VERMICOMPOST ENRICHED WITH ORGANIC ADDITIVES FOR SUSTAINABLE SOIL HEALTH

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DECLARATION

I hereby declare that this thesis entitled "**Vermicompost enriched with organic additives for sustainable soil health**" 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.

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CERTIFICATE

Certified that this thesis entitled "**Vermicompost enriched with organic additives for sustainable soil health**" is a record of research work done independently by Ms. Sheeba P.S. (2002-11-21) 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.

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Dedicated to
My Family

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CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	–	Per cent
μSm^{-1}	–	Micro siemens per metre
B:C ratio	–	Benefit – cost ratio
BD	–	Bulk density
BM	–	Bone meal
CEC	–	Cation exchange capacity
cm	–	Centimetre
cmole	–	Centimole
CRD	–	Completely randomised design
DAT	–	Days after transplanting
EC	–	Electrical conductivity
et al.	–	And others
EVC	–	Enriched vermicompost
Fig.	–	Figure
FYM	–	Farmyard manure
g	–	Gram
ha	–	Hectare
ha^{-1}	–	Per hectare
IU	–	International unit
kg	–	Kilogram
mg	–	Milligram
$Mg\ m^{-3}$	–	Mega gram per cubic metre
NC	–	Neem cake
OVC	–	Ordinary vermicompost
RBD	–	Randomised block design
SE	–	Standard error
t	–	Tonne
VC	–	Vermicompost
viz.	–	Namely
WHC	–	Water holding capacity

INTRODUCTION

1. INTRODUCTION

Agriculture continues to be the backbone of Indian economy. Modern agriculture with its potential to take the country out of the food trap and to reach the era of self sufficiency in food grain production brought a plethora of environmental problems and declining productivity in agriculture and depletion of soil fertility. Continuous use of synthetic materials such as fertilizers, pesticides and weedicides results in soil pollution, water pollution, air pollution and create potential health hazards in food. Food quality is also deteriorating day by day. Indiscriminate use of chemical pesticides to control insect pest and diseases over the years has naturally destroyed the biological control agents. Long term field experiments have made clear the negative impact of continuous use of chemicals on soil health (Yadav, 2003). The occurrence of multi nutrient deficiencies and overall decline in the productivity of soil under intensive fertilizer use have widely reported (Chhonkar, 2003). The solution lies in bringing about a change to a more ecologically sound, sustainable and self generating agricultural system *i.e.,* organic farming. Organic farming is defined as a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides and growth regulators and it is a technique to build up soil fertility for sustainable production, mainly using local natural resources and with least external inputs. Recognizing soil as a Dynamic Living Entity, which promote beneficial biological activities in soil and root zone of plant is central to the theme of organic agriculture. Organic farming is today's answer not only for higher and sustained productivity but also for safe nutritious food and it is increasingly demanded by enlightened consumers around the world. Organically grown agricultural produces fetch a premium in the market.

The key component of organic farming is the availability of cheap and good quality organic manures to retain the fertility and nutrient supplying power of the soil. Organic matter plays a very important role in organic farming system. Hence every efforts should be made to enrich soil with high organic matter content. The draw back of organic manure is the low content of plant nutrients and slow release characteristics. They are required in bulk and transporting the bulk quantity over distance is very costly. In order to overcome this problem, these bulky organic manures can be produced in the farm itself. Large quantities of organic manures are required to meet the entire requirements of crops. There are several limitations to get sufficient quantities of organic matter. Recycling of organic wastes is the possible alternative to meet the growing demand for organic manures by using different methods of composting. Conventional methods of composting are time consuming, product obtained are very low in nutrient content and acidic in reaction. A modification over the earlier method of composting in a very economic way and in a short time by using selected species of earthworms which form one of the major secondary decomposing organisms. The method of producing compost from non-toxic biodegradable waste using earthworm as biological agent is called vermicomposting. Vermicompost is a potential organic source due to the presence of readily available plant nutrients, growth enhancing substances, beneficial microbes like nitrogen fixing, P solubilising and cellulose decomposing organisms. These organisms are known to induce many biochemical transformations like mineralisation of organically bound forms of materials, exchange reactions, fixation of atmospheric nitrogen, solubilisation of insoluble P and various other changes leading to better availability of nutrients. The nutrient content in vermicompost are much less compared to standard inorganic fertilizers and its quality can be further enhanced by improved composting techniques like enriching biowaste with organic additives *viz.*, neem cake and bone meal at the time of composting. The organic additives may enhance the multiplication of microorganisms in close association with earthworms and vermicompost, which may enhance the composting process and improve nutritive value of vermicompost.

Leafy vegetables play an important role in supplying vitamins and minerals in human diet. Amaranthus is a most popular leafy vegetable grown in homesteads of Kerala. It is capable of producing several crops in a year making more acceptable to farmers. The general term protective food applied to vegetables is very much suited to amaranthus as it is a rich source of protein, vitamins and minerals. It contains protein 4.0 g, fibre 1.0 g, vitamin A 9200 I.U., riboflavin 0.10 mg, thiamin 0.03 mg, vitamin C 99.00 mg, iron 25.50 mg, calcium 397 mg per 100 g of edible portion (Choudhury, 1996).

With the above background in view the following object was set for the programme by taking amaranthus as the test crop.

To assess the effect of vermicompost enriched with organic additives on physico-chemical and biological properties of soil, to study its impact on crop performance and feasibility of substituting FYM and inorganic fertilizers.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In recent years the organic farming is gaining considerable momentum due to disastrous side effects of the chemical farming on soil health and environment and people now prefer organically grown food products and spices. The success of organic farming depends on the availability of sufficient quantities of good quality organic manures so badly required for our soils. Vermicompost is an alternate source of organic manure where organic waste materials are converted into nutritious product by the activities of earthworms. But the nutrient content of vermicompost is low. However, there is scope for increasing the nutrient content of vermicompost when enriched with organic additives like neem cake and bone meal. The literature pertaining to enriched vermicompost is scanty. Hence available literature relevant to the present investigation has been reviewed here under.

2.1 EFFECT OF ORGANIC MANURES ON SOIL PROPERTIES

According to Sathianathan (1982) in cassava, neem and mahua cake treatments were efficient in retaining more nitrogen in the ammoniacal form under field condition. These oil cakes, reduced leaching losses and extended the period of availability of nitrogen to the crop from applied 'N'.

Application of FYM has favourable effects on soil aggregation compared to chemical fertilizers. It was reported by Rabindra *et al.* (1985).

Application of some organic waste products such as liquid and dehydrated slurry, keratin bark urea granule, sewage sludge, FYM and NPK improved the soil physico-chemical properties except the acidification caused by keratin bark urea granule (Debicki *et al.*, 1988).

Lal and Mather (1988) reported that application of N, P, K fertilizers reduced the pH from 5.5 to 3.8 but FYM application maintained or increased the pH of the soil, while the combination of fertilizers and manures decreased the pH.

Mbagwu (1989) reported that the application of organic waste like poultry manure, compost, sawdust, rice shavings and cashew leaves improves the soil structure, water retention property, total porosity, macroporosity and saturation hydraulic conductivity, but it decreases the bulk density.

From a long term field experiment in England, Rose (1990) reported that continuous application of farmyard manure increases the total porosity of soil.

In another experiment, a decrease in bulk density by the addition of organic matter residues over long time was observed by Rasmussen *et al.* (1991).

Hudson (1994) reported that organic matter is an important determinant of available water content and it increases the available water content in sandy textured soils only.

In an experiment it was reported that green manuring with sun hemp reduces the soil pH and organic matter content of surface soil. Soil nitrate nitrogen decreases during sun hemp growth. Green manuring increases soil water retention and reduces the bulk density in 0-0.1 m soil depth, as a result infiltration rate increased (Ghuman *et al.*, 1997).

Application of FYM to soyabean crop resulted in significant improvement in soil properties. Organic carbon, total N, available P and K in the soil is improved by FYM application (Babhulkar *et al.*, 2000).

Incorporation of organic waste significantly increased the soil pH and nutrient status of an acid soil (Lal *et al.*, 2000).

Application of bagasse waste *i.e.,* having high water holding capacity and containing small amount of Ca, K, P and N increases the total cation level of treated soil but the variation in SAR and EC of saturation extract were not consistent across the site suggesting neither excessive salinity nor sodicity (Hughes *et al.*, 2001).

Fuhua *et al.* (2002) reported that application of sewage sludge improved the physico-chemical properties of soil. The content of organic matter, total nitrogen, Fe, Ca, Cu, Mn and total P were also improved, but K, Mn and heavy metal content did not vary significantly.

Dhevagi *et al.* (2003) reported that application of paper mill effluent along with amendment increased the BD from 1.14 to 1.45, pH from 7.82 to 8.31, EC from 0.26 dSm^{-1} to 0.31 dSm^{-1} and organic matter content from 0.51 to 0.67 per cent in groundnut.

2.2 EFFECT OF ORGANIC MANURES ON AVAILABILITY AND UPTAKE OF NUTRIENTS

Srivastava (1985) observed that increased use of nitrogenous fertilizers decreased organic carbon content and total N, while FYM increased the above parameters.

Dhargawa *et al.* (1991) observed a significant increase in 'P' availability in soil following the application of FYM.

Raju *et al.* (1991) observed FYM to be more effective in increasing nitrogen uptake in chickpea.

Singh and Tomar (1991) found that application of FYM and K had a positive effect on the uptake of N by wheat crop

Connel *et al.* (1993) observed an increase in the available nitrogen content of soil by the application of municipal solid waste.

Balaji (1994) recorded higher levels of total N, available P and K in treatments which received either vermicompost alone or in combination with FYM or chemical fertilizers than control.

Ammal and Muthiah (1994) reported that application of composted coirpith plus potassium recorded the highest uptake of potassium by rice plants compared with raw coirpith plus potassium or potassium alone.

Mather (1994) reported that incorporation of spent mushroom substrate increased the 'K' content of soil.

Dhanokar *et al.* (1994) found that continuous use of FYM raised the available 'K' content of soil by 1.3 to 5.4 folds over control.

Humus by virtue of its chelating properties increases the availability of N, P, S and other nutrients to plants growing in humus rich soils. The humus substance increases 'P' availability as they have very high exchange capacity (Gaur, 1994).

More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon, available nitrogen, available phosphorus and available potassium of the soil.

Minhas and Sood (1994) found that application of FYM was beneficial in enhancing the uptake of 'P' by potato and maize.

Bharadwaj (1995) reported the most significant role of organic matter in supplying K.

Application of water hyacinth compost as an organic source enhanced the uptake of 'N' by groundnut, maize and barley (Rabie *et al.*, 1995).

FYM application resulted in lowest acidity due to the increase in exchangeable or soluble 'Al' in the soil (Patiram, 1996).

According to Meera (1998) use of vermicompost coated seeds produced the maximum uptake of N, P and K at peak flowering stage and harvest. Soil application of vermicompost recorded the highest uptake of Ca, Mg, Cu and Mn during peak flowering stage. Soil analysis for available nutrients revealed that the different treatment had significant influence on the Ca, Mg, Zn, Cu and Mn content in soil.

In bhindi N and P uptake were highest for FYM + neem cake whereas K uptake was maximum for FYM + poultry manure at N_3 level of nitrogen (150 kg ha^{-1}) and with *Azospirillum* inoculation. The available N, P and K status of the soil were highest in FYM + neem cake, FYM + enriched compost and FYM alone treated plots respectively at N_3 level of nitrogen (150 kg ha^{-1}) and *Azospirillum inoculation* (Raj, 1999).

Sailajakumari (1999) reported that application of enriched vermicompost *i.e.*, vermicompost enriched with rock phosphate registered significant increase in soil available N, P, K and uptake of macronutrients. Enriched compost registered maximum mean value for the uptake of all the macronutrients.

Vermiwash applied through foliage along with full inorganic fertilizers increased the plant uptake of major and micro nutrients (Jasmin, 1999).

Cuevas *et al.* (2000) reported that application of dried composted municipal solid waste (MSW) to a degraded semi arid shrubland significantly increased the availability of P, K, nitrate nitrogen and EC. It also increases the concentration of total soil heavy metal like Zn, Pb, Cd, Ni, Cr and Cu but increase is significant only for Zn, Pb and Cu.

Sharma *et al.* (2001) reported that conjoint use of N along with FYM markedly influenced the NPK uptake, which might be due to the supply of these nutrients and improvement of soil physical properties for better plant growth.

FYM application along with different levels of S, Mo, Fe, Zn and Co increased the uptake of major and micro nutrients by cowpea at harvest (Sharma *et al.*, 2002).

Addition of FYM or decomposed rice straw improved the N, P and K status of soil (Bandgopadhyay *et al.*, 2002).

According to Patidar *et al.* (2002) application of FYM on the sorghum field increases the available nutrient content *i.e.*, N and P content in the soil.

Application of household compost and solid pig manure showed an increased accumulation of N and P. It also resulted in stimulation of some biological activity (Peterser *et al.*, 2003).

2.3 EFFECT OF ORGANIC MANURES ON MICROBIAL PROPERTIES

Satchell (1984) reported that earthworm activity stimulate the microbial phosphate production.

Increase in number of nitrogen fixing fungi and bacteria in the soil when earth worms were introduced into experimental plots was observed by Kale *et al.* (1989).

Many workers reported that application of organic manures usually increases the soil microbial biomass (Sakamoto and Oba, 1991; Goyal *et al.*, 1993).

Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in nitrogen fixation and phosphate mobilization leading to higher nutrient uptake by plants.

Presence of VAM fungi on the casts of *Lumbricus terratris* was demonstrated by the successful inoculation of sterile grown onion plants (Harinikumar and Bagyaraj, 1994).

Reddy and Mahesh (1995) found that microbial population was high in vermicompost applied field.

Manna *et al.* (1996) studied the effect of different levels of FYM on soil microbial biomass and an increased microbial biomass at 4 t ha^{-1} FYM was reported, but further increase in FYM level caused reduction in biomass turnover.

Batcharyya *et al.* (2001) reported that application of municipal solid waste compost variably increased the microbial biomass.

2.4 EFFECT OF ORGANIC MANURES ON QUALITY OF VEGETABLES

Kansal *et al.* (1981) reported that application of FYM (20 t ha^{-1}) increased the ascorbic acid content in spinach leaves.

Sharma *et al.* (1987) noticed improvement in grain protein content on azotobacter inoculation.

Sudhakar *et al.* (1989) reported that seed inoculation with *Rhizobium* increased the seed protein content of blackgram. Bhalu *et al.* (1995) also obtained a similar result.

Lampkin (1990) reported that better storage life of spinach grown with organic manures was found to be associated with lower free aminoacid content, nitrate accumulation and higher protein nitrogen to nitrate nitrogen.

Montogu and Ghosh (1990) found that fruit colour of tomato was significantly increased as a result of application of organic manures of animal origin.

Abhusaleha (1992) recommended equal quantity or more organic form of nitrogen for getting good quality okra fruits.

Rhizobium inoculation in combination with Mn and Mo application significantly increased the grain protein content of cowpea (Baldeo *et al.*, 1992).

Organic manures like FYM, compost, oil cakes, green leaf, poultry manure etc. improved the quality of vegetable crops like tomato, onion, gourd, chillies etc. Increase in 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).

Anitha (1997) reported that chilli plants treated with poultry manure recorded the maximum ascorbic acid content in fruits as compared to vermicompost and control treatments.

Vermicompost application increased the sweetness of Njalipoovan fruit (Ushakumari *et al.*, 1997).

Joseph (1998) observed that in snakegourd poultry manure treated plants recorded the highest crude protein and lowest crude fibre content as compared to that of FYM and vermicompost treatments. She also reported that when vermicompost was used as nutrient source in snakegourd field, it produced fruits with more shelf life, P and K content over FYM and poultry manure.

Meera (1998) reported that coating seeds with vermicompost combined with application of full inorganic fertilizers and farmyard manure as organic source recorded the highest grain yield. From the analysis of grain samples, it was inferred that only K and Ca content of grain was significantly influenced by different treatment.

FYM application *i.e.,* as an organic amendment increased the dry matter production of bhindi crop (Senthilkumar and Sekar, 1998).

Starch content of sweet potato tuber was maximum when nitrogen was given as vermicompost (Sureshkumar, 1998).

Raj (1999) reported that crude protein content and ascorbic acid content were maximum for FYM + poultry manure and FYM + enriched compost respectively in Bhindi. FYM + enriched compost and FYM + neem cake recorded comparable and lowest crude fibre content and highest keeping quality of fruits.

Jasmin (1999) found that soil application of vermiwash produced fruits with more shelf life. The different concentration of vermiwash produced positive influence on the lycopene content of tomato, but no influence on the ascorbic acid and crude fibre content. Nutrient content of plant and fruits were influenced by vermiwash application.

Sailajakumari (1999) found the superiority of vermicompost enriched with rock phosphate on yield and quality of cowpea.

Arunkumar (2000) reported that application of vermicompost to amaranthus crop recorded significantly high ascorbic acid content as compared to POP. Ascorbic acid content increased with increasing the level of organic manures. Lower fibre content was also reported in vermicompost plants.

Protein content of cowpea grains were more in vermicompost treated plot compared to farmyard manure application (Sailajakumari and Ushakumari, 2001).

Rao *et al.* (2001) studied the effect of organic manures like FYM, neem leaf, vermicompost, neem cake, *Azospirillum* and phosphobacterium on the growth and yield of brinjal. Effect of these organic manures on leaf number, leaf area index, dry matter production and other growth and yield characters were better than inorganic fertilizers. The highest fruit yield of 12.3 t ha^{-1} was obtained with the treatment FYM + vermicompost followed by FYM + neem cake.

Bhadoria *et al.* (2001) reported that protein and total mineral content of okra fruit was high, when it was treated with FYM.

