NUTRIENT MANAGEMENT IN TURMERIC (*Curcuma longa* L.) THROUGH ORGANIC MANURES

RAKHEE, C.K.

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Department of Plantation Crops and Spices
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

DECLARATION

I hereby declare that this thesis entitled "**Nutrient management in turmeric (*Curcuma longa* L.) through organic manures**" 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,
30-12-2002.

Rakhee

RAKHEE. C.K.
(2000 – 12 – 06)

CERTIFICATE

Certified that this thesis entitled "**Nutrient management in turmeric (*Curcuma longa* L.) through organic manures**" is a record of research work done independently by Ms.Rakhee. C.K. (2000 – 12 – 06) 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,
30-12-2002.

Dr. B.K.JAYACHANDRAN
(Chairman, Advisory Committee)
Associate Professor and Head,
Department of Plantation Crops & Spices
College of Agriculture, Vellayani
Thiruvananthapuram.

Approved by

Chairman :

Dr. B.K.JAYACHANDRAN
Associate Professor and Head,
Department of Plantation Crops & Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

2/4/03

Members :

Dr. G.R. SULEKHA
Associate professor
Department of Plantation Crops & Spices,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

2/4/03

Shri. S. M. SHAHUL HAMEED
Associate professor
Department of Agronomy,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

2/4/03

Dr. K. USHAKUMARI
Associate Professor,
Department of Soil Science &
Agricultural Chemistry,
College of Agriculture, Vellayani,
Thiruvananthapuram-695522.

2/4/03

External Examiner :

2/4/2003
(M. Vijayakumar)
Professor of Horticulture
Dept of Spices and Plantation crops
College of Horticulture
TNAU Coimbatore

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RAKHEE. C. K

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

@	at the rate of
%	per cent
^0C	degree Celsius
μ	Micro
BR	Bulking rate
CD	Critical difference
CGR	Crop growth rate
cm	centimetre
cv.	Cultivar
DAP	days after planting
day^{-1}	Per day
DMP	Dry matter production
et al.	and others
Fig.	Figure
FYM	Farm yard manure
g	gram
ha^{-1}	per hectare
HI	Harvest index
K	potassium
KAU	Kerala Agricultural University
kg	kilogram
LAD	Leaf area duration
LAI	Leaf area index
m	metre
m^{-2}	Per metre square
MAP	Month after planting
Mg	Mega gram
mm	Millimetre

LIST OF ABBREVIATIONS Contd.....

N	nitrogen
NAR	Net assimilation rate
P	phosphorus
POP	Package of practice
q	Quintal
RBD	Randomised block design
RGR	Relative growth rate
s	second
SE	Standard crror
t	tonnes

INTRODUCTION

1. INTRODUCTION

Awareness of health and environmental issues is spreading fast globally in recent years. Sustainability in production has become the prime concern in agriculture development. The organic method of farming is the best option to ensure that the air, water and soil around us remain unpolluted, leaving the environment safe for present and future generations.

India is one of the major spice producing and exporting countries of the world and Kerala is the leading spice producing state of India. Turmeric is one of the most important and ancient spices of India and a traditional item of export, which is used daily by all classes of people in the preparation of tasty curried dishes and as an ingredient of medicinal preparations. The healing property of turmeric is long acknowledged by practitioners of traditional medicine and scientists working in the US and Britain have discovered evidence to back up claims that turmeric acts as an anti-cancer agent (Anon., 1994). Increase in popularity of Indian curry powder and other spice blends which are the 'growth items' in world markets shows the future prospects of turmeric. Though many reports reveal that organic manuring for turmeric is essential, detailed studies on the role of organic manuring in the maintenance of soil fertility and on growth and productivity of turmeric are limiting (Rethinam *et al.*, 1994).

Organic agriculture is now growing as a movement with far reaching implications in rural society. Organic farming use nature as the best role model for agriculture and considers soil as a living system. It is environment friendly, ecologically balanced and socially just. In order to achieve the dual objective of environmental care and increasing productivity we have to adopt organic farming.

Addition of organic manures improves soil physical, chemical and biological properties and thereby enhances the productivity of soil. Organic manures besides forming stable aggregates in soil, promotes air circulation, root penetration and helps in retention of moisture in soil.

Compost is a good organic supplement to soil. Poultry manure is a good source of nutrients, particularly nitrogen. Neem cake is not only a good source of organic manure but also has insect repellent action and hence is useful for pest management. Coir pith which is abundantly available in Kerala as a by-product from coir industries, is found to be a good source of organic manure after narrowing down its C:N ratio with *Pleurotus sajor caju*. Green manuring is a low cost but effective technology in minimizing investment cost on fertilizers and in safeguarding the productive capacity of the soil without any impoverishment. The biodigested slurry has a great potential as organic manure and it can be applied to all crops. There is a wide scope to recycle and use homestead organic wastes by vermicomposting. Vermicompost which is produced by decomposition of bio-waste by earthworm activity contains higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. Conversion and utilization of native agriculture waste resources, which may otherwise cause environmental pollution is the prime need of the present day agriculture of the country.

The global demand of turmeric by 2000 AD is estimated as 31,000 tonnes and by 2005 it becomes 35,000 tonnes with a growth rate of two per cent (Peter, 1999). The statistics indicates the necessity of increasing production of turmeric for meeting export as well as the increasing internal demand. In Kerala, the possibility of area expansion under monocropping is very limited, but the shade tolerant nature of turmeric and availability of large area in coconut gardens provide opportunities for enhancing production of turmeric.

Keeping the above views under consideration, the investigation entitled "Nutrient management in turmeric (*Curcuma longa* L.) through organic manures" has been taken up with the objectives of evaluating the effect of organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden and to assess the relative efficiency of organic manures as substitute to inorganic fertilizers.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Turmeric is one of the most important and ancient spices of India and a traditional item of export which is cultivated along with other perennial plantation crops mostly as intercrop because of its shade tolerant or loving nature. The global demand of turmeric by 2000 AD is 31,000 tonnes and by 2005 it becomes 35,000 tonnes with a growth rate of two per cent (Peter, 1999). The production of turmeric has to be increased to meet the future needs.

In recent years there has been a welcome awareness for ecofriendly organic products because of increasing awareness for the safety of food consumed and environmental protection. Though many reports reveal that organic manuring for turmeric is essential, detailed studies on the role of organic manuring on the maintenance of soil fertility and on growth and productivity of turmeric are limiting (Rethinam *et al.*, 1994).

Organic manures can effectively act as slow release fertilizers and many of the organic amendments bring about pest suppression (Gaur *et al.*, 1984). Organic farming has the potential to provide benefits in terms of environmental protection, conservation of non-renewable resources, improved food quality, reduction in output of surplus products and reorientation of agriculture towards areas of market demands (Lampkin, 1990).

The relevant literature on the effect of different organic manures on growth, yield and quality of turmeric are reviewed in this chapter. Wherever information is lacking, pertinent literature on other crop has been included.

2.1 ORGANIC MANURE

Organic manures contain more or less all nutrient elements required for plant growth. When it is applied to soil, it helps to improve soil aeration, permeability, aggregation, water and nutrient holding capacity and biological properties of soil. The organic acids like hydroxy and tartaric acid, citric acid *etc.* trap the toxic elements like Fe and Al through chelation and remove them from root environment by forming insoluble precipitates. It also acts as a buffer and keeps the soil pH within the desired range (Banerjee, 1998).

2.1.1 Effect of Organic Manures on Growth, Yield and Quality of Crops

Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches than inorganically grown ones. They yielded 26.18 t ha^{-1} which was on par with recommended dose of FYM (25 t ha^{-1}) and NPK (120:100:100 kg ha^{-1}). The beneficial effect of organic amendments in increasing the growth parameters were reported by Pushpa (1996) in tomato and Anitha (1997) in chilli.

Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). The usefulness of organic manures in increasing crop yield is well documented (Muthuswamy *et al.*, 1990). The increased yield in rice could be attributed to the favourable effects of organic matter on the soil physical conditions and microbial activity, which in turn increased the availability of nutrients (Anilakumar *et al.*, 1993). Addition of organic matter enhanced the growth and biomass of the vines (Mustika *et al.*, 1994; Sivakumar and Wahid, 1994). Field experiments in the Cook Islands (Purea and Mataora, 1995) revealed that organic fertilizers compared with NPK generally increased yield in *Dioscorea* spp. Organic farming can improve black pepper productivity (Zulkify, 1996).

Curcumin content has been found to vary depending upon soil organic carbon, available nitrogen and manganese (Vijayakumar *et al.*, 1992). Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetable crops (Rani *et al.*, 1997).

2.2 FARM YARD MANURE

This is the traditional organic manure and is most readily available to the farmers. On an average well rotten farm yard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O (Gaur *et al.*, 1971).

2.2.1 Effect of FYM on Growth Characters

Application of FYM resulted in higher vegetative mass, dry weight, plant height and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980 and Valsikova and Ivanic, 1982). They also reported that application of chemical fertilizers in the absence of FYM retarded the formation of vegetative organs and subsequently the reproductive organs and has resulted in lower flower production. Sahota (1983) found that FYM application increased plant height and number of leaves per plant in potato. Arunkumar (1997) reported that in amaranthus FYM application was found to be superior to vermicompost in inducing better plant height, root biomass production, leaf area index and yield. Joseph (1998) observed that in snake gourd, growth characters *viz.*, weight of the root plant^{-1} and dry matter production ha^{-1} were highest in FYM treated plants as compared to poultry manure or vermicompost treated plants.

2.2.2 Effect of FYM on Yield and Yield Attributes

Basal application of FYM at 12.5 t ha^{-1} to cassava (Ashokan and Sreedharan, 1977) was beneficial in enhancing the yield and improving the quality of tubers. Higher efficiency of FYM in producing higher yield compared to castor oil cake and urea was revealed in a study conducted by Gomes *et al.* (1983). Experiments conducted in Karnataka to find out the response to FYM showed a 30.6 per cent yield increase over control by sweet potato and 11.8 per cent yield increase over control by cassava (Gaur *et al.*, 1984). Application of FYM alone resulted in higher yields in elephant foot yam (Patel and Mehta, 1987). In the long-term field experiment for seven years at Jalandhar, Sharma *et al.* (1988) revealed that FYM was more effective in increasing tuber yield of potato than green manuring with dhaincha. Higher yield of turmeric with the sole application of FYM reported by Balashanmugham *et al.* (1989). From studies at different places it was found that FYM to supply 100 kg P_2O_5 ha^{-1}, about 30 t ha^{-1}, not only met P and K needs of the crop but also kept the potato yield level at a higher level than the combined use of P and K fertilizers (Sud and Grewal, 1990). Minhas and Sood (1994) reported that FYM application significantly increased crop yield.

While studying the effect of different organic manures in arrowroot intercropped in coconut garden, Maheswarappa *et al.* (1997) found that application of FYM resulted in significantly higher harvest index, number and length of rhizomes and higher starch and crude protein contents. Joseph (1998) reported that in snake gourd yield attributing characters *viz.*, length, weight and number of fruits per plant were highest in FYM applied plants as compared to poultry manure or vermicompost applied plants. FYM had a profound influence on the number of rhizomes per plant and yield of arrowroot. FYM @ 20 t ha^{-1} recorded maximum number of rhizomes per plant and rhizome yield of arrow root (Vidhyadharan, 2000).

2.2.3 Effect of FYM on Quality Aspects

Kansal *et al.* (1981) reported that application of 20 t FYM ha^{-1} increased the ascorbic acid content in spinach leaves. Ravindran and Balanambisan (1987) observed that the quality of tuber in sweet potato was not much affected by different doses of FYM.

2.3 VERMICOMPOST

Application of one tonne of vermicompost could substitute 25 to 50 per cent recommended dose of fertilizers in sorghum (Sarawad *et al.*, 1996). Vermicompost is a potential source of readily available plant nutrients, growth enhancing substances and a number of beneficial microorganisms like nitrogen fixing, phosphorous solubilising and cellulose decomposing organisms.Vermicompost can substitute or complement chemical fertilizers. It contains various amino acids and minerals which humidified the organic matter and surrounding soil and act as a biofertilizers for plants (Shanbhag, 1999).

2.3.1 Effect of Vermicompost on Growth Characters

Evangelista (1986) found that application of pure earthworm cast showed significant effect on the weight of roots, nitrogen, phosphorus, calcium and magnesium contents of the lettuce leaves. Plants treated with 50 per cent earthworm cast and 50 per cent soil showed highly significant effect on the fresh weight of plant and dry weight of leaves. Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. Stolyurenko *et al.* (1992) reported that application of vermicompost stimulated the shoot and root growth of maize plantlets. Krishnakumar *et al.* (1994) reported that use of vermicompost in potting medium helped better growth and development of seedlings in cardamom nursery. Patil (1995) reported that number of leaves per plant of potato were significantly increased due to application of vermicompost @ 4 t ha^{-1}. Vermicompost is an ideal organic manure with rich mixture of major and minor plant nutrients in available form and with increased activity of beneficial microbes (Singh and Sudarshan, 1995). Pushpa (1996) observed that biometric observation *viz.*, height of the plant, number of leaves, number of flowers and number of fruits were greatly influenced by the application of vermicompost in tomato. According to Vadiraj *et al.* (1996) the effect of vermicompost in turmeric was pronounced. The varieties Armour and Suroma when treated with vermicompost had 30 per cent increase in plant height and 70 per cent increase in leaf area over the control.

2.3.2 Effect of Vermicompost on Yield and Yield Attributes

Desai (1993) observed that the yield of capsicum sp in vermicompost treated plot was comparable to that of chemical fertilizer application. Vermicompost application alone or in combination with inorganic fertilizers was found to increase the yield of turmeric (Vadiraj *et al.*, 1996). In rice increase in crop yield was reported due to application of vermicompost (Vasanthi and Kumaraswamy, 1996). Among organic manures tested by Maheswarappa *et al.* (1997) in arrowroot intercropped in coconut garden, vermicompost recorded higher rhizome yield and harvest index compared to composted coir pith. In an experiment conducted at College of Agriculture, Vellayani during 1998-1999 to find out the effect of different sources and levels of organic manures on yield and quality of amaranthus it was found that vermicompost @ 25 t ha^{-1} during all harvests except the third where it was second to FYM @ 93.75 t ha^{-1} recorded maximum yield. Higher levels of these two manures were always superior to POP recommendations of KAU (Arunkumar, 2000)

2.3.3 Effect of Vermicompost on Quality Aspects

Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokinins, auxins and group B Vitamins, which can be applied alone or in combination with organic or inorganic fertilizers so as to get better quality of diverse crops (Gavrilov, 1962; Tomati *et al.*, 1983; Bano *et al.*, 1987). Tomati *et al.* (1990) observed that incorporation of vermicompost increased protein synthesis by 24 per cent and 32 per cent in lettuce and radish, respectively as compared to control, thus improving the quality of these crops.

2.4 OIL CAKES

Oil cakes of non edible types like castor, neem and karanja are widely used as organic manures. Most of the non edible oil cakes are valued much due to their alkaloid content which inhibit the nitrification process in soil. Neem cake is a concentrated organic manure rich in plant nutrients. In addition to nutrients, it contains the alkaloids, nimbin and nimbidin and certain sulphur compounds which effectively inhibit the nitrification process (Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981). As a result, it acts like a slow releasing N fertilizer by inhibiting the nitrification process of soil and N is made available within a period of 2-3 months according to the crop demand.

2.4.1 Effect of Oil Cakes on Growth Characters

Increase in plant height of bhindi due to oil cake application was reported by Singh and Sitaramaiah (1963). Som *et al.* (1992) observed the influence of organic manures on growth and yield of brinjal. The different oil cakes tried were karanja, mahua, mustard and neem cake. The maximum plant height of 70.77 cm was recorded in the treatment receiving neem cake @ 50 q ha^{-1} followed by mustard cake at its higher dose. Arunkumar (2000) reported that when neemcake was used as an organic manure in amaranthus, an increase in number of leaves compared to POP recommendations of KAU was recorded at later growth stages. In chilli, growth characters like plant height, number of branches, DMP and LAI obtained by application of neem cake were found to be on par with POP (20 t FYM + 75:40:25 kg NPK ha^{-1}) as observed by Sharu (2000).

2.4.2 Effect of Oil Cakes on Yield and Yield Attributes

Application of neem cake @ 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990). According to Sadanandan and Hamza (1998) application of organic cakes increased nutrient availability as well as improved physical condition of the soil and also increased the yield and oleoresin production in ginger.

2.4.3 Effects of Oil Cakes on Quality Aspects

For turmeric, NPK @ 60:50:120 kg ha^{-1} is found to be on par with neem cake (2 t ha^{-1}) or groundnut cake (1 t ha^{-1}) with regard to yield but organic cake was found to be superior with regard to curcumin recovery (Sadanandan and Hamza, 1996). Sharu (2000) reported that mean weight of fruit and keeping quality were maximum when nutrients were supplied to chilli through neem cake alone.

2.5 GREEN MANURE

Green manure is considered as a good source of nitrogen. In addition to supplying N, green manure can increase the availability of P, K and secondary and trace elements in the soil. Green manure is a "plant material incorporated with the soil while green or soon after the maturity for improving the soil" (SSSA, 1971). Field experiments conducted at CTCRI revealed that FYM application to cassava can be substituted by green manuring *in situ* with cowpea (Prabhakar and Nair, 1987; Nayar and Mohankumar , 1989; Nayar *et al.*,1993; Nayar and Potty,1996).

2.5.1 Effect of Green Manures on Growth Characters

Squire (1981) found that a green manure crop of groundnut ploughed in before planting cassava increased cassava root and shoot weight. In a field experiment conducted at Tamil Nadu Agricultural University, Coimbatore, application of sunhemp (12.5 t ha^{-1}) to rice enhanced dry matter production and nutrient uptake, when applied in combination with super phosphate or mussorie rock phosphate (Srikantan, 1987). Nayar *et al.* (1993) emphasized that green manuring *in situ* with cowpea was instrumental in promoting greater dry matter accumulation in the storage roots and sustaining the productivity of cassava.

2.5.2 Effect of Green Manure on Yield Attributes

Sevenorio and Escalada (1983) obtained highest total tuber yield of 9.4 t ha^{-1} when sweet potatoes were planted 21 days after soil incorporation of green manure, *Vigna mungo* or soyabean. In an on-farm research trial at Oyo state Nigeria, Otu and Agboola (1991) 16 per cent yield increase was obtained in *Dioscorea rotundata* due to addition of three prunings of *Glyricidia sepium*.

2.5.3 Effect of Green Manure on Quality Aspects

Green manures were found to improve the quality of rice, compared to ammonium sulphate. Green manured rice contained more protein, phosphoric acid and potash (Murthy, 1978). Thampan (1993) reported that application of green manure crops improved the quality of foodgrains and fruits. Vitamin and protein contents of rice have been found to be increased by green manuring of rice crops.

2.6 POULTRY MANURE

In poultry manure 60 per cent of nitrogen is present as uric acid, which readily changes to ammoniacal form of nitrogen which becomes available to plant immediately and thereby increases growth and yield of the plant (Smith, 1950). Singh *et al.* (1973) attributed the higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen.

2.6.1 Effect of Poultry Manure on Growth Characters

Singh *et al.* (1973) reported that, in potato, application of poultry manure exhibited better response than FYM on growth attributes like height of the plant, number of shoots and number of leaves per plant. Anitha (1997) reported that, in chilli various growth attributes like plant height, number of branches and DMP were better with poultry manure application as compared to FYM or vermicompost. In chilli, LAI and DMP was highest for poultry manure treated plots (Sharu, 2000).

2.6.2 Effect of Poultry Manure on Yield and Yield Attributes

According to Abusaleha (1981) early flowering and highest yield of 18.02 t ha^{-1} were obtained in bhindi with the application of half nitrogen through ammonium sulphate and half through poultry manure. Dahama (1996) pointed out that substitution of inorganic nitrogen with poultry manure upto 120 kg ha^{-1} increased the potato yield to 108 q ha^{-1} compared to control. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost application (Anitha, 1997). In brinjal maximum production of flowers was recorded by plants which received poultry manure as treatment and thus leading to maximum fruit set. The marketable fruit yield was also highest for the above treatment (Rekha, 1999).

2.6.3 Effect of Poultry Manure on Quality Aspects

The protein content of potato gradually increased with higher levels of poultry manure (Singh *et al.*, 1970). Anitha (1997) reported that plants treated with poultry manure recorded the maximum ascorbic acid content of fruits as compared to vermicompost treated plants and control treatments in chilli. Joseph (1998) observed that in snakegourd, poultry manure treated plants recorded the highest crude protein content and lowest crude fibre content as compared to that of FYM and vermicompost treated plants. Poultry manure application registered maximum keeping quality of chilli fruits (Sharu, 2000).

2.7 BIOGAS SLURRY

Biogas slurry is in a better physical condition and more easily incorporated in the soil than conventional compost. On an average biogas slurry contained 8.2 per cent dry matter, 71.8 per cent organic matter, 37.5 per cent carbon, 2.12 per cent N, 0.41 per cent P and 1.0 per cent K. The C: N ratio was 17.6 (Swamy, 1991).

