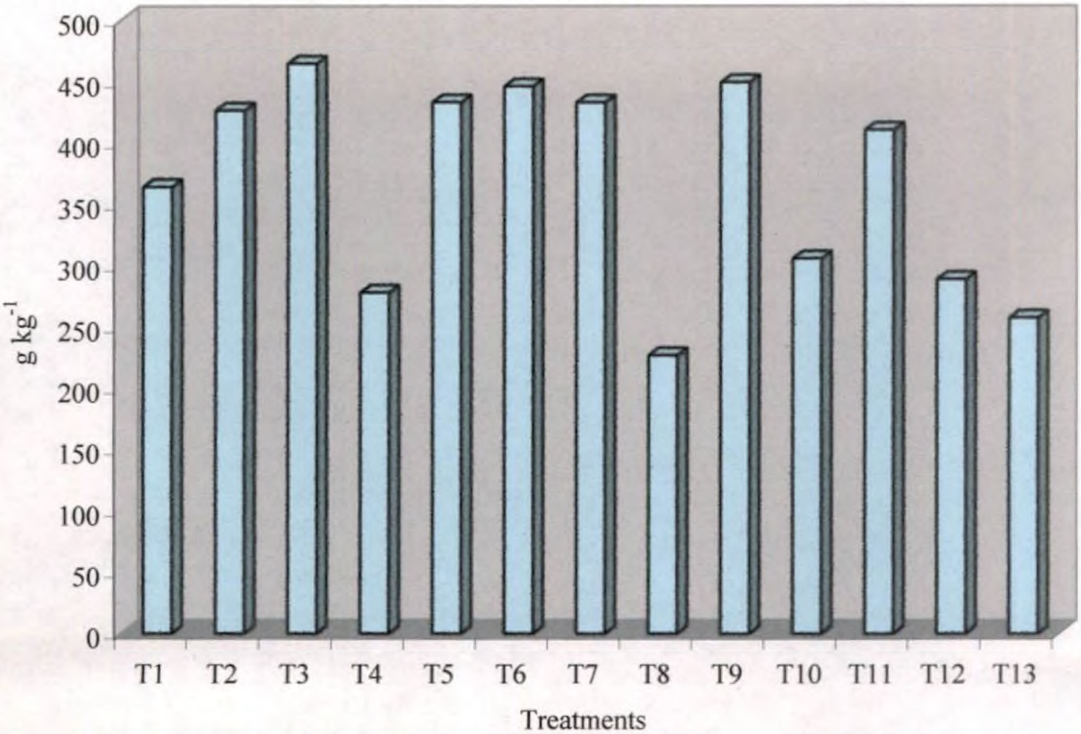


Fig. 12. Effect of organic manures and microbial inoculants on alcohol soluble extracts of roots of *P. rosea* at the time of harvest, g kg^{-1} of dried roots