Soorianathasundaram *et al.* (2001) studied the possibility of reducing the use of inorganic N fertilizer by partial substitution with organic sources and the effects of such substitution on growth and yield of banana cv. Nendran. Application of 75 percent N as urea along with 25 per cent as FYM resulted in bunch trait that are on par with bunches produced when inorganic sources was used alone to provide required nitrogen.

Sathiabama *et al.* (2001) studied the effect of humic acid applied as potassium humate (@ 10&30 kg ha^{-1}) with and without NPK fertilizers (75 per cent and 100 per cent) on growth, yield and nutrient content of amaranthus cv. Co-5. The results showed that application of 10 kg humic acid ha^{-1} along with 75 per cent recommended NPK found to influence the green matter production significantly besides recording higher nutrient content.

Chitdeshwari *et al.* (2002) reported that application of sewage biosolid compost increases the biomass yield of amaranthus.

Omae *et al.* (2003) reported that cattle compost application increased freshness and vitamin C content in melon (*Cucumis melo* L.)

2.5 ROLE OF VERMICOMPOST AS AN ORGANIC SOURCE

Increased availability of N in earthworm casts compared non-ingested soil had been reported by several workers (Romero and Chamooro, 1993; Parkin and Berry, 1994; Rao *et al.*, 1996).

Parkin and Berry (1994) found that earthworms are actively involved in the cycling of C and N in soil and earthworm casts are enriched in mineral N. Worm cast have elevated denitrification rate.

Bohlen and Edwards (1995) reported that earth worms had significant effect on amount of extractable nitrate and they increased the nitrate content at 0-5 cm soil depth by 1.88 fold in microcosms supplied with earth worms.

Vermicompost contains about three times more nutrients than FYM. It was reported by Prabhakumari *et al.* (1995).

Reddy and Mahesh (1995) reported an increased availability of 'N' in soil by the application of vermicompost compared to FYM.

Das *et al.* (1996) found that content of K_2O in vermicompost obtained from sericultural waste was about one per cent.

According to Handreck (1996) vermicompost could supply the initial improvement of 'K' for the growth of *Mathiola incana.* Vermicompost can fully supply the requirement of trace elements for the growth of *Mathiola incana* stocks, when used as a potting mixture.

According to Bano and Devi (1996) N level in vermicompost ranged from 1.4 to 2.17 per cent.

Vasanthi and Kumaraswami (1996) reported highest concentration of micronutrients in the treatments that received vermicompost along with NPK fertilizer compared to the treatment that received NPK alone.

According to Sailajakumari (1999) nutrient composition of ordinary vermicompost was 1.83 per cent N, 1.37 per cent P_2O_5, 2.66 per cent K_2O, 0.46 per cent Ca and 1.3 per cent Mg.

2.6 MICROORGANISMS ASSOCIATED WITH VERMICOMPOST

Mba (1994) found that earth worm cast of *Pentoscolex correthrurus* were found to contain tolerant actinomycetes and efficient rock phosphate solubilizers.

Devliegher and Verstrete (1995) found that nutrient enrichment processes are responsible for the increased number of microorganisms reported in the presence of earthworms.

Karsten and Druke (1995) found that the rate of microbes capable of growing under aerobic condition was high in the worm intestine than in the soil.

Earthworms encourage mutualism and biodiversity in soil. Mobilization of nutrients and organic resources through mutualism with soil microbes was encouraged by earthworms (Lavelle *et al.*, 1995).

Reddy and Mahesh (1995) found that microbial population was high when vermicompost was applied in the soil.

Indira *et al.* (1996) reported that an examination of vermicompost revealed the presence of 10^6 bacteria, 10^5 fungi and 10^5 actinomycetes by dilution plate technique. Population of beneficial organisms like P solubilizing bacteria, N_2 fixing organisms and entamophagous fungi were in the range of 10^5 to 10^6. Among the 'P' solubilizing species *Bacillus* and *Aspergillus* are dominant while species belonging to *Acetobactor, Azospirillum* and *Rhizobium* are in the N_2 fixing group.

Jiji (1997) reported that vermicompost produced with *Eudrillus eugeniae* was superior over control with respect to the count of fungi and bacteria.

Earthworm cast of *Eudrillus eugeniae* contain rock phosphate solubilizing microbes (Mba, 1997).

The presence of nitrogen fixing bacteria as a part of the surface and more important the gut microflora of earthworm had been reported by Nair *et al.* (1997)

In an experiment Meera (1998) reported that vermicompost contains about 67 x 10^6 bacteria, 8.3 x 10^5 actinomycetes and 1.3 x 10^5 fungi g^{-1} of compost.

According to Sailajakumari (1999) microbial population of enriched compost was bacteria 64 x 10^4, fungi 1.8 x 10^5 and actinomycetes 25 x 10^4.

Suja (1999) reported 9.4 x 10^6 bacteria, 2.6 x 10^4 fungi and 49.7 x10^4 actinomycetes in vermicompost.

2.7 EFFECT OF VERMICOMPOST ON YIELD AND UPTAKE OF CROPS

Application of vermicompost resulted in higher yield of paddy crop to the tune of 95 per cent increase in grain and 128 per cent in straw and root production (Senapathi *et al.*, 1985).

Ismail *et al.* (1993) conducted a comparative evaluation of vermicompost, FYM and fertilizers on yields of bhindi and watermelon and observed an increase in yield in all the cases with vermicompost.

Jiji *et al.* (1996) found that the requirement for chemical fertilizers in cowpea var. Malika and bitter gourd var. Preethi was significantly reduced when recommended dose of farmyard manure was substituted by an equal quantity of vermicompost.

Reddy and Mahesh (1995) observed a significant increase in grain yield of greengram due to the application of vermicompost compared to farmyard manure.

According to Madhukeshwara *et al.* (1996) vermicompost could be used as an ideal organic substrate for raising healthy tomato seedlings. Significant improvement in growth parameters like shoot height, root length and leaf area of the seedlings were also obtained.

Pushpa (1996) and Rajalekshmi (1996) have reported increased uptake of nutrients and higher yields in tomato and chilli respectively by vermicompost application.

According to Vasanthi and Kumaraswamy (1996) P content of rice plants was higher in treatments that received vermicompost + NPK.

Vadiraj *et al.* (1996) found that vermicompost application resulted in increased plant height and leaf area of turmeric over the control.

Ushamukari *et al.* (1996) found that Package of Practices Recommendations with cattle manure as the organic source, vermicompost as organic source along with half the recommended dose of inorganic fertilizer and vermicompost as the sole source of nutrients, all recorded almost the same yield.

Ushakumari *et al.* (1997) reported that vermicompost when applied to supply the recommended doses of inorganic nitrogen in banana recorded the highest bunch yield, number of hands bunch^{-1}, number of fingers hand^{-1}, mean weight of hands etc., but fruit size was small compared to the treatment where compost was used as the organic source along with the recommended dose of inorganic fertilizer. Vermicompost as organic source improved the sweetness of fruit also.

Meera (1998) reported that coating of seeds with vermicompost significantly influenced the grain yield of cowpea and also the number of pods plant^{-1}. Coating seeds with vermicompost combined with the application of full inorganic fertilizers and FYM as organic source recorded the highest grain yield.

Use of vermicompost as an organic manure and also as a substitute for inorganic fertilizer enhanced the vegetative growth in sweet potato. Significant treatment effect could be observed in total tuber yield and marketable tuber yield. So by using vermicompost as an organic manure it is possible to bring down the use of chemical fertilizers (Sureshkumar, 1998).

Jasmin (1999) reported that application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield. At higher concentration (50 and 25 per cent) of vermiwash, inorganic fertilizer could be reduced to half of the recommended dose without any yield reduction.

Vermicompost application *i.e.*, as an organic source along with full recommended dose of NPK increases the growth and yield of okra (Ushakumari *et al.*, 1999).

Vasanthy and Kumaraswamy (1999) reported that application of vermicompost increased the rice grain yield and soil fertility status.

Rajkhowa *et al.* (2000) reported that application of vermicompost showed significant positive effect on yield and dry matter production of greengram. Highest dry matter production and seed per plant were obtained with the application of 75 per cent nitrogen as urea along with 5 t ha^{-1} vermicompost and it was found to be on par with nitrogen as vermicompost alone. Significant increase in nutrient content in plant was observed due to the application of vermicompost.

Vermicompost application improved the growth characters and yield of cowpea was reported by Sailajakumari *et al.* (2001).

Application of vermicompost alone or in combination with chemical fertilizers recorded better seed germination and quality than other treatments was reported by Rotondo *et al.* (2003) *i.e.*, vermicompost may effectively used as a valid alternative for the traditional substrate with or without chemical fertilizers.

2.8 EFFECT OF VERMICOMPOST ON SOIL PROPERTIES

Increase in total and available P_2O_5 content in soil due to vermicompost application was reported by Gaur (1990). This may be due to greater mineralisation of organic matter with the aid of microflora associated with earthworms. Increased P_2O_5 content is due to high phosphatase activity.

Shuxin *et al.* (1991) reported that by introducing earthworms and applying organic manures in the red arid soil improved the soil structure and fertility status.

Basker *et al.* (1992) reported increased concentration of available and exchangeable 'K' by vermicompost application.

Logsdon and Linden (1992) reported that earthworms create channels that allow deeper root penetration through hard pan. These channels can increase infiltration and reduce runoff, increasing soil water availability or in other words deep percolation to maintain favourable water status for crop growth.

Bhawalkar and Bhawalkar (1993) found that earthworms participate in soil forming process by influencing soil pH by acting as agent of physical decomposition, promoting humus formation, improving soil structure and by enriching the soil. They further observed that in addition to physical mixing of the soil by burrowing activities. Soil enrichment is achieved by speeding up mineralisation of organic matter 2-3 times by earthworms.

Vijayalekshmi (1993) reported that soil physical properties such as porosity, soil aggregation, soil transmission, conductivity and dispersive power of worm cast fertilized soil were improved when compared with no worm cast amended soil. Rajalekshmi (1996) had also reported favourable effect of vermicompost / vermiculture on most of the soil properties.

Bijulal (1997) reported that the major effect of vermicompost application in soil was a reduction in P fixation and thus increasing the P availability in acidic soils.

2.9 EFFECT OF VERMICOMPOST ON GROWTH AND YIELD OF AMARANTHUS

Sagayaalfred and Gunthilagaraj (1996) obtained a more germination percentage of amaranthus seeds raised in beds incorporated with earthworms. They also obtained higher yield in amaranthus with the incorporation of earthworms into the seedbed.

Arunkumar (1997) reported that in amaranthus FYM application was found to be superior to vermicompost in better plant height, root biomass production, leaf area index and yield.

Niranjana (1998) reported that vermicompost application gave higher biomass yield till 45 DAT in amaranthus.

According to Arunkumar (2000) FYM and vermicompost application was superior to POP with respect to yield and growth characters. Highest marketable yield was recorded for vermicompost.

2.10 EFFECT OF ENRICHED ORGANIC MANURE ON SOIL PROPERTIES AND SOIL FERTILITY

An incubation study conducted by Prasad *et al.* (1989) showed that the application of manures enriched with urea or single super phosphate maintained higher level of N and P in the soil for longer period than when the soil is treated with fertilizer alone

Thakur *et al.* (1998) studied the effect of inoculation of azotobacter and addition of varying levels of rock phosphate on N and P transformation. During composting inoculation with azotobacter at 30 days of composting increasing NH_4^+, NO_3^- total nitrogen content and decreased water soluble P and C/N ratio. Rock phosphate enrichment, accelerated decomposition and improved the nitrogen mineralisation. Phospohrus from rock phosphate was solubilized during composting and transformed into available form. .

According to Raj (1999) available N, P_2O_5 and potassium status of the enriched FYM (FYM + neem cake) was high. The available phosphorus content in FYM + poultry manure was comparable with FYM + enriched compost. Available nitrogen status of soil improved with *Azospirillum* inoculation.

Application of vermicompost enriched with rock phosphate increased the available N, P_2O_5 and K_2O status of the soil (Sailajakumari, 1999).

Srikanth *et al.* (2000) studied the direct and residual effect of enriched compost, FYM, vermicompost and fertilizers on the properties of alfisol. According to him soil nutrient value was found to be high in enriched compost amended soil after the harvest of first or second crop.

Slight decrease in bulk density of soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment alone was noticed.

Latha *et al.* (2001) reported that the enrichment of manures with $ZnSO_4$ resulted in increased Zn availability in all stages of maize crop. It may be due to the direct addition of Zn by the organic matter besides the involvement of decomposition products in solubilization and complexation reaction.

2.11 EFFECT OF ENRICHED MANURE ON CROP GROWTH AND YIELD

Banerjee and Das (1988) reported that application of enriched compost improved the growth attributes of potato as compared to uninoculated control.

Dinakaran and Savithri (1995) reported that effect of Vesicular Arbuscular Mycorrhizal fungi (VAM) in increasing dry matter production was positive and it was more pronounced at higher levels of P application in onion.

Gowda *et al.* (1995) reported that rice yield with SSP alone was comparable to MRP along with green leaf manure and 'P' solubilising fungi.

Savithri *et al.* (1995) reported that incubating rock phosphate with coir pith resulted in 28 per cent increased grain yield in rice over the sole application of rock phosphate.

Manjaiah *et al.* (1995) observed a significant increase in nodule number when treated with combination of organic amendments and P solubilizers plus MRP.

Rock phosphate enriched compost increased the yield of rice and the yield increase was comparable to SSP (Singh and Amberger, 1995).

Srivastava and Ahlawat (1995) reported a significant increase in nodulation in cowpea by seed inoculation with rhizobium or P bacteria and phosphate fertilizers. There was overall improvement in growth of the crop.

Sunilkumar *et al.* (1995) observed that 1:1 mixture of MRP and single superphosphate with green leaf manure in rice resulted in higher straw yield. There was no significant difference in grain yield between those treatments.

Application of *Eudrillus* compost inoculated with *Azospirillum* and P solubilizing organisms had the highest plant height, number of leaves and shoot : root ratio (Zachariah, 1995).

A pot culture experiment conducted by Devarajan and Krishnamoorthy (1996) revealed that Zn enriched organic manures increased the grain and straw yield of rice than the recommended level of organic manures alone.

From field experiment with soyabean in a Vertisol, Dubey (1996) observed an improved growth and uptake of nutrients in soybean by the use of *Pseudomonas striata* either alone or in conjunction with SSP and MRP.

Stoffella and Graetz (1996) reported that the total tomato yield was larger in plots amended with sugarcane filter cake compost as compared to control plots without compost.

Mahimairaja and Perumal (1997) revealed that combined with organics or biofertilizers MRP performed equally good to that of DAP but gave significantly higher rice yield than control.

Sudhirkumar *et al.* (1997) reported that combined application of rock phosphate and organic amendments significantly increased the grain and straw yield in chickpea.

Singh *et al.* (1998) reported that combined application of Zn and biogas slurry was more effective than single application in enhancing the crop yield in rice.

Vermicompost and phosphobacteria in combination with two inorganic P sources namely single superphosphate and Tumis rock phosphate (TRP) were verified in a calcareous black soil for their effect on yield parameters of black gram (Co-5) and cotton (LRA 5155). The application of TRP (100 per cent) along with vermicompost and phosphobacteria in black gram recorded the highest grain and haulm yield. In cotton, effect of SSP and TRP on Kapar yield and Stover yield were on par (Thiyageswhwari and Perumal, 1998).

Raj (1999) reported that growth characters like plant height, LAI, DMP, yield attributes like fruit number per plant, fruit weight, fruit length and fruit yield were higher in organic manure treated plots. FYM + neem cake recorded maximum number of fruits $plant^{-1}$, FYM + neem cake and FYM + green leaf recorded comparable and maximum yield of 158 and 153 q ha^{-1} respectively.

According to Sailajakumari (1999) application of enriched vermicompost (vermicompost enriched with RP) increased the plant height, number of branches, nodule number and yield in cowpea.

Sharanappa (2002) showed that application of FYM enriched with 10 per cent by weight each of rock phosphate and gypsum maximized the grain yield of maize.

Namdeo *et al.* (2003) reported that application of 60 kg P_2O_5 ha^{-1} or Jhabua rock phosphate charged phosphocompost 2.5 t ha^{-1} or 25 per cent Jhabua rock phosphate charged phosphocompost 1.5 t ha^{-1} showed statistically identical performance for growth and yield parameters of soybean and it was found to be superior than control (without P).

2.12 EFFECT OF ORGANIC MANURES ON NUTRIENT ECONOMY

Sarawad *et al.* (1996) reported that application 1 t of vermicompost could substitute 25-50 per cent recommended dose of fertilizers.

Yield of radish, spinach and green peas were better with 50 per cent dose of NPK through chemical fertilizers and rest through vermicompost (Jambhakar, 1996).

Seed coating with vermicompost along with half recommended nitrogen produced 30 per cent increase in yield over POP. Quantity of fertilizer can be reduced to half when vermicompost was used as seed inoculant (Meera, 1998).

According to Niranjana (1998) B:C ratio and net returns were maximum for dual inoculation with 75 per cent POP and *Azospirillum* with 50 per cent POP in amaranthus. All the treatments got good profit.

By using vermicompost as organic manure in sweet potato it is possible to bring down the use of chemical fertilizer. Vermicompost with half or ¾ NPK produced highest yield (Sureshkumar, 1998).

Phosphorus recommendation for cowpea can be reduced to half by priming vermicompost with rock phosphate (Sailajakumari, 1999).

Mohanty and Sharma (2000) reported use of locally available organic materials such as chopped straw, farmyard manure, water hyacinth compost, azolla and green manures like sunhemp and daincha can substitute nitrogen fertilizer upto 50 per cent of total crop requirement in rice- rice cropping system in the laterite soil.

Phosphocompost application to groundnut @ 2.5 t ha^{-1} saved 50 per cent recommended NPK fertilizers (Saha and Hajra, 2001).