2.7.1 Effect of Biogas Slurry on Growth Characters

Biogas slurry is a valuable manure, even superior to FYM. In a green house experiment conducted at Banaras Hindu University, Varanasi, with rice as the test crop, it has been shown that the effect of dipping the roots of rice seedlings in biogas slurry containing 22.5 ppm of nitrogen was comparable to soil application of 45 ppm nitrogen (Srivastava, 1985).

2.7.2 Effect of Biogas Slurry on Yield and Yield Attributes

The effectiveness of biogas slurry in combination with chemical fertilizer was studied. Application of slurry to replace half nitrogen gave better yields in vegetable crops (Dahia and Vasudevan, 1986). When compared to FYM application, the yields of wheat, finger millet and sunhemp were found to increase with the addition of dry slurry. The studies at Diary Research Institute, Karnal revealed that the yields of fodder oats were increased due to biogas slurry addition (Swamy, 1991). The author reported increased yield in potato by biogas slurry application. Seed treatment of tomato variety Pusa Ruby was done using biogas slurry. It was observed that the 4 hour treatment recorded higher yield of 44 t ha^{-1} which was around 56 per cent higher over control (Shakila, 1992). The application of recommended dose of biodigested slurry as manure in rice @ 10 tonnes per ha in irrigated areas and @ 5 tonnes per ha in dry land areas, increases the yield by 10-20 per cent (Pugalendhi *et al.*, 2000).

2.8 COIR PITH COMPOST

Coir pith is a light fluffy refuse obtained during the separation of coir fibre from coconut husk. Normally about 10,000 husks yield one tonne of coir fibre and another one tonne of coir pith as a waste material (Nagarajan *et al.*, 1985). He also observed that coir pith is having about 533 per cent of maximum water holding capacity. As coir pith is found to contain appreciable amount of K, studies revealed that 50 per cent of K fertilizer could be saved by its application to irrigated maize and finger millet in Tamil Nadu (Savithri *et al.*, 1993). Coir pith is rich in potash and would be available for plants over the years (Singh, 2001).

2.8.1 Effect of Coir Pith Compost on Growth Characters

An increased plant height and dry matter production has been reported in rice following the application of partially decomposed coir pith in rice field with sandy clay loam soil (Thilagavathi and Mathan, 1995). Suharban *et al.* (1997) in a pot culture experiment with bhindi reported that plant height was significantly influenced by coir pith compost treatment. A maximum plant height of 1.37 m obtained in coir pith compost treated plants and lowest (0.97 m) in plants grown under POP recommendation.

2.8.2 Effect of Coir Pith Compost on Yield and Yield Attributes

Coir pith compost has beneficial effect as organic manure in increasing the yield of crops like turmeric (Selvakumari *et al.*, 1991). Usefulness of coir pith in increasing the yield of many crops like groundnut, sorghum, pearl millet, finger millet, maize and cotton under rainfed condition to the extent of 10-30 per cent over control has been reported (Savithri and Khan, 1994). They have also reviewed the beneficial effects of coir pith application in tannery effluent areas and sodic soils. Lourdraj *et al.* (1996) reported an increased yield, net returns and high benefit cost ratio in groundnut when the crop was raised in soil incorporated with composted coir pith. Yield of Sesamum could be increased by 63 per cent with the application of coir pith compost over farmer's practice (Venkatakrishnan and Ravichandran, 1996).

2.8.3 Effect of Coir Pith Compost on Quality Aspects

In arrowroot, Maheswarappa *et al.* (1997) found that application of coir pith compost produced lower values of chlorophyll content and quality parameters like starch and crude protein contents compared to application of FYM and vermicompost. In yams tuber quality in terms of starch and crude protein were markedly improved by coir pith compost application (Suja, 2001).

2.9 INTEGRATED NUTRIENT MANAGEMENT

Integrated nutrient management practices involving judicious combinations of organic manures, fertilizers and biofertilizers can be feasible and viable to sustain agriculture as a commercial and profitable proposition ensuring high yields of crops without deteriorating the quality of the produce. Combination of organic manure with inorganic fertilizers had a moderating effect on soil reaction particularly under acidic soil and improvement in sustained availability of N, P, K and S and the micronutrients particularly Zn (Nambiar and Abrol, 1989). Further, integrated nutrient management practices will restore, enhance and sustain the productivity of the farm soils even under intensive commercial farming (Badanur and Bellakki, 1997).

Kannan and Nair (1965) reported that ginger is an exhaustive crop and requires heavy manuring with 25 to 30 t FYM as basal dose and fertilizer mixture of N, P and K (8:8:16) at the rate of 450 kg ha^{-1} for increased production. In an experiment with inorganic fertilizers and organic manures like FYM, the mixture of fertilizers and manure gave better results than organic manure given alone (Chinnaswamy, 1967). According to Malik (1999) from the long term fertilizer experiments conducted at different locations in the country, it has now been very well established that the rice plots receiving organic manure (FYM) along with NPK sustained the soil fertility and productivity.

In ginger, Mohanthy and Sharma (1979) in an agronomic trial reported that the treatment receiving 25 t FYM, 75:50:50 kg NPK ha^{-1} had produced significantly more number of tillers m^{-2} (2.15), more number of leaves per tiller (23.30), highest plant height (58.20 cm), leaf size (23 x 1.6 cm) and highest rhizome yield (234.7 q ha^{-1}) compared to control which produced an yield of 82.7 q ha^{-1}

In Kerala (Wyanad), where turmeric is grown under rainfed conditions, application of 100 kg N ha^{-1} along with a basal dose of 15 t ha^{-1} of FYM and 50 t of green leaves as mulch applied at planting and 60 DAP was sufficient for maximum yield (Muralidharan and Balakrishnan, 1972). Increase in yield due to combined application of FYM and inorganic fertilizers has been reported in turmeric (Rao *et al.*, 1975). A combination of 12.5 t ha^{-1} FYM and 50 per cent recommended dose of fertilizer was found to be beneficial for improving the yield (Subbiah *et al.*, 1983a). Balanced use of NPK fertilizer in conjunction with FYM produced the highest yield and maintained the available NPK status in the soil at a high level (Muthuswamy *et al.,* 1990). Nutrient requirement studies on Amorphophallus conducted by Kabeerathumma and George (1992) revealed that maximum corm yield, highest DMP as well as highest nutrient uptake were recorded for the treatment NPK @ 100:50:150 kg ha^{-1} + FYM @ 25 t ha^{-1} than lower levels of N, P, and K with and without FYM. Maheswarappa *et al.* (1997) opined that combined application of FYM @ 20 t ha^{-1} and 75:50:50 kg NPK ha^{-1} recorded significantly higher rhizome yield of arrowroot (17.1 t ha^{-1}) intercropped in coconut garden. The combined use of NPK and FYM could produce an yield increase of four times higher in cassava than FYM or any of the nutrients (N, P, or K) applied individually (Mohankumar *et al.*, 2000).

2.10 GROWTH PERFORMANCE OF CROPS UNDER PARTIALLY SHADED CONDITION

Sundararaj and Tulasidas (1976) reported that eventhough turmeric is cultivated mainly as pure crop under open conditions it also comes up well in partially shaded coconut or arecanut garden as intercrop.

Ginger plants grown under full sunlight were found to be shorter compared to shaded plants (Aclan and Quisumbing, 1976). Bai and Nair (1982) observed positive influence of shading on plant height in ginger, turmeric, coleus and sweet potato. Thangaraj *et al.* (1983) recorded significant differences in plant height among the ginger varieties grown in partially shaded arecanut garden. Varughese (1989) observed a decrease in the number of tillers with an increase in shade at all growth stages in ginger. Plant height was found to increase in ginger when the shade intensity was increased from open to 75 per cent. (Varughese, 1989; Jayachandran *et al.*, 1991; Ancy, 1992). Decrease in the number of tillers with increasing levels of shade in turmeric was observed by Jayachandran *et al.* (1992). They also noticed significant difference in turmeric growth and yield when it was grown under open and 25 per cent shaded conditions.

Monteith (1969) reported that the maximum amount of dry matter production by a crop was strongly correlated with the amount of light interrupted by its foliage. Ramadasan and Satheesan (1980) reported highest crop growth rate with three turmeric cultivars grown in open condition compared to shaded condition. Sensviratne *et al.* (1985) studied the influence of shade on rooting and growth of black pepper propagules at Peradeniya and Srilanka and concluded that the longest roots and maximum leaf area can be obtained at 50 and 35 per cent shade. Ravisankar and Muthuswamy (1988) observed that fresh rhizome yield increased when ginger was grown as an intercrop in partially shaded arecanut plantation.

Many workers have reported the higher yields of turmeric and ginger when grown as intercrops compared to open space (Ramanathan *et al.*, 1982; Satheesan, 1984; Satheesan and Ramadasan, 1988; Jayachandran *et al.*, 1991; Latha *et al.*, 1995).

Ravisankar and Muthuswamy (1988) reported that NAR was higher in ginger grown in low light intensities. In turmeric, the highest yield was recorded under 25 per cent shade (Varughese, 1989). Yield of turmeric at 25 per cent shade was on par with open condition and therefore turmeric can be considered as a shade tolerant crop (Jayachandran *et al.*, 1992).

According to Ravisankar and Muthuswamy (1987) ginger CV. Rio-de-Janeiro grown as an intercrop in a six year old arecanut plantation recorded highest volatile oil and non-volatile ether extract contents followed by those grown in two year old arecanut plantation compared to those grown in the open. Curcumin content in turmeric rhizome showed a progressive decrease with increase in shade (Varughese, 1989). He also reported an increase in N and K uptake from 0 to 25 per cent shade in ginger and the highest K uptake at 50 per cent shade in turmeric. Babu (1993) recorded the lowest content of volatile oil from 25 per cent shade which was on par with open. However, with further increase in shade, the volatile oil was found to increase. Joseph and Jayachandran (1993) recorded highest rhizome volatile oil content (2.19 % on dry weight basis) in ginger under 25 per cent shade, higher non-volatile ether extract (NVEE) content under 25 or 50 per cent shade than under open or 100 per cent shade.

2.11 EFFECT OF ORGANIC N SOURCES ON SOIL PROPERTIES

The increase in total and available N in the soils as a result of the addition of organic manures indicated that the N present in the manures may be readily available to the crops as reported by Pandalai *et al.* (1958). Olsen *et al.* (1970) reported that addition of manures increased the soil pH. 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. Aravind (1987) observed a continuous improvement in hydraulic conductivity of black soils due to continuous addition of organics in combination with inorganics. Organic residue incorporation to the soil improves the overall physical, chemical and biological properties of the soil and the regular return of crop residue to the soil contribute to the soil nutrient pool in a gradual manner, besides offering other indirect benefits (Srivastava, 1988).

Decrease in bulk density, increase in porosity and better water conducting properties of the soil is mainly due to the action of gum compounds, poly sacharides and fulvic acid compounds of organic matter on the soil structure (Manickam, 1993). More (1994) reported that addition of farm waste and organic manures increased the status of available nitrogen and available phosphorus of the soil. Incorporation of organic residues have long been known to improve soil-water retention by increasing organic matter (OM) content of soils (Sharma and Datta 1994). Soils with near neutral pH, high organic matter and high base saturation with Ca and Mg enhanced the productivity in black pepper (Mathew *et al.*, 1995). When organic manures are applied to coarse textured soils, there is a decrease in the bulk density due to better aggregation properties (Biddappa *et al.*, 1996). Marinissen and Hillenaar (1997) indicated the formation of most stable aggregates in high organic input fields compared to low organic input fields. Soils of dryland regions, which occupy about 40 per cent of the land area, remain perpetually deficient in organic matter (Katyal and Vlek, 2000).

Gattani *et al.* (1976) reported that the continuous use of FYM had increased the organic carbon level of the soil to a greater extent. Prasad and Singh (1980) observed that continuous application of FYM in combination with chemical fertilizers was found to be beneficial in increasing the water holding capacity of soil. Farm yard manure is beneficial in increasing the water stable aggregates in the soil (Kanwar and Prihar, 1982). Use of FYM prevented the occurrence of zinc (Katyal and Randhawa, 1983) and sulphur deficiencies (Nambiar and Abrol, 1989). Higher efficiency of FYM in producing higher yield and improving chemical properties of soil compared to castor oil cake and urea was revealed in a study conducted by Gomes *et al.* (1993).

FYM has favourable effect on soil aggregation compared to chemical fertilizers (Rabindra *et al.*, 1985). Srivastava (1985) observed that increased use of nitrogenous fertilizer decreased organic C content and total N, while FYM increased the above parameters. Carbon content of soil increased from 0.91 to 1.58 per cent by the continuous application of organic manures, and among the organic manures, FYM had a significant influence (Udayasoorian *et al.*, 1988). Application of FYM, increased the activity of phosphatase enzymes which enhanced P availability (Bopaiah and Shetty, 1991). FYM application improved the soil structure and also supplied the essential plant nutrients (Prasad and Venkateswarlu, 1991). In an intercropping experiment with arrowroot in coconut garden, Maheswarappa *et al.* (1999) found that FYM and vermicompost decreased bulk density and improved soil porosity and water holding capacity to a greater extent. Moreover organic carbon, soil pH, microbial population and dehydrogenase activity were also higher under these organic treatments. On the other hand, composted coir pith influenced these parameters to a lesser extent than FYM and vermicompost but to a greater extent than control. However, water holding capacity was highest in plots that received composted coir pith.

Vermicompost enhances the soil structure, improves the water holding capacity and porosity and facilitates the root penetration and growth (Lee, 1985). In rice increase in soil nutrient status (Vasanthi and Kumaraswamy, 1996) was reported due to application of vermicompost.

Greenmanure increases the microbiological, physical and chemical properties of the soil (Singh and Singh, 1961) and is a cheaper and a sure source of improving mechanical, physical, chemical and biological properties of the soil

(Rao *et al.*, 1971). Prabhakar and Nair (1987) noted that incorporation of green manure cowpea in cassava field could improve the nitrogen status of the soil from the initial level of 0.075 per cent to 0.083 per cent. The effect of glyricidia prunings on soil properties and performance of white yam was investigated by Otu and Agboola (1991) at Nigeria. The nutrient contribution after decomposition of prunings upgraded the soil nutrient status. There was 14 per cent decrease in soil bulk density and 16 per cent decrease in soil moisture content under prunings. Enhancement in the organic carbon, available N, P and K contents of soil due to green manuring *in situ* was also noticed by Nayar *et al.* (1993). Green manuring can aid in recycling of nutrients from the deeper profiles into the root zone of cardamom (Hegde *et al.*, 1995). Nayar and Potty (1996) concluded that P application to the green manure cowpea cassava sequence can be reduced to 50 kg P_2O_5 as indigenous rock phosphate and N dosage by 50 per cent and observed higher uptake of N and K in cassava under green manuring.

Total N and available N status of soils increased with biogas slurry application. In an experiment conducted at China, it was revealed that the slurry application cause an increase of organic matter content, total N, P and soil physical conditions. The available N and P contents of soil increased by 6 per cent and 20 per cent respectively due to application of 40 t ha^{-1} of biogas slurry (Swamy, 1991).

Increase in water holding capacity of the soil due to coir pith application has been reported by Bhowmic and Debnath (1985). The use of coir pith as a soil conditioner in tropical farming is well established (Nagarajan *et al.*, 1990). Application of coconut husk and coir dust to the palms increased soil available water, porosity and decreased bulk density of both lateritic and sandy soil (Liyanage *et al.*, 1993).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

An experiment was laid out at the college of Agriculture, Vellayani, Thiruvananthapuram, Kerala with an objective of studying the effect of organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden. The study also aims to assess the relative efficiency of organic manures as substitute to inorganic fertilizers.

3.1 EXPERIMENTAL SITE

The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani situated at 8^0 30' N latitude and 76^0 54' E longitude and at an altitude of 29 m above MSL

3.1.1 Soil

The soil of the experimental site was red loam belonging to Vellayani series which comes under the order oxisol. The initial data on physical and chemical properties of the soil and the methods adopted for the analysis are presented below:

Table 1. Soil characteristics of the experimental site

A. Physical properties

Parameters	Mean value	Method
Bulk density, Mg m^{-3}	1.60	Core method (Gupta and Dakshinamoorthy, 1980)
Water holding Capacity, %	23.77	
Soil aggregation, %	42.99	Wet sieving (Gupta and Dakshinamoorthy, 1980)

B. Chemical properties

Parameters	Mean value	Method
Organic carbon (%)	0.52	Walkley and Black's rapid titration method (Jackson, 1973)
pH	5.25	pH meter with electrodes (Jackson, 1973)
Available N (kg ha^{-1})	109.21	Alkaline permanganate Method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	29.13	Bray extraction and Klett Summerson Photo electric colorimeter (Jackson, 1973)
Available K_2O (kg ha^{-1})	161.94	Neutral normal ammonium acetate method (Jackson, 1973)

3.1.2 Season

The field experiment was conducted from June 2001 to February 2002. The crop was planted on 5th June and harvested on February 7th.

3.2 MATERIALS

3.2.1 Planting Material

Turmeric cultivar kanthi was used for the experiment. Healthy disease and pest free rhizome bits weighing 20 g was used as planting material.

3.2.2 Manuring

Seven organic manures were used in the experiment. *viz.*, FYM, vermicompost, neem cake, glyricidia leaves, poultry manure, biogas slurry and coir pith compost. The organic manures were applied as per treatment on nitrogen equivalent basis. The nutrient content of seven organic manures used is given below :

Table 2. Nutrient content of organic manures

Manure	Nutrient content (%)		
	N	P_2O_5	K_2O
FYM	0.70	0.77	0.24
Vermicompost	0.50	0.40	0.60
Neem cake	1.40	0.15	1.98
Glyricidia leaves	3.64	0.40	1.50
Poultry manure	1.61	1.14	2.50
Biogas slurry	1.50	1.66	0.11
Coir pith compost	1.20	0.05	1.00

3.2.3 Mulching

The crop was mulched immediately after planting with green leaves at the rate of 15 t ha^{-1} and it was repeated for a second time after 50 days with the same quantity of green leaves (KAU, 1996).

3.3 METHODS

3.3.1 Layout of the Experiment

The experiment was laid out in RBD. The number of replications was three (Fig. 1).

Replication- I

1 T_1	2 T_{10}	3 T_8	4 T_9	5 T_3	6 T_6	7 T_5	8 T_7	9 T_2	10 T_{11}	11 T_4
12 T_1	13 T_{10}	14 T_8	15 T_9	16 T_3	17 T_6	18 T_5	19 T_7	20 T_2	21 T_{11}	22 T_4

Replication - II

23 T_{10}	24 T_3	25 T_{11}	26 T_2	27 T_6	28 T_1	29 T_9	30 T_8	31 T_4	32 T_5	33 T_7
34 T_{10}	35 T_3	36 T_{11}	37 T_2	38 T_6	39 T_1	40 T_9	41 T_8	42 T_4	43 T_5	44 T_7

Replication- III

45 T_7	46 T_{11}	47 T_2	48 T_8	49 T_1	50 T_4	51 T_5	52 T_6	53 T_3	54 T_9	55 T_{10}
56 T_7	57 T_{11}	58 T_2	59 T_8	60 T_1	61 T_4	62 T_5	63 T_6	64 T_3	65 T_9	66 T_{10}

T_1-FYM

T_2-Vermicompost

T_3-Neemcake

T_4-Green leaves

T_5-Poultry manure

T_6-Biogas slurry

T_7-Coir pith compost

T_8-POP (30:30:60 kg NPK ha^{-1} + 40 t ha^{-1} FYM)

T_9-NPK alone as per POP

T_{10}-Control (40 tha^{-1} FYM)

T_{11}-Absolute control

Fig. 1. Lay out plan- RBD

3.3.2 Outline of the Technical Programme

Material : Turmeric cv. Kanthi

Design : RBD

Replication : 3

Plot size . : 2 beds of size 3m x 1m

The field experiment was laid out in partially shaded coconut garden above the age of 30 years. The light intensity was recorded periodically.The mean value recorded was 1315 μ E m^{-2} s^{-1}.

Different organic manures as per treatments were applied.

Treatments :

Organic manures (on N equivalent basis)

1. FYM
2. Vermicompost
3. Neem cake
4. Green leaves (Glyricidia leaves)
5. Poultry manure
6. Biogas slurry
7. Coir pith compost
8. POP (30:30:60 kg NPK/ha + 40 t/ha FYM)
9. NPK alone as per POP
10. Control (40 t/ha FYM alone)
11. Absolute control

FYM @ 40 t ha^{-1} (KAU, 1996) was applied to all treatments, except treatments 9 and 11. Additional quantity of P and K requirements as per organic manure treatments were supplied as rock phosphate and ash. The NPK content of the organic manures were analyzed before the experiment (Table 2).

3.3.3 Planting

Rhizome bits were planted at a depth of 5 cm with buds facing upwards at a spacing of 25 cm x 25 cm and covered with soil.