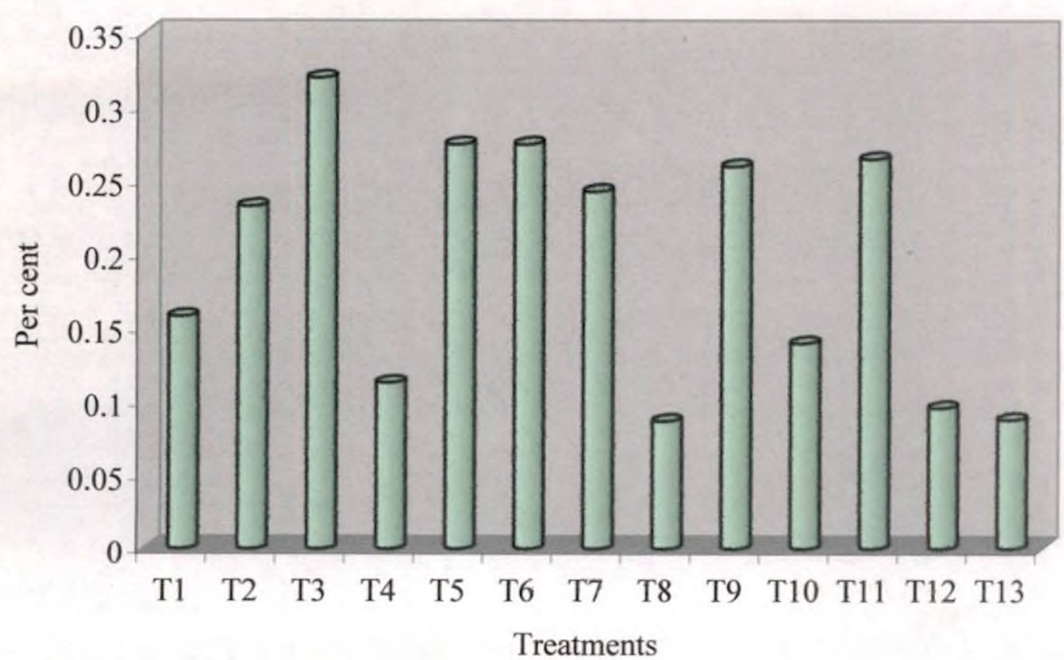
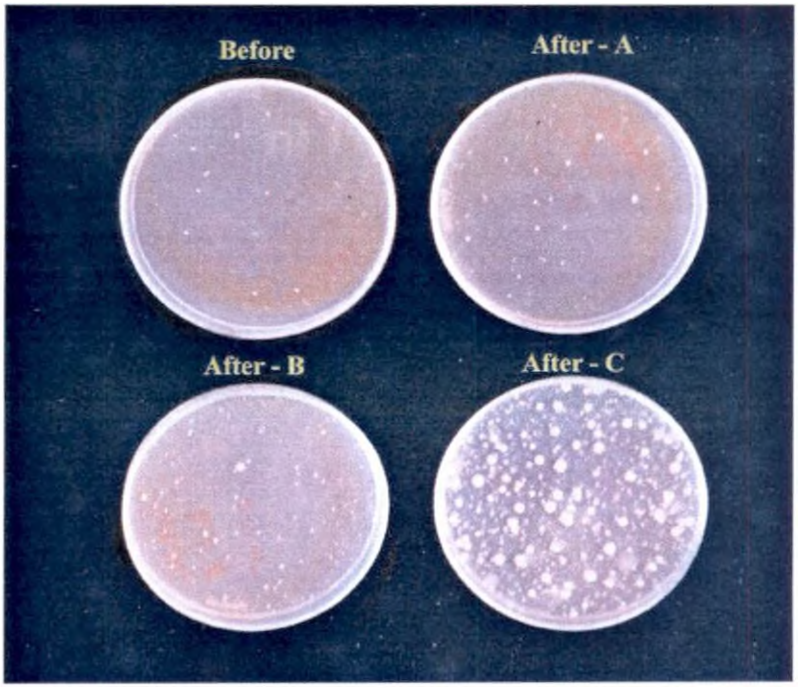


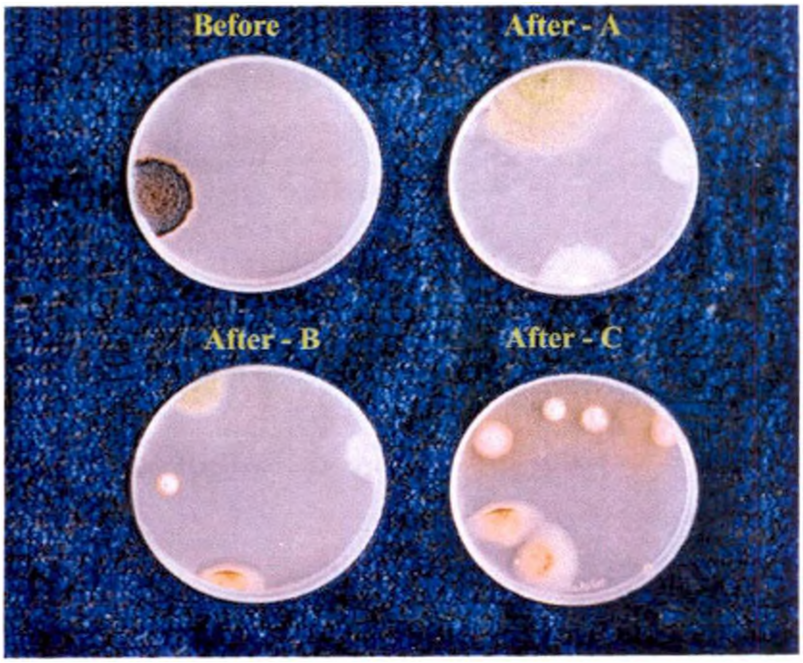
Fig. 13. Effect of organic manures and microbial inoculants on plumbagin content of roots of *P. rosea* at the time of harvest, per cent