Arunkumar (2000) reported that in amaranthus, B:C ratio was maximum for highest dose of vermicompost. Most of the treatments fetched good profit except coirpith compost and lower level of neem cake.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Vermicompost enriched with organic additives for sustainable soil health" has been carried out at College of Agriculture, Vellayani during 2002-2004. The main objective of the study was to assess the effect of vermicompost enriched with organic additives on physico-chemical and biological properties of soil, to study its impact on crop performance and the feasibility of substituting FYM and inorganic fertilizers. The investigation consisted of three parts (1) preparation of vermicompost and enriched vermicompost (2) Incubation study and (3) field experiment. The materials used and the methods adopted for the studies are briefly described in this chapter.

3.1 LOCATION

The experiment was carried out at College of Agriculture, Vellayani. The site is situated at $8^0 30'$ N latitude and $76^0 54'$E longitude and at an altitude of 29 m above MSL.

3.2 PREPARATION OF VERMICOMPOST

Vermicomposting was carried out in tanks of 2.5 x 1 x 0.5 m size using dried banana leaves and pseudostem as raw materials. The raw material were chopped and mixed with cowdung in the ratio 8:1 on volume basis and vermicompost was prepared according to Package of Practices Recommendation (POP) of Kerala Agricultural University (KAU) using earthworm sp. *Eudrillus eugeniae* (KAU, 2002).

3.3 PREPARATION OF ENRICHED VERMICOMPOST USING ORGANIC ADDITIVES

Organic additives like neem cake and bone meal were used for the preparation of enriched vermicompost. Neem cake 2 per cent, bone meal 2 per cent and combination of neem cake 1 per cent and bone meal 1 per cent were used separately for enrichment on the basis of total weight of biowaste and cowdung mixture. These additives were added initially to the biowaste-cowdung mixture during vermicomposting. Preparation of enriched vermicompost was done in cement tanks of 2.5 x 1 x 0.5 m size using earthworm sp. *Eudrillus eugeniae*.

3.4 ANALYSIS OF COMPOST MATERIALS

Vermicompost and enriched vermicompost were analysed for pH, EC, total organic carbon, total nitrogen, total phosphorus, total potassium, C:N ratio, calcium, magnesium, zinc, iron, copper, manganese and microbial count using standard analytical procedures (Table 1) and data are presented in Table 2.

Table 1. Analytical procedures followed in the analysis of vermicompost and enriched vermicompost

Sl. No.	Parameter	Methods	Reference
1	Organic carbon	Loss on ignition method	Jackson (1973)
2	Nitrogen	Digestion in H_2SO_4 and microkjeldhal distillation	Jackson (1973)
3	Phosphorus	Nitric – perchloric (9:4) digestion and colorimetry	Jackson (1973)
4	Potassium	Nitric – perchloric (9:4) digestion and flame photometry	Jackson (1973)
5	Calcium	Nitric – perchloric (9:4) digestion and estimation by Versenate method	Jackson (1973)
6	Magnesium	Nitric – perchloric (9:4) digestion and estimation by Versenate method	Jackson (1973)
7	Fe, Mn, Cu, Zn	Nitric – perchloric (9:4) digestion and atomic absorption spectrophotometry	Jackson (1973)
8	pH	pH meter method	Jackson (1973)
9	EC	Conductivity meter method	Jackson (1973)
10	Microbial count	Serial dilution method	Timonin (1940)

Table 2. Property of vermicompost and enriched vermicompost

Sl. No	Properties	Ordinary vermicompost	Enriched vermicompost (neem cake 2 %)	Enriched vermicompost (bone meal 2 %)	Enriched vermicompost (neem cake 1 % + bone meal 1 %)
1	Organic carbon(%)	25.00	46.15	22.00	26.00
2	Nitrogen(%)	1.30	4.00	1.90	2.40
3	P_2O_5 (%)	1.65	1.92	4.42	1.83
4	K_2O (%)	1.06	1.63	1.54	1.73
5	Calcium(%)	0.68	1.12	1.20	0.85
6	Magnesium(%)	1.14	1.25	1.54	1.45
7	Zinc(mg kg^{-1})	598.00	870.00	935.00	1170.00
8	Iron(mg kg^{-1})	629.80	812.80	994.00	1528.00
9	Manganese(mg kg^{-1})	927.00	1151.00	1237.00	1358.00
10	Copper(mg kg^{-1})	Trace	Trace	Trace	Trace
11	pH	6.86	6.91	7.02	7.34
12	EC (milliSeimen cm^{-1})	4.83	5.59	4.97	5.88
13	C/N ratio	19.23	11.54	11.58	10.83
14	Microbial count /g				
	a. Bacteria	40 x 10^6	45 x 10^6	60 x 10^6	53 x 10^6
	b. Fungi	16 x 10^4	18 x 10^4	23 x 10^4	25 x 10^4
	c. Actinomycetes	5 x 10^8	7 x 10^8	6 x 10^8	5 x 10^8

3.5 LABORATORY INCUBATION EXPERIMENT

The incubation study was conducted in the laboratory condition during July to August 2003. Main objective of the study was to assess the relative efficiencies of different organic sources in releasing nutrients from the soil. Different organic sources *viz.*; FYM, ordinary vermicompost, vermicompost enriched with NC 2 per cent, Vermicompost enriched with B.M 2 per cent and vermicompost enriched with NC 1 per cent + BM 1 per cent (combined application) were used for the study.

3.5.1 Collection and Preparation of Soil Sample for Incubation Experiment

Soil for the incubation experiment was collected from the 4th block of the Instructional Farm, attached to the College of Agriculture, Vellayani. The soil was classified as fine Loamy Kaolinitic Isohyperthermic Typic Kandiustult. The surface soil (0-15 cm) collected was air dried and sieved through a 2 mm sieve. A 2 kg portion of sieved soil was mixed thoroughly with required amount of organic source (50 g) and was taken in plastic containers of uniform size. To this added pre determined quantity of water so as to raise the moisture content of the samples to the field capacity. These moist samples were incubated under laboratory condition with constant moisture content for 60 days.

3.5.2 Design of Incubation Experiment

The study was programmed in CRD with six treatments replicated thrice. The following were the treatments.

T_0 – Absolute control (soil alone)

T_1 – soil + FYM

T_2 – Soil + Ordinary vermicompost

T_3 – Soil + enriched vermicompost (neem cake 2 %)

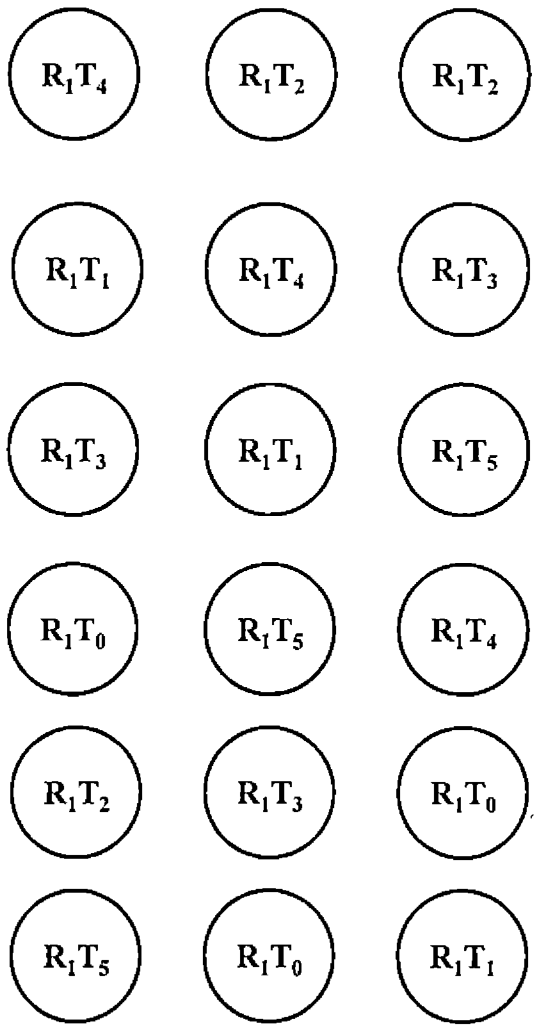
T_4 – Soil + enriched vermicompost (bone meal 2 %)

T_5 – Soil + enriched vermicompost (bone meal 1 % + neem cake 1 %)

Lay out of incubation experiment was given in Fig. 1.

3.5.3 Sampling

Sampling was done at 15 days intervals *i.e.*, 0th, 15th, 30th, 45th and 60th day after incubation. Samples were drawn in duplicate for analysis and a third sample was drawn simultaneously for moisture determination and the results were expressed on oven dry basis.



Design : CRD Treatments : 6 Replication : 3

Fig. 1 Layout of incubation study

3.5.4 Analysis of the Sample

The following properties were analysed at the time interval specified above.

3.5.4.1 Chemical Properties

3.5.4.1.1 Soil Reaction (pH)

The pH was determined in a 1:2.5 soil water suspension using Elico pH meter (Jackson, 1973).

3.5.4.1.2 Electrical Conductivity (EC)

Electrical conductivity was determined from the same soil water suspension prepared for the determination of soil reaction using a conductivity bridge (Jackson, 1973).

3.5.4.1.3 Organic Carbon

The wet digestion method suggested by Walkley and Black (1934) was employed for the estimation of organic carbon using ferroin as indicator (Jackson, 1973).

3.5.4.1.4 Available Nitrogen

Available nitrogen in soil was determined by alkaline permanganate method (Subbiah and Asija, 1956).

3.5.4.1.5 Available Phosphorus

Available P in soil was extracted by Bray No.1 reagent (Bray and Kurtz, 1945) and was determined colorimetrically by ascorbic acid blue colour method (Murphy and Riley, 1962)

3.5.4.1.6 Available Potassium

Available potassium was extracted using neutral normal ammonium acetate and estimated flame photometrically (Jackson, 1973).

3.5.4.2 Physical Properties

3.5.4.2.1 Bulk Density

Bulk density was determined by core sampling method (Gupta and Dakshinamoorthy, 1980).

3.5.4.2.2 Water Holding Capacity

WHC is also determined by undisturbed core sampling method (Gupta and Dakshinamoorthy, 1980).

3.5.4.3 Biological Property

3.5.4.3.1 Microbial Analysis

The total number of bacteria, fungi and actinomycetes in the incubated soil samples were determined by serial dilution plate method (Timonin, 1940). The media used for isolation of different groups of microorganisms are given in Appendix I.

3.6 FIELD EXPERIMENT

The field experiment was undertaken in the 4^{th} block of instructional farm, College of Agriculture, Vellayani with the objective of assessing the effect of enriched vermicompost on growth, yield and quality of amaranthus and the feasibility of substituting farmyard manure and inorganic fertilizers.

3.6.1 Season

The field study was conducted during the period from October 2003 to January 2004. Average rainfall, temperature and relative humidity at weekly intervals collected from meteorological observatory attached to the College of Agriculture, Vellayani during the cropping periods were given in Appendix II and graphically presented in Fig. 2.

3.6.2 Soil

The soil of the experimental site was sandy clay loam belonging to the family of Loamy Kaolinitic Isohyperthermic Typic Kandiustult. The

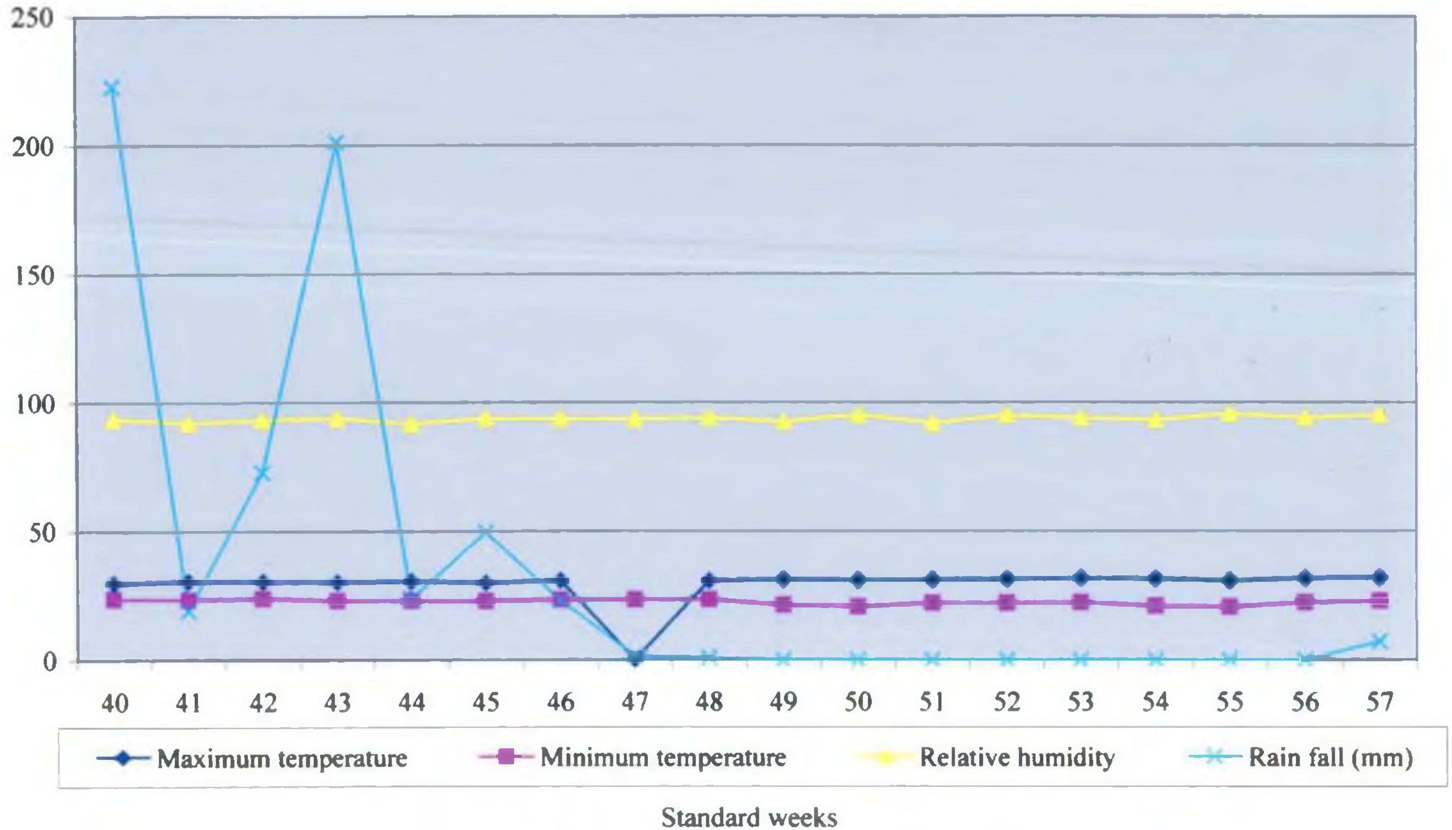


Fig. 2. Weather parameters during field experiment

initial data on physical, chemical and biological properties of the soil where the field experiment conducted are given in Table 3.

Table 3. Physical, chemical and biological properties of soil of the experimental site

Sl. No.	Parameter	Content	Method	References
1	Mechanical composition Coarse sand Fine sand Silt Clay	 49.15 (%) 14.4 (%) 6.25 (%) 27.5 (%)	International Pipette method	Piper (1966)
2	Texture	Sandy clay loam		
3	Bulk density	1.75 Mg m^{-3}	Core method	Gupta and Dakshinamoorthy (1980)
4	pH (soil:water 1:2.5)	5.5	pH meter with glass electrode	Jackson (1973)
5	EC (soil:Water, 1:2.5)	152μSm^{-1}	Conductivity meter	Jackson (1973)
6	CEC	4.2 c mol (p^+) kg^{-1}	Neutral normal ammonium acetate method	Jackson (1973)
7	Organic carbon	0.6 % (medium)	Walkley and Black's rapid titration method	Jackson (1973)
8	Available N ($KMNO_4$-N)	288.88 kg ha^{-1} (medium)	Alkaline permanganate method	Subbiah and Asija (1956)
9	Available P_2O_5 (Bray-IP)	107.02 kg ha^{-1} (high)	Colorimetric method	Jackson (1973)
10	Available K_2O	123.34 kg ha^{-1} (Low)	Flamephoto Meter method	Jackson (1973)
11	Microbial count / g Fungi Bacteria Actinomycetes	 15x10^4 21 x 10^6 2 x 10^8	Serial dilution plate method	Timonin (1940)

3.6.3 Crop and Variety

The study was conducted using amaranthus as test crop. Variety used was Arun. It is a photoinsensitive multicut variety with purple leaves evolved by mass selection. Seeds were collected from the instructional Farm, College of Agriculture, Vellayani.

3.6.4 Design and Layout of the Experiment

Design	–	Randomised block design
Treatments	–	10
Replications	–	3
Gross plot size	–	2.4 x 2 m
Net plot size	–	1.8 x 1.2 m
Spacing	–	30 x 20 cm
Crop	–	Amarathus
Variety	–	Arun

3.6.5 Treatments

T_0 – FYM + full NPK (POP recommendation)

T_1 – full NPK

T_2 – Vermicompost + full NPK

T_3 – Vermicompost + ½ NPK

T_4 – Enriched vermicompost (Neem cake 2 %) + full NPK

T_5 – Enriched vermicompost (Neem cake 2 %) + ½ NPK

T_6 – Enriched vermicompost (Bone meal 2%) + full NPK

T_7 – Enriched vermicompost (Bone meal 2%) +½ NPK

T_8 – Enriched vermicompost (Neem cake 1% +Bone meal 1%) + full NPK

T_9 – Enriched vermicompost (Neem cake 1% + Bone meal 1%) + ½ NPK

Layout of the field experiment is given in Fig. 3.