3.3.4 Aftercare

Hand weeding was done as and when necessary

3.3.5 Plant Protection

No disease was observed but there was the incidence of shoot borer *(Conogethes punctiferalis)* in the early stages which was effectively controlled by spraying neem oil.

3.3.6 Harvest

Destructive sampling was done at bimonthly intervals starting from 2 MAP of crop for taking different observations. During final harvest top yield as well as rhizome yield was recorded.

3.4 OBSERVATIONS

Random sampling method was adopted. For recording the different biometric observations at biomonthly intervals, five plants were selected at random from each treatment as observational plants, preharvest observations started 2 MAP and continued up to 8 MAP.

3.4.1 Morphological Parameters

3.4.1.1 Growth Characters

3.4.1.1.1 Plant height

The height of the plants was measured at bimonthly intervals from 2MAP from the base of the main pseudostem to the tip of the top most leaf and plant height was expressed in cm.

3.4.1.1.2 Number of tillers

Number of tillers were determined by counting the number of aerial shoots arising around a single plant at bimonthly intervals from 2 MAP.

3.4.1.1.3 Number of leaves

Number of leaves were determined by counting the number of leaves of all the tillers at bimonthly intervals from 2 MAP.

3.4.1.2 Rhizome Characters

3.4.1.2.1 Rhizome spread

The horizontal spread of rhizome was measured at bimonthly intervals from 2 MAP and expressed in cm.

3.4.1.2.2 Rhizome thickness

Rhizome thickness was measured at bimonthly intervals from 2MAP using micrometer and expressed in cm.

3.4.1.3 Root Characters

3.4.1.3.1 Root length

The plants were uprooted at bimonthly intervals from 2 MAP and maximum length of roots was measured and mean length expressed in cm.

3.4.1.3.2 Root spread

Root spread was measured at bimonthly intervals from 2 MAP by spreading the root system on a marked paper and measuring the spread of the root system at its broadest part. The root spread was expressed in cm.

3.4.1.3.3 Root weight plant^{-1}

Roots separated from individual plants at bimonthly intervals from 2 MAP were taken and dried in hot air oven at 70-80^{0}C and its weight was then taken and expressed in g plant^{-1}.

3.4.1.3.4 Root volume plant^{-1}

Root volume per plant was found at bimonthly intervals from 2 MAP by displacement method and expressed in cm^3 plant^{-1}.

3.4.1.4 Physiological Parameters

3.4.1.4.1 Dry matter production (DMP)

Leaves, petioles, pseudostem, rhizomes and roots of the uprooted plants were separated and dried to a constant weight at 105^{0}C in a hot air oven at bimonthly intervals from 2 MAP. The sum of these individual components gave the total dry matter yield of the plant and expressed as g $plant^{-1}$.

3.4.1.4.2 Crop growth rate (CGR)

CGR was worked out using the formula of Watson (1958) at bimonthly intervals from 2 MAP and expressed as g m^{-2} day^{-1}.

CGR = NAR x LAI

NAR = Net assimilation rate

LAI = Leaf area index.

3.4.1.4.3 Relative growth rate (RGR)

RGR was calculated as per the method described by Blackman (1919) at bimonthly intervals from 2 MAP and is expressed as g day^{-1}.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Where W_1 and W_2 are total dry weights per plant at time t_1 and t_2 respectively.

3.4.1.4.4 Net assimilation rate (NAR)

The procedure given by Watson (1958) as modified by Buttery (1970) was followed in calculating the NAR at bimonthly intervals from 2 MAP. The following formula was used to derive NAR and expressed in g m^{-2} day^{-1}.

$$NAR = \frac{W2 - W_1}{(t_2 - t_1)\,(A_1 + A_2)/2}$$

Where,

W_2 = total dryweight of the plant g m^{-2} at time t_2

W_1 = total dryweight of the plant g m^{-2} at time t_1

t_2-t_1 = time interval in days

A_2 = Leaf area index at time t_2

A_1 = Leaf area index at time t_1

3.4.1.4.5 Leaf area index (LAI)

Leaf area index was calculated at bimonthly intervals from 2MAP. Five sample plants were randomly selected for each treatment and the number of leaves on each plant counted. The length and width of leaves were measured at bimonthly intervals from 2 MAP and the leaf area in cm^2 was calculated based on the length and breadth method.

The following relationship was utilized for computing the leaf area (Randhawa *et al.*, 1985).

Y= 4.09 + 0.564 (Length x Breadth)

Where,

Y	=	leaf area
Length	=	Length of the leaf in cm
Breadth	=	Breadth of the leaf in cm

$$LAI = \frac{\text{Sum of leaf area of N sample plants } (cm^2)}{\text{Area of land covered by N plants } (cm^2)}$$

3.4.1.4.6 Leaf area duration (LAD)

LAD was calculated using the formula given by Power *et al.* (1967) at bimonthly intervals from 60 DAP.

$$LAD = \frac{Li + (Li + 1) \times (t_2 - t_1)}{2}$$

Where,

Li = LAI at first stage

Li+1 = LAI at second stage

t_2-t_1 = Time interval between these stages

3.4.1.4.7 Harvest index (HI)

HI was calculated at final harvest as

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

where,

Y econ = total dry weight of rhizome

Y biol = total dry weight of the plant.

3.4.1.4.8 Root : shoot ratio

Root : shoot ratio was calculated as the ratio between the average of root dry weight and shoot dry weight of each plant at bimonthly intervals from 2 MAP.

3.4.2 Yield and Yield Components

3.4.2.1 Rhizome Yield

The yield of fresh rhizome from each treatment was recorded at 240 DAP and expressed as g $plant^{-1}$.

3.4.2.2 Top Yield

The yield of above ground portion in individual treatment was recorded at 8 MAP and expressed in g $plant^{-1}$ on dry weight basis.

3.4.2.3 Dry Turmeric

Immediately after each harvest, at bimonthly intervals from 60 DAP rhizome samples were taken. The rhizomes were washed and kept to dry under sun for one week. After this it was kept in hot air oven at 70^0 c. The dry weight of turmeric was expressed in g $plant^{-1}$.

3.4.2.4 Bulking Rate (BR)

Bulking rate was worked out at bimonthly intervals from 60 DAP on the basis of increase in dry weight of rhizome and expressed in g $plant^{-1}$ day^{-1}.

$$BR = \frac{W_2 - W_1}{t_2 - t_1}$$

where,

W_1 = dry weight of rhizome at time t_1

W_2 = dry weight of rhizome at time t_2.

3.5 QUALITY ANALYSIS

3.5.1 Volatile Oil

The content of volatile oil was estimated by Clevenger distillation method (A.O.A.C., 1975) and expressed as % (V/W) on dry weight basis.

3.5.2 Curcumin Content

Curcumin content of rhizomes was estimated by the official analytical method suggested by ASTA (1968) using ethanol and expressed as percentage on moisture free basis.

$$\text{Percentage of curcumin} = \frac{Y \times 0.25 \times 25 \times 100 \times 100}{0.42 \times 1000 \times 0.1 \times 1}$$

Where,

Y = optical density

3.6 SOIL ANALYSIS

3.6.1 Physical Properties

3.6.1.1 Bulk Density and Water Holding Capacity

Core samples were collected from 0 - 15 cm depth and analysed for bulk density and water holding capacity as described by Gupta and Dakshinamoorthy (1980).

3.6.1.2 Soil Aggregation

Aggregate analysis was carried out by wet sieving method (Gupta and Dakshinamoorthy, 1980).

3.6.2 Chemical Properties

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples after passing through a 2 mm sieve were analysed for available N, available P_2O_5 and available K_2O content as per the standard analytical methods described below.

3.6.2.1 Organic Carbon

Organic carbon content of soil was estimated by Walkley and Black's rapid titration method (Jackson, 1973).

3.6.2.2 Soil pH

Soil pH was estimated using 1: 2.5 soil water suspension using pH meter with glass electrode (Jackson, 1973).

3.6.2.3 NPK Content

Available nitrogen content was estimated by potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus and potassium were extracted by Bray's method and ammonium acetate method and estimated by colorimetry and flame photometry respectively (Jackson, 1973).

3.7 CHEMICAL ANALYSIS OF ORGANIC MANURES

NPK content of organic manures were analysed before the experiment. N in the organic manure determined using modified micro kjeldahl method (Jackson, 1973) P content estimated colorimetrically (Jackson, 1973) and K content by flame photometric method (Piper, 1966).

3.8 WEED BIOMASS

Weeds coming inside the quadrate were pulled out carefully with roots intact, washed, dried under shade and then oven dried to a constant weight. The dry weight was recorded in g m^{-2}. Weed dry weight was recorded at 2 months intervals starting from 2 MAP.

3.9 BENEFIT : COST RATIO

The economics of cultivation of turmeric was worked out and benefit: cost ratio was calculated as follows:

$$\text{Benefit: cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.10 STATISTICAL ANALYSIS

Data relating to each character were analysed by applying the analysis of variance technique as applied to randomised block design described by Cochran and Cox (1965) and the significance was tested by F test (Snedecor and Cochran, 1967). In case where the effects were found to be significant, CD values were calculated.

RESULTS

4. RESULTS

An investigation was conducted at the College of Agriculture, Vellayani to assess the effect of different sources of organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden during the period from June 2001 to February 2002. The data collected were statistically analysed and the results of the experiment are presented in this chapter.

4.1 MORPHOLOGICAL CHARACTERS

4.1.1 Growth Characters

4.1.1.1 *Plant Height*

The data presented in Table 3 shows the effect of various treatments on plant height. The effect of treatments on plant height was significant at all stages of growth except at 4 MAP.

At 2 MAP the plants grown under treatment T_1 (FYM) attained maximum height of 32.13 cm and was on par with T_2, T_3, T_4, T_5, T_7, T_8, T_9 and T_{10}. Only treatment T_{11} was inferior to package of practices recommendations of Kerala Agricultural University (T_8) and recorded a lowest height of 25.33 cm.

At 6 MAP T_7 (coir pith compost) recorded the maximum height of 48.6 cm and was on par with T_1, T_2, T_5, T_8 and T_{10}. The treatments T_9 and T_{11} were inferior to the treatment which received the manurial schedule as per the POP recommendation of KAU. Treatment T_{11}(absolute control) recorded the lowest height of 40 cm.

At 8 MAP also T_7 recorded maximum height of 54.33 cm and was on par with T_1, T_2, T_5, T_8, T_9 and T_{10}. Only T_{11} was inferior to POP recommendations of KAU (T_8) and recorded a lowest height of 45.33 cm.

Table 3. Effect of organic manures on height of turmeric, cm

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	32.13	43.27	46.73	52.00
T_2	30.93	42.60	46.60	52.07
T_3	30.87	41.40	43.60	49.27
T_4	30.73	42.00	44.93	50.07
T_5	30.13	41.87	46.53	51.43
T_6	27.93	41.80	44.67	49.87
T_7	31.33	42.70	48.60	54.33
T_8	31.00	42.00	46.40	51.67
T_9	30.37	37.60	40.33	52.27
T_{10}	30.00	40.73	47.20	52.73
T_{11}	25.33	37.53	40.00	45.33
$F_{10, 20}$	2.78*	1.41	5.45**	3.04*
SE	1.13	1.63	1.19	1.35
CD	3.34	-	3.46	3.99

* Significant at 5 per cent level ** Significant at 1 per cent level

4.1.1.2 Number of Tillers

The mean number of tillers presented in Table 4 show the effect of various treatments on tiller production during various growth stages.

There was significant effect of treatments on the number of tillers on all stages of growth except at 2 MAP.

At 4 MAP FYM (T_1) produced maximum tillers (1.60) and was on par with vermicompost (T_2) which recorded a tiller number of 1.40. T_1 superior to package of practices recommendations of Kerala Agricultural University (T_8). T_{11} recorded lowest number of tillers (1.13).

At 6 MAP, coir pith compost (T_7) recorded maximum tiller number (2.33) and was on par with T_1 (2.13). T_1 and T_7 were superior to T_8 also. T_{11} recorded lowest tiller number (1.47).

At 8 MAP also T_7 recorded maximum tiller number (2.80) which was on par with T_1 (2.53) and these two were superior to T_8. T_{11} recorded a lowest tiller number of 1.87.

Table 4. Effect of organic manures on tiller number plant^{-1} of turmeric

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	1.27	1.60	2.13	2.53
T_2	1.20	1.40	1.73	2.13
T_3	1.07	1.27	1.53	2.00
T_4	1.13	1.27	1.60	2.13
T_5	1.07	1.27	1.53	1.93
T_6	1.07	1.20	1.53	1.87
T_7	1.13	1.33	2.33	2.80
T_8	1.07	1.27	1.67	2.07
T_9	1.13	1.27	1.60	2.00
T_{10}	1.13	1.33	1.73	2.07
T_{11}	1.00	1.13	1.47	1.87
$F_{10,20}$	1.89	2.67*	12.42**	9.74**
SE	0.05	0.07	0.08	0.09
CD	-	0.22	0.23	0.27

*Significant at 5 per cent level   **Significant at 1 per cent level

4.1.1.3 Number of Leaves

The data presented in Table 5 show the effect of various treatments on number of leaves per plant.

At 2 MAP T_1 was superior in the case of production of leaves (8.07) and was on par with T_7, T_8 and T_9. T_{11} recorded the lowest leaf number (6.47) and was inferior to (T_8).

At 4 MAP the effect of various organic manures were not significant.

At 6 MAP T_7 recorded the highest leaf number (14.73) and was on par with T_1, T_2, T_5, T_8 and T_{10}. T_6 and T_{11} were inferior to T_8. Lowest value was recorded by T_{11} (9.87).

At 8 MAP also T_7 recorded the highest value (16.77) and was on par with T_1, T_2 and T_{10}. T_7 was superior to T_8. T_6 and T_{11} were inferior to T_8. The least number of leaves were produced by T_{11} (11.13).

Table 5. Effect of organic manures on number of leaves plant^{-1} of turmeric

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	8.07	13.33	14.47	15.07
T_2	7.27	11.33	14.07	14.77
T_3	7.20	10.97	11.03	12.80
T_4	7.20	11.13	11.80	13.00
T_5	7.20	12.13	13.40	14.27
T_6	7.13	9.80	10.40	11.87
T_7	7.93	11.47	14.73	16.77
T_8	7.73	11.00	13.37	14.20
T_9	7.40	11.53	12.07	14.40
T_{10}	7.13	10.77	14.00	15.70
T_{11}	6.47	9.60	9.87	11.13
$F_{10,20}$	2.74*	2.07	4.50**	4.57**
SE	0.27	0.71	0.80	0.78
CD	0.786	-	2.368	2.298

* Significant at 5 per cent level ** Significant at 1 per cent level

4.1.2 Rhizome Characters

4.1.2.1 *Rhizome Spread*

Table 6. Effect of organic manures on rhizome spread of turmeric, cm

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	3.67	11.50	15.39	19.83
T_2	3.50	10.00	12.67	16.50
T_3	3.33	8.83	13.33	16.67
T_4	3.45	10.83	15.50	16.83
T_5	3.67	8.50	14.00	17.33
T_6	3.33	10.00	13.67	13.83
T_7	4.33	12.83	16.50	20.00
T_8	3.58	11.17	16.17	17.33
T_9	3.58	10.50	12.33	16.83
T_{10}	3.67	9.67	13.50	16.67
T_{11}	3.33	9.83	12.00	13.00
$F_{10, 20}$	0.70	0.97	1.11	9.5**
SE	0.34	1.25	1.48	0.68
CD	-	-	-	1.99

** Significant at 1 per cent level

The effect of various treatments on rhizome spread is shown in Table 6. The effect was significant only at 8 MAP. At 8 MAP the maximum response of rhizome spread was from coir pith compost (T_7) which recorded a rhizome spread of 20.00 cm which was on par with FYM (T_1) which recorded a rhizome spread of 19.83 cm. T_7 and T_1 were superior to package of practices recommendations of Kerala Agricultural University (T_8) which recorded a rhizome spread of 17.33 cm. T_6 and T_{11} were inferior to T_8. T_{11} recorded the lowest value of 13.00 cm.

4.1.2.2 Rhizome Thickness

Table 7. Effect of organic manures on rhizome thickness of turmeric, cm

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	23.33	30.50	32.00	33.00
T_2	21.17	29.00	29.67	30.83
T_3	22.50	26.17	27.67	27.83
T_4	21.25	29.83	31.17	31.83
T_5	23.67	27.67	29.33	30.33
T_6	23.00	30.00	30.67	31.67
T_7	26.33	30.83	32.33	33.67
T_8	25.00	30.33	31.33	32.17
T_9	24.67	25.83	28.00	30.00
T_{10}	25.00	27.00	28.67	30.33
T_{11}	21.17	23.00	23.83	26.00
$F_{10, 20}$	0.83	2.11	2.25	2.90*
SE	1.94	1.71	1.64	1.31
CD	-	-	-	3.855

* Significant at 5 per cent level

The effect of various treatments on rhizome thickness is depicted in Table 7.

The effect of various treatments on rhizome thickness were significant only at 8 MAP.

At 8 MAP rhizome thickness was maximum for treatment T_7 (33.67 cm) which was on par with T_1, T_2, T_4, T_5, T_6, T_8, T_9 and T_{10}. Treatments T_3 and T_{11} were inferior to package of practices recommendations of Kerala Agricultural University (T_8) which recorded a rhizome thickness of 32.17cm. Lowest rhizome thickness (26 cm) was recorded by the treatment T_{11}.

4.1.3 Root Characters

4.1.3.1 Root Length

Table 8 depicts the effect of various treatments on root length.

Table 8. Effect of organic manures on root length of turmeric, cm

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	7.50	11.33	16.00	15.33
T_2	8.17	13.17	16.50	15.67
T_3	6.33	12.17	16.33	15.17
T_4	7.50	11.17	14.17	13.33
T_5	8.67	10.83	15.00	13.00
T_6	7.50	11.83	15.00	13.83
T_7	8.83	14.33	19.00	17.17
T_8	7.83	13.33	18.67	16.83
T_9	7.50	13.00	14.33	13.17
T_{10}	7.33	11.33	14.83	13.83
T_{11}	6.33	11.17	13.17	13.00
$F_{10, 20}$	0.74	1.13	4.34**	2.86*
SE	0.93	1.07	0.74	1.08
CD	-	-	2.172	3.175

* Significant at 5 per cent level ** Significant at 1 per cent level

At 2 MAP and 4 MAP the effect of various treatments on root length were insignificant.

At 6 MAP the influence of various treatments on root length was significant. Maximum root length was recorded by the treatment T_7 (19 cm) which was on par with treatments T_2, T_3, T_1 and T_8. Treatments T_6, T_4, T_5, T_9, T_{10} and T_{11} were inferior to package of practice recommendations of Kerala Agricultural University (T_8) and the lowest root length was recorded by T_{11} (13.17 cm).

At 8 MAP also the influence of various treatments on the root length was significant.

Treatment T_7 gave the maximum root length (17.17 cm) which was on par with T_2, T_3, T_6 and T_8. Treatments T_1, T_4, T_5, T_9, T_{10} and T_{11} were inferior to T_8. The lowest value was given by treatment T_{11} (13 cm).

4.1.3.2 Root Spread

The effect of various treatments on root spread is given in Table 9. The effect of various treatments were insignificant in all growth stages except at 6 MAP.

Table 9. Effect of organic manures on root spread of turmeric, cm

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	3.92	9.33	12.17	11.17
T_2	3.83	9.83	15.33	11.33
T_3	3.67	9.17	9.67	9.50
T_4	3.83	10.67	12.00	10.83
T_5	4.17	9.17	11.83	10.83
T_6	3.83	9.67	11.33	10.50
T_7	5.17	12.67	15.67	13.50
T_8	4.17	11.42	12.33	11.83
T_9	4.00	11.33	11.37	10.67
T_{10}	4.17	9.50	10.33	10.16
T_{11}	3.67	9.17	10.00	9.50
$F_{10, 20}$	1.83	1.60	5.02**	0.77
SE	0.31	0.93	0.88	1.28
CD	-	-	2.569	-

** Significant at 1 per cent level

At 6 MAP the maximum root spread was recorded by treatment T_7 (15.67 cm) which was on par with T_2 (15.33 cm). T_7 and T_2 were superior to package of practice recommendations of Kerala Agricultural University (T_8) also which recorded a root spread of 12.33 cm. Treatment T_3 was inferior to T_8 and recorded a lowest value of 9.67 cm which was on par with T_{11} (10 cm).

4.1.3.3 Root Weight

Table 10. Effect of organic manures on root weight of turmeric, g

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	0.45	0.95	1.10	1.22
T_2	0.16	0.86	1.22	1.47
T_3	0.18	0.31	0.50	0.68
T_4	0.13	0.32	0.41	0.52
T_5	0.08	0.38	0.69	0.84
T_6	0.21	0.41	0.45	0.47
T_7	0.41	1.12	1.41	1.58
T_8	0.39	0.84	1.03	1.27
T_9	0.26	0.52	0.97	1.13
T_{10}	0.41	0.52	0.75	0.93
T_{11}	0.08	0.31	0.36	0.44
$F_{10, 20}$	9.27**	11.78**	11.12**	11.54**
SE	4.59	8.56	0.11	0.12
CD	0.140	0.250	0.317	0.348

** Significant at 1 per cent level

The data on dry weight of the root as affected by various treatments was depicted in Table 10.