The soil was found low in fertility status. This might be attributed to the previous crop grown in the experimental area. Prior to the experiment, the plot was used for cassava cultivation which is an exhaustive crop (Susan *et al*., 1998). Before the experiment the soil had 188.16 kg N ha^{-1}, 41.4 kg P ha^{-1} and 138.08 kg K ha^{-1}. The soil microbial population was also low. It had a bacterial, fungal and actinomycetes count of 9×10^7, 1×10^5 and 1×10^5 respectively.

After experiment, the soil samples were grouped into three, based on the dry root yield. It was estimated that the plots with higher yield had higher soil N and K. Soil P was found to be high in all the plots. These soils also recorded higher count of soil microbial population (Table 20 and 21), which might have influenced N and P availability of soil for better plant uptake. Subbiah (1990) observed that when adequate amount of farmyard manure was added to the soil with biofertilizers, it improved biofertilizer efficiency and ultimately nutrient status of soil. In the present study, the available N content increased after experiment. Similar result was observed in organic farming in ginger (Sreekala, 2004). The effect of organic manures in increasing available soil N, P and K was reported by many workers (Srivastava, 1985; Kabeerathumma *et al*., 1990; More, 1994; Susan *et al*., 1998). The influence of FYM in increasing soil nutrient status has also been reported in other crops (Aravind, 1987; Gomes *et al*., 1993; Hegde *et al*., 1998; Venkatesh *et al*., 2003). Neem cake can influence metered supply of N over a stipulated period of crop growth (Hulagur, 1993). Vermicompost also enhances availability of N (Rao *et al*., 1996; Hegde *et al*., 1998). In the present study, increased P availability was also observed in plots treated with microbial inoculants. Similar observation was reported by Kucey *et al*. (1989), Sharma *et al*. (2002) and Zahir *et al*. (2004). Soil productivity is enhanced by organic matter addition (Sangeetha, 2004).



a. Bacterial count



b. Fungal count

Plate 5. Soil microbial population

Hence it can be concluded that the higher soil microbial population and the consequent better availability of nutrients attributed to the production of higher dry root yield of *P. rosea*.

5.4.4 Economics of Cultivation

The treatments consisting of organic manures recorded superior benefit cost ratio (BCR) over control (T_1). The treatment T_7 {FYM + NC (50 %) + mi} recorded significantly high BCR (Table 22). Treatments T_3, T_4, T_{11} and T_{10} also recorded better BCR. Control (T_1) recorded the lowest BCR (1.14). The other treatments with lower BCR were T_8 (FYM + VC) and T_2 (FYM alone) (Table 20). Significance of microbial inoculants in enhancing BCR was observed in various treatments. FYM + NC + mi generated higher profit. Similar result was observed in ginger (Sreekala, 2004). The influence of neem cake in enhancing BCR was reported in okra (Raj, 1999) and acid lime (Ingle *et al.*, 2001). Even though FYM has low nutrient availability, the use of microbial inoculants resulted in better utilization of nutrients. The high cost of neem cake can be compensated by the higher yield from the neemcake applied treatments. The results indicated that judicious combination of organic manures and microbial inoculants can result in higher profit in *P. rosea* cultivation. The microbial inoculants can save N fertilization upto 50 per cent. Use of microbial inoculants as a cost effective supplement was reported by Pandey and Kumar (2002). Effect of microbial inoculants in enhancing BCR was reported in bhindi (Asha, 1999), ginger (Nath and Korla, 2000) and rosemary (Anuradha *et al.*, 2003). According to Kanuja and Narayanan (2003), microbial inoculants can save N/P requirement upto 50 per cent and increase yield by 18 to 50 per cent in vegetables. The profit was lower for T_1 plants and the reason can be attributed to lesser yield (Table 23).