R_1T_0	R_1T_5	R_1T_8	R_1T_7	R_1T_4
R_1T_9	R_1T_3	R_1T_6	R_1T_2	R_1T_1
R_1T_6	R_1T_5	R_1T_2	R_1T_3	R_1T_8
R_1T_7	R_1T_4	R_1T_0	R_1T_9	R_1T_1
R_1T_0	R_1T_7	R_1T_1	R_1T_8	R_1T_3
R_1T_5	R_1T_4	R_1T_6	R_1T_9	R_1T_2

Design : RBD Treatments : 10 Replication : 3

Fig. 3. Lay out of field experiment

3.6.6 Manures and Fertilizers

Different organic sources used for the field experiment are FYM, ordinary vermicompost and vermicompost enriched with different organic additives like bone meal 2 per cent, neem cake 2 per cent and bone meal 1 per cent + neem cake 1 per cent (combined addition).

Nutrient composition of different organic sources is given in Table 2.

Urea (46 % N), Rock phosphate (20 % P_2O_5) and MOP (60 % K_2O) were used as chemical nutrient sources in the treatments T_0 (POP recommendation) and T_1 (inorganics alone).

3.6.7 Nursery

A small area adjacent to the experimental site was cleared dug well and prepared fine nursery bed. Amaranthus seeds were sown and all other operations were done as per Package of Practices Recommendation of KAU for amaranthus (KAU, 2002). Seedlings were ready for transplanting to the main field after 25 days.

3.6.8 Application of Manures and Fertilizers

In the control plot (T_0) manures and fertilizers applied as per POP recommendation (FYM @ 50 t/ha and 50:50:50 kg NPK/ha) and inorganic fertilizers alone (50:50:50 kg NPK/ha) were given in treatment T_1

In treatments T_2 to T_9 basal dose of organic manures and nitrogen were applied through respective organic manures. Additional requirement of P and K as per treatment were supplied as rock phosphate and ash.

3.6.9 Transplanting

Transplanting was done at a spacing of 30 x 20 cm. Shade was provided till the establishment of crop.

3.6.10 After Cultivation

Gap filling with healthy seedlings were done from stand by nursery to replace unestablished seedlings. Irrigation was given as and when required. Plots were maintained neatly by hand weeding.

3.6.11 Harvesting

Three harvest were done at 30th, 45th and 60th day after transplanting.

3.6.12 Biometric Observations

Observations were made on important parameters associated with growth, yield and quality of amaranthus. Five plants from each plot were selected randomly for recording biometric observations and average values were recorded. A destructive row was ear marked at the first outer row of net plot in each plot uniformly. Parameters considered and methods followed are briefly described here.

3.6.12.1 Height of the Plant

The height of the plant was measured at 3 stages of plant growth viz. 30th, 45th and 60th DAT from the base of the plant to the tip of the growing point. The mean values were computed and expressed in 'cm'.

3.6.12.2 Number of Leaves

Total number of leaves in each observational plant was counted and the average recorded for each plant at 3 growth stages viz., 30th, 45th and 60th DAT.

3.6.12.3 Number of Branches

The total number of branches of observational plants were counted and the mean workedout for each plant at 3 growth stages *viz.*, 30th, 45th and 60th DAT.

3.6.12.4 Stem Girth

The girth of the main stem at the collar region was taken using a twine at three stages of growth viz., 30th, 45th and 60th DAT. The mean girth was worked out and expressed in 'cm'.

3.6.12.5 Leaf Stem Ratio

Leaf stem ratio was obtained by dividing the dry weight of leaves by the dry weight of the stem. Leaf/stem ratio was worked out for three cuttings *viz.*, 30th, 45th and 60th DAT.

3.6.13 Yield Characters

3.6.13.1 Yield per Cutting

Total weight of leaf and stem portion 10 cm above the ground leaving woody portion were recorded for each plot and expressed in t ha^{-1}.

3.6.13.2 Total Yield per Plant

Yield per plant from the three cuttings were recorded separately and then added to get the total yield per plant and expressed in grams per plant.

3.6.13.3 Total Marketable Yield

Total weight of disease and pest free leaf and stem portions were recorded as marketable yield and expressed in t ha^{-1}. Marketable yield also excluded the plants which flowered.

3.6.13.4 Total Dry Matter Production

Plant left for destructive sampling was cut close to the ground and oven dried at 70^{0}C till constant weights were obtained. The weight was averaged and expressed in t ha^{-1}.

3.6.14 Quality Analysis

3.6.14.1 Moisture Content

It was obtained by oven drying the fresh weighed sample to a constant weight at 70^{0}C. From the data moisture content was worked out and expressed in percentage.

3.6.14.2 Protein

The total nitrogen of the oven dried samples was estimated by modified microkjeldhal method (Jackson, 1967). The nitrogen values were multiplied by a factor 6.25 to obtain the protein content and expressed as percentage on dry weight of leaves (Simpson *et al.*, 1965).

3.6.14.3 Fibre

The fibre content of the leaves was estimated by acid and alkali digestion method (Sadasivam and Manickam, 1992) and is expressed in percentage.

3.6.14.4 β-carotene

Carotene content of fresh leaves was estimated according to the method proposed by Sadasivam and Manickam, 1992.

3.6.14.5 Oxalate

Oxalate content is the antiquality or antinutrient factor present in amaranthus and was estimated by the method proposed by AOAC (1984).

3.6.15 Plant Uptake of NPK

Plant parts were analysed for NPK content using standard procedures and total uptake was calculated based on their contents in the parts and their corresponding dry matter weight.

3.6.16 Chemical Analysis of Soil

3.6.16.1 Post harvest Soil Analysis

The soil samples collected from the plot after the harvest of the crop was processed and analysed for available N, P_2O_5 and K_2O using standard procedures.

3.6.17 Microbial Analysis of Samples

The total number of bacteria, fungi and actinomycetes in vermi compost, enriched vermicompost and soil samples (before and after the experiment) were determined by serial dilution plate method (Timonin, 1940).

Various media compositions used for the determination of these microorganisms are given in Appendix II.

3.7 ECONOMIC ANALYSIS

Economic analysis of cultivation was worked out for the field experiment after taking into account the cost of cultivation and prevailing market price of amaranthus. The benefit cost ratio was calculated as follows.

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Total expenditure}}$$

3.8 STATISTICAL ANALYSIS

Data relating to each characters were analysed by applying the analysis of variance technique and significance was tested by F- test (Snedecor and Cochran, 1975). In case where the effects were found to be significant CD was calculated by using standard technique.

RESULTS

Plate 1 Vermicomposting yard

value reduced to 10.83 from 19.23. Microbial population also increased considerably by enriching vermicompost with organic additives. Secondary and micronutrient contents were also enhanced by enrichment except copper, copper was present in trace only. pH and EC also recorded increased values on enrichment of vermicompost.

4.2 INCUBATION STUDY

The incubation experiment was conducted to evaluate relative efficiency of different organic sources to release nutrients from soil and their influence on physico-chemical and biological properties of soil. Some important properties of soil namely available N, P, K, pH, EC, organic carbon, water holding capacity, bulk density, microbial count etc. influenced by different organic manures for a period upto 60 days were periodically analysed and recorded at an interval of 15 days and presented in Table 4 to 14.

4.2.1 Available Nitrogen

Table 4 shows the data on available nitrogen content of incubated soil for different periods *viz.*, 0^{th}, 15^{th}, 30^{th}, 45^{th} and 60^{th} day of incubation. Significant variation between the treatments were observed for all the five periods. The treatment T_3 representing soil + vermicompost enriched with neem cake 2 per cent recorded the maximum available nitrogen content and was significantly superior to all other treatments throughout the incubation period. Initially (0^{th} day), *treatment T_3 (soil +* EVC – NC 2 per cent) recorded the highest mean values of 229.17 kg ha^{-1} which was on par with T_4 (soil + EVC – BM 2 per cent) and T_2 (soil + FYM) with available nitrogen contents of 226.14 kg ha^{-1} and 224.77 kg ha^{-1} respectively. In general there was increase in available nitrogen content with advancement of time upto 45 days. The highest value of 359.23 kg ha^{-1} available nitrogen content was recorded by T[illegible] the 45^{th} day of

Table 4 Influence of different organic sources on available nitrogen content (kg ha^{-1}) of soil

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	219.04	232.15	227.14	240.82	270.52
T_1 (Soil + FYM)	222.71	244.02	328.73	352.06	326.43
T_2 (Soil + VC)	224.77	250.35	265.51	298.59	329.36
T_3 (Soil + EVC NC 2%)	229.17	283.46	354.38	359.23	353.16
T_4 (Soil + EVC BM 2 %)	226.14	263.66	302.21	343.55	301.17
T_5 (Soil + EVC NC 1% + BM 1 %)	220.86	266.35	328.43	318.25	313.34
SE	1.77	4.73	6.63	5.67	14.22
CD (0.05)	5.450	14.573	20.440	17.465	43.827

Table 5 Influence of different organic sources on available P_2O_5 (kg ha^{-1})

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	35.38	48.98	52.92	38.54	26.80
T_1 (Soil + FYM)	42.80	62.06	67.73	69.74	56.85
T_2 (Soil + VC)	41.96	68.76	71.33	70.29	65.81
T_3 (Soil + EVC NC 2%)	46.68	72.49	77.18	80.27	71.31
T_4 (Soil + EVC BM 2 %)	50.85	76.58	93.68	102.14	78.42
T_5 (Soil + EVC NC 1% + BM 1 %)	48.79	82.42	84.20	84.46	77.33
SE	1.64	2.63	2.53	2.24	2.10
CD (0.05)	5.063	8.107	7.826	6.908	6.498

incubation. Lowest values of soil nitrogen was recorded by T_0 (soil alone) which recorded a mean value of 219.04 kg ha^{-1} and was on par with T_5 and T_1.

During the 15th day of incubation highest mean value for available nitrogen was recorded by the treatment T_3 *i.e.*, 283.46 kg ha^{-1} and was found to be superior to all other treatments. As expected treatment T_0 (soil alone) recorded the lowest mean value of 232.15 kg ha^{-1} and was found to be on par with T_1 (soil + FYM). Critical observation of the data reveals that samples drawn after 30th, 45th and 60th days of incubation also showed similar trend as in the case of previous sampling with respect to changes in available nitrogen content. Highest values of 354.38 kg ha^{-1}, 359.23 kg ha^{-1}, 353.16 kg ha^{-1} was recorded by the treatments T_3 (soil + EVC – NC 2 per cent) during the 30th, 45th and 60th day of incubation respectively. The treatment T_0 (soil alone) recorded lowest values for available nitrogen content with a mean value of 227.14 kg ha^{-1}, 240.82 kg ha^{-1} and 270.52 kg ha^{-1} during 30th, 45th and 60th day of incubation respectively. On 45th day of incubation, the available N content recorded by the treatment T_3 was found to be on par with T_1 and T_4. During 60th day of incubation the available N content produced by treatment T_3, T_2, T_1 and T_5 were on par.

4.2.2 Available Phosphorus

Critical evaluation of data on available P_2O_5 content of soil shows significant variation among different treatments (Table 5). The treatment T_4 (soil + EVC – BM 2 per cent) recorded the maximum P_2O_5 content. There was an increase in P_2O_5 content upto 45 days of incubation, thereafter declined. The second highest value was recorded by the treatment T_5 (soil + EVC – NC 1 per cent + BM 1 per cent) through out the incubation period. During the initial sampling (0th day) treatment T_4 found to be on par with T_5 and T_3 with respect to available P_2O_5 content. The mean values recorded are 50.85 kg ha^{-1}, 48.75 kg ha^{-1} 46.68 kg ha^{-1}

respectively. The treatments T_3, T_1 and T_2 were also found to be on par initially.

On 15th day of incubation, treatment T_4 recorded highest mean value of 82.42 kg ha^{-1}, T_5 76.58 kg ha^{-1}, T_2 68.76 kg ha^{-1} and lowest values of 48.98 kg ha^{-1} was recorded by treatment To. Similar trends were observed during 30th, 45th and 60th day of incubation. The treatment T_4 recorded the maximum available P_2O_5 content of 93.68 kg ha^{-1}. 102.14 kg ha^{-1}, 78.42 kg ha^{-1} respectively. In all the periods of incubation lowest value was recorded by the treatment T_0.

4.2.3 Available K_2O

Data in Table 6 indicate the available K_2O content of soil due to various treatments. The trend of available K_2O release of the incubated soil was same as that of available P_2O_5. There was significant variation between the treatment with respect to K_2O content. The treatment T_4 representing soil + EVC (BM 2 per cent) recorded the maximum value for K_2O content in soil through out the incubation period. As expected treatment T_0 (soil alone) recorded the lowest value during the incubation period. Available K_2O content increase upto 45 days of incubation and then declined.

During 0th day (initial sampling) the highest mean value of 119.61 kg ha^{-1} was shown by the treatment T_4 and it was found to be on par with T_3 and T_5.

During the second sampling the treatment T_4 recorded highest mean value of 317.35 kg ha^{-1} followed by T_5. T_4 was significantly superior to others.

During 30th day the treatments are significantly different with respect to K_2O content. The treatment T_4 (soil + EVC – BM 2 per cent)

Table 6 Influence of different organic sources on available K_2O (kg ha^{-1})

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	98.74	123.20	182.93	227.73	224.00
T_1 (Soil + FYM)	105.13	208.30	261.37	291.43	257.60
T_2 (Soil + VC)	109.96	235.20	324.80	360.83	321.06
T_3 (Soil + EVC NC 2%)	116.69	265.07	324.80	369.63	291.20
T_4 (Soil + EVC BM 2 %)	119.61	317.35	362.20	384.59	347.33
T_5 (Soil + EVC NC 1% + BM 1 %)	115.48	280.01	350.18	339.74	302.40
SE	1.93	8.32	10.98	11.66	8.50
CD (0.05)	5.932	25.652	33.841	35.916	26.195

Table 7 Influence of different organic sources on organic carbon (%)

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	0.47	0.46	0.27	0.23	0.09
T_1 (Soil + FYM)	0.58	0.78	0.67	0.40	0.40
T_2 (Soil + VC)	0.65	0.790	0.49	0.46	0.19
T_3 (Soil + EVC NC 2%)	0.63	0.74	0.47	0.57	0.19
T_4 (Soil + EVC BM 2 %)	0.68	0.79	0.53	0.56	0.23
T_5 (Soil + EVC NC 1% + BM 1 %)	0.62	0.65	0.37	0.52	0.28
SE	0.02	0.04	0.04	0.04	0.03
CD (0.05)	0.064	0.125	0.494	0.114	0.102

recorded the highest value of 362.2 kg ha^{-1} and was on par with T_5 (350.18 kg ha^{-1}). In the 45[th] day the treatment T_4 (soil + EVC – BM 2 per cent) shows the highest value of 384.59 kg ha^{-1} and it was found to be on par with T_3 and T_2.

Available K_2O content of soil during 60[th] day of incubation was also influenced by different treatments and the K_2O content was found to be decreased on 60[th] day of incubation. The treatment T_4 showed the highest mean value for available K_2O (347.33 kg ha^{-1}) which is significantly superior to all other treatments.

4.2.4 Organic Carbon

Organic carbon content of soil during incubation influenced by different treatments are presented in Table 7. Treatments showed significant variation with respect to organic carbon content. Organic carbon content of incubated soil increased upto 15[th] day of incubation. Then show a declining trend. As expected T_0 recorded lowest value through out the incubation period and the organic carbon content was found to be decreased on increasing the period of incubation.

During initial sampling (0[th] day) the treatment T_4 (soil + EVC – BM 2 per cent) recorded the highest mean value for organic carbon, which registered a value of 0.68 per cent and it was found to be on par with T_2 and T_3.

The treatment T_2 (soil + VC) and T_4 (soil + EVC-BM 2 per cent) showed the highest values for organic carbon content of incubated soil on 15[th] day of incubation. It registered a maximum value of 0.79 per cent and was found to be on par with T_1 and T_3. During the 30[th] day of incubation organic carbon content shows a declining trend. Highest mean value of 0.67 per cent was shown by the treatment T_1 (soil + FYM) and found to be superior to all other treatments. Treatments T_2, T_3 and T_4 were on par.

Organic carbon content of incubated soil during the 45th day of incubation indicated that maximum value was recorded by the treatment T_3 (0.57 per cent) (soil + EVC – NC 2 per cent) and was found to be on par with T_4, T_5 and T_2.

During the final stage of incubation (60th day) highest mean value was recorded by the treatment T_1 (soil + FYM) (0.4 per cent) and was found to be significantly superior to others. T_2, T_3, T_4 and T_5 were on par.

4.2.5 pH

Changes of pH in soil incubated for different periods is given in Table 8. From the table it is observed that there was a clear cut increase in soil pH in all the treatments. In all the periods T_0 (soil alone) recorded minimum value.

During the initial stage (0th day) the highest mean value for pH was shown by the treatment T_4 (soil + EVC–BM 2 per cent) (5.45). It was found to be on par with T_1 and T_2. During the second sampling stage (15th day) the treatment T_5 (soil + EVC–NC 1 per cent + BM 1 per cent) showed higher value for pH (5.83). The treatment T_5 was on par with T_4 and T_1 was on par with T_0.

At 30th day of incubation, the treatment T_4 (soil + EVC–BM 2 per cent) shows the highest mean value (6.01). The treatment T_4 was found to be on par with T_1, T_5 and T_3. During 45th day of incubation the treatment T_5 showed highest mean values for pH (6.12) followed by T_4 and T_1. T_5, T_4, T_1 were on par.

During final stage of incubation, highest mean value for pH was shown by the treatment T_3 (6.5) (soil + EVC–NC 2 per cent) and found to be significantly superior to all other treatments.