At 2 MAP treatment T_1 recorded the maximum dry weight of the root (0.45 g) which was on par with T_7, T_8 and T_{10}. Treatments T_2, T_3, T_4, T_5, T_6 and T_{11} were inferior to package of practice recommendations of Kerala Agricultural

University (T_8). Lowest root dry weight was recorded by treatments T_5 and T_{11} (0.08 g).

At 4 MAP T_7 recorded maximum dry weight of roots (1.12 g) which was on par with T_1 (0.95 g). Also T_7 was superior to T_8 and T_2. All other treatments were inferior to T_8. Lowest root dry weight given by T_3 and T_{11} (0.31 g).

At 6 MAP also T_7 recorded maximum root dry weight (1.41 g) which was on par with T_1 and T_2 and was also superior to T_8 (1.03 g). T_3, T_4, T_6 and T_{11} were inferior to T_8. T_{11} recorded the lowest root dry weight of 0.36 g.

Again at 8 MAP also T_7 recorded highest value (1.58 g) which was on par with T_2 and T_8. Treatments T_3 to T_6 and T_{11} were inferior to T_8. T_{11} recorded the lowest dry weight of 0.44 g.

4.1.3.4 Root Volume

Table 11 depicts the effect of various treatments on root volume.

The effect of various treatments on root volume were significant at all growth stages except at 8 MAP.

At 2 MAP the highest root volume obtained from treatment T_7 (4.00 cm^3) which was on par with T_1 (3.50 cm^3). These two were also superior to (T_8) which recorded a root volume of 2.17 cm^3. No treatment was inferior to T_8. The lowest value was obtained from T_{11} (2.00 cm^3).

At 4 MAP T_7 recorded maximum root volume (7.00 cm^3) which was on par with T_3 and T_8. Treatments T_5 and T_{11} were inferior to T_8 and recorded a lowest value of 3.00 cm^3.

At 6 MAP T_7 recorded maximum root volume (14.33 cm^3) which was on par with T_2 and T_1. T_7 was superior to T_8 which recorded a root volume of 10.50 cm^3. No treatment was inferior to T_8. T_{11} recorded lowest root volume of 7.33 cm^3.

Table 11. Effect of organic manures on root volume of turmeric, cm^3

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	3.50	4.42	12.17	13.17
T_2	2.83	4.00	12.83	14.33
T_3	2.00	5.33	10.00	11.83
T_4	2.83	4.50	9.67	12.67
T_5	2.33	3.00	11.00	14.17
T_6	2.17	4.67	10.83	13.17
T_7	4.00	7.00	14.33	16.83
T_8	2.17	5.10	10.50	13.17
T_9	2.00	4.10	7.50	12.83
T_{10}	2.17	3.17	8.50	11.50
T_{11}	2.00	3.00	7.33	10.50
$F_{10, 20}$	3.80**	2.89*	4.08**	2.22
SE	0.35	2.69	1.08	1.12
CD	1.021	2.050	3.173	-

** Significant at 1 per cent level

4.1.4 Physiological Parameters

4.1.4.1 Dry Matter Production

Total dry matter production recorded at various stages are presented in Table 12. At 2 MAP treatment T_1 was superior (15.53 g $plant^{-1}$) and was on par with T_7 (15.33 g $plant^{-1}$). These two were superior to package of practice recommendations of Kerala Agricultural University (T_8). T_4, T_5 and T_{11} were inferior to T_8. All other treatments were on par with T_8 which recorded a value of 11.60 g $plant^{-1}$.

Table12. Effect of organic manures on dry matter production of turmeric, g plant^{-1}

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	15.53	34.77	63.31	69.84
T_2	9.44	30.54	46.23	73.43
T_3	9.61	16.32	42.35	68.50
T_4	8.38	16.98	36.78	60.86
T_5	8.18	14.84	39.39	55.71
T_6	9.70	13.76	32.04	46.17
T_7	15.33	30.70	65.70	75.25
T_8	11.60	27.99	41.87	66.37
T_9	10.04	16.80	41.58	66.62
T_{10}	9.49	12.19	42.07	73.98
T_{11}	7.89	10.49	32.68	37.21
$F_{10, 20}$	8.37**	108.86**	34.97**	14.10**
SE	0.92	0.83	1.86	3.25
CD	2.703	2.456	5.487	9.578

** Significant at 1 per cent level

At 4 MAP treatment T_1 performed significantly superior to T_8 and recorded the highest DMP (34.77 g plant^{-1}). T_2 and T_7 were also superior to T_8. T_3, T_4, T_5, T_6, T_9 and T_{11} were inferior to T_8. The lowest value was recorded by T_{11} (10.49 g plant^{-1}).

At 6 MAP T_7 recorded the highest value (65.70 g plant^{-1}) and was on par with T_1. These two treatments were significantly superior to T_8. T_6 and T_{11} were found inferior to T_8 which recorded a DMP of 41.87 g plant^{-1}. The lowest value recorded by T_6 (32.04 g plant^{-1}).

At 8 MAP also T_7 recorded the highest value (75.25 g plant^{-1}) and was on par with T_1 to T_3 and T_8 to T_{10}. T_{11} recorded the lowest value (37.21 g plant^{-1}).

4.1.4.2 Crop Growth Rate

Table 13 shows the effect of various treatments on the crop growth rate.

Table 13. Effect of organic manures on crop growth rate of turmeric, g m^{-2} day^{-1}

Treatments	60-120 DAP	120-180 DAP	180-240 DAP
T_1	0.337	0.650	0.117
T_2	0.350	0.260	0.440
T_3	0.107	0.430	0.463
T_4	0.143	0.343	0.407
T_5	0.127	0.420	0.267
T_6	0.073	0.300	0.220
T_7	0.257	0.577	0.183
T_8	0.283	0.243	0.407
T_9	0.103	0.363	0.430
T_{10}	0.050	0.517	0.530
T_{11}	0.047	0.340	0.080
$F_{10, 20}$	47.67**	3.75**	5.48**
SE	0.017	0.067	0.070
CD	0.049	0.199	0.194

** Significant at 1 per cent level

At different growth stages the effect of various treatments on CGR were significant.

At 60 -120 DAP maximum CGR was recorded by treatment T_2 (0.350 g m^{-2} day^{-1}) which was on par with treatment T_1 (0.337 g m^{-2} day^{-1}). Also T_1 and T_2 were superior to T_8 which recorded a value of 0.283 g m^{-2} day^{-1}. All other treatments were inferior to T_8 except T_7 which was on par with T_8. Lowest CGR recorded from treatment T_{11} (0.047 g m^{-2} day^{-1}).

At 120 - 180 DAP T_1 recorded maximum CGR (0.650 g m^{-2} day^{-1}) and was on par with T_7 and T_{10}. Lowest CGR recorded by T_8 (0.243 g m^{-2} day^{-1}).

At 180 - 240 DAP T_{10} recorded maximum CGR (0.530 g m^{-2} day^{-1}) which was on par with T_2, T_3, T_4, T_8 and T_9. The minimum CGR recorded by T_{11} (0.080 g m^{-2} day^{-1}).

4.1.4.3 Relative Growth Rate

Table 14. Effect of organic manures on relative growth rate of turmeric, g day^{-1}

Treatments	60-120 DAP	120-180 DAP	180-240 DAP
T_1	0.013	0.010	0.001
T_2	0.019	0.006	0.007
T_3	0.009	0.016	0.008
T_4	0.012	0.012	0.008
T_5	0.009	0.016	0.006
T_6	0.006	0.014	0.006
T_7	0.011	0.012	0.002
T_8	0.014	0.008	0.007
T_9	0.008	0.015	0.007
T_{10}	0.004	0.020	0.009
T_{11}	0.004	0.019	0.002
$F_{10, 20}$	11.97**	8.48**	4.74**
SE	0.001	0.001	0.001
CD	0.0039	0.0043	0.0037

** Significant at 1 per cent level

Table 14 shows the effect of various treatments on relative growth rate.

The effect of various treatments on RGR were significant at various stages of growth.

At 60-120 DAP T_2 gave the maximum value for RGR (0.019 g day^{-1}) which was superior to T_8 (0.014 g day^{-1}). Treatments T_3, T_5, T_6, T_9, T_{10} and T_{11} were inferior to T_8. Minimum RGR recorded by T_{10} (0.004 g day^{-1}) and T_{11} (0.004 g day^{-1}).

At 120-180 DAP T_{10} recorded maximum RGR (0.020 g day^{-1}) which was on par with T_3, T_5 and T_{11}. Treatments T_3, T_5, T_6, T_9, T_{10} and T_{11} were superior to T_8. T_2 recorded minimum RGR (0.006 g day^{-1}) which was on par with T_8.

At 180-240 DAP T_{10} recorded maximum RGR (0.009 g day^{-1}) which was on par with T_2, T_3, T_4, T_6, T_8 and T_9. Treatments T_1, T_7 and T_{11} were inferior to T_8. T_1 recorded minimum RGR (0.001 g day^{-1}).

4.1.4.4 Net Assimilation Rate

Table 15 shows the effect of various treatments on net assimilation rate.

Table 15. Effect of organic manures on net assimilation rate of turmeric, g m^{-2} day^{-1}

Treatments	60-120 DAP	120-180 DAP	180-240 DAP
T_1	0.063	0.080	0.013
T_2	0.083	0.037	0.050
T_3	0.027	0.073	0.067
T_4	0.040	0.067	0.070
T_5	0.030	0.063	0.037
T_6	0.020	0.053	0.033
T_7	0.057	0.077	0.020
T_8	0.067	0.037	0.057
T_9	0.027	0.087	0.060
T_{10}	0.013	0.080	0.063
T_{11}	0.017	0.083	0.010
$F_{10, 20}$	18.22**	3.08*	5.11 **
SE	0.006	1.01	0.09
CD	0.016	0.030	0.027

* Significant at 5 per cent level ** Significant at 1 per cent level

The effect of various treatments on NAR were significant at various growth stages.

At 60-120 DAP vermicompost (T_2) recorded maximum NAR of 0.083 g m^{-2} day^{-1} and was on par with POP recommendations of KAU (T_8) which recorded a NAR of 0.067 g m^{-2} day^{-1}. All other treatments were inferior to T_8.

At 120-180 DAP treatment T_9 recorded maximum NAR (0.087 g m^{-2} day^{-1}) which was on par with T_1, T_3, T_4, T_5, T_7, T_{10} and T_{11}. Lowest NAR recorded by T_2 and T_8 (0.037 g m^{-2} day^{-1}).

At 180-240 DAP maximum NAR was recorded by treatment T_4 (0.070 g m^{-2} day^{-1}) which was on par with T_2, T_3, T_8, T_9 and T_{10}. T_1, T_7 and T_{11} were inferior to T_8. Lowest NAR was recorded by T_1 (0.013 g m^{-2} day^{-1}).

4.1.4.5 Leaf Area Index

Table 16 shows the effect of various treatments on leaf area index.

Table 16. Effect of organic manures on leaf area index of turmeric

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	3.18	7.53	8.63	9.07
T_2	2.55	5.98	8.29	9.40
T_3	2.24	5.66	6.50	7.58
T_4	2.32	4.83	5.49	6.37
T_5	2.44	6.03	7.26	8.34
T_6	2.06	5.56	6.05	7.32
T_7	3.00	6.29	8.82	9.77
T_8	2.78	5.98	7.43	8.21
T_9	2.65	4.71	5.42	8.76
T_{10}	2.57	5.42	7.50	9.40
T_{11}	1.56	3.97	4.26	5.48
$F_{10,20}$	2.88*	2.74*	8.90**	4.95**
SE	0.26	0.57	0.49	0.61
CD	0.778	1.671	1.446	1.796

* Significant at 5 per cent level ** Significant at 1 per cent level

At 2 MAP T_1 recorded maximum leaf area index of 3.18 which was on par with T_2, T_5, T_7, T_8, T_9 and T_{10}. T_{11} was inferior to package of practice recommendations of Kerala Agricultural University (T_8) which recorded a LAI of 1.56.

At 4 MAP T_1 recorded maximum leaf area index of 7.53 which was on par with T_2, T_5, T_7 and T_8. T_{11} was inferior to T_8 and recorded a leaf area index of 3.97.

At 6 MAP T_7 recorded maximum LAI of 8.82 which was on par with T_1, T_2, T_8 and T_{10}. Treatments T_4, T_9 and T_{11} inferior to T_8. Lowest LAI recorded by T_{11} (4.26).

At 8 MAP T_7 recorded maximum LAI of 9.77 which was on par with T_1, T_2 T_5, T_8, T_9 and T_{10} . T_4 and T_{11} inferior to T_8. Minimum LAI recorded by T_{11} (5.48).

4.1.4.6 Leaf Area Duration

Table 17 shows the effect of various treatments on leaf area duration.

At 60 - 120 DAP T_1 recorded maximum LAD of 227.39 which was on par T_2, T_5, T_7 and T_8. T_{11} was inferior to package of practice recommendations of Kerala Agricultural University (T_8) and recorded a LAD of 119.88.

At 120 - 180 DAP T_7 recorded maximum LAD (267.74) which was on par with T_1, T_2, T_8 and T_{10}. T_4, T_9 and T_{11} inferior to T_8. T_{11} recorded lowest LAD of 129.88.

At 180 - 240 DAP T_7 recorded maximum LAD of 297.61, which was on par with T_1, T_2, T_5, T_8, T_9 and T_{10}. T_4 and T_{11} inferior to T_8 . Treatment T_{11} recorded lowest LAD of 166.43

Table 17. Effect of organic manures on leaf area duration of turmeric

Treatments	60-120 DAP	120-180 DAP	180-240 DAP
T_1	227.39	262.76	276.52
T_2	180.67	251.79	286.04
T_3	171.02	197.93	230.65
T_4	145.96	167.21	193.74
T_5	183.42	220.83	253.93
T_6	167.73	184.38	223.02
T_7	190.09	267.74	297.61
T_8	180.89	225.99	250.12
T_9	142.52	165.05	265.51
T_{10}	163.88	227.61	285.75
T_{11}	119.88	129.88	166.43
$F_{10, 20}$	2.77*	8.88**	5.03**
SE	16.98	14.86	18.39
CD	50.098	43.831	54.263

* Significant at 5 per cent level ** Significant at 1 per cent level

4.1.4.7 Harvest Index

Table 18 shows the effect of various treatments on harvest index at 240 DAP.

The harvest index measured for the turmeric plants grown under various treatments at 240 DAP was insignificant. Maximum harvest index was observed from treatment T_7 (0.873). T_{11} recorded a lowest harvest index of 0.670.

Table 18. Effect of organic manures on harvest index of turmeric

Treatments	HI
T_1	0.697
T_2	0.750
T_3	0.680
T_4	0.767
T_5	0.836
T_6	0.797
T_7	0.873
T_8	0.710
T_9	0.673
T_{10}	0.747
T_{11}	0.670
$F_{10, 20}$	1.85
SE	0.05
CD	-

4.1.4.8 Root : Shoot Ratio

Table 19 shows the effect of various treatments on root : shoot ratio.

The effect of various treatments on root :shoot ratio were significant at all stages of growth except at 8 MAP.

At 2 MAP the root: shoot ratio was found to be maximum for T_1 (0.048) and was on par with T_8 and T_{10}. Treatments T_2 , T_3, T_4, T_5 and T_{11} inferior to POP recommendations of KAU (T_8). Lowest root: shoot ratio was recorded by T_{11} (0.015).

At 4 MAP T_7 recorded maximum root: shoot ratio of 0.065 which was on par with T_{10}. T_7 was superior to T_8 which recorded a root: shoot ratio of 0.038. No treatment was inferior to T_8. T_{11} and T_4 recorded lowest value of 0.031.

At 6 MAP T_7 recorded highest root: shoot ratio of 0.047 which was on par with all treatments except T_3, T_4 and T_{11}. T_4 and T_{11} recorded a lowest value of 0.021. T_3, T_4 and T_{11} were inferior to T_8.

Table 19. Effect of organic manures on root: shoot ratio of turmeric

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	0.048	0.033	0.037	0.093
T_2	0.019	0.048	0.042	0.086
T_3	0.020	0.032	0.022	0.034
T_4	0.017	0.031	0.021	0.047
T_5	0.016	0.033	0.034	0.107
T_6	0.026	0.038	0.041	0.068
T_7	0.028	0.065	0.047	0.109
T_8	0.040	0.038	0.043	0.088
T_9	0.029	0.045	0.038	0.055
T_{10}	0.048	0.051	0.031	0.079
T_{11}	0.015	0.031	0.021	0.037
$F_{10, 20}$	4.63**	3.58**	2.71*	1.69
SE	0.005	0.005	0.006	0.021
CD	0.0169	0.0169	0.0169	-

*Significant at 5 per cent level   ** Significant at 1 per cent level

4.2 YIELD AND YIELD COMPONENTS

4.2.1 Rhizome Yield

The data presented in Table 20 show the effect of various treatments on the rhizome yield of turmeric at 240 DAP.

Various treatments had a significant effect on the fresh rhizome yield of turmeric at 240 DAP. The maximum yield was recorded by treatment T_7 (34.32 t ha^{-1}) which was on par with treatment T_1 (29.22 t ha^{-1}). T_1 and T_7 were also superior to package of practice recommendations of Kerala Agricultural University (T_8) which recorded an yield of 20.88 t ha^{-1}. T_{11} was inferior to T_8 with a minimum yield of 11.57 t ha^{-1}.

Table 20. Effect of organic manures on the rhizome yield, t ha^{-1} and top yield, g $plant^{-1}$ of turmeric

Treatments	Rhizome yield, t ha^{-1}	Top yield, g $plant^{-1}$
T_1	29.22	13.52
T_2	25.58	17.17
T_3	21.32	21.32
T_4	20.57	14.03
T_5	21.82	8.27
T_6	15.54	9.36
T_7	34.32	14.32
T_8	20.88	18.77
T_9	18.34	21.58
T_{10}	24.72	18.67
T_{11}	11.57	11.76
$F_{10, 20}$	5.97**	2.15
SE	2.56	3.09
CD	7.558	-

** Significant at 1 per cent level

4.2.2 Top Yield

Table 20 shows the effect of various treatments on top yield at 240 DAP.

The effect of various treatments on top yield at 8 MAP were insignificant. The highest top yield of 21.58 g plant^{-1}was obtained from plants which received NPK alone as per POP of KAU (T_9).

4.2.3 Dry Turmeric

The data on table 21 show the effect of various treatments on the dry turmeric per plant during various growth stages.

Significant effect was shown by various treatments on the weight of dry turmeric.

At 2 MAP treatment T_7 recorded highest dry turmeric weight of 1.62 g and was superior to package of practice recommendations of Kerala Agricultural University (T_8). No treatment was inferior T_8. Lowest value given by treatment T_{11} (0.657 g).

At 4 MAP treatment T_2 was superior in dry turmeric weight (12.13 g). Treatments T_2 and T_7 were superior to T_8 which recorded a weight of 5.18 g. Treatments T_3, T_5, T_6, T_9, T_{10} and T_{11} were inferior to T_8. Lower value recorded by treatment T_{11} (0.93 g).

At 6 MAP T_7 was superior in dry weight of turmeric (37.90 g). T_1, T_2, T_5, T_7, T_9 and T_{10} superior to T_8 which recorded a value of 11.4 g. No treatment was inferior to T_8 . T_{11} recorded lowest dry weight of 9.87 g.

At 8 MAP T_7 recorded maximum dry weight of turmeric (59.35 g) and was on par with T_1, T_2, T_{10} and these four treatments were superior to T_8. Treatments T_6, T_{11} were inferior to T_8. Lowest value recorded by T_{11} (25.02 g).

Table 21. Effect of organic manures on dry turmeric, g plant^{-1}

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	0.823	5.15	30.57	55.09
T_2	0.993	12.13	16.48	54.80
T_3	0.717	3.90	10.02	46.30
T_4	0.800	4.82	14.65	46.50
T_5	0.767	3.22	17.82	46.60
T_6	0.887	3.14	13.15	36.67
T_7	1.620	8.00	37.90	59.35
T_8	1.010	5.18	11.40	46.33
T_9	0.923	2.92	16.25	43.90
T_{10}	0.723	1.47	20.23	54.38
T_{11}	0.657	0.93	9.87	25.02
$F_{10,20}$	3.38**	106.4**	15.83**	15.84**
SE	0.144	0.306	1.48	2.42
CD	0.424	0.894	4.38	7.790

** Significant at 1 per cent level

4.2.4 Bulking Rate

The data presented in Table 22 show the effect of various treatments on bulking rate.

At 60 -120 DAP T_2 recorded maximum bulking rate (0.351) which was on parwith T_1 (0.321). T_2 was superior to POP recommendations of KAU (T_8) which recorded a value of 0.273. Treatments T_3, T_4, T_5, T_6, T_9, T_{10} and T_{11} were inferior to T_8 . Minimum bulking rate for treatment T_{11} (0.043).