In conclusion, the study revealed that T_7 [FYM + NC (50 % N) + mi] and T_3 {FYM + mi (75 % N)} had significant effect in enhancing growth, yield and quality of chethikkoduveli (*P. rosea*). From the point of view of quality (plumbagin content) FYM + mi (75 % N) is found to be the best treatment. For farmers FYM + NC + mi (50 % N) can be adopted for better fresh and dry root yield. Based on the benefit cost ratio, the treatment supplying only 50 % N of POP recommendation through FYM and neem cake along with microbial inoculants can be considered as the best for better root yield, quality and profit in *P. rosea* when grown as an intercrop in coconut plantations.

Future lines of work

1) The residual effect of the organic manure-microbial inoculant combination is to be studied.
2) Impact of organic farming to the main crop (coconut) needs to be studied.

Summary

6. SUMMARY

An experiment entitled "Organic nutrient management in chethikkoduveli" was carried out in the Instructional farm, College of Agriculture, Vellayani during 2004-05 to study the combined effect of organic manures and microbial inoculants on the growth, yield and plumbagin content of chethikkoduveli (*Plumbago rosea* L.) so as to formulate an organic manurial schedule for this in a coconut based cropping system. The study also aimed at assessing the relative efficiency of organic manures and microbial inoculants as substitutes for inorganic fertilizers and comparing the economics of cultivation of various treatment combinations.

The major findings of the experiment are summarized below:

The study revealed that the application of different combinations of organic manures and microbial inoculants greatly influenced the morphological, physiological and yield parameters of *P. rosea.*

Morphological parameters

Morphological parameters *P. rosea* were significantly influenced by the application of different combinations of organic manures and microbial inoculants.

FYM (75 % N) + mi (T_3) applied plots showed significantly highest height at all stages of observation. Shortest plants were observed in control plot (T_1).

There was no significant difference in the number of branches of the plants from various treatments, at any stages of growth.

At the time of harvest T_7 (FYM + NC + mi) plants had significantly highest leaf count which was on par with T_4 and T_{10}.

T_3 plants recorded significantly highest leaf area throughout the crop growth.

The fresh weight of plants were highest in T_7 (FYM + NC + mi) plants and lowest in T_2 (FYM alone) plants.

Physiological parameters

The results of the present study indicated that application of different combinations of organic manures and mi greatly influenced the physiology of *P. rosea*.

The effect of organic manures and/or microbial inoculants on LAI was significant at all stages of crop growth except at 10 MAP. The treatment supplied with FYM (75% N of POP) + mi recorded the highest LAI.

The treatment supplied with FYM (50% N of POP) + NC + *mi* (T_7) recorded highest TDM. In general, total dry matter production was significantly higher in organic manure treated plants than inorganic fertilizers applied plants (T_1).

In the study, the treatment containing FYM + mi (T_3) recorded highest specific leaf weight.

During the entire crop growth, highest NAR was recorded by plants supplied with FYM + VC+ mi (T_9). At the time of harvest the treatments supplying 50: 50: 50 kg NPK ha^{-1} (T_1), FYM (50% N of POP) + mi (T_4) and T_{10} {FYM+VC (50% N of POP) + mi} also recorded superior NAR.

The treatments (T_{11}, T_9, T_{10}, T_4, T_7 and T_3) supplied with microbial inoculants recorded highest CGR in addition to T_1 (50: 50: 50 kg NPK ha^{-1}).

The treatments supplied with FYM + NC + mi (T_7 and T_6), FYM + NC + VC (T_{11}) and FYM + mi (T_4 and T_3) recorded highest HI throughout the crop growth.

Plant Analysis

The analysis of the plant samples from the present study indicated that the application of organic manures and mi at different combinations altered the chemistry of *P. rosea.*

All the treatments varied significantly in the total chlorophyll content of the leaves. T_7 had maximum chlorophyll content of 1.25 per cent and T_{10} the minimum (0.265 %). T_{13} and T_{11} had slightly lower total chlorophyll content (0.879 and 0.874 respectively) than T_7 plants.

The alcohol soluble extracts which give an indication of the concentration of active ingredient of the plants differed significantly among the various treatments. The treatment T_3 { FYM (75 % N of POP) + mi } recorded the highest value. This was on par with T_9 (FYM + VC + mi) and T_6 (FYM + NC + mi).