Table 8 Influence of different organic sources on pH

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	5.21	5.36	5.03	5.41	5.81
T_1 (Soil + FYM)	5.27	5.41	5.93	5.94	6.11
T_2 (Soil + VC)	5.24	5.55	5.67	5.69	6.38
T_3 (Soil + EVC NC 2%)	5.38	5.65	5.84	5.89	6.50
T_4 (Soil + EVC BM 2 %)	5.45	5.77	6.01	5.98	6.34
T_5 (Soil + EVC NC 1% + BM 1 %)	5.35	5.83	5.92	6.12	6.16
SE	0.03	0.03	0.07	0.06	0.06
CD (0.05)	0.090	0.096	0.221	0.190	0.170

Table 9 Influence of different organic sources on electrical conductivity (milli Seimen cm^{-1})

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	0.32	0.34	0.36	0.37	0.33
T_1 (Soil + FYM)	0.33	0.38	0.52	0.52	0.66
T_2 (Soil + VC)	0.33	0.37	0.51	0.53	0.68
T_3 (Soil + EVC NC 2%)	0.33	0.39	0.52	0.54	0.55
T_4 (Soil + EVC BM 2 %)	0.33	0.37	0.49	0.54	0.56
T_5 (Soil + EVC NC 1% + BM 1 %)	0.34	0.36	0.55	0.58	0.61
SE	0.002	0.006	0.004	0.005	0.005
CD (0.05)	0.008	0.019	0.013	0.017	0.016

The observation revealed an increasing trend in pH due to the addition of organic manures.

4.2.6 Electrical Conductivity

Different treatments significantly influenced electrical conductivity of the soil. Electrical conductivity of the incubated soil was presented in Table 9. During the incubation period general trend was that there was an increase in electrical conductivity due to the addition of organic manures. Lowest values for EC was recorded during initial stages of incubation and conductivity increased as the period of incubation progressed. In all the periods T_0 (soil alone) recorded the lowest value.

At the 0^{th} day the treatment T_5 (soil + EVC–NC 1 per cent + BM 1 per cent) recorded the highest mean value for EC. It was found to be on par with T_4 and T_3. During the 15^{th} day, treatment T_3 (soil + EVC–NC 2 per cent) shows highest mean value for EC (0.39 dSm^{-1}) and was found to be on par with T_1 (soil + FYM).

During the third sampling (30^{th} day) the highest mean values for EC was recorded by the treatment T_5 (Soil + EVC–NC 1 per cent + BM 1 per cent) (0.55 dSm^{-1}) and was found to be significantly superior to all other treatments.

During the 4^{th} period of incubation (45^{th} day) also electrical conductivity showed same trend as in 30^{th} day *i.e.*, T_5 (soil + EVC –NC 1 per cent + BM 1 per cent) recorded the highest value (0.58 dSm^{-1}). During the final sampling stage highest value for EC was recorded by the treatment T_2 (soil + VC) (0.68 dSm^{-1}) followed by the treatment T_1. By enrichment of vermicompost with organic additives, there is decrease in EC.

4.2.7 Bulk Density

Table 10 shows the bulk density values of incubated soils. Bulk density was influenced by different treatments. Through out the incubation period T_0 (soil alone) recorded highest value. All treatments registered the lowest value for bulk density during fourth sampling (45th day).

At 0th day, treatment T_0 (soil alone) showed the highest value (1.45 Mg m^{-3}). The treatment T_3 (soil + EVC–NC 2 per cent) showed the minimum value for bulk density (1.34 Mg m^{-3}). The treatment T_0 was found to be on par with T_4 and T_5.

Highest mean value for bulk density was shown by the treatment T_0 (soil alone) at the second sampling period and it recorded a mean value of 1.51 Mg m^{-1}. Lowest values for bulk density was shown by the treatment T_5 (soil + EVC –NC 1 per cent + BM 1 per cent). The treatment T_0 was found to be on par with T_2. T_1, T_3 and T_4 are found to be on par.

During the 30th day of incubation highest mean value for bulk density was shown by the treatment. T_3 (soil + EVC –NC 2 per cent) (1.44 Mg m^{-3}) and it was on par with T_1. The treatment T_4 (soil + EVC–BM 2 per cent) (1.31 Mg m^{-3}) recorded the lowest value for bulk density.

At 45th day the treatment T_0 shows the highest mean value for bulk density (1.34 Mg m^{-3}). Lowest value was recorded by the treatment T_4 (soil + EVC –BM 2 per cent) (1.15 Mg m^{-3}). The treatment T_0 was on par with T_3. During the final period of incubation the treatment T_0 (soil alone) showed the highest mean values (1.53 Mg m^{-3}). T_0 was found to be on par with T_2 and T_5. T_1 recorded the minimum mean value for bulk density (1.13 Mg m^{-3}).

4.2.8 Water holding capacity

Table 11 shows the water holding capacity of incubated soil. Water holding capacity recorded an increasing trend as time progress. The water

Table 10 Influence of different organic sources on bulk density (Mg m^{-3})

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	1.45	1.51	1.43	1.34	1.53
T_1 (Soil + FYM)	1.34	1.28	1.37	1.22	1.13
T_2 (Soil + VC)	1.36	1.52	1.32	1.26	1.48
T_3 (Soil + EVC NC 2%)	1.34	1.31	1.44	1.30	1.39
T_4 (Soil + EVC BM 2 %)	1.42	1.33	1.31	1.15	1.28
T_5 (Soil + EVC NC 1% + BM 1 %)	1.37	1.26	1.32	1.24	1.47
SE	0.02	0.05	0.02	0.01	0.03
CD (0.05)	0.077	0.139	0.075	0.039	0.100

Table 11 Influence of different organic sources on water holding capacity (per cent)

Treatments	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day
T_0 (Soil alone)	27.67	26.88	26.24	34.30	28.32
T_1 (Soil + FYM)	28.07	32.78	36.31	35.36	32.43
T_2 (Soil + VC)	29.90	31.31	32.80	39.97	36.10
T_3 (Soil + EVC NC 2%)	28.69	28.85	32.00	40.04	31.28
T_4 (Soil + EVC BM 2 %)	31.50	30.59	33.74	35.00	36.80
T_5 (Soil + EVC NC 1% + BM 1 %)	30.29	35.35	38.03	37.60	32.46
SE	-	1.24	0.95	0.84	0.85
CD (0.05)	NS	3.834	2.933	2.594	2.608

holding capacity increased upto 45 days after incubation, then it gradually decreased.

During the initial period of incubation WHC was not significantly influenced by different treatments, eventhough the highest value was shown by treatment T_4 and lowest value by T_0.

During 15th day of incubation, T_5 shows the highest mean value for WHC (35.35 per cent) and lowest values is shown by the treatment T_0 (26.88 per cent). T_5 was found to be significantly superior to other treatments. The treatments T_3 and T_0 are found to be on par.

Highest mean value for WHC was shown by the treatment T_5 (soil + EVC NC 1 per cent + BM 1 per cent) at the third sampling period (30th day) and it recorded a value of 38.03 per cent. Lowest value for WHC was noted by the treatment T_0 (soil alone) (26.24 per cent). The treatment T_5 was found to be on par with T_1.

The treatment T_3 (soil + EVC -NC 2 per cent) shows highest mean values for WHC (40.04 per cent) during 45th day of incubation, and it was found to be on par with T_2 and T_5. Lowest value was shown by the treatment T_0 (soil alone) (34.3 per cent) and was on par with T_1 and T_4.

During last periods of incubation (60th day) T_4 recorded the highest mean value (36.8 per cent) and the lowest mean value of 28.32 per cent was shown by the treatment T_0. The treatment T_4 was found to be on par with T_2. In general WHC of the soil improved due to the presence of organic manure.

4.2.9 Microbial Count

Different treatments significantly influenced the microbial count and is presented in Tables 12 to 14.

4.2.9.1 Fungus

Table 12 shows the fungal count of incubated soil for different periods of incubation. Lowest value was shown by T_0 (soil alone) throughout incubation period and organic manure addition enhanced the fungal population. Fungal count of incubated soil increased upto 45 days, then it decreased. During the first stage of incubation (0^{th} day), T_3 (soil + EVC–NC 2 per cent) showed the higher value *i.e.*, 8 and lower value by T_0 (soil alone) (5). But the treatment effects were not significant.

During the second sampling stage different treatments significantly influenced the fungal count. The highest mean value of 13.33 was shown by the treatment T_5 and was on par with T_4 and T_3. During 15^{th} day of incubation enriched vermicompost greatly influenced the fungal population.

At the 30^{th} day (third sampling) microbial count (fungal count) gradually increased, but the treatments were not significantly different. However the treatment T_5 (soil + EVC–NC 1 per cent + BM 1 per cent) showed the highest mean value for fungal count (12.64).

At the fourth sampling stage different treatments greatly influenced the fungal count. The treatment T_5 (soil + EVC–NC 1 per cent + BM 1 per cent) recorded the highest mean value for fungal count (15.00) and was found to be on par with T_1, T_2, T_3 and T_4. Lowest mean value was shown by the treatment T_0 (7.67) (Soil alone).

During the final sampling stage (60^{th} day of incubation) the fungal count gradually decreased. The treatments T_3 showed higher mean value (11.00) for fungi and was on par with T_5, T_4, T_2 and T_1. The lowest mean value of 3.00 was shown by the treatment T_0 (soil alone).

Table 12 Influence of different organic sources on fungal population (count/ g)

Treatments	Dilution 10^4				
	0th day	15th day	30th day	45th day	60th day
T_0 (Soil alone)	5.00	6.67	7.67	7.67	3.00
T_1 (Soil + FYM)	5.33	8.33	11.33	13.67	7.67
T_2 (Soil + VC)	6.00	9.67	12.33	12.00	10.33
T_3 (Soil + EVC NC 2%)	8.00	10.33	12.00	12.67	11.00
T_4 (Soil + EVC BM 2 %)	7.00	13.00	11.33	13.33	9.67
T_5 (Soil + EVC NC 1% + BM 1 %)	7.00	13.33	12.64	15.00	10.33
SE	-	1.12	-	1.16	1.29
CD (0.05)	NS	3.458	NS	3.582	4.000

NS – Non significant

Table 13 Influence of different organic sources on bacterial population (count/g)

Treatments	Dilution 10^6				
	0th day	15th day	30th day	45th day	60th day
T_0 (Soil alone)	11.00	12.33	19.67	20.33	17.64
T_1 (Soil + FYM)	13.00	20.00	19.67	21.00	19.33
T_2 (Soil + VC)	13.00	15.00	21.00	22.33	19.00
T_3 (Soil + EVC NC 2%)	14.00	16.00	20.67	22.00	19.67
T_4 (Soil + EVC BM 2 %)	14.00	18.00	21.34	22.33	17.67
T_5 (Soil + EVC NC 1% + BM 1 %)	15.00	15.00	21.00	20.33	15.67
SE	-	0.92	-	-	-
CD (0.05)	NS	2.844	NS	NS	NS

NS – Non significant

4.2.9.2 Bacterial Count

During the initial stages of incubation different treatment did not show any significant effect on the bacterial count (Table 13). However the treatment T_5 showed the highest mean value for bacterial count (15.00) and lowest value of (11.00) was recorded by the treatment T_0.

At the second sampling period (15^{th} day) there was significant difference between treatments on the bacterial count. Treatment T_1 (soil + FYM) (20.00) showed the highest mean value for bacterial count and was on par with T_4 (soil + EVC–BM 2 per cent). Lowest value was recorded by the treatment T_0 (soil alone) (12.33). During 30^{th}, 45^{th} and 60^{th} days of incubation there was no treatment effect on bacterial count however the count was found to increase upto 45^{th} day of incubation and thereafter declined.

4.2.9.3 Actinomycete Count

Table 14 shows the actinomycete count of incubated soil. The actinomycete count increased slightly from 0^{th} day upto 30^{th} day, then it gradually decreased. The result showed that the actinomycete count was not significantly influenced by different treatments.

4.3 FIELD EXPERIMENT

A field experiment was conducted using amaranthus as a test crop to study the influence of enriched vermicompost on growth, yield and quality of amaranthus and the feasibility of substituting farmyard manure and inorganic fertilizers.

4.3.1 Biometric Observations

The data of various observations are presented in Tables 15 to 17. Various growth character of the crop *viz.*, height of the plant, number of

Table 14 Influence of different organic sources on actinomycetes population (count/g)

Treatments	Dilution 10^8				
	0th day	15th day	30th day	45th day	60th day
T_0 (Soil alone)	1.00	1.33	1.33	0.64	0.33
T_1 (Soil + FYM)	1.00	3.00	3.33	1.33	0.67
T_2 (Soil + VC)	1.33	1.67	2.33	1.67	0.67
T_3 (Soil + EVC NC 2%)	1.67	2.67	3.00	2.00	1.00
T_4 (Soil + EVC BM 2 %)	1.33	1.67	2.67	2.33	1.33
T_5 (Soil + EVC NC 1% + BM 1 %)	2.00	3.00	2.67	1.67	1.33
SE	-	-	-	-	-
CD (0.05)	NS	NS	NS	NS	NS

NS – Non significant

Plate 3. General view of field experiment

leaves, number of branches, stem girth and leaf/stem ratio at different stages of plant growth (30^{th}, 45^{th} and 60^{th} day after planting) were recorded and presented in Tables 15 to 17. Application of different organic sources had very significant influence on the growth parameters of amaranthus.

4.3.1.1 Plant Height

Plant height was significantly influenced by the application of different organic sources (Table 15)

For the first cutting, highest mean value for plant height (65.07 cm) was recorded by the treatment T_0 (FYM + full NPK) and was significantly superior to all other treatments. Second best treatment was T_4 (EVC-NC 2 per cent + full NPK). The lowest value of 50.75 cm was recorded by the treatment T_9 (EVC - NC 1 per cent + BM 1 per cent + ½ NPK). The treatment T_9 was on par with T_2, T_5, T_7 and T_1.

For the second cutting highest mean value for plant height was recorded by the treatment T_2 which represents VC + full NPK (88.17 cm). T_2 was on par with T_4 (81.10 cm) and T_0 (82.07 cm). The treatment T_7 (EVC-BM 2 per cent + ½ NPK) recorded the lowest mean value of 65.13cm.The treatment T_2 was on par with T_0 and T_4 .The treatment T_0 was on par with T_4, T_6 and T_5. T_8, T_1, T_3, T_9 and T_7 were on par.

For the third cutting T_2 (VC + full NPK) represented highest mean value for plant height (75.20 cm). The lowest value for plant height was recorded by the treatment T_9 (EVC - NC 1 per cent + BM 1 per cent + ½ NPK). The treatment T_2 was on par with T_4, T_0, T_6 and T_3. T_9 was on par with T_8, T_5 and T_7. In general plant height showed an increasing tendency upto 45^{th} day (2^{nd} cutting) thereafter it declined. During second cutting enhanced plant height was recorded irrespective of treatments.

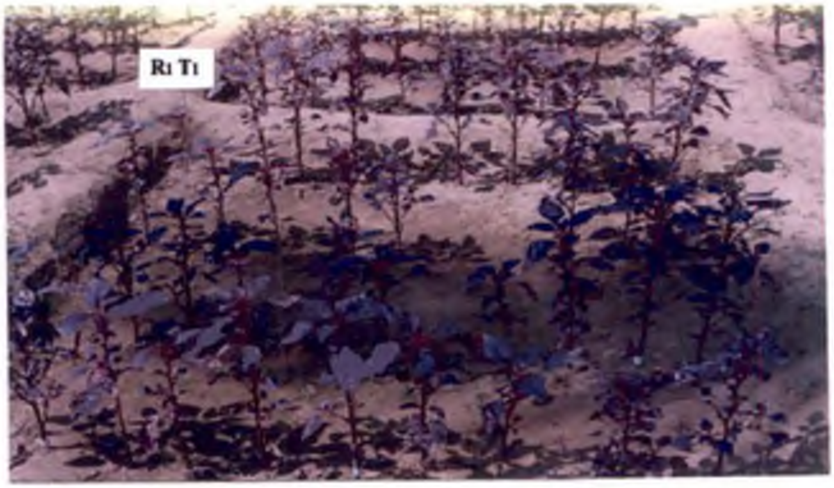


Plate 4. Plots treated with inorganics alone (NPK)

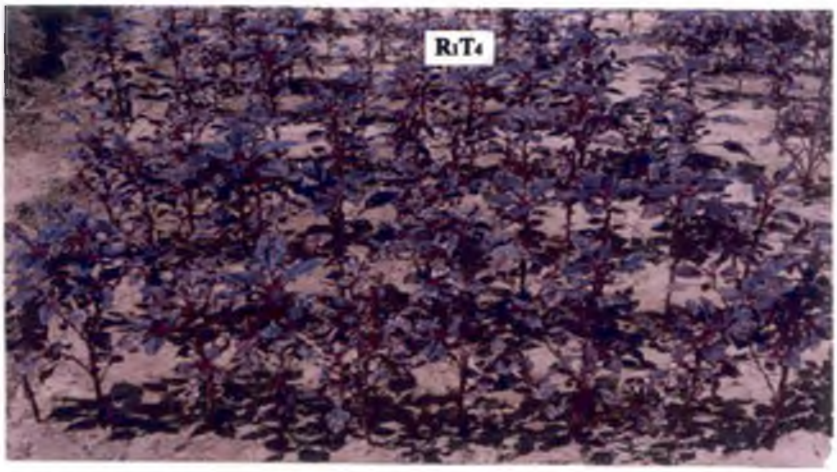


Plate 5. Plots treated with enriched vermicompost (neem cake 2 per cent + full NPK) as organic