At 120 - 180 DAP T_7 recorded maximum bulking rate (0.583) which was on par with T_{10} (0.498). T_1, T_3, T_4, T_5, T_7, T_9, T_{10} and T_{11} were superior to T_8. No treatment was inferior to T_8 (0.231).

At 180 - 240 DAP T_{10} recorded maximum bulking rate (0.531) which was on par with T_2, T_3, T_4, T_8 and T_9. Treatments T_1, T_7 and T_{11} inferior to T_8. Lowest bulking rate recorded by treatment T_{11} (0.075).

Table 22. Effect of organic manures on bulking rate of turmeric

Treatments	60-120 DAP	120-180 DAP	180-240 DAP
T_1	0.321	0.475	0.108
T_2	0.351	0.261	0.453
T_3	0.111	0.433	0.436
T_4	0.139	0.330	0.401
T_5	0.083	0.409	0.272
T_6	0.094	0.304	0.235
T_7	0.256	0.583	0.159
T_8	0.273	0.231	0.408
T_9	0.112	0.413	0.417
T_{10}	0.045	0.498	0.531
T_{11}	0.043	0.369	0.075
$F_{10, 20}$	36.23**	10.17**	5.68 **
SE	0.019	0.033	0.064
CD	0.0551	0.0979	0.1917

** Significant at 1 per cent level

4.3 QUALITY ANALYSIS

4.3.1 Volatile Oil

Table 23 shows the effect of various treatments on volatile oil content of turmeric rhizome at 240 DAP.

The influence of various treatments on volatile oil content were significant The maximum volatile oil content was recorded from treatment T_7 (5.37 %) which was on par with T_8, T_9 and T_{10}. Treatments T_1, T_2, T_3, T_4, T_5, T_6 and T_{11} were inferior to POP recommendations of KAU (T_8) which recorded a value of 5.1 per cent. T_{11} recorded minimum volatile oil content (3.82 %).

Table 23. Effect of organic manures on volatile oil content, per cent and curcumin content, per cent of turmeric

Treatments	Volatile oil, %	Curcumin, %
T_1	4.17	5.20
T_2	4.30	4.87
T_3	4.13	4.82
T_4	3.85	5.00
T_5	3.90	4.63
T_6	3.83	4.60
T_7	5.37	5.00
T_8	5.10	5.17
T_9	5.03	5.16
T_{10}	5.33	4.96
T_{11}	3.82	4.60
$F_{10, 20}$	11.73**	1.79
SE	0.185	0.17
CD	0.547	-

** Significant at 1 per cent level

4.3.2 Curcumin

Data presented in Table 23 show the influence of various treatments on curcumin content.

The effect of various organic manures on curcumin content was insignificant. The highest value was shown by treatment T_1 (5.2 %).

4.4 SOIL ANALYSIS

4.4.1 Physical Properties

The effect of various treatments on soil physical properties like bulk density, water holding capacity and soil aggregation were insignificant. The data were presented in Table 24.

Table 24. Effect of organic manures on bulk density, Mg m^{-3}, water holding capacity, per cent and soil aggregation, per cent

Treatments	Bulk density, Mg m^{-3}	Water holding capacity, %	Soil aggregation. %
T_1	1.50	24.67	43.48
T_2	1.54	23.91	43.57
T_3	1.55	24.07	43.50
T_4	1.56	24.37	43.13
T_5	1.59	24.40	43.20
T_6	1.53	24.43	43.03
T_7	1.56	24.76	43.43
T_8	1.55	23.87	43.50
T_9	1.54	24.10	43.40
T_{10}	1.58	24.40	43.20
T_{11}	1.60	23.75	42.97
$F_{10, 20}$	1.69	0.97	0.64
SE	0.02	0.34	0.26
CD	-	-	-

Bulk density was high in the soil during initial period (1.60 Mg m^{-3}). After the experiment bulk density decreases for all treatments except absolute control. But there was no significant difference between the treatments. In the case of soil aggregation and water holding capacity the initial value was 23.77 and 42.99 per cent respectively. After the experiment there was an increase in soil aggregation and water holding capacity but no significant difference between treatments was observed. Maximum water holding capacity was obtained from plots which received coir pith compost treatment (24.76 %) and maximum soil aggregation was obtained from plots which received vermicompost (43.57 %).

4.4.2 Chemical Properties of Soil

4.4.2.1 Soil pH and Organic Carbon

Table 25. Effect of organic manures on soil pH and organic carbon, per cent

Treatments	Soil pH	Organic carbon, %
T_1	5.74	0.58
T_2	5.64	0.55
T_3	5.52	0.54
T_4	5.44	0.54
T_5	5.43	0.56
T_6	5.44	0.54
T_7	5.31	0.57
T_8	5.26	0.54
T_9	5.53	0.56
T_{10}	5.34	0.56
T_{11}	5.24	0.51
$F_{10, 20}$	1.07	2.06
SE	0.15	0.01
CD	-	-

The effect of various treatments on soil chemical properties like soil pH and organic carbon were insignificant (Table 25).

The organic carbon content of the soil during the initial period was 0.52 per cent. After the experiment the organic carbon content of the soil increases though there was no significant variation among treatments. Maximum organic content was obtained from plots which received FYM (T_1) as treatment (0.58 %) and lowest value was recorded by absolute control (0.51 %).

Similar trend was noticed in the case of soil pH also. The final pH was highest for the plots that received FYM (T_1) which recorded a pH of 5.74 and lowest pH recorded by absolute control (5.24).

4.4.2.2 NPK Content

Soil sample analysed after the experiment to assess the available nutrient status of soil with different organic sources are presented in the Table 26.

Table 26.Effect of organic manures on available NPK content of soil, kg ha^{-1}

Treatments	Available N, kg ha^{-1}	Available P, kg ha^{-1}	Available K, kg ha^{-1}
T_1	170.13	39.23	167.37
T_2	181.21	39.79	170.50
T_3	169.31	37.81	167.53
T_4	185.12	42.97	172.30
T_5	168.18	36.63	166.20
T_6	166.90	36.17	164.37
T_7	170.01	39.87	169.17
T_8	138.67	36.43	163.20
T_9	140.97	34.23	162.33
T_{10}	167.07	38.83	166.97
T_{11}	104.24	28.34	161.12
$F_{10, 20}$	115.49**	8.78**	11.01**
SE	2.17	1.28	1.05
CD	6.415	3.772	3.087

** Significant at 1 per cent level

With respect to nitrogen content, treatment T_4 recorded a maximum value of 185.12 kg ha^{-1} which was on par with T_2 (181.21 kg ha^{-1}). Treatments T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_{10} were superior to POP recommendations of KAU (138.67 kg ha^{-1}). Only treatment T_{11} inferior to T_8 with nitrogen content of 104.24 kg ha^{-1}.

In the case of final P status of soil, treatment T_4 recorded maximum value of 42.97 kg ha^{-1}which was on par with T_1, T_2 and T_7. Only T_4 superior to POP recommendations of KAU. T_{11} inferior to POP recommendations of KAU with a P content of 28.34 $kgha^{-1}$.

In the case of soil K also T_4 recorded maximum value of 172.3 kg ha^{-1} which was on par with T_2 (170.5 kg ha^{-1}). Treatments T_1, T_2, T_3, T_4, T_7, and T_{10} were superior to POP recommendations of KAU which recorded a K value of 163.2 kg ha^{-1}. No treatment inferior to POP recommendations of KAU. T_{11} recorded lowest soil K (161.12 kg ha^{-1}).

4.5 WEED BIOMASS

Table 27. Effect of organic manures on weed biomass, g m^{-2}

Treatments	2 MAP	4 MAP	6 MAP	8 MAP
T_1	0.027	0.027	0.127	0.377
T_2	0.017	0.037	0.127	0.297
T_3	0.027	0.050	0.090	0.370
T_4	0.020	0.050	0.130	0.363
T_5	0.027	0.043	0.090	0.380
T_6	0.033	0.047	0.100	0.377
T_7	0.027	0.053	0.090	0.334
T_8	0.023	0.043	0.087	0.330
T_9	0.027	0.047	0.093	0.367
T_{10}	0.023	0.050	0.090	0.333
T_{11}	0.030	0.053	0.097	0.380
$F_{10, 20}$	0.27	0.44	0.83	0.09
SE	0.09	0.01	0.010	0.090
CD	-	-	-	-

Table 27 depicts weed biomass of turmeric plots as influenced by various organic manures.

Various organic manures has no significant influence on weed biomass at different stages of growth.

4.6 BENEFIT : COST RATIO

Table 28. Effect of organic manures on BC ratio of turmeric

Treatments	B : C ratio
T_1	1.94
T_2	1.61
T_3	1.24
T_4	1.34
T_5	1.68
T_6	1.04
T_7	2.09
T_8	1.36
T_9	1.40
T_{10}	1.47
T_{11}	1.00
$F_{10, 20}$	4.00**
SE	0.17
CD	0.503

** Significant at 1 per cent level

Table 28 depicts B:C ratio for turmeric as influenced by various organic manures.

From Table 28 it is clear that coir pith compost treatment T_7 (2.09) performed superior to T_8 (1.36) and was on par with T_1, T_2 and T_5. Treatment T_1 (1.94) also was superior to T_8. No treatment was inferior to T_8. Lowest B:C ratio was recorded by T_{11} (1.00).

DISCUSSION

5. DISCUSSION

The results of the experiment conducted to study the effect of various organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden are discussed.

5.1 MORPHOLOGICAL CHARACTERS

5.1.1 Growth Characters

Results of the study indicated that different organic manures had a positive influence on the growth characters of the plant.

5.1.1.1 Plant Height

A general increasing trend in plant height was observed at various growth stages of the plant (Table 3 and Fig. 2). At 2 MAP maximum plant height (32.13 cm) was recorded by plants which received FYM (T_1). FYM was on par with vermicompost (T_2), neem cake (T_3), glyricidia leaves (T_4), poultry manure (T_5), coir pith compost (T_7), manuring as per package of practice recommendations of Kerala Agricultural University (T_8), NPK alone as per POP recommendations of KAU (T_9), and FYM alone as per POP recommendations of KAU (T_{10}). These treatments recorded a plant height of 30.93 cm, 30.87 cm, 30.73 cm, 30.13 cm, 31.33 cm, 31 cm, 30.37 cm and 30 cm respectively. As expected the lowest plant height of 25.33 cm was recorded by absolute control (T_{11}). Compared to inorganically grown tomato plants, organically grown ones were taller with more number of branches, Thamburaj (1994).

The beneficial effect of organic and inorganic manures and their combination in increasing the growth parameters were reported by Singh *et al.* (1973) and KAU (1991). Though FYM was on par with the above treatments including package of practice recommendations of Kerala Agricultural University it recorded maximum value for plant height and it might be due to the comparatively increased supply of nutrients especially N along with improvement in the soil properties brought about by FYM. Arunkumar (1997) reported that in

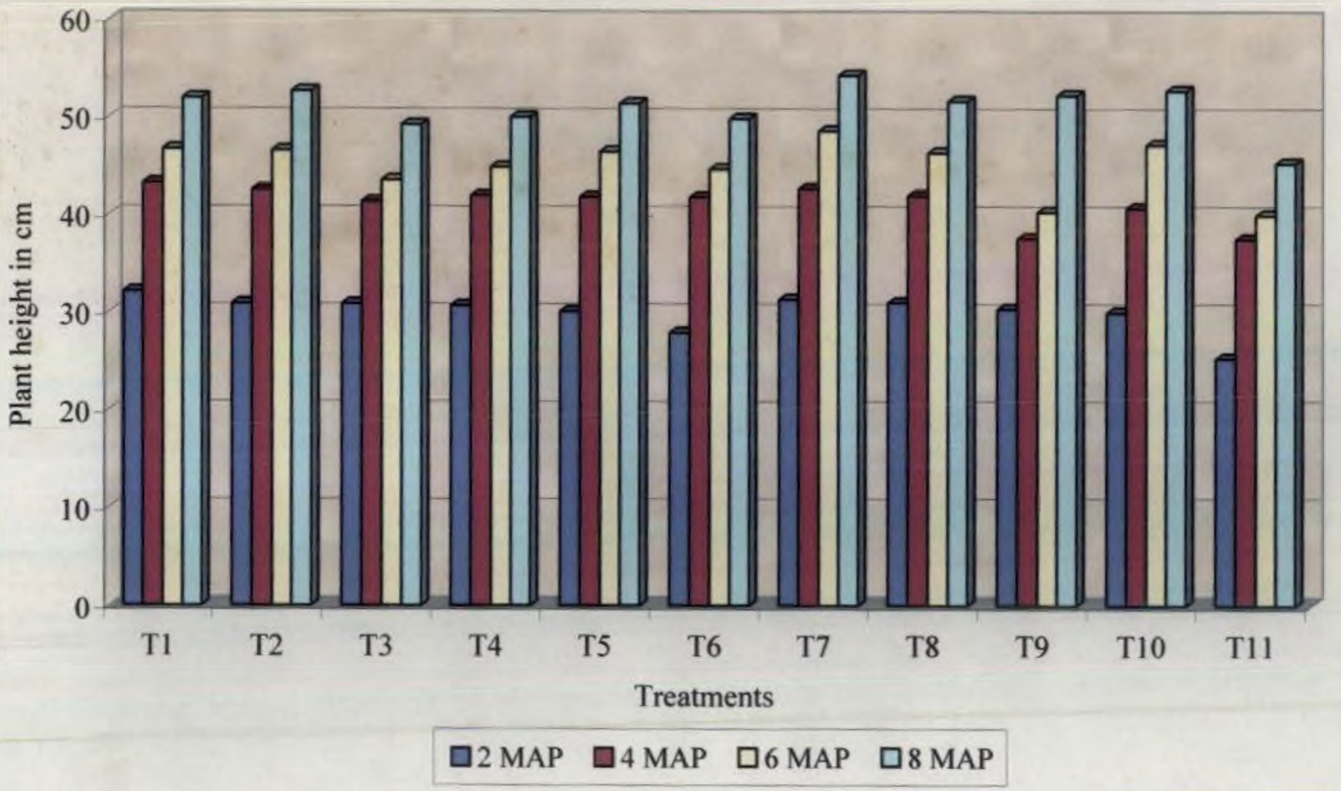

Fig. 2 Effect of organic manure on plant height in turmeric

amaranthus FYM application was found to be superior to vermicompost in inducing better plant height.

At 4 MAP the effect of various organic manures on plant height was not significant.

At 6 MAP plants which received coir pith compost recorded a maximum plant height of 48.6 cm and was on par with FYM (46.73 cm) vermicompost (46.60 cm), poultry manure (46.53 cm), POP recommendations of KAU (46.4 cm) and FYM alone as per POP recommendations of KAU (47.2 cm).

At 8 MAP also plants which received coir pith compost performed better by producing longer plants of 54.33 cm and was on par with FYM (52 cm), vermicompost (52.07 cm), poultry manure (51.43 cm), POP recommendations of KAU (51.67 cm), NPK alone as per POP recommendations of KAU (52.27 cm) and FYM alone as per POP recommendations of KAU (52.73 cm). In both stages of growth eventhough coir pith compost was on par with many other organic manures it produced maximum longer plants. The gradual and controlled release of essential plant nutrients *viz.*, N, P, K, Ca, Mg, Fe, Mn, Zn and Cu particularly nitrogen from coir pith compost might have resulted in favourable crop growth conditions. Similar finding was reported by Suja (2001) in yams. It is an established fact that nitrogen helps to promote vegetative growth. According to Thilgavathi and Mathan (1995) an increased plant height has been reported in rice following the application of partially decomposed coir pith in rice field with sandy clay loam soil. Also Suharban *et al.* (1997) in a pot culture experiment with bhindi reported that plant height was significantly influenced by coir pith compost treatment.

5.1.1.2 Number of Tillers

Organic manure application favoured tiller growth at various stages of crop growth except at 2 MAP (Table 4). The beneficial effect of organic amendments in increasing the growth parameters was reported by Zhang *et al.* (1988) and Pushpa (1996) in tomato, Almazov and Kholuyaka (1990) in vegetables and Anitha (1997) in chilli.

At 4 MAP, plants which received FYM (T_1) recorded highest tiller number (1.6) and was on par with vermicompost (T_2) received plants which recorded a tiller number of 1.4. T_1 was superior to package of practice recommendations of Kerala Agricultural University (1.27). Lowest tiller number was recorded by absolute control (T_{11}) which recorded a value of 1.13 and was on par with T_8.

At 6 MAP and 8 MAP coir pith compost (T_7) received plants recorded maximum tiller number of 2.33 and 2.80 respectively and was on par with T_1 (2.13 and 2.53 respectively). At both stages T_{11} recorded lowest tiller number (1.47 and 1.87 respectively). At 8 MAP T_6 also recorded the same tiller number as T_{11} and was on par with T_8. T_1 and T_7 were superior to POP recommendations of KAU.

At different stages of growth FYM and coir pith compost performed superior to POP recommendations of KAU (T_8). The significant effect of organic manure on tiller number might be due to the improvement in physico chemical properties of the soil, which in turn influenced the growth of the crop. This is in conformity with the results obtained by Sharma (1994) in rice. FYM showed more significance during initial stages through its high nutrient supplying capacity. The gradual and controlled release of nutrients by coir pith compost might attributed to its better performance later. But Subbiah *et al.* (1983b) found that incorporation of organic residues had no influence in increasing tillers per square meter in rice.

5.1.1.3 Number of Leaves

The trend followed in plant height was noticed in the case of leaf production also (Table 5). At 2 MAP the treatment FYM (T_1) favoured production of maximum number of leaves (8.07) and was on par with coir pith compost (T_7), package of practice recommendations of Kerala Agricultural University (T_8) and NPK alone as per POP recommendations of KAU (T_9). The leaf production by these treatments were 7.93, 7.73 and 7.40 respectively. Absolute control (T_{11}) recorded lowest leaf number of 6.47 and was inferior to POP recommendations of KAU.

At 4 MAP the effect of various treatments on leaf production was insignificant.

At 6 MAP and 8 MAP coir pith compost treated plots recorded highest leaf number (14.73 and 16.77 respectively).

At 6 MAP coir pith compost was on par with FYM (14.47), vermicompost (14.07), poultry manure (13.40), POP recommendations of KAU (13.37) and FYM alone as per POP recommendations of KAU (14.00).

At 8 MAP coir pith compost was on par with FYM (15.07), vermicompost (14.77) and FYM alone as per POP recommendations of KAU (15.70). At both stages biogas slurry and absolute control performed inferior to POP recommendations of KAU. Plants which received FYM and coir pith compost recorded maximum leaf number at different growth stages though on par with different treatments. At final stage of growth coir pith compost shown superiority over POP recommendations of KAU.

The better performance of FYM might be due to the increased supply of nutrients along with the improvement in the soil properties. In groundnut, Prasad and Venkateswarlu (1991) reported that FYM application improved the soil structure and also supplied the essential plant nutrients Nitrogen being the most essential element for the vegetative growth and development of plants, its availability would have helped the plant to produce more leaves. Coir pith compost showed its superiority by the gradual and controlled release of essential plant nutrients particularly nitrogen which might have resulted in favourable crop growth conditions. Similar finding was reported by Suja (2001) in yams. The importance of N in leaf development of pepper was reported by Nybe and Nair (1987).

5.1.2 Rhizome Characters

The effect of organic manures on rhizome spread (Table 6) and rhizome thickness (Table 7) were significant only at 8 MAP. Coir pith compost (T_7) recorded maximum rhizome spread (20.00 cm) and rhizome thickness (33.67 cm) at 8 MAP. In the case of rhizome spread coir pith compost was on par with FYM

(T_1) which recorded a rhizome spread of 19.83 cm and both FYM and coir pith compost was superior to package of practice recommendations of Kerala Agricultural University and for rhizome thickness T_7 was on par with all treatments except neem cake and absolute control. T_{11} recorded lowest rhizome spread and thickness. Coir pith compost produced maximum rhizome development though it was on par with many organic manures. Coir pith compost contributed a number of essential plant nutrients both macro and micro in addition to N, *viz.*, P, K, Ca, Mg, Fe, Mn, Zn, and Cu for crop nourishment. In yams the uptake of N and K was more from coir pith compost applied plots (Suja, 2001). Because of sponge like structure coir pith helps to retain water and improve aeration (Savithri and Khan, 1994). Thus the capacity of coir pith compost to supply all essential nutrients along with the positive influence on soil aeration and soil moisture conservation might have helped for better rhizome growth and development. The better performance of FYM may be attributed to the increased supply of nutrients and other growth substances along with improvement in the soil properties.