Organic manures and microbial inoculants significantly influenced the root plumbagin content. T_3 (FYM supplying 75 % N + mi) plants recorded the highest alcohol soluble extracts and plumbagin content.

Plant NPK uptake

The application of organic manures and mi at different combinations significantly increased the nutrient uptake of *P. rosea.*

The influence of microbial inoculants on N uptake was significant in all the treatments. The treatment T_7 {FYM + NC (50 % N of POP) +mi} which gave the highest root yield recorded the highest N uptake also.

In general, the use of organic manures significantly influenced P uptake. FYM + NC + mi (T_7) application resulted in higher P uptake which was on par with FYM + mi (T_3).

Higher uptake of N and K was also noticed in T_7. These treatments produced the highest root yield. The organic manured plants

Yield and yield parameters

The results of the present study showed that application of organic manures and mi at different combinations could significantly increase the yield of *P. rosea* over the control plants.

The fresh weight of roots was better for organic manured plants. The plants supplied with FYM + NC + mi (T_7) gave significantly higher fresh root yield. The treatments T_3 and T_4 (FYM + mi) also recorded superior fresh root yield.

The treatments can be clearly grouped into three based on the dry root weight of plants. The treatments supplied with organic manures and microbial inoculants recorded better dry root yield.

The treatments supplied with FYM + NC + mi (T_6) and FYM + VC + mi (T_9) recorded highest number of roots. The plants treated with FYM + NC + VC + mi (T_{13}) and FYM + NC + VC (T_{11}) also recorded superior values.

Highest root length was recorded by T_7 (FYM + NC + mi) which was followed by T_{10} (FYM + VC + mi) and T_4 (FYM + mi).

The girth of roots was significantly high for FYM + mi (T_3), FYM + NC + mi (T_7), FYM + VC + mi (T_{10}) and FYM + NC + VC + mi (T_{12}) applied plants.

In the present study, the highest root yield was recorded in the treatment FYM + NC (50 % N of POP) + mi. The yield from FYM + mi (T_3 and T_4) applied plots were also superior. Microbial inoculants treated plots recorded better root yield than plots treated with organic manure alone. The plants treated with inorganic fertilizers (T_1) recorded the least yield which was on par with T_8 (FYM + VC).

showed better K uptake over the inorganically treated plants (T_1). Among the organic manures, FYM + NC + mi (T_7) *recorded the highest K uptake.* Microbial inoculants had significant role in plant uptake.

Soil analysis

The soil samples after experiment were grouped into three based on the dry weight of roots. These samples were analysed for all the major nutrients and microbial population. The results showed that the nutrient supplying capacity of soil and the microbial population had a direct correlation.

Noticeable increase in soil N content was noticed after the experiment. There was not much difference in the soil P content before and after the experiment. A slight decrease in the soil K content was noticed after the experiment.

Marked increase in the soil microbial population was noticed after the experiment. Soil bacterial count was found to be directly proportional to the dry root yield of plants. Soil fungal count was also directly proportional to the dry root yield. The actinomycetes population was also more than that of the soil before experiment.

Pest and disease incidence

No major pests or diseases were noticed throughout the crop growth.

Economics of cultivation

All the treatments varied significantly in the BCR. The treatment supplied with FYM + NC (50 % N of POP) + mi (T_7), recorded the highest BCR (2.73) which was significantly different from the rest of the treatments. T_3 and T_4 were the other treatments with higher BCR of 2.2 and 2.05 respectively. The control plot (T_1) had the lowest BCR (1.14) which was on par with T_8, T_2 and T_9 (1.47, 1.37 and 1.2 respectively).

In conclusion, the study revealed that T_7 [FYM + NC (50 % N) + mi] and T_3 [FYM (75 % N) + mi] had significant effect in enhancing growth, yield and quality of chethikkoduveli (*P. rosea*). From the point of view of quality (plumbagin content) FYM + mi (75 % N) is found to be the best treatment. Based on the benefit cost ratio, the treatment supplying only 50 % N of POP recommendation through FYM and neem cake along with microbial inoculants can be considered as the best for better root yield and profit in *P. rosea* when grown as an intercrop in coconut plantations.