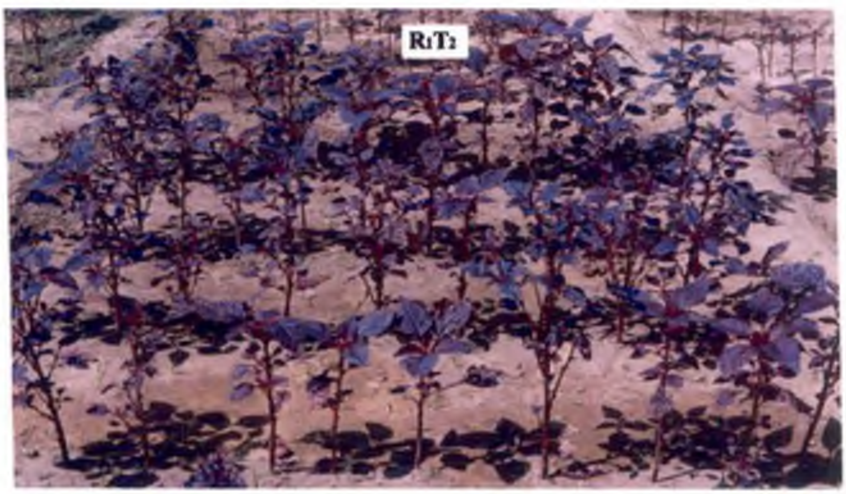


Plate 6. Plots treated with ordinary vermicompost + full NPK as organic

Table 15 Plant height (cm) and number of leaves affected by different organic manures on amaranthus

Treatments	Plant height (cm)			Number of leaves		
	1st cutting	2nd cutting	3rd cutting	1st cutting	2nd cutting	3rd cutting
T_0	65.07	82.07	71.88	75.73	100.07	80.50
T_1	50.87	68.67	67.43	52.27	85.80	70.70
T_2	51.59	88.17	75.20	62.73	104.73	79.53
T_3	52.28	68.67	71.06	58.33	93.50	71.43
T_4	58.69	81.10	75.04	72.93	107.43	84.47
T_5	51.32	76.33	62.80	61.67	91.77	75.27
T_6	56.00	77.10	71.42	72.56	109.13	83.90
T_7	50.91	65.13	61.82	54.20	86.33	74.07
T_8	55.97	71.73	63.24	84.97	104.53	76.53
T_9	50.75	67.50	59.05	69.20	94.30	72.97
SE	0.47	2.82	2.51	1.26	-	2.18
CD (0.05)	1.400	8.407	7.452	3.747	NS	6.474

NS – Non significant

T_0 FYM + Full NPK
T_1 Full NPK
T_2 VC + Full NPK
T_3 VC + ½ NPK
T_4 EVC-NC 2 % + full NPK
T_5 EVC-NC 2% ½ NPK
T_6 EVC-BM 2% + full NPK
T_7 EVC-BM 2% + ½ NPK
T_8 EVC-NC 1 % + BM 1% + full NPK
T_9 EVC-NC 1 % + BM 1% + ½ NPK

4.3.1.2 Number of Leaves

Table 15 presents the mean number of leaves at each cutting. It was observed that there was significant difference in the number of leaves due to different treatments *i.e.,* first and third cutting. During first cutting highest mean value of 84.97 was recorded by the treatment T_8 that represents (EVC - NC 1 per cent + BM 1 per cent + full NPK) and was significantly different from all other treatments. The treatment T_1 (NPK alone) recorded the lowest value, which registered a mean value of 52.27. The treatment T_1 was on par with T_7. T_0 was on par with T_4 and T_6. T_2 was on par with T_5, T_5 was on par with T_3.Eventhough more number of leaves were produced by all treatments during the 2nd cutting, number of leaves was not significantly influenced by different treatments. However, treatment T_6 (EVC – BM 2 per cent + Full NPK) recorded the highest value of 109.13 and lowest value of 85.80 is recorded by the treatment T_1 (NPK alone).

The different treatments had shown significant variation on the number of leaves produced at the time of 3rd cutting. The highest mean values of 84.47 was recorded by the treatment T_4 (EVC –NC 2 per cent + full NPK) and lowest value of 70.70 was registered by the treatment T_1 (NPK alone). The treatment T_4 was on par with T_6, T_0 and T_2. T_1 was on par with T_3, T_5, T_9 and T_8. After 45th day of planting the number of leaves produced showed a declining trend.

4.3.1.3 Number of Branches

Number of branches per plant at three harvests (1st, 2nd and 3rd cuttings) were significantly influenced by different treatments (Table 16).

During first cutting highest mean value of 32.67 was registered by the treatment T_4 (EVC –NC 2 per cent + full NPK) which was on par with T_5 (EVC –NC 2 per cent + 1/2 NPK). The treatment T_1 (NPK alone)

Table 16 Number of branches and stem girth (cm) affected by different organic manures on amaranthus

Treatments	Number of branches			Stem girth (cm)		
	1st cutting	2nd cutting	3rd cutting	1st cutting	2nd cutting	3rd cutting
T_0	21.23	33.80	18.17	4.79	6.34	4.89
T_1	17.60	28.53	14.47	3.79	5.94	4.57
T_2	24.43	32.80	15.60	4.33	5.08	4.67
T_3	22.93	30.03	14.47	3.80	4.85	4.39
T_4	32.67	37.87	18.60	4.30	5.74	4.83
T_5	29.20	35.07	17.53	4.04	5.09	4.93
T_6	25.83	43.00	17.13	4.59	5.23	4.56
T_7	23.73	34.63	16.37	4.20	4.93	4.51
T_8	25.00	31.27	19.33	4.43	5.33	4.92
T_9	23.00	30.83	18.30	4.20	5.17	4.66
SE	1.46	2.648	0.48	0.09	0.27	0.11
CD (0.05)	4.337	7.668	1.417	0.295	0.798	0.326

T_0 FYM + Full NPK
T_1 Full NPK
T_2 VC + Full NPK
T_3 VC + ½ NPK
T_4 EVC-NC 2 % + full NPK
T_5 EVC-NC 2% ½ NPK
T_6 EVC-BM 2% + full NPK
T_7 EVC-BM 2% + ½ NPK
T_8 EVC-NC 1 % + BM 1% + full NPK
T_9 EVC-NC 1 % + BM 1% + ½ NPK

registered lowest mean value (17.60) followed by T_0 and were on par.

During second cutting (45th day) all the treatments statistically showed a substantial increase in number of branches. The treatment T_6 (EVC –BM per cent + full NPK) registered the highest mean value of 43 and it was on par with T_4 and T_5 and the lowest mean value for number of branches was recorded by the treatment T_1 (NPK alone), which registered a mean value of 28.53. T_1 was on par with T_3. The treatment T_4 was on par with T_5, T_7, T_0, T_2, T_8 and T_9.

At the time of third cutting treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK) registered the highest mean value of 19.33 and was on par with T_6, T_9 and T_4. Lowest mean value of 14.47 was recorded by the treatment T_1 (NPK alone) and T_3 (VC+½ NPK) which was on par with T_2.Drastic reduction in number of branches produced were observed at the time of 3rd cutting.

4.3.1.4 Stem Girth

Stem girth of plant at all three harvests was significantly influenced by different treatments (Table 16). The treatment T_0 (FYM + full NPK) recorded the highest mean value for stem girth which registered a value of 4.79 cm and closely followed by T_6 and the lowest mean value of 3.79 cm was reported by the treatment T_1 (NPK alone). The treatment T_0 was on par with T_6 and T_3 was on par with T_1.

During second cutting highest mean value of 6.34 cm was registered by the treatment T_0 (FYM + full NPK) and the lowest value of 4.85 cm was recorded by the treatment T_3 (VC+½NPK). The treatment T_0 was on par with T_1 and T_4. T_8, T_6, T_9, T_5, T_2, T_7 and T_3 were on par.

At third harvest the highest mean value for stem girth was recorded by the treatment T_5 (EVC – NC 2 per cent + ½ NPK) which registered a mean value of 4.93 cm. The treatment T_3 (VC + ½ NPK) recorded the lowest mean value of 4.39cm. The treatments T_5 was on par with T_8, T_0, T_4, T_9 and T_1. T_2, T_9, T_1, T_6, T_7 and T_3 were also on par.

4.3.1.5 Leaf / Stem Ratio

Table 17 reveals that leaf stem ratio of plant was significantly influenced by different treatments. Highest ratio was registered by T_0 (FYM + full NPK) in all three harvests. T_0 recorded the highest mean value of 2.10 at first harvest. Lowest value is recorded by the treatment T_7 (EVC–BM 2 per cent + ½ NPK) which registered a mean value of 1.08. The treatment T_0 was superior to all other treatments. T_1 and T_7 are found to be on par. Treatments T_9, T_4, T_6, T_2, T_5 and T_3 are also found statistically on par.

During second cutting the treatment T_0 (FYM + full NPK) recorded the highest mean value of 2.22 and was found to be significantly superior to all other treatments. Lowest mean value of 1.11 was registered by the treatment T_1 (NPK alone). Treatments T_3, T_4, T_5, T_6, T_7 and T_9 were found to be on par. T_1 and T_3 also on par.

The highest mean value of 1.83 was recorded by the treatment T_0 (FYM + full NPK) at third harvest and was superior to all other treatments. The lowest mean value for leaf / stem ratio was recorded by the treatment T_9 (EVC - NC 1 per cent + BM 1 per cent + ½ NPK). The treatments T_4, T_2, T_6, T_3, T_5, T_7, T_1 and T_9 are found to be on par.

4.3.2 Yield Cutting^{-1} (t ha^{-1})

The result revealed that the yield cutting^{-1} was significantly influenced by different treatments (Table 18). The highest mean value of 6.13 t ha^{-1} was recorded by the treatment T_0 (FYM + full NPK) and it was found to be on par with T_4 and T_8 during first cutting. The minimum yield

Table 17 Leaf / stem ratio affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	2.10	2.22	1.83
T_1 (Full NPK)	1.12	1.11	0.94
T_2 (VC + Full NPK)	1.26	1.83	1.12
T_3 (VC + ½ NPK)	1.13	1.24	1.01
T_4 (EVCNC 2 % + full NPK)	1.32	1.39	1.19
T_5 (EVC-NC 2% ½ NPK)	1.22	1.30	0.99
T_6 (EVC-BM 2% + full NPK)	1.27	1.36	1.10
T_7 (EVC-BM 2% + ½ NPK)	1.08	1.36	0.95
T_8 (EVC-NC 1 % + BM 1% + full NPK)	1.66	1.72	1.35
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	1.37	1.43	0.90
SE	0.08	0.13	0.10
CD (0.05)	0.251	0.381	0.297

Table 18 Yield per cutting (t ha^{-1}) affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	6.13	17.22	9.35
T_1 (Full NPK)	2.99	8.97	6.08
T_2 (VC + Full NPK)	4.74	14.93	8.32
T_3 (VC + ½ NPK)	3.68	12.59	6.38
T_4 (EVCNC 2 % + full NPK)	5.77	15.48	11.06
T_5 (EVC-NC 2% ½ NPK)	4.21	11.61	8.24
T_6 (EVC-BM 2% + full NPK)	5.02	12.90	9.57
T_7 (EVC-BM 2% + ½ NPK)	3.94	10.68	7.34
T_8 (EVC-NC 1 % + BM 1% + full NPK)	5.77	11.39	9.38
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	3.70	9.61	6.99
SE	0.29	0.83	0.46
CD (0.05)	0.848	2.471	1.374

of 2.99 t ha^{-1} was recorded by the treatment T_1 (NPK alone). Treatments T_9, T_3 and T_1 found to be on par. T_5 was on par with T_7, T_9 and T_3.

During second cutting the maximum yield of 17.22 t ha^{-1} was recorded by the treatment T_0 (FYM + full NPK) and was on par with T_4 (EVC–NC 2 per cent + full NPK) and recorded a mean value of 15.48 t ha^{-1}. The lowest mean value of 8.97 t ha^{-1} was recorded by the treatment T_1 (NPK alone). The treatments T_7, T_9 and T_5 are found to be on par. The treatment T_6 was on par with T_3, T_5, T_8 and T_7. In the first and second cuttings (upto 45 days) yield due to enriched vermicompost (neem cake) equals to that of POP (T_0).

During third cutting highest mean value of 11.06 t ha^{-1} yield was registered by the treatment T_4 (EVC–NC 2 per cent + full NPK) and was significantly superior to all other treatments. Lowest mean value of 6.08 t ha^{-1} was recorded by the treatment T_1 (NPK alone). Treatments T_9, T_3 and T_7 were on par with each other. The treatment T_6 was on par with T_8, T_0, T_2 and T_5.

4.3.3 Total Yield $Plant^{-1}$ (g $plant^{-1}$)

There was significant difference among treatments for total yield $plant^{-1}$ (Table 19). The treatment T_0 (FYM + full NPK) yielded maximum of 196.1 g $plant^{-1}$ followed by T_4 194.04 g $plant^{-1}$ and were on par. The lower mean value of 108.26 g $plant^{-1}$ was recorded by the treatment T_1 (NPK alone) and it was on par with T_9. The treatment T_2 was on par with T_8 and T_6.

4.3.4 Total Marketable Yield (t ha^{-1})

Different treatments significantly influenced total marketable yield of amaranthus (Table 19). The highest mean value of 31.40 t ha^{-1} was recorded by the treatment T_0 (FYM + full NPK) and was found to be on

Table 19 Total yield per plant (g plant^{-1}), total marketable yield (t ha^{-1}), total dry matter production (t ha^{-1}) and B:C ratio

Treatments	Total yield per plant (g plant^{-1})	Total marketable yield (t ha^{-1})	Total dry matter production (t ha^{-1})	BC Ratio
T_0	196.10	31.40	4.98	3.34
T_1	108.26	15.44	3.03	2.23
T_2	167.94	26.49	4.90	2.96
T_3	135.77	21.07	2.86	2.37
T_4	194.04	30.91	4.69	2.61
T_5	144.37	22.70	4.34	1.94
T_6	167.92	25.41	4.21	2.01
T_7	131.76	21.04	3.32	1.62
T_8	165.71	24.70	5.09	2.01
T_9	121.84	18.13	3.43	1.49
SE	5.24	2.54	0.23	0.287
CD (0.05)	15.578	0.856	0.689	0.10

T_0 FYM + Full NPK
T_1 Full NPK
T_2 VC + Full NPK
T_3 VC + ½ NPK
T_4 EVC-NC 2 % + full NPK
T_5 EVC-NC 2% ½ NPK
T_6 EVC-BM 2% + full NPK
T_7 EVC-BM 2% + ½ NPK
T_8 EVC-NC 1 % + BM 1% + full NPK
T_9 EVC-NC 1 % + BM 1% + ½ NPK

par with T_4 representing EVC-NC 2 per cent + full NPK (30.91 t ha^{-1}). Lowest value of 15.44 t ha^{-1} was recorded by the treatment T_1 (NPK alone). Treatments T_6 was on par with T_8 and T_3 was on par with T_7.

4.3.5 Total Dry Matter Production (t ha^{-1})

Total dry matter production was significantly influenced by different treatments (Table 19). The treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + Full NPK) recorded the highest mean value of 5.09 t ha^{-1} and the lowest dry matter production (2.86 t ha^{-1}) was registered by the treatment T_3 (VC + ½ NPK). The treatment T_8 was on par with T_0, T_2 and T_4. Also the treatments T_9, T_7, T_1 and T_3 were on par.

4.3.6 Economics of Cultivation

Table 19 shows economics of cultivation of amaranthus crop. Data showed that the treatment T_2 (VC + full NPK) recorded the highest B:C ratio (4.23) followed by the treatment T_4 (EVC – NC 2 per cent + full NPK). T_2 was found to be superior than all other treatment. Lowest B:C ratio was recorded by the treatment T_9 (EVC –NC 1 per cent + BM 1 per cent + ½ NPK) which recorded the mean value of 2.13. T_3 was on par with T_0, T_6 was on par with T_8. T_7, T_1 and T_9 were also on par

4.3.7 Plant Content of Nutrients

The plant samples were analysed for their nutrient composition at three harvests. Major nutrient contents of the plants were greatly influenced by different treatments (Table 24 to Table 26).

4.3.7.1 Nitrogen

Treatment T_4 (EVC–NC 2 per cent + full NPK) recorded the highest mean value for nitrogen content in all the three cuttings as 2.42 per cent,

Table 20 Nitrogen content (per cent) affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	1.70	2.24	1.75
T_1 (Full NPK)	1.43	1.56	0.97
T_2 (VC + Full NPK)	1.98	1.94	1.42
T_3 (VC + ½ NPK)	1.85	1.61	1.21
T_4 (EVCNC 2 % + full NPK)	2.42	2.46	2.00
T_5 (EVC-NC 2% ½ NPK)	2.28	1.81	1.53
T_6 (EVC-BM 2% + full NPK)	1.79	2.03	1.92
T_7 (EVC-BM 2% + ½ NPK)	1.72	1.68	1.27
T_8 (EVC-NC 1 % + BM 1% + full NPK)	2.20	2.13	1.68
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	2.07	2.05	1.14
SE	0.03	0.09	0.09
CD (0.05)	0.101	0.26	0.27

2.46 per cent and 2.00 per cent in first, second and third cuttings respectively (Table 20).

During first cutting the nitrogen content in T_4 is significantly superior than all other treatments. Lowest mean value for nitrogen content was recorded by the treatment T_1 (NPK alone) and it was found to be significantly inferior to all other treatments. Treatment T_5 was on par with T_8. T_6 was on par with T_7 and T_0.

For second cutting highest mean value for nitrogen content was recorded by the treatment T_4 (EVC–NC 2 per cent + full NPK), which registered a mean value of 2.46 per cent and it was found to be on par with T_0 (FYM + full NPK). The treatment T_1 recorded lower value for nitrogen content (1.57 per cent). The treatments T_5 was on par with T_7, T_3 and T_1. Also T_8 was on par with T_9, T_6 and T_2.

For the third cutting, the treatment T_4 (EVC –NC 2 per cent + full NPK) recorded the highest mean value for nitrogen content *i.e.*, it recorded a mean value of about 2.00 per cent. The minimum value of 0.97 per cent was recorded by the treatment T_1 (NPK alone). T_4 was on par with T_6 and T_3 was on par with T_9 and T_1.