5.1.3 Root Characters

5.1.3.1 Root Length and Root Spread

Significant effect on root length was present only at 6 MAP and 8 MAP (Table 8). At both the stages of growth maximum root length was produced by plants which received coir pith compost treatment (19 and 17.17 cm respectively) At both the stages it was on par with vermicompost (16.50 and 15.67 cm respectively), neem cake (16.33 and 15.17 cm respectively), FYM (16 and 15.33 cm respectively) and package of practice recommendations of Kerala Agricultural University (18.67 and 16.83 cm respectively). At both stages absolute control (T_{11}) recorded lowest root length (13.17 and 13 cm respectively). At later stages of growth (8 MAP) there was a decline in the root length compared to initial stages of growth and it may be due to the death of the roots formed initially. According to Jayachandran (1998) the number of roots originating from the first daughter rhizome was more than that from the later produced daughter rhizomes. The possible reason for the rate of reduction in root length can be due to the fact that the fresh rhizomes (daughter rhizomes) are also producing roots which may not get sufficient growing periods to produce longer roots as in the case of initial roots.

The effect of treatments on root spread was significant only at 6 MAP (Table 9). At 6 MAP the maximum root spread was recorded by plants which received coir pith compost treatment (15.67 cm) and was on par with vermicompost (15.33 cm). Lowest root spread was recorded by T_3 which was on par with T_{11}. Coir pith compost and vermicompost treatment were superior to package of practice recommendations of Kerala Agricultural University. Phosphorous plays a key role in root development, energy transformation and metabolic processes of plants and thus its ample availability perhaps resulted in greater translocation of photosynthetic towards root (Tisdale *et al.*, 1995). Inspite of the low phosphorous in coir pith, the treatments which received coir pith showed higher values for available P content in the soil and higher crop yield with increased P uptake indicating the positive effect of coir pith in P transformation in the soil (Savithri and Khan, 1994). The high water holding capacity of coir pith compost might have helped the roots for better moisture and nutrient availability which contributed to its better development. According to Singh (2001) coir pith has 400-600 per cent water holding capacity and this technique will be of immense value in long-term moisture conservation. Vermicompost application increased the availability of P to plants by higher phosphatase activity (Shuxin *et al*, 1991).

5.1.3.2 Root Weight

The application of various treatments produced significant effect on root weight of the plant at all growth stages (Table 10).

At 2 MAP, FYM (T_1) recorded maximum root weight (0.45 g) and was on par with coir pith compost (0.41 g), package of practice recommendations of Kerala Agricultural University (0.39 g) and FYM alone (0.41 g) as per POP recommendations of KAU. The performance of coir pith compost (T_7) was evident during later stages (4 MAP, 6 MAP, 8 MAP) and recorded a root weight of 1.12 g, 1.41 g and 1.58 g respectively. At 4 MAP coir pith compost was on par with FYM (0.95 g) and at 6 MAP it was on par with FYM (1.1 g) and vermicompost (1.22 g) and at 8 MAP it was on par with vermicompost (1.47 g) and POP recommendations of KAU (1.27 g). The initial superiority of FYM become evident from the maximum root weight at the initial stage. The contribution of essential nutrients at early stage by FYM might have contributed to better root growth and development, which in turn contributed to high root weight. According to Prasad and Venkateswarlu (1991) FYM application improved the soil structure and also supplied the essential plant nutrients.

At later stages the greater root length and root spread caused by P availability from coir pith compost might be the reason for greater root weight of coir pith compost treated plants and thus it performed superior to POP recommendations of KAU.

5.1.3.3 Root Volume

Various organic manures produced significant effect on root volume at all stages of growth except at 8 MAP (Table 11). At 2 MAP coir pith compost (T_7) recorded maximum root volume of 4 cm^3 and was on par with FYM (T_1) which recorded a root volume of 3.5 cm^3. At 4 MAP and 6 MAP also coir pith compost hold good and recorded a root volume of 7 cm^3 and 14.33 cm^3 respectively. At 4 MAP it was on par with neem cake (5.33 cm^3) and package of practice recommendations of Kerala Agricultural University (5.11 cm^3) and at 6 MAP it was on par with vermicompost (12.83 cm^3) and FYM (12.17 cm^3). FYM and coir pith compost performed superior to POP recommendations of KAU at different stages. The initial superiority of FYM might be due to its initial influence on root development. The superiority of coir pith compost in root volume might be due to the greater root length and root spread recorded by coir pith compost treatment.

5.1.4 Physiological Parameters

5.1.4.1 Dry Matter Production

Various organic manures produced significant influence on dry matter production of the plant (Table 12 and Fig. 3). Both at 2 MAP and 4 MAP, FYM

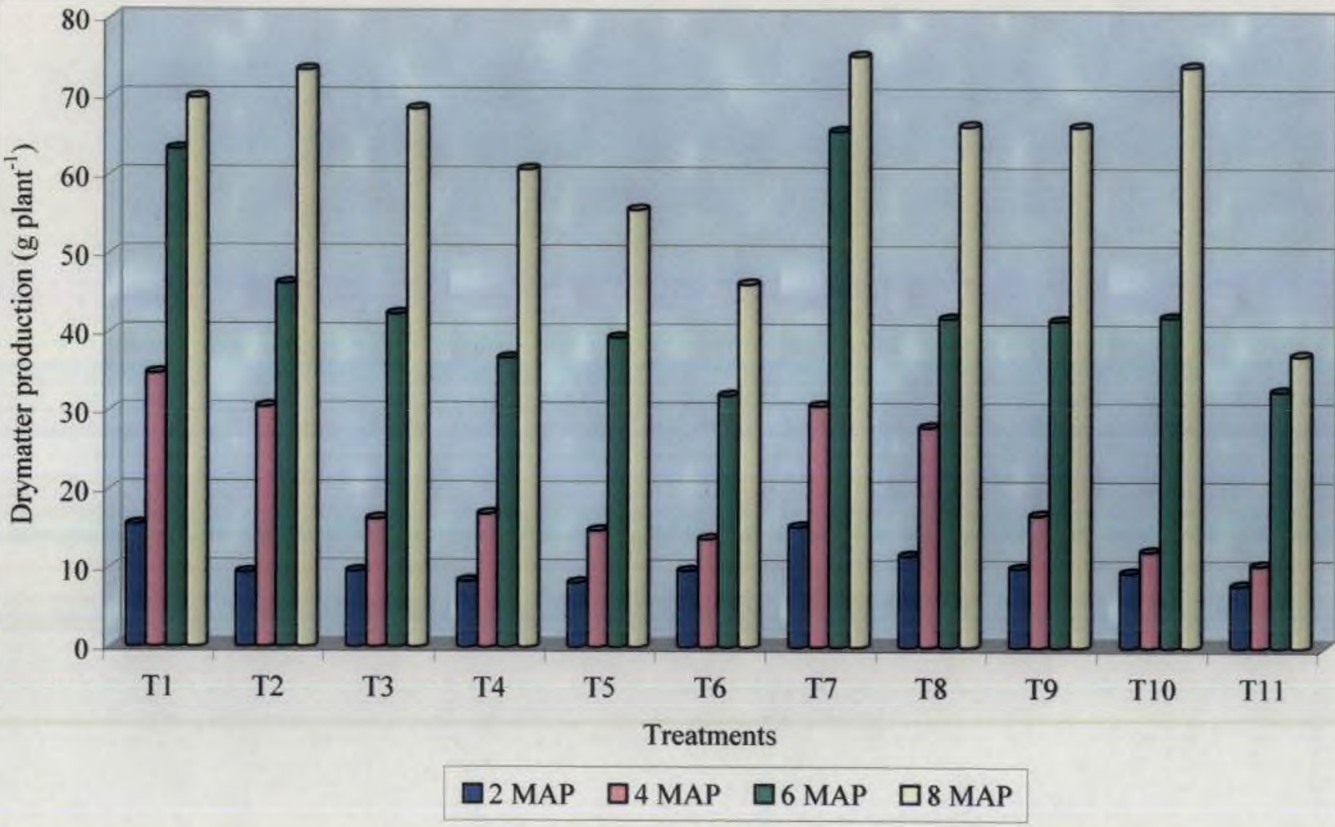

Fig. 3 Effect of organic manures on drymatter production in turmeric

(T_1) recorded maximum dry matter production (15.53 g plant $^{-1}$ and 34.77 g plant^{-1} respectively) and at 2 MAP it was on par with coir pith compost (T_7) which recorded a dry matter production of 15.33 g plant^{-1}.

At 6 MAP and 8 MAP coir pith compost produced maximum dry matter (65.7 g plant^{-1} and 75.25 g plant^{-1} respectively). At 6 MAP it was on par with FYM (63.31 g plant^{-1}) and at 8 MAP with FYM (69.84 g plant^{-1}), vermicompost (73.43 g plant^{-1}) neem cake (68.50 g plant^{-1}), package of practice recommendations of Kerala Agricultural University (66.37 g plant^{-1}), NPK alone as per POP recommendations of KAU (66.62 g plant^{-1}), FYM alone as per POP recommendations of KAU (73.98 g plant^{-1}). In the case of DMP, FYM, vermicompost and coir pith compost showed superiority over POP recommendations of KAU. The positive influence of FYM on tiller and leaf production at initial stages might have resulted in high dry matter production by FYM in the initial stages. This indicated the favourable effect of FYM on the growth and yield of turmeric. FYM application as an organic amendment increasing the dry matter production of bhindi was reported by Senthilkumar and Sekar (1998). The positive influence of vermicompost on vegetative characters contributed to its superiority over POP recommendations of KAU at 4 MAP. Worm cast when used in organic manure significantly influenced vegetative characters (Kale and Krishnamoorthy, 1981). Biometric observations *viz.*, height of the plant and number of leaves in tomato were greatly influenced by the application of vermicompost (Pushpa, 1996). The positive influence of coir pith compost on number of leaves and tillers on later stages of growth might have contributed to higher dry matter production by coir pith compost at later stages. According to Suja (2001) yam plants treated with coir pith compost put forth vigorous vegetative structures, maintained higher LAI during critical phases of tuber development and produced tubers with greater size and dry matter content.

5.1.4.2 Crop Growth Rate

At 60-120 DAP maximum CGR was recorded by vermicompost (T_2) treated plants (0.350 g m^{-2} day^{-1}) and was on par with FYM (T_1) which recorded a CGR of 0.337 g m^{-2} day^{-1}(Table 13). T_1 and T_2 were superior to package of practice recommendations of Kerala Agricultural University (T_8). At 120-180 DAP FYM recorded a maximum CGR of 0.650 g m^{-2} day^{-1} and was on par with coir pith compost (T_7) and FYM alone as per POP recommendations of KAU (T_{10}). These two treatments recorded a CGR of 0.577 g m^{-2} day^{-1} and 0.517 g m^{-2} day^{-1} respectively. T_1, T_7 and T_{10} were superior to POP recommendations of KAU (T_8). At 180-240 DAP FYM as per POP recommendations of KAU recorded maximum CGR of 0.530 g m^{-2} day^{-1} and was on par with vermicompost (0.440 g m^{-2} day^{-1}), neem cake (0.463 g m^{-2} day^{-1}), glyricidia leaves (0.407 g m^{-2} day^{-1}), POP recommendations of KAU (0.407 g m^{-2} day^{-1}) and NPK as per POP recommendations of KAU (0.430 g m^{-2} day^{-1}). From the table it was clear that FYM, vermicompost, coir pith compost and FYM alone as per POP recommendations of KAU shown superiority over POP recommendations of KAU at different stages of growth. George (1996) reported that the growth stimulating effect of vermicompost @ 5 t ha^{-1} was on par with farm yard manure @ 10 t ha^{-1} when applied alone as well as with a booster dose of 25 per cent NPK. Nutrients in the vermicompost were in a more readily available form (Albanell *et al.*, 1988). So in the present study higher CGR recorded by vermicompost and FYM treated plots might be due to the higher availability of nutrients and sufficiently good dry matter production by them. High dry matter production by coir pith compost might have contributed to its superiority in CGR over POP recommendations of KAU.

5.1.4.3 Relative Growth Rate

At 60-120 DAP vermicompost (T_2) recorded maximum RGR of 0.019 g day^{-1} (Table 14). At 120-180 DAP FYM as per package of practice recommendations of Kerala Agricultural University (T_{10}) recorded maximum RGR of 0.020 g day^{-1} and was on par with neem cake, poultry manure and absolute control. At 180- 240 DAP also T_{10} recorded maximum RGR of 0.009 g day^{-1} and was on par with vermicompost (0.007 g day^{-1}), neem cake (0.008 g day^{-1}), glyricidia leaves (0.008 g day^{-1}), biogas slurry (0.006 g day^{-1}), package of practice recommendations of Kerala Agricultural University (0.007 g day^{-1}) and NPK alone as per POP recommendations of KAU (0.007 g day^{-1}) Various treatments showed superiority over POP recommendations of KAU and these superiority vary with stages. The high rate of increase in dry matter production might have attributed to the varying superiority shown by the treatments in RGR.

5.1.4.4 Net Assimilation Rate

During initial stages of growth the effect of organic manures on NAR was not significant (Table 15). At 120-180 DAP NPK as per package of practice recommendations of Kerala Agricultural University (T_9) recorded maximum NAR of 0.087 g m^{-2} day^{-1} which was on par with FYM (0.080 g m^{-2} day^{-1}), neem cake (0.073 g m^{-2} day^{-1}), glyricidia leaves (0.067 g m^{-2} day^{-1}), poultry manure (0.063 g m^{-2}), coir pith compost (0.077 g m^{-2} day^{-1}) FYM alone as per POP recommendations of KAU (0.080 g m^{-2} day^{-1}) and absolute control (0.083 g m^{-2} day^{-1}). At 180-240 DAP maximum NAR was recorded by glyricidia leaves (0.070 g m^{-2} day^{-1}) which was on par with vermicompost (0.050 g m^{-2} day^{-1}), neem cake (0.067 g m^{-2} day^{-1}), POP recommendations of KAU (0.057 g m^{-2} day^{-1}), NPK alone as per POP recommendations of KAU (0.060 g m^{-2} day^{-1}) and FYM alone as per POP recommendations of KAU (0.063 g m^{-2} day^{-1}). High rate of NAR was an indication of high rate of photosynthesis. At 120-180 DAP T_1, T_3, T_7, T_{10} and T_{11} showed superiority over POP recommendations of KAU. The superiority of treatments might be due to the rate of increase in dry matter production.

5.1.4.5 Leaf Area Index

At 2 MAP and 4 MAP FYM (T_1) recorded maximum LAI of 3.18 and 7.53 respectively (Table 16 and Fig. 4). At 2 MAP FYM was on par with vermicompost (2.55), poultry manure (2.44), coir pith compost (3.00), package of practice recommendations of Kerala Agricultural University (2.78), NPK alone as per POP recommendations of KAU (2.65), and FYM alone as per POP recommendations of KAU (2.57) and at 4 MAP it was on par with vermicompost (5.98), poultry manure (6.07), coir pith compost (6.29) and POP recommendations

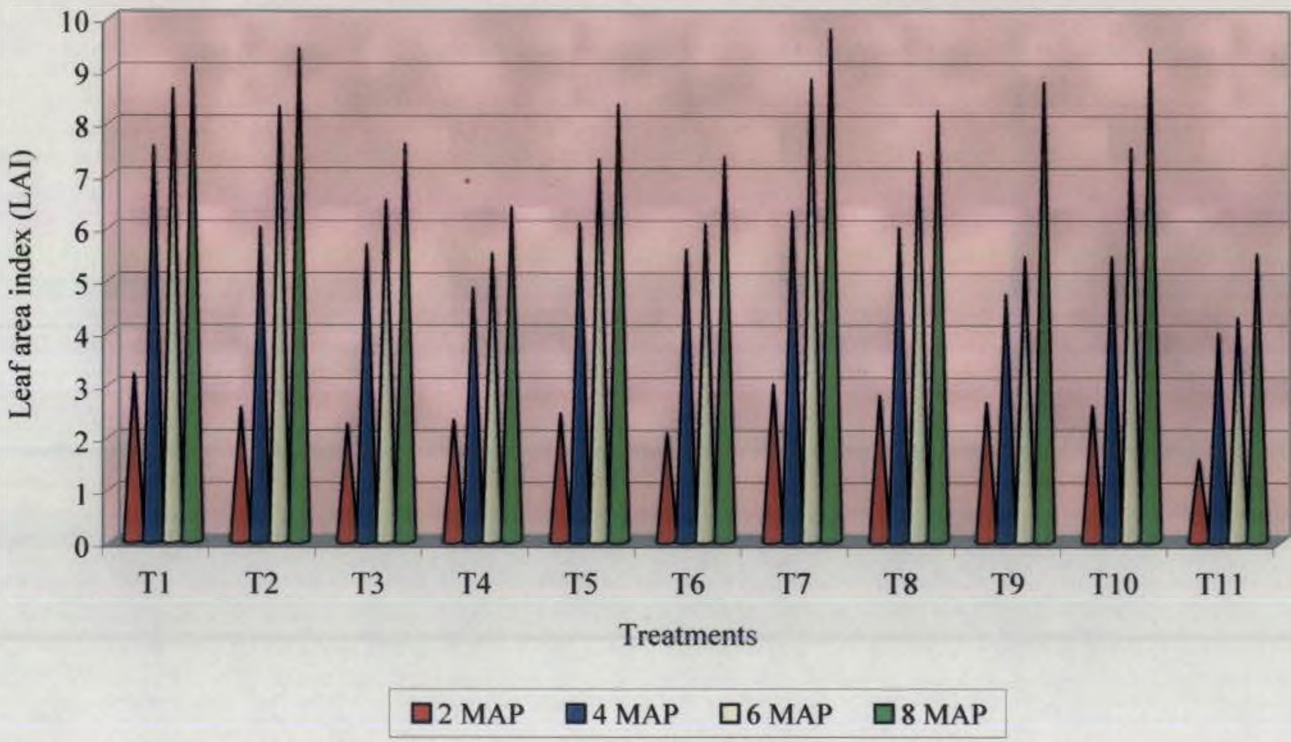

Fig. 4 Effect of organic manures on leaf area index in turmeric

of KAU (5.98). In the case of LAI the treatments which recorded maximum values were on par with POP recommendations of KAU (T_8) and no treatment performed superior to POP recommendations of KAU. The superiority of FYM at early stages might be due to its positive influence on leaf production. Enhanced production of leaves and increased longivity of leaves exhibited by plants receiving higher level of nutrients might have contributed to higher LAI in amaranthus (Arunkumar, 2000).

At 6 MAP T_7 recorded maximum LAI of 8.82 and was on par with FYM (8.63), vermicompost (8.29), package of practice recommendations of Kerala Agricultural University (7.43) and FYM alone as per POP recommendations of KAU (7.50). At 8 MAP also T_7 performed better by recording maximum LAI of 9.77 and was on par with FYM (9.07), vermicompost (9.40), poultry manure (8.34), POP recommendations of KAU (8.21), NPK alone as per POP recommendations of KAU (8.76) and FYM alone as per POP recommendations of KAU (9.40). The substantial contribution of a number of essential plant nutrients especially N coupled with higher uptake of N from coir pith compost increased the number of functional leaves and leaf size which in turn might have led to higher LAI. Similar finding was reported by Suja (2001) in yams.

5.1.4.6 Leaf Area Duration

The effect of organic manures on LAD was significant at various stages of growth (Table 17). At 60-120 DAP, FYM (T_1) recorded maximum LAD of 227.39 and was on par with vermicompost (180.67), poultry manure (183.42), coir pith compost (190.09) and package of practice recommendations of Kerala Agricultural University (180.89). At 120-180 DAP coir pith compost (T_7) recorded maximum LAD of 267.74 and was on par with FYM (262.76), vermicompost (251.79), POP recommendations of KAU (225.99) and FYM alone as per POP recommendations of KAU (227.61). At 180 - 240 DAP also coir pith compost performed superior with a LAD of 297.61 and was on par with all treatments except glyricidia leaves and absolute control. In the case of LAD also treatments which recorded maximum LAD were on par with POP recommendations of KAU. Increase in number of leaves leading to high LAI might have contributed to higher value of LAD.

5.1.4.7 Harvest Index

The effect of various treatments on harvest index was non significant. The maximum value was recorded by plants which received coir pith compost treatment (T_7) which recorded a HI of 0.873. Absolute control recorded a minimum HI of 0.670 (Table 18).

5.1.4.8 Root: Shoot Ratio

Root: shoot ratio was found to be significant at all stages of growth except at 8MAP (Table 19). At 2 MAP both FYM (T_1) and FYM alone as per POP recommendations of KAU (T_{10}) recorded maximum root : shoot ratio of 0.048 and was on par with package of practice recommendations of Kerala Agricultural University (0.040). At 4 MAP and 6 MAP coir pith compost recorded maximum root : shoot ratio of 0.065 and 0.047 respectively and at 4 MAP it was on par with FYM as per POP recommendations of KAU (0.051) and at 6 MAP it was on par with FYM (0.037), vermicompost (0.042), poultry manure (0.034), biogas slurry (0.041), POP recommendations of KAU (0.043), NPK as per package of practice recommendations of Kerala Agricultural University (0.038) and FYM alone as per POP recommendations of KAU (0.031) . Coir pith compost performed superior to POP recommendations of KAU (T_8). FYM though recorded high values at initial stages it was on par with T_8. Coir pith compost recorded high root weight at various stages of growth. Superiority in the root : shoot ratio might be due to the high root weight and low shoot weight at different stages of growth.