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*Original not seen

Appendices

APPENDIX -I

Weather parameters during the cropping period (June 2004 to May 2005)

Month and Year	Maximum temperature (°C)	Minimum temperature (°C)	Total rainfall (mm)	Evaporation (cm)
June 04	30.50	21.04	223.16	3.3
July 04	29.50	21.09	295.00	3.10
Aug 04	30.00	21.25	71.70	3.83
Sep 04	30.58	20.23	220.50	3.78
Oct 04	31.02	20.98	182.40	3.38
Nov 04	29.04	20.76	206.60	2.21
Dec 04	32.53	19.88	16.00	2.55
Jan 05	32.72	21.92	1.00	3.23
Feb 05	34.52	22.24	0.20	3.87
Mar 05	35.06	24.15	1.10	4.73
Apr 05	33.06	23.98	333.8	4.18
May 05	32.68	25.25	128.9	3.67

APPENDIX - II

Quantity of major nutrients added through manures and fertilizers, kg ha^{-1}

Treatments		N		P		K
T_1	–	50	:	50	:	50
T_2	–	50	:	50	:	67.2
T_3	–	37.5	:	50	:	50
T_4	–	25	:	50	:	50
T_5	–	50	:	50	:	92.5
T_6	–	37.5	:	50	:	50
T_7	–	25	:	50	:	50
T_8	–	50	:	50	:	75
T_9	–	37.5	:	50	:	50
T_{10}	–	25	:	50	:	50
T_{11}	–	50	:	50	:	18
T_{12}	–	37.5	:	50	:	54.6
T_{13}	–	25	:	50	:	50

ORGANIC NUTRIENT MANAGEMENT IN CHETHIKKODUVELI (*Plumbago rosea* L.)

NIHAD, K.

Abstract of the
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Department of Plantation Crops and Spices
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM-695 522

ABSTRACT

A field experiment was conducted at Instructional Farm, College of Agriculture, Vellayani during 2004-05 to study the effect of organic manures and microbial inoculants on growth, yield and quality of chethikkoduveli (*Plumbago rosea* L.), so as to formulate an organic manurial schedule for chethikkoduveli in a coconut based cropping system.

The experiment was laid out in RBD with three replications and the treatments included three different combinations of organic manures (FYM, NC and VC), three microbial inoculants (AMF, *Azospirillum* and Phosphobacteria) and one control (package of practice recommendation of Kerala Agricultural University, 2002).

The treatment supplied with FYM (75 % N of POP) and microbial inoculants (T_3) recorded highest plant height, leaf area, CGR, specific leaf weight, LAI and HI. Highest HI was recorded by the treatments supplied with FYM and NC supplying 50% N of POP and microbial inoculants (T_7), which also had the highest leaf count, fresh weight of plants, total dry matter production and highest fresh and dry root yield per plant. The treatments supplied with organic manures and microbial inoculants recorded better dry root yield. The fresh root yield was the highest for the treatment T_7 followed by T_3. The highest root length and root girth were recorded by T_7 and T_3 plants respectively. T_3 (FYM supplying 75 % N + mi) plants recorded the highest alcohol soluble extracts and plumbagin content. The application of organic manures and mi at different combinations significantly increased the nutrient uptake of *P. rosea.* Analysis of the soil samples before and after the experiment revealed that the nutrient supplying capacity of soil and the microbial population had a direct correlation. Soil microbial population was the highest for plots with better yield. From the results it can be concluded that microbial inoculants can be effectively used as nutrient substitutes. In the above treatments 25 %

and 50 % of N is substituted by microbial inoculants in T_3 and T_7 plants respectively.

In conclusion, the study revealed that treatments T_7 {FYM + NC + mi (50 % N)} and T_3 {FYM + mi (75 % N)} had significant effect in enhancing growth, yield and quality of chethikkoduveli (*P. rosea*). From the point of view of quality (plumbagin content) FYM + mi (75 % N) is found to be the best treatment. Based on the benefit cost ratio, the treatment supplying only 50 % N of POP recommendation through FYM and neem cake along with microbial inoculants can be considered as the best for better root yield, quality and profit in *P. rosea* when grown as an intercrop in coconut plantations.