4.3.7.2 Phosphorus

For 'P' various treatments significantly influenced the P content of plant (Table 21). For the first cutting, highest mean value for phosphorus was recorded by the treatment T_6 (EVC–BM 2 per cent + Full NPK) which is significantly superior to all other treatments. The treatment T_6 recorded a mean value of 0.41 per cent. Lowest value for P content was recorded by the treatment T_1 (NPK alone) (0.24 per cent). The treatments T_3 was on par with T_1 and T_4 was on par with T_0.

Table 21 Phosphorus content (per cent) affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	0.331	0.260	0.227
T_1 (Full NPK)	0.240	0.197	0.143
T_2 (VC + Full NPK)	0.030	0.240	0.184
T_3 (VC + ½ NPK)	0.258	0.201	0.166
T_4 (EVCNC 2 % + full NPK)	0.350	0.310	0.289
T_5 (EVC-NC 2% ½ NPK)	0.298	0.253	0.233
T_6 (EVC-BM 2% + full NPK)	0.410	0.340	0.308
T_7 (EVC-BM 2% + ½ NPK)	0.367	0.280	0.270
T_8 (EVC-NC 1 % + BM 1% + full NPK)	0.354	0.310	0.276
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	0.303	0.269	0.233
SE	0.01	0.01	0.12
CD (0.05)	0.020	0.032	0.008

There was significant variation among treatment for P content during second cutting. Highest mean value for P content was recorded by the treatment T_6 (EVC–BM 2 per cent + Full NPK) which recorded a mean value of 0.34 per cent. Treatment T_6 was on par with T_8 and T_4. The treatment T_1 (NPK alone) recorded minimum value for P content (0.197 per cent).

During third cutting highest value is recorded by the treatment T_6 (EVC–BM 2 per cent + Full NPK) and it registered a value of 0.31 per cent. The lowest mean value was recorded by the treatment T_1 (NPK alone) (0.14 per cent). The treatment T_6 was on par with T_4. T_1 was on par with T_3 and T_2.

4.3.7.3 Potassium

A lot of variation in the K content of the plant was noticed due to various treatments (Table 22). For the first cutting, the treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK) recorded the highest mean value of 4.13 per cent and was found to be on par with T_6, T_9 and T_2. Lowest value of 2.27 per cent was recorded by the treatment T_5 (EVC–NC 2 per cent + ½ NPK). Treatment T_5 was on par with T_1, T_0, T_3, T_4 and T_7.

During second cutting the treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK) recorded the highest mean value of 3.96 per cent and it was superior to all other treatments. The treatment T_1 (NPK alone) recorded lowest mean value for K content (2.34 per cent). T_3 was on par with T_1.

For the third cutting also the treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK) recorded the highest mean value (3.33 per cent) and the lowest value was recorded by the treatment T_3 (VC + ½ NPK) (2.03 per cent). Treatment T_8 was on par with T_9. T_9 was on par with T_0 and T_6. T_3 and T_1 were also on par.

Table 22 Potassium content (per cent) affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	2.67	3.61	3.01
T_1 (Full NPK)	2.67	2.34	2.19
T_2 (VC + Full NPK)	3.47	2.72	2.53
T_3 (VC + ½ NPK)	2.53	2.39	2.03
T_4 (EVCNC 2 % + full NPK)	2.93	3.23	2.73
T_5 (EVC-NC 2% ½ NPK)	2.27	2.60	2.43
T_6 (EVC-BM 2% + full NPK)	3.6	3.32	2.97
T_7 (EVC-BM 2% + ½ NPK)	2.93	3.01	2.71
T_8 (EVC-NC 1 % + BM 1% + full NPK)	4.13	3.96	3.33
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	3.47	3.59	3.15
SE	0.25	0.10	0.08
CD (0.05)	0.736	0.306	0.227

4.3.8 Plant Uptake of Nutrients

Perusal of data on plant nutrient uptake revealed that different treatments significantly influenced the uptake of nutrients (Table 23).

4.3.8.1 Nitrogen Uptake (Table 23)

In the case of nitrogen T_4 (EVC –NC 2 per cent + full NPK) recorded the highest mean value of 111.52 kg ha^{-1} which was found to be on par with T_0 (FYM + full NPK) and T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK). Lowest mean value for N uptake was recorded by the treatment T_1 (NPK alone), which registered a value of 40.92 kg ha^{-1} and was on par with T_3. T_0 was on par with T_8, T_5, T_6 and T_2. T_9 was on par with T_7.

4.3.8.2 Phosphorus Uptake (Table 23)

There was significant difference due to various treatments on P uptake. For 'P' highest mean value for uptake was recorded by the treatment T_6 (EVC - BM 2 per cent + Full NPK) (15.94 kg ha^{-1}) which was found to be on par with T_8 and T_4. The lowest mean value of 5.51 kg ha^{-1} was shown by the treatment T_1 (NPK alone). The treatments T_3 and T_1 are found to be on par. T_0, T_5 and T_2 were on par.

4.3.8.3 Potassium Uptake (Table 23)

Various treatments influenced the 'K' uptake significantly. The treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + Full NPK) recorded the highest mean value and it recorded a value of 196.17 kg ha^{-1}. The lowest mean value of 68.55 kg ha^{-1} was recorded by the treatment T_3 (VC + ½ NPK) and was on par with T_1. Treatments T_0, T_6, T_4 and T_2 were found to be on par.

Table 23. Plant uptake of major nutrients (kg ha^{-1}) affected by different organic manures on amaranthus

Treatments	N	P	K
T_0 (FYM + Full NPK)	99.48	13.30	162.09
T_1 (Full NPK)	40.92	5.51	70.83
T_2 (VC + Full NPK)	88.05	11.41	137.61
T_3 (VC + ½ NPK)	45.50	5.95	68.55
T_4 (EVCNC 2 % + full NPK)	111.52	14.14	145.86
T_5 (EVC-NC 2% ½ NPK)	91.67	12.93	105.99
T_6 (EVC-BM 2% + full NPK)	90.83	15.94	152.60
T_7 (EVC-BM 2% + ½ NPK)	54.93	8.18	103.91
T_8 (EVC-NC 1 % + BM 1% + full NPK)	98.93	15.22	196.17
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	62.43	9.35	121.24
SE	4.52	0.87	10.24
CD (0.05)	13.43	2.59	30.44

4.3.9 Quality Analysis

4.3.9.1 Moisture Content

There was significant difference among treatments with respect to moisture content at all the three cuttings (Table 24). During first cutting the treatment T_3 (VC + ½ NPK) recorded the highest mean value for moisture content (87 per cent). The lowest value of 76.67 per cent was recorded by the treatment T_5 (EVC –NC 2 per cent + ½ NPK). The treatment T_3 was significantly superior to all other treatments. The treatment T_0 was on par with T_9, T_2, T_6 and T_1. T_8 was on par with T_4, T_7, T_0 and T_9.

During second cutting the highest mean value was recorded by the treatment T_3 (87.23 per cent). The treatment T_5 (EVC –NC 2 per cent + ½ NPK) recorded the lowest mean value of 78.73 per cent. The treatment T_3 was on par with T_4 and T_0. T_0 was on par with T_7, T_1, T_9 and T_6. T_8 and T_5 were also on par.

The highest mean value for moisture content was recorded by the treatment T_3 representing VC + ½ NPK (86.13 per cent) during the third cutting. The treatment T_5 (EVC –NC 2 per cent + ½ NPK) recorded the lowest value (80.57 per cent). The treatment T_3 was on par with T_0 and the treatments T_6, T_1, T_4 and T_7 were on par.

4.3.9.2 β-carotene Content

Data on β-carotene content at different growth stages of plants are presented in Table 25. Different treatments significantly influenced the β-carotene content of plant. In all the three harvests T_8 (EVC-NC 1 per cent + BM 1 per cent + full NPK) recorded the highest values for β-carotene content and least value was recorded by the treatment T_1 (NPK alone) and was found to be significantly inferior to all other treatments.

Table 24 Moisture content (per cent) affected by different organic manures on amaranthus

Treatments	1st cutting	2nd cutting	3rd cutting
T_0 (FYM + Full NPK)	82.50	85.00	85.67
T_1 (Full NPK)	81.00	82.90	84.63
T_2 (VC + Full NPK)	82.00	82.67	82.57
T_3 (VC + ½ NPK)	87.00	87.23	86.13
T_4 (EVCNC 2 % + full NPK)	83.83	85.67	84.30
T_5 (EVC-NC 2% ½ NPK)	76.67	78.73	80.57
T_6 (EVC-BM 2% + full NPK)	81.83	82.27	84.80
T_7 (EVC-BM 2% + ½ NPK)	83.57	83.73	84.30
T_8 (EVC-NC 1 % + BM 1% + full NPK)	84.40	79.60	81.47
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	82.77	82.67	82.60
SE	0.80	0.92	2.42
CD (0.05)	2.377	2.738	0.815

During the first cutting maximum value for β-carotene was recorded by the treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK). It recorded a mean value of 3867.37 μg per100g and it was found to be superior to all other treatments. The treatments T_6 was on par with T_9 . T_9 was on par with T_0. T_0 was on par with T_4 and T_2 was on par with T_3 and T_5.

At second harvest, treatment T_8 (EVC-NC 1 per cent + BM 1 per cent) + full NPK) had a significant and superior effect on β-carotene content. It showed the highest mean value 4108.11 μg per100 g and as expected the treatment T_1 (NPK alone) recorded the least value (3171.17 μg per 100 g).

During third cutting also same trend was observed with respect to β-carotene content. The maximum value of 3930.88 μg per 100 g was reported by the treatment T_8 (EVC-NC 1 per cent + BM 1 per cent + full NPK) which was found to be on par with T_6 (3860.67 μg per 100 g). The minimum value of 3090.52 μg per 100 g was registered by the treatment T_1 (NPK alone). The treatments T_2 was on par with T_3. T_4 and T_0 were on par.

4.3.9.3 Protein Content

Various treatments significantly influenced the protein content of amaranthus crop to a great extent (Table 25). T_4 recorded maximum protein content at all harvests and was significantly superior to all other treatments and T_0 (NPK alone) recorded the minimum value in all the three cuttings and was significantly inferior to all other treatments.

During the first cutting the maximum value (15.11 per cent) for protein was recorded by the treatment T_4 (EVC –NC 2 per cent + full NPK). The treatment T_1 recorded the lowest mean value (8.94 per cent). The treatments T_5 was on par with T_8. T_9 was on par with T_2. T_3 was on par with T_6. T_6 was on par with T_7 and T_0.

Table 25 β-carotene (μg $100g^{-1}$) and protein content (per cent) affected by different organic manures on amaranthus

Treatments	β-carotene content (μg $100g^{-1}$)			Protein content (per cent)		
	1st cutting	2nd cutting	3rd cutting	1st cutting	2nd cutting	3rd cutting
T_0	3584.80	3720.40	3662.30	10.65	14.00	10.96
T_1	2973.64	3171.17	3090.52	8.94	9.80	6.07
T_2	3225.63	3450.45	3373.92	12.36	12.13	8.87
T_3	3208.66	3317.12	3341.46	11.56	10.03	7.58
T_4	3530.40	3792.79	3678.11	15.11	15.38	12.48
T_5	3208.50	3414.41	3330.30	13.90	11.32	9.57
T_6	3704.23	3871.17	3860.67	11.21	12.72	12.02
T_7	3371.45	3539.19	3493.22	10.72	10.50	7.93
T_8	3867.37	4108.11	3930.88	13.78	13.30	10.50
T_9	3665.73	3776.58	3763.75	12.94	12.83	7.12
SE	31.08	56.78	25.17	0.25	0.55	0.56
CD (0.05)	92.401	168.716	74.784	0.731	1.628	1.678

T_0 FYM + Full NPK
T_1 Full NPK
T_2 VC + Full NPK
T_3 VC + ½ NPK
T_4 EVC-NC 2 % + full NPK
T_5 EVC-NC 2% ½ NPK
T_6 EVC-BM 2% + full NPK
T_7 EVC-BM 2% + ½ NPK
T_8 EVC-NC 1 % + BM 1% + full NPK
T_9 EVC-NC 1 % + BM 1% + ½ NPK

During second cutting the highest mean value for protein content (15.38 per cent) was recorded by the treatment T_4 (EVC –NC 2 per cent + full NPK) and it was found to be on par with T_0 (FYM + full NPK). The treatment T_1 (NPK alone) recorded the lowest mean value for protein content (9.8 per cent). The treatment T_1 was found to be on par with T_5, T_7 and T_3.

Different treatments greatly influenced protein content of plant at harvest during third cutting. The treatment T_4 (EVC–NC 2 per cent + full NPK) recorded the highest value of 12.48 per cent and the lowest value was registered by the treatment T_1 (NPK alone) (6.07 per cent). The treatments T_4 was on par with T_6 and T_0. T_1, T_3 and T_9 were also on par.

4.3.9.4 Fibre Content

There was significant treatment effect on the fibre contents of the plants (Table 26) in all three cuttings.

During first cuttings the treatment T_1 was found to be superior to other treatments with respect to fibre content and recorded a maximum value of 15.83 per cent. All other treatments showed lower values than T_1 (NPK alone). Least value was recorded by the treatment T_2 (VC + full NPK) (12.33 per cent). The treatments T_4, T_8 and T_2 are found to be on par. T_7, T_6, T_9, T_5 were also on par.

Treatment T_1 (NPK alone) recorded the highest mean value of 13.77 per cent in the second cutting. T_1 was found to be on par with T_7, T_0, T_6 and T_5. Lowest value of 10.63 per cent was recorded by the treatment T_2 (VC + full NPK) which were found to be significantly inferior to all other treatments.

Fibre content of plant at the time of third cutting was significantly influenced by different treatments. The treatment T_1 (NPK alone) recorded the highest value of 14.9 per cent. The treatment T_2 recorded the

Table 26 Fibre content and oxalate content affected by different organic manures on amaranthus, per cent

Treatments	Fibre content			Oxalate content		
	1st cutting	2nd cutting	3rd cutting	1st cutting	2nd cutting	3rd cutting
T_0	14.77	13.50	13.63	1.97	2.03	1.98
T_1	15.83	13.77	14.90	2.04	2.26	2.07
T_2	12.33	10.63	11.57	1.63	1.76	1.75
T_3	13.00	11.80	12.77	1.64	1.71	1.72
T_4	12.93	12.40	12.83	1.74	1.95	1.90
T_5	13.50	13.07	13.23	1.55	1.77	1.76
T_6	13.8	13.23	14.10	2.11	2.20	2.14
T_7	14.10	13.63	13.77	1.82	2.02	1.91
T_8	12.60	11.60	11.97	1.89	2.03	1.96
T_9	13.73	12.70	13.37	1.52	1.86	1.72
SE	0.21	0.25	0.33	0.045	0.05	0.45
CD (0.05)	0.635	0.733	0.994	0.138	0.151	0.136

T_0 FYM + Full NPK
T_1 Full NPK
T_2 VC + Full NPK
T_3 VC + ½ NPK
T_4 EVC-NC 2 % + full NPK
T_5 EVC-NC 2% ½ NPK
T_6 EVC-BM 2% + full NPK
T_7 EVC-BM 2% + ½ NPK
T_8 EVC-NC 1 % + BM 1% + full NPK
T_9 EVC-NC 1 % + BM 1% + ½ NPK

lowest value of 11.57 per cent. The treatment T_1 was on par with T_6.Also T_4 was found to be on par with T_3, T_8 and T_2. The fibre content was found to be reduced during second cutting (45th day) and thereafter showed slight increase.

4.3.9.5 Oxalate Content

Various treatments showed a significant difference in oxalate content at all harvests (Table 26).

For the first cutting highest mean value for oxalate content was recorded by the treatment T_6 (EVC - BM 2 per cent + Full NPK) (2.11 per cent) followed by the treatment T_1. The treatments T_6 and T_1 are found to be on par. The minimum value for oxalate content was recorded by the treatment T_9 (EVC - NC 1 per cent + BM 1 per cent + ½ NPK) and it was found to be on par with T_2 and T_5.

During second cutting the treatment T_1 recorded highest mean value of 2.26 per cent and the lowest value is recorded by the treatment T_3 (VC + ½ NPK) (1.71 per cent). T_1 was on par with T_6. Treatments T_9, T_5, T_2 and T_3 were also on par.

During third cutting also similar trend was noticed as in the previous cutting. The treatment T_6 (EVC - BM 2 per cent + Full NPK) recorded the highest mean value for oxalate content (2.14 percent) and was on par with T_1 (2.07 per cent). The lowest value of 1.72 per cent was recorded by T_3 (VC + ½ NPK) and T_9 (EVC - NC 1 per cent + BM 1 per cent + ½ NPK). The treatments T_5, T_2, T_9 and T_3 were on par.

4.3.10 Post Harvest Analysis of Soil

4.3.10.1 pH

There were significant differences among treatment for pH values of soil (Table 27). The highest value for pH was recorded by the treatment

Table 27. Post harvest analysis of soil for pH, EC and BD

Treatments	pH	EC (dSm^{-1})	Bulk density ($mg\ m^{-3}$)
T_0 (FYM + Full NPK)	5.63	0.360	1.58
T_1 (Full NPK)	5.20	0.213	1.65
T_2 (VC + Full NPK)	6.05	0.374	1.40
T_3 (VC + ½ NPK)	5.84	0.310	1.53
T_4 (EVCNC 2 % + full NPK)	5.86	0.398	1.56
T_5 (EVC-NC 2% ½ NPK)	5.47	0.345	1.43
T_6 (EVC-BM 2% + full NPK)	5.96	0.475	1.46
T_7 (EVC-BM 2% + ½ NPK)	5.61	0.421	1.55
T_8 (EVC-NC 1 % + BM 1% + full NPK)	5.91	0.438	1.62
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	5.73	0.301	1.52
SE	0.075	0.012	0.05
CD (0.05)	0.231	0.0038	0.158

T_2 (VC + full NPK) which registered a mean value of 6.05. The lowest value was recorded by the treatment T_1 (5.2) followed by T_5 (5.47). The treatment T_2 was on par with T_6, T_8 and T_4.