5.2 YIELD AND YIELD COMPONENTS

5.2.1 Rhizome Yield

The effect of organic manures on the rhizome yield of turmeric at 8 MAP was found to be significant (Table 20 and Fig. 5). Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). Coir pith compost received plots (T_7) recorded highest yield of 34.32

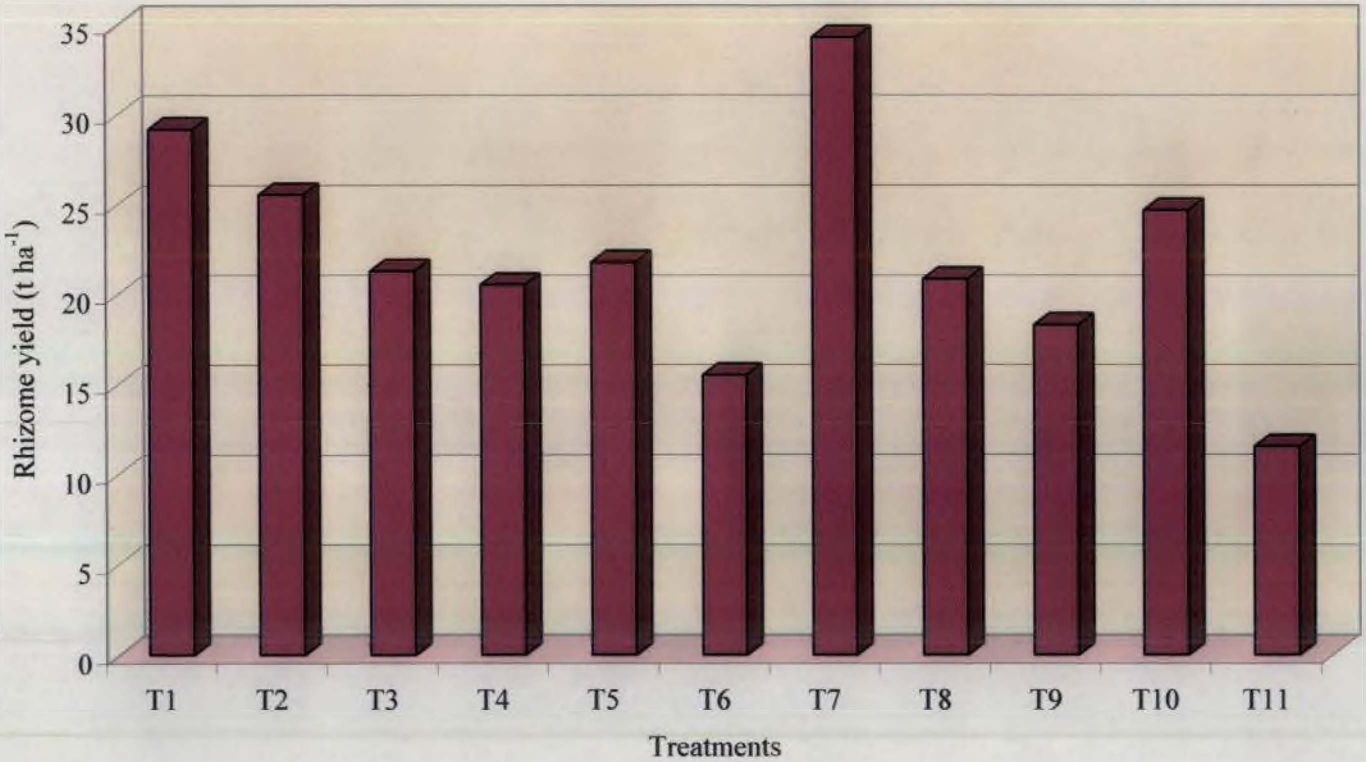

Fig. 5 Effect of organic manures on rhizome yield in turmeric

t ha^{-1} which was on par with FYM (T_1) applied plots (29.22 t ha^{-1}). Both coir pith compost and FYM performed superior to package of practice recommendations of Kerala Agricultural University (T_8) in the case of rhizome yield. The superiority in yield over POP recommendations of KAU shown by FYM and coir pith compost was 39.9 per cent and 64.37 per cent respectively. The positive influence of FYM in rhizome yield might be due to improvement in soil structure and increased availability of nutrients in FYM applied plots. Effect of FYM alone resulted in higher yields in elephant foot yam (Patel and Mehta, 1987) and turmeric (Balashanmugham *et al.*, 1989). Coir pith compost had beneficial effect as organic manure in increasing the yield of crops like turmeric (Selvakumari *et al.*, 1991). An increase in characters like plant height which had a positive influence on the rhizome yield might have contributed to high rhizome yield recorded by FYM and coir pith compost. Plant height was found to be positively associated with rhizome yield in turmeric (Govind *et al.*, 1981). Because of the sponge like structure of coir pith compost it helps to retain water and oxygen and prevent loss of vital nutrients and enhance the nutrient availability and thus plants might get sufficient nutrients from coir pith compost treated plots. Also coir pith has positive influence on physico-chemical properties of soil. Higher yield under coir waste might be due to more moisture retention capacity, improved soil physical conditions such as hydraulic conductivity and bulk density which resulted in loose and friable soil conditions conduce for better pod formation in groundnut (Rajagopal *et al.*, 1995). Introducing the coir dust based compost into INM systems would become a valuable tool for the farmers of southern states for sustaining the productivity of the soil (Kadalli *et al.*, 2000).

5.2.2 Top Yield

The influence of various treatments on top yield were insignificant at 240 DAP (Table 20). However the maximum top yield was recorded by NPK alone as per package of practice recommendations of Kerala Agricultural University (T_9) which gave a value of 21.58 g and the lowest value given by poultry manure (8.27 g).

5.2.3 Dry Turmeric

At 2 MAP coir pith compost (T_7) recorded higher dry turmeric weight of 1.62 g plant^{-1}. At 4 MAP vermicompost (T_2) recorded the maximum weight for dry turmeric (12.13 g plant^{-1}). At 6 MAP FYM (T_1) was superior in dry weight of turmeric (30.57 g plant^{-1}) and at final stage of growth (8 MAP) coir pith compost recorded a maximum dry turmeric weight of 59.35 g plant^{-1} (Table 21). The greater uptake of N and K from coir pith compost might have resulted in high dry matter accumulation of rhizome. Similar findings were reported by (Suja, 2001) in yams. Many treatments like FYM, vermicompost, poultry manure, coir pith compost, NPK alone as per package of practice recommendations of Kerala Agricultural University and FYM alone as per POP recommendations of KAU were superior to POP recommendations of KAU at different stages. This shows the positive effect of organic manures on yield characters. Organic manures improve the yield of vegetable crops like tomato, onion, gourds, chillies *etc* (Rani *et al.*, 1997).

5.2.4 Bulking Rate

At 60-120 DAP vermicompost (T_2) recorded a bulking rate of 0.351 (Table 22) and was superior to POP recommendations of KAU and it was on par with FYM. At 120-180 DAP coir pith compost recorded maximum bulking rate of 0.583 which was on par with FYM alone as per package of practice recommendations of Kerala Agricultural University (T_{10}) and recorded a value of 0.498 and at this stage all other treatments except vermicompost and biogas slurry were superior to POP recommendations of KAU. Vermicompost and biogas slurry were on par with POP recommendations of KAU. At 180-240 DAP FYM (T_{10}) recorded maximum bulking rate of 0.531 and was on par with vermicompost (0.453), neem cake (0.436), glyricidia leaves (0.401), POP recommendations of KAU (0.408) and NPK alone as per POP recommendations of KAU (0.417). Superiority shown by the treatments might be due to the significant effect on growth characters and increased rate of dry matter production.

5.3 QUALITY ANALYSIS

5.3.1 Volatile Oil

The maximum volatile oil content was recorded from coir pith compost (T_7) treated plots (5.37 %) and was on par with package of practice recommendations of Kerala Agricultural University (5.10 %), NPK alone as per POP recommendations of KAU (5.03%) and FYM alone as per POP recommendations of KAU (5.33 %) (Table 23 and Fig. 6). Profound influence of N on the oil content of coriander seeds was reported by Rao *et al.* (1983). N showed significant effect on the volatile oil content in bush pepper (Devadas, 1997). In an experiment using micronutrients in solution in lemon grass it was seen that the oil content reduced from 1.22 to 0.67 per cent and 0.50 per cent respectively in Cu and Fe deficient plants (Anon.1983). Coir pith compost contributed a number of essential plant nutrients both macro and micronutrients like N, P, K, Ca, Mg, Fe, Mn, Zn and Cu for crop nourishment (Suja, 2001) in yams. The supply of essential nutrients by coir pith compost might have lead to an increase in volatile oil content.

5.3.2 Curcumin

The effect of organic manures on curcumin content were not significant. The highest value was recorded by FYM (T_1) which recorded a curcumin content of 5.20 percent and lowest value of 4.60 per cent by absolute control (Table 23).

5.4 SOIL ANALYSIS

5.4.1 Physical Properties

The physical parameters of the soil did not differ significantly due to the influence of various organic manures (Table 24). As explained by Brady (1996), organic matter stimulates the formation and stabilization of granular and crumb type aggregrates, facilitates greater pore space and lowers the specific gravity of soils. It is important to note that the extent of physical improvements in the soil brought about by the various organic manures evaluated in this study was not significant though there was an increase from the initial soil values.

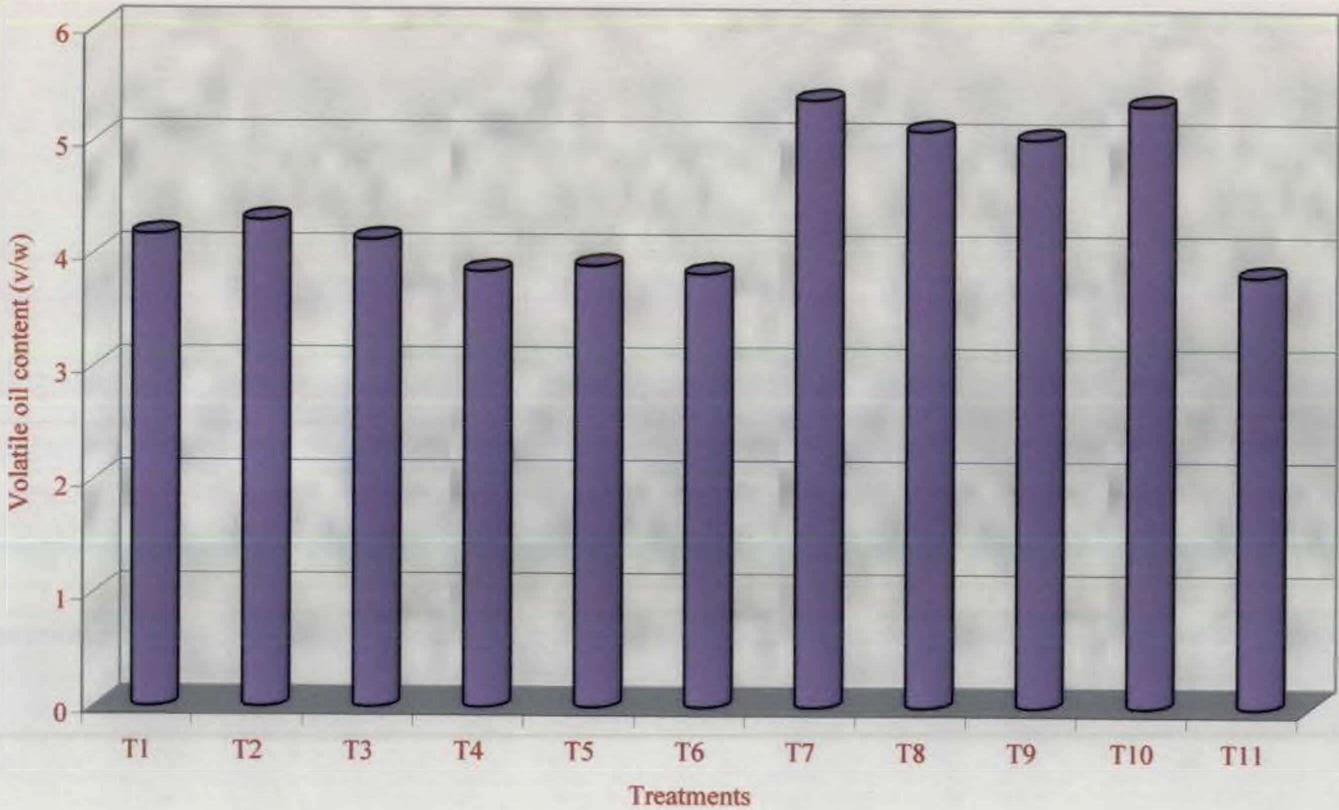

Fig. 6 Effect of organic manures on volatile oil content in turmeric

5.4.2 Chemical Properties of Soil

The effect of organic manures on soil pH and organic carbon were insignificant (Table 25). However FYM (T_1) recorded high value for soil pH (5.74) and organic carbon content (0.58 %).

Organic manures recorded significant effect on NPK status of soil (Table 26 and Fig 7). Srivastava (1985) observed that the application of organic manures resulted in increased total N and available P and K status of soil. Green manure crops prevent leaching of nutrients to the lower layers (Ramakrishnan and Rangarajan, 1993).

In the case of nitrogen the content was significantly higher (185.12 kg ha^{-1}) in plots that received glyricidia leaves (T_4) which was on par with vermicompost (T_2) applied plots (181.21 kg ha^{-1}). Green manuring enhances available N content of soils (Russell, 1973 ; Singh *et al.*, 1991; Singh *et al.*, 1992). Prabhakar and Nair (1987) and Nayar *et al.* (1993) also noted similar effects of *in situ* green manuring using cowpea in cassava.

In the case of soil P glyricidia leaves (T_4) significantly enhanced available P status of soil and recorded a value of 42.97 kg ha^{-1} and was on par with FYM (T_1), vermicompost (T_2) and coir pith compost (T_7) treatment. Enhancement in the available P content of soil due to green manuring was also noticed by Nayar *et al.* (1993) in cassava. Utilization of insoluble phosphates through the well developed root system of green manures and its subsequent mineralization (Gu and Wen, 1981) coupled with the mineralization of organically bound P due to the interaction of organic acids with soil components during the course of decomposition of green manures (Bin, 1983; Watnabe, 1984) would have enriched the pool of available P.

Glyricidia leaves (T_4) recorded significant difference in soil K content and recorded a value of 172.30 kg ha^{-1} which was on par with vermicompost (T_2). Nayar *et al.* (1993) observed similar effect of cowpea green manuring in cassava. This is attributed to the organic acid dissolution of insoluble K minerals consequent to green manure decomposition (Agboola, 1974) and recycling of K

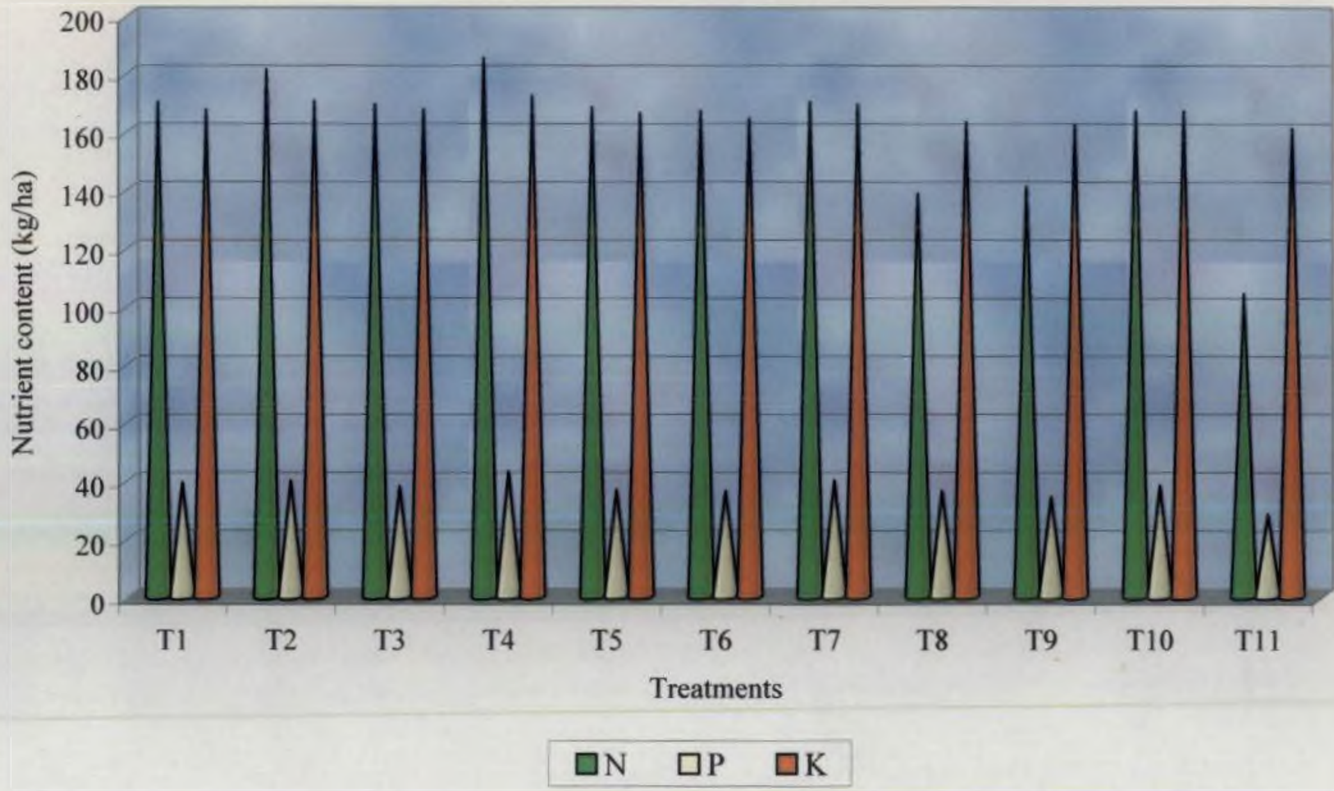

Fig. 7 Effect of organic manures on residual soil nutrient status

from the subsurface layer by the extensive root system of the legume (Hargrove, 1986).

In the case of soil N and K almost all treatments except T_9 and T_{11} were superior to package of practice recommendations of Kerala Agricultural University which indicates the positive influence of organic manures on soil nutrient status. In the case of soil P all treatments except absolute control was on par with POP recommendations of KAU and T_4 was superior to POP recommendations of KAU. Srivastava (1985) observed that the application of organic manures resulted in increased total N and available P and K status of soil.

5.5 WEED BIOMASS

Organic manures produced no significant effect on weed biomass at different stages of growth (Table 27).

5.6 B : C RATIO

Maximum B:C ratio was recorded by coir pith compost (T_7) treatment (2.09). The next best option was FYM (T_1) which gave a BCR of 1.94 (Table 28 and Fig. 8). These two treatments showed superiority over package of practice recommendations of Kerala Agricultural University. Per unit cost of FYM (Rs. 0.28 kg^{-1}) is less than that of coir pith compost (Rs. 3 kg^{-1}). Therefore substitution of coir pith compost with FYM can be done if situation warrants. Though per unit cost of FYM was less than coir pith compost, coir pith compost showed its superiority by recording highest yield. Since coir pith is available in plenty in our state, efforts should be taken for its full utilization which will reduce environmental pollution. In sandy soil coir waste application at 10 t/ha resulted in increased pod yield of pea nut and realization of higher benefit-cost ratio (Arunachalam, 1987).