4.3.10.2 Electrical Conductivity

Table 27 revealed that electrical conductivity of soil was significantly influenced by different treatments. In general, electrical conductivity of the soil increased by the application of different organic manures. Lowest value was recorded by T_1 (0.213 dSm^{-1}) and the highest value is recorded by T_6 (0.475 dSm^{-1}) which is statistically superior to all other treatments.

4.3.10.3 Bulk Density

From the results (Table 27) it can be inferred that bulk density of soil was influenced by different treatments. The treatment T_1 (NPK) registered the maximum value of 1.65 Mg m^{-3} and was found to be on par with T_8. The lowest value (1.40) for bulk density is recorded by the treatment T_2. T_2 (vermicompost + full NPK) was on par with T_5.

4.3.10.4 Organic Carbon

Table 28 shows the organic carbon content of soil after the harvest of crop. The result indicated that different treatments did not significantly affect organic carbon content of soil. However the organic carbon content of the soil improved after the experiment. The values range from 0.683 per cent to 0.840 per cent.

4.3.10.5 Available Nitrogen

Available nitrogen in the soil after the harvest of the crop was significantly influenced by different treatments (Table 28). The treatment T_4 (EVC–NC 2 per cent + full NPK) registered the highest mean value of

Table 28 Post harvest analysis of soil for major nutrients

Treatments	Organic carbon (%)	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_0 (FYM + Full NPK)	0.753	265.52	124.95	90.35
T_1 (Full NPK)	0.687	245.36	97.98	70.19
T_2 (VC + Full NPK)	0.840	267.6	136.20	88.11
T_3 (VC + ½ NPK)	0.743	255.24	113.11	69.44
T_4 (EVCNC 2 % + full NPK)	0.757	307.33	119.27	103.04
T_5 (EVC-NC 2% ½ NPK)	0.753	288.51	100.38	80.64
T_6 (EVC-BM 2% + full NPK)	0.790	271.63	163.29	97.81
T_7 (EVC-BM 2% + ½ NPK)	0.743	262.38	128.81	75.41
T_8 (EVC-NC 1 % + BM 1% + full NPK)	0.683	298.96	147.36	114.99
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	0.713	275.97	121.86	96.29
SE	-	1.62	2.28	2.013
CD	NS	4.821	6.796	5.981

NS – Non significant

307.33 kg ha^{-1} followed by T_8 representing (EVC - NC 1 per cent + BM 1 per cent + full NPK). T_1 (NPK alone) registered the lowest value of 245.36 kg ha^{-1}. The treatment T_4 is significantly superior to all other treatments. The treatment T_9 was on par with T_6 and T_2 was on par with T_0.

4.3.10.6 Available Phosphorus

There was significant difference among treatment for available phosphorus content of soil (Table 28). The treatment T_6 (EVC - BM 2 per cent + Full NPK) registered highest mean value of 163.29 kg ha^{-1} and is superior to all other treatments. As expected lowest value of 97.98 kg ha^{-1} was recorded by the treatment T_1 (NPK alone). The treatment T_1 was on par with T_5. T_0 was on par with T_9 and T_4. T_4 and T_3 were also on par.

4.3.10.7 Available Potassium

Available potassium content of soil after the harvest of the crop was influenced by different treatments and is presented in Table 28. The treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + full NPK) showed the highest mean value of 114.99 kg ha^{-1}. Lowest value was recorded by the treatment T_3 (VC + ½ NPK) (69.44 kg ha^{-1}). The treatment T_8 was superior to all other treatments. The treatment T_3 was on par with T_1. T_7 was on par with T_1. Treatment T_4 was on par with T_6, T_6 was on par with T_9 and T_9 was on par with T_0.

4.3.10.8 Microbial Count

Table 29 shows the changes in microbial population due to various treatments under field conditions. Among microbes fungal and bacterial population was significantly influenced by different treatments.

Regarding the fungal count treatment T_8 (EVC-NC 1 per cent + BM 1 per cent + Full NPK) recorded the highest mean value (22.67) followed by the treatments T_4 (21.67) and T_6 (21) .Lowest mean value was recorded

Table 29 Post harvest analysis of soil for microbial population (count per gram of soil)

Treatments	Fungus (Dilution 10^4)	Bacteria (Dilution 10^6)	Actinomycetes (Dilution 10^8)
T_0 (FYM + Full NPK)	18.33	25.67	2.67
T_1 (Full NPK)	16.00	23.00	2.33
T_2 (VC + Full NPK)	19.67	25.33	3.67
T_3 (VC + ½ NPK)	17.33	23.00	2.67
T_4 (EVCNC 2 % + full NPK)	21.67	31.67	4.00
T_5 (EVC-NC 2% ½ NPK)	19.67	25.00	2.33
T_6 (EVC-BM 2% + full NPK)	21.00	29.00	3.00
T_7 (EVC-BM 2% + ½ NPK)	20.00	28.00	2.67
T_8 (EVC-NC 1 % + BM 1% + full NPK)	22.67	29.33	3.67
T_9 (EVC-NC 1 % + BM 1% + ½ NPK)	18.67	26.33	3.00
SE	0.887	2.98	-
CD (0.05)	2.521	1.05	NS

NS – Non significant

by the treatment T_1(NPK alone) (16). The treatment T_8 was on par with T_4 and T_6. T_4 was on par with T_6, T_7, T_5 and T_2.Mean values of T_5 and T_2 are same.

For bacteria highest mean value was recorded by the treatment T_4 (EVC-NC 2 per cent + Full NPK)(31.67) and the lowest values are shown by T_1 (NPK alone) and T_3 (VC+1/2 NPK) (23) (Mean values of T_1 and T_3 are same). T_4 was on par with T_8. T_8 was on par with T_6 and T_7. The treatments T_0, T_2, T_5, T_1 and T_3 were also on par.

Eventhough the actinomycetes population was not influenced by different treatments, highest mean value was recorded by the treatment T_4 (EVC-NC 2 per cent + Full NPK) and the lowest mean value was recorded by the treatment T_1 (NPK alone) and T_5 (EVC-NC 2 per cent+ ½ NPK). The mean values were 4 and 2.33 respectively. The mean values of T_1 and T_5 were same.

DISCUSSION

5. DISCUSSION

The experimental findings detailed in the previous chapter have been briefly discussed here in the light of published information and fundamental theoretical knowledge.

5.1 PREPARATION AND ANALYSIS OF ENRICHED VERMICOMPOST

The success of sustainable agriculture is very much dependent upon the availability of cheap and good quality organic manures. Among the sources of available organic manures, vermicompost is a potential source due to the presence of readily available plant nutrients, growth enhancing substances and a number of beneficial microbes like nitrogen fixing, P solubilising and cellulose decomposing organisms. The nutrient content of ordinary vermicompost is low compared to inorganic fertilizers. It is observed that when vermicompost is enriched with organic additives like neem cake and bone meal its nutrient status is expected to be increased.

On perusal of data in Table 2 indicated that ordinary vermicompost recorded lesser values for all the nutrient contents compared to enriched vermicompost. C:N ratio was narrowed down by enrichment and it is an indication for maturity of compost and enhanced mineralisation consequent to high microbial activity. Microbial count also enhanced by enriching vermicompost with organic additives like neem cake and bone meal. The abundance of microorganisms in different organic sources was in the order of bacteria>fungi>actinomycetes. Bone meal enriched vermicompost registered high P_2O_5 content and this may be due to solubilisation of P from bone meal during composting and transformed into available form due to the presence of P solubilising microorganisms associated with vermicompost and earthworms (Mba, 1997).

5.2 INCUBATION STUDY

The results of various soil parameters investigated *viz.*, organic carbon, available N, P_2O_5, K_2O, pH, EC, water holding capacity, bulk density and microbial count influenced by different organic sources for a period of 60 days are discussed hereunder.

Table 4 shows the data on available nitrogen content of incubated soil upto 60 days. There was significant difference between the treatments and it was observed that in general there is an increasing trend in the available nitrogen upto 45 day of incubation and then a decrease. Among the treatments highest value of available nitrogen was recorded by soil treated with neem cake 2 per cent enriched vermicompost. This might be due to the presence of substantial amount of nitrogen (4.0 per cent) in neem cake enriched vermicompost. The soil treated with different organic sources registered high content of available nitrogen and T_0 (soil alone) recorded the lowest value. The difference between those treatments received organic manures and those without organic manures had been found to be pronounced with the advancement of time.

The increase in available nitrogen is due to the enhanced mineralisation of organic matter consequence of high microbial activity. The process of aminisation, ammonificatoin and oxidative deamination all brought about by microbially mediated systems are believed to be active in organic sources treated medium. Thus contributing more of soluble nitrogen to the soil. Available nitrogen content show declining trend after 45^{th} day. This might be due to decline in microbial population. Available nitrogen content in the treatment T_0 (soil alone) show slight change throughout the incubation period, it may be due to stabilized nature of organic matter (Dinesh and Dubey, 1999).

Available P_2O_5 content showed significant variation (Table 5). Highest value was recorded by T_4 (soil + EVC- bone meal 2 per cent) and

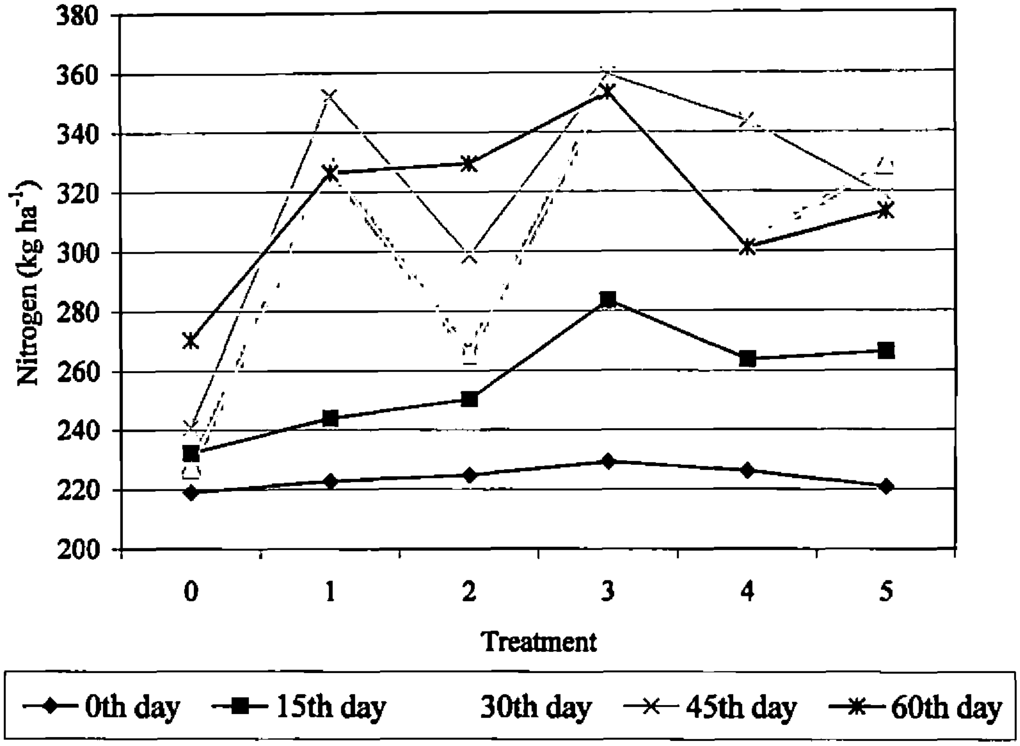


Fig. 4 Influence of different organic sources on available nitrogen content (kg ha^{-1}) of soil

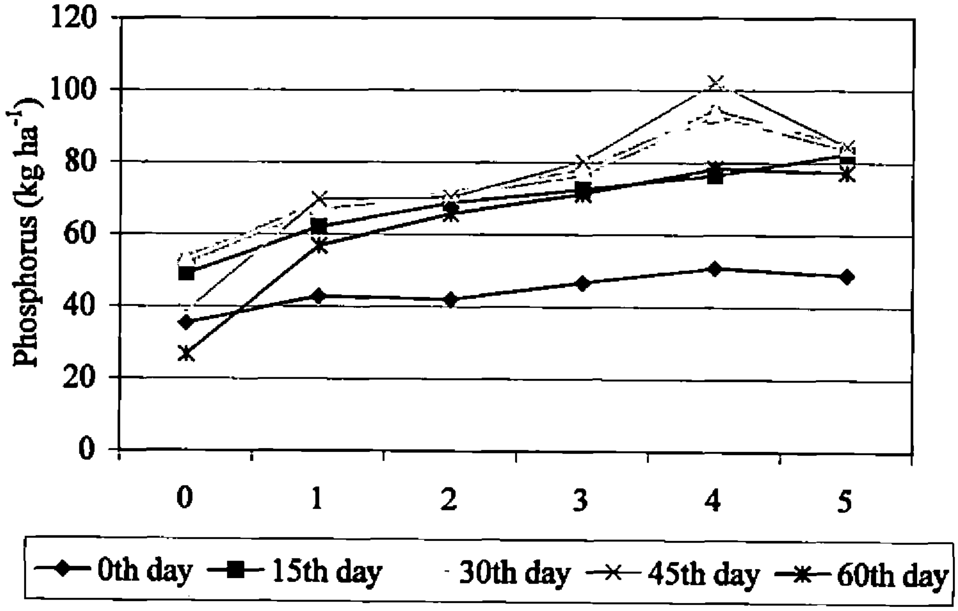


Fig. 5 Influence of different organic sources on available phosphorus content (kg ha^{-1}) of soil

second highest value by T_5 (soil + EVC - neem cake 1 per cent + bone meal 1 per cent) throughout the incubation period. In general there was a gradual increase in available P_2O_5 content with advancement of time and then declined. The high content of P in T_4 and T_5 is due to increased mineralistion in presence of high microbial population and transformed insoluble P to available form. The increase in available P_2O_5 content due to vermicompost application was reported by Gaur (1990). This may be due to the greater mineralisation of organic matter with the aid of microorganisms associated with earthworms and increased phosphatase activity. Organic matter and soil humus have a positive beneficial effect on P availability (Vyas, 1971). There is chance for increase in available P content of acid soil due to complex formation with Fe and Al and hydrous oxides thereby preventing from reacting with phosphates (Brady, 2001). Mackey *et al.* (1983) found that incorporation of earthworm to soil incubated with phosphate rock resulted in a 32 per cent increase in bray extractable P after 70 days.

Different treatments significantly influenced available potassium content of incubated soil (Table 6) . The highest value for available K_2O was registered by vermicompost enriched with bone meal 2 per cent and maximum release noticed at 45^{th} day of incubation. Reason for higher potassium may be due to accelerated mineralisation due to high microbial activity and release of K from exchange site due to interaction of organic matter with clay (Tan,1982). Increased availability of K by earthworm activity was reported by Rao *et al.* (1996). As the major portion of K_2O is obtained from mineralisation of organic matter the peak concentration of available K_2O also synchronized with the peak time of mineralisation (Dhanokar *et al.*, 1994). Bhaskar *et al.* (1994) inferred from the incubation experiment that the exchangeable potassium content increased significantly due to earthworm activity. The higher concentration of exchangeable potassium of the soil with worms compared with that of the

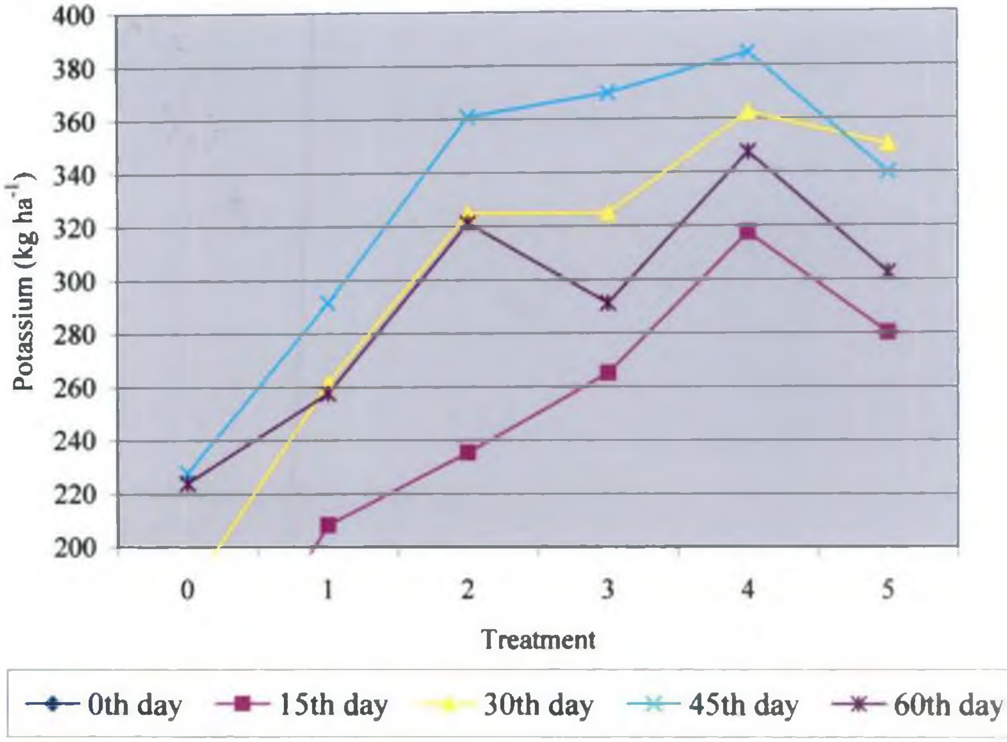


Fig. 6 Influence of different organic sources on available potassium content (kg ha^{-1}) of soil