The study clearly revealed the significant effect of organic manures on growth yield and quality of turmeric grown as an intercrop in coconut garden. In the case of growth characters though FYM and coir pith compost were found to be the best sources, other organic manures like vermicompost, neem cake, green leaves, poultry manure and biogas slurry gave comparable results at various stages

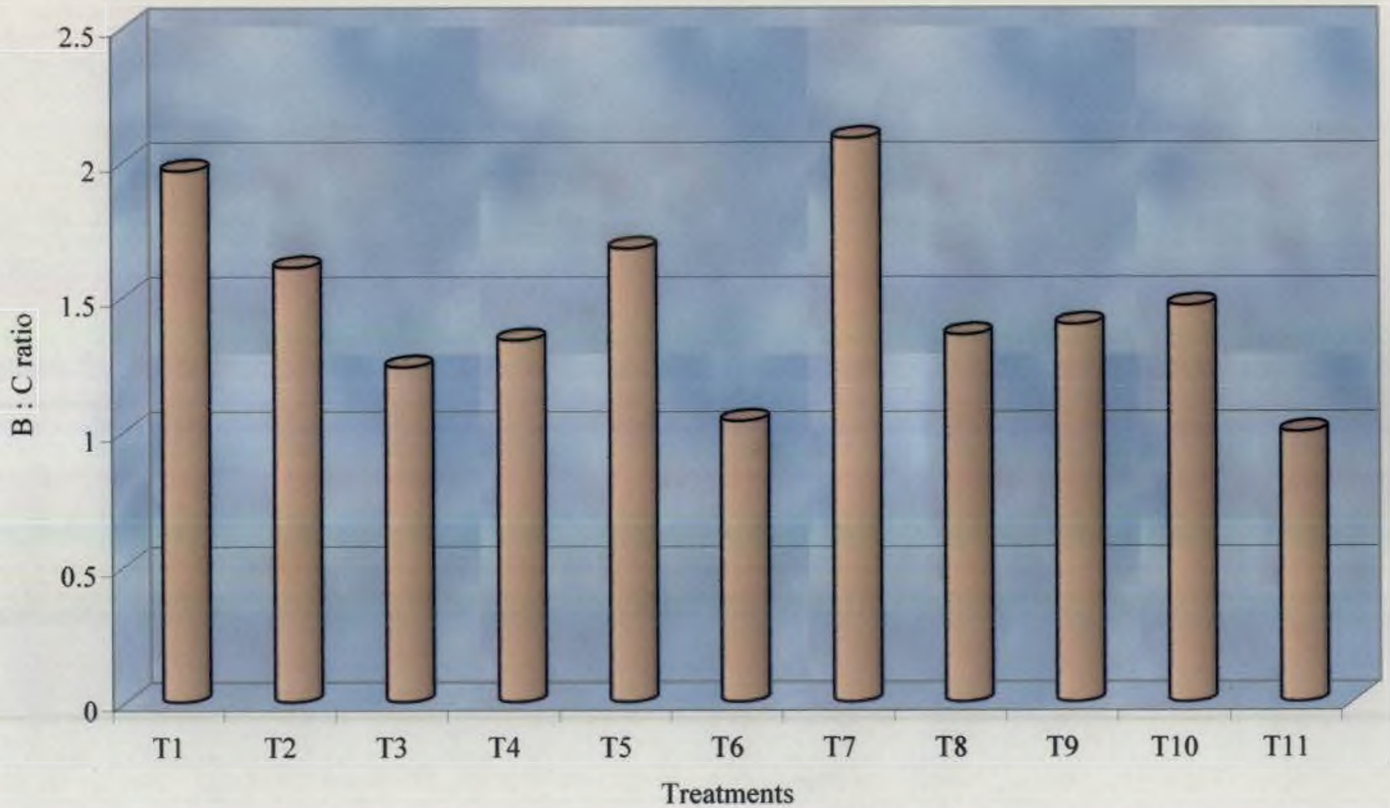

Fig. 8 Effect of organic manures on B : C ratio of turmeric

of growth. In the case of rhizome yield, coir pith compost and FYM performed superior to POP recommendations of KAU and these two treatments were on par. Rest of the organic manures were on par with POP recommendations of KAU. In the case of quality aspects maximum volatile oil content was obtained from plants which received coir pith compost and was on par with POP recommendations of KAU, NPK alone as per POP recommendations of KAU and FYM alone as per POP recommendations of KAU. Thus the significant impact of organic manures in the current research brings out the suitability of organic manures as a substitute for inorganic fertilizers for successful turmeric cultivation. Further more such a system of intercropping provides gainful employment and fetches high return.

Future Line of Work

Considering the over all beneficial influence of organic sources on soil and plant environment, it would be more appropriate to initiate studies on the various combinations of organic manures. The study has to be continued for second and third year also to get confirmatory results. Since the residual soil nutrient values were high in the experimental plots raising another crop without further addition of organic manure will be useful to assess the residual effect of organic manures on crop growth. Also, productivity of coconut as influenced by intercrop and the effect of coconut on intercrops should be studied in future. Similar study with coir pith compost and other organic manures on other spice crops will explore the importance of these manures in augmenting the spice production of the state.

SUMMARY

6. SUMMARY

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from June 2001 to February 2002. The main objectives of the study were to find out the effect of organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden and to assess the relative efficiency of organic manures as substitute to inorganic fertilizers.

The trial was conducted in Randomised Block Design (RBD) with eleven treatments and three replications. The treatments included seven sources of organic manures, organic and inorganic fertilizers as per package of practice recommendations of Kerala Agricultural University (30:30:60 Kg NPK ha^{-1} + 40 t ha^{-1} FYM), NPK alone as per POP recommendations of KAU, FYM alone as per POP recommendations of KAU and an absolute control. The organic manures consisted of FYM, vermicompost, neem cake, green leaves (glyricidia leaves), poultry manure, biogas slurry and coir pith compost. The treatments (except absolute control) were tried on nitrogen equivalent basis. The findings of the investigation are summarized below:

1. The height of the plant was significantly influenced by organic manures at all stages of growth except at 4 MAP. At 2 MAP maximum plant height of 32.13 cm was showed by plants which received FYM. At 6 MAP and 8 MAP maximum plant height of 48.6 cm and 54.33 cm respectively were recorded by plants which received coir pith compost as treatment. FYM showed its superiority during initial stage of growth and coir pith compost showed its superiority during later stages of growth. At all stages of growth, absolute control showed lowest plant height. Vermicompost, neem cake, glyricidia leaves, poultry manure, organic and inorganic fertilizers as per package of practice recommendations of Kerala Agricultural University and FYM alone as per POP recommendations of KAU gave good performance at different growth stages.

2. Organic manures had significant influence on number of tillers per plant at all growth stages except at 2 MAP. At 4 MAP, FYM produced maximum tillers (1.60) and it was on par with vermicompost. At 6 MAP and 8 MAP coir pith compost received plants produced maximum tiller number of 2.30 and 2.80 respectively and was on par with FYM at both stages. At all stages of growth absolute control performed poor with lowest number of tillers per plant.

3. Different organic manures influenced the number of leaves per plant at all stages except at 4 MAP. At 2 MAP, FYM recorded the highest number of leaves where as coir pith compost recorded the highest leaf number at 6 MAP and 8 MAP. Organic and inorganic fertilizers as per package of practice recommendations of Kerala Agricultural University, NPK alone as per POP recommendations of KAU, vermicompost, poultry manure and FYM alone as per POP recommendations of KAU gave good performance at different growth stages.

4. Rhizome spread was influenced by organic manures only at 8 MAP during which maximum rhizome spread was recorded by coir pith compost treatment and it was on par with FYM.

5. The effect of organic manures on rhizome thickness was significant only at 8 MAP during which maximum rhizome thickness was produced by coir pith compost treatment and was on par with FYM, vermicompost, glyricidia leaves, poultry manure, biogas slurry, organic and inorganic fertilizers as per package of practice recommendations of Kerala Agricultural University, NPK alone as per POP recommendations of KAU and FYM alone as per POP recommendations of KAU.

6. The influence of organic manures on root length was significant only at later stages of growth like 6 MAP and 8 MAP. At both these stages coir pith compost treatment produced maximum root length and was on par with vermicompost, neem cake, FYM and organic and inorganic fertilizers as per package of practice recommendations of Kerala Agricultural University.

7. Different organic manures influenced root spread of turmeric plant at 8 MAP only, highest value being recorded by coir pith compost treatment which was on par with vermicompost. These two treatments were superior to package of practice recommendations of Kerala Agricultural University.

8. Organic manures had significant influence on root weight at different stages of growth. At 2 MAP, FYM produced maximum root weight. At 4 MAP, 6 MAP and 8 MAP coir pith compost treatment produced maximum root weight. Package of practice recommendations of Kerala Agricultural University, FYM alone as per POP recommendations of KAU, vermicompost gave good performance at different stages. At 4 MAP and 6 MAP coir pith compost was superior to POP recommendations of KAU.

9. Different organic manures had significant effect on root volume at all stages except at 8 MAP. At 2 MAP, 4 MAP and 6 MAP coir pith compost recorded maximum root volume and was superior to package of practice recommendations of Kerala Agricultural University at 2 MAP and 6 MAP. FYM, neem cake, and vermicompost gave good performance at different stages.

10. FYM was found to be the best organic manure for the highest DMP during 2 MAP and 4 MAP. At 2 MAP and 4 MAP, FYM was superior to package of practice recommendations of Kerala Agricultural University and was on par with coir pith compost. At 6 MAP and 8 MAP coir pith compost treatment produced maximum DMP. At 6 MAP coir pith compost was on par with FYM and these two treatments were superior to POP recommendations of KAU. At 8 MAP coir pith compost was on par with FYM, vermicompost, neem cake, POP recommendations of KAU, NPK alone and FYM alone as per POP recommendations of KAU.

11. Significant influence of organic manures on CGR was observed at all growth stages. At various stages of growth different treatments showed superiority in CGR. At 60-120 DAP maximum CGR was produced by vermicompost and was on par with FYM and these two treatments superior to package of practice recommendations of Kerala Agricultural University. At 120-180 DAP FYM

produced maximum CGR and was on par with coir pith compost and FYM alone as per POP recommendations of KAU. At 180-240 DAP FYM alone as per POP recommendations of KAU produced maximum CGR and was on par with vermicompost, neem cake, glyricidia leaves, POP recommendations of KAU and NPK alone as per POP recommendations of KAU.

12. RGR was appreciably influenced by organic manures. At 60-120 DAP maximum RGR recorded by vermicompost and was superior to package of practice recommendations of Kerala Agricultural University. At 120-180 DAP and 180-240 DAP FYM alone as per POP recommendations of KAU recorded maximum RGR and at 120-180 DAP it was superior to POP recommendations of KAU.

13. Organic manures had profound influence on NAR at all growth stages. At 60-120 DAP vermicompost recorded maximum NAR and at 120-180 DAP NPK alone as per package of practice recommendations of Kerala Agricultural University recorded maximum NAR and was superior to POP recommendations of KAU and at 180-240 DAP maximum NAR was recorded by glyricidia leaves.

14. Organic manures had significant effect on LAI at all stages of growth. At 2 MAP and 4 MAP; FYM produced maximum LAI and at 6 MAP and 8 MAP coir pith compost produced maximum LAI. No treatment was superior to package of practice recommendations of Kerala Agricultural University.

15.Organic manures had positive influence on LAD at various stages. AT 60-120 DAP, FYM recorded maximum LAD and at 120-180 DAP and at 180- 240 DAP coir pith compost recorded maximum LAD. No treatment was superior to package of practice recommendations of Kerala Agricultural University.

16. Except at 8 MAP organic manures have positive influence on root: shoot ratio. At 2 MAP, FYM produced maximum root : shoot ratio. At 4 MAP and 6 MAP coir pith compost recorded maximum root : shoot ratio. At 4 MAP coir pith

compost treatment was superior to package of practice recommendations of Kerala Agricultural University.

17. Different organic manures exerted significant difference in rhizome yield. The highest rhizome yield was produced by coir pith compost treatment and the lowest by absolute control. The rhizome yield produced by coir pith compost was on par with FYM and these two treatments were superior to package of practice recommendations of Kerala Agricultural University.

18. Coir pith compost as the source of organic manure recorded the highest value of dry turmeric at 2 MAP and 8 MAP and was superior to package of practice recommendations of Kerala Agricultural University during both the stages. AT 4 MAP vermicompost was superior in dry turmeric weight. The next best value was given by coir pith compost treatment and these two were superior to POP recommendations of KAU. At 6 MAP FYM produced maximum dry turmeric and except neem cake, green leaves, biogas slurry and absolute control all treatments were superior to POP recommendations of KAU at this stage of growth.

19. Rhizome bulking rate was influenced by different organic manures at all growth stages. At 60-120 DAP vermicompost recorded maximum rhizome bulking rate and was on par with FYM. Vermicompost was superior to package of practice recommendations of Kerala Agricultural University. At 120-180 DAP coir pith compost recorded maximum bulking rate and was on par with FYM alone as per POP recommendations of KAU. At this stage, no treatment was inferior to POP recommendations of KAU. At 180-240 DAP, FYM alone as per POP recommendations of KAU produced maximum bulking rate. Vermicompost, neem cake, glyricidia leaves, POP recommendations of KAU and NPK alone as per POP recommendations of KAU gave comparable values during this stage

20. Various organic manures have positive influence on the quality aspect like volatile oil content. Maximum volatile oil content was produced by coir pith compost treatment which was on par with package of practice recommendations

of Kerala Agricultural University, NPK alone as per POP recommendations of KAU and FYM alone as per POP recommendations of KAU. Absolute control recorded minimum volatile oil content.

21. Organic manures had no significant influence on the physical properties of soil.

22. Among the chemical properties of soil organic manures had not significantly influenced soil pH and organic carbon content. But the NPK status of the soil was much influenced by organic manures. In the case of soil N, glyricidia leaves recorded maximum value and was on par with vermicompost. Except NPK alone as per package of practice recommendations of Kerala Agricultural University and absolute control all other treatments were superior to POP recommendations of KAU. In the case of soil P and K also glyricidia leaves recorded maximum value and in the case of soil P glyricidia leaves was superior to POP recommendations of KAU. FYM, vermicompost and coir pith compost also gave comparable results in the case of soil P. In the case of soil K, glyricidia leaves was on par with vermicompost. Except poultry manure, biogas slurry, NPK alone as per POP recommendations of KAU and absolute control, all other treatments were superior to POP recommendations of KAU.

23. B:C ratio was maximum for coir pith compost treatment and was superior to package of practice recommendations of Kerala Agricultural University. FYM, vermicompost and poultry manure treatments also gave comparable values. Lowest B: C ratio was recorded by absolute control.

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*Original not seen

APPENDICES

Appendix I: Weather parameters during the crop period -weekly averages

Standard week	Temperature, °C		Relative Humidity, %		Rainfall, mm	Evaporation, mm	Sunshine hours	Wind speed, km hr^{-1}
	Maximum	Minimum	7.22 am	2.22 pm				
22 (May 28-June 3)	29.47	21.68	83.28	27.14	38.20	3.42	41.10	6.28
23 (June 4-June 10)	28.64	20.08	85.85	77.43	31.00	2.47	38.40	6.33
24 (June 11-June 17)	28.70	20.92	93.00	82.57	71.20	2.11	34.60	5.42
25 (June 18-June 24)	30.00	21.90	90.60	74.10	46.90	3.30	36.50	8.50
26 (June 25-July 1)	29.70	20.80	89.00	75.90	36.80	3.40	37.00	6.60
27 (July 2-July 8)	28.50	20.00	93.90	80.40	102.00	3.00	34.40	3.70
28 (July 9-July 15)	29.80	20.60	88.30	74.10	169.70	3.30	37.00	3.70
29 (July 16-July 22)	29.90	20.70	87.40	68.40	0.00	6.40	62.30	11.00
30 (July 23-July 29)	29.30	20.20	90.40	75.00	22.40	3.60	37.80	7.10
31 (July 30-Aug 5)	27.60	19.30	91.00	76.90	63.10	3.80	38.40	8.00
32 (Aug 6-Aug 12)	30.40	21.20	87.60	77.10	0.00	5.00	59.80	11.10
33 (Aug13-Aug 19)	30.50	21.20	93.00	78.60	13.20	3.60	55.10	9.70
34 (Aug 20-Aug 26)	29.70	21.10	91.10	75.60	106.60	3.40	37.20	10.60
35 (Aug 27-Sep 2)	29.20	23.70	91.90	79.30	5.20	3.80	49.50	11.40
36 (Sep 3-Sep 9)	31.00	23.80	88.10	68.30	0.00	6.90	70.40	11.70

Appendix I: (Continued…)

Standard week	Temperature,°C		Relative Humidity, %		Rainfall, mm	Evaporation, mm	Sunshine hours	Wind speed, km hr^{-1}
	Maximum	Minimum	7.22 am	2.22 pm				
37 (Sep 10-Sep 16)	32.90	23.60	82.40	67.70	0.00	6.30	63.00	10.90
38 (Sep 17-Sep 23)	29.50	23.60	92.30	81.30	294.00	2.80	33.90	6.00
39 (Sep 24-Sep 30)	28.20	23.30	94.90	86.10	264.40	3.00	39.10	6.90
40 (Oct 1-Oct 7)	30.00	24.40	89.70	73.90	15.80	3.30	53.50	9.70
41 (Oct 8-Oct 14)	40.00	23.70	91.90	72.90	30.80	4.80	52.07	8.30
42 (Oct 15-Oct 21)	29.50	24.00	93.10	79.70	89.60	3.00	39.60	8.60
43 (Oct 22-Oct 28)	30.25	23.9	92.00	71.42	3.00	2.90	38.80	6.30
44 (Oct 29-Nov 4)	31.10	24.17	93.14	70.42	0.00	3.50	53.30	6.28
45 (Nov 5-Nov 11)	30.44	30.27	92.57	73.14	54.20	2.80	31.40	6.00
46(Nov 12-Nov 18)	29.72	23.14	92.85	75.28	146.00	3.62	28.40	6.00
47 (Nov 19-Nov 25)	30.54	23.47	96.14	69.85	37.90	2.80	45.30	6.57
48 (Nov 26-Dec2)	30.52	23.2	93.00	68.42	0.00	3.04	58.30	6.00
49 (Dec 3-Dec 9)	31.01	22.9	94.57	69.42	8.60	2.72	59.00	5.66
50 (Dec 10-Dec 16)	30.55	20.05	91.00	59.00	0.00	3.11	53.70	6.33

Appendix I: (Continued...)

Standard week	Temperature, °C		Relative Humidity, %		Rainfall, mm	Evaporation, mm	Sunshine hours	Wind speed, km hr^{-1}
	Maximum	Minimum	7.22 am	2.22 pm				
51 (Dec 17-Dec 23)	30.97	22.38	94.42	67.43	3.70	2.40	42.60	5.14
52 (Dec 24-Dec 30)	30.90	23.5	94.28	69.28	8.30	2.94	52.20	6.85
53 (Dec 31-Jan 6)	31.37	23.01	95.42	62.85	0.00	2.36	65.10	6.57
54 (Jan 7-Jan 13)	30.98	22.95	95.42	64.57	0.00	3.11	60.40	6.28
55 (Jan 14-Jan 20)	30.72	19.45	94.28	55.85	0.00	3.30	62.30	7.14
56 (Jan 21-Jan27)	31.21	23.37	94.71	67.85	0.00	3.40	42.40	8.00
57 (Jan 28-Feb 3)	30.24	23.00	92.85	66.14	15.00	2.80	31.00	4.85
58 (Feb 4-Feb 10)	31.22	22.70	93.42	61.28	0.00	3.00	46.60	6.28

APPENDIX-II

Quantity of organic manures (on N equivalent basis) (kg) applied to substitute inorganics

Bed size : 3m x 1 m

Organic manure	Quantity (on wet weight basis)
FYM	6.12
Vermicompost	8.57
Neem cake	3.06
Glyricidia leaves	1.17
Poultry manure	2.67
Biogas slurry	2.86
Coirpith compost	3.57

NUTRIENT MANAGEMENT IN TURMERIC (*Curcuma longa* L.) THROUGH ORGANIC MANURES

RAKHEE, C.K.

Abstract of the
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Department of Plantation Crops and Spices
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM 695522

8. ABSTRACT

An experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani during June 2001 to February 2002 to evaluate the effect of organic manures on growth, yield and quality of turmeric grown as an intercrop in coconut garden and to assess the relative efficiency of organic manures as substitute to inorganic fertilizers. The experiment consisted of eleven treatments and three replications laid out in RBD. The organic manures used were FYM, vermicompost, neem cake, green leaves, poultry manure, biogas slurry and coir pith compost. Organic manures were applied on nitrogen equivalent basis.

The results of the study revealed that the growth characters, rhizome yield as well as quality aspects like volatile oil content of turmeric were significantly influenced by various organic manures. But harvest index, top yield, curcumin content, soil properties except NPK content were not significantly influenced by various organic manures. In the case of weed biomass also no significant influence was noticed. FYM, vermicompost and coir pith compost performed well in the case of growth characters. Though FYM and coir pith compost maintained their superiority at various growth stages regarding plant height, number of leaves, number of tillers, dry matter production, LAI, LAD, and root: shoot ratio, other organic manures like neem cake, green leaves, poultry manure and biogas slurry gave comparable results at various stages of growth.

Regarding rhizome spread and thickness, coir pith compost performed superior and the superiority was present only during later stages of growth. . In the case of root spread, root length and root volume also coir pith compost was the best treatment. At initial stage of growth maximum root weight was produced by FYM and at later stages coir pith compost performed better.

In the case of CGR and RGR, FYM and vermicompost performed better. In the case of NAR maximum values were produced by vermicompost, green leaves and NPK alone as POP recommendations of KAU.

Coir pith compost as the source of organic manure had positive influence on rhizome yield which was on par with FYM. Coir pith compost, vermicompost and

FYM performed better than other treatments in the case of dry turmeric and bulking rate at various stages of growth. Absolute control treatment recorded lower values in the case of growth and yield characters.

Quality of turmeric improved with various organic manures. Volatile oil content was highest in the case of coir pith compost treatment and it was on par with POP recommendations of KAU, NPK alone as per POP recommendations of KAU and FYM alone as per POP recommendations of KAU.

In the case of residual nutrients high soil NPK values were registered by green leaves.

B: C ratio was maximum when coir pith compost was used as the organic manure and it was on par with FYM, vermicompost and poultry manure.

The significant impact of organic manures in the current research brings out the suitability of organic manures as a substitute for inorganic fertilizers for successful turmeric cultivation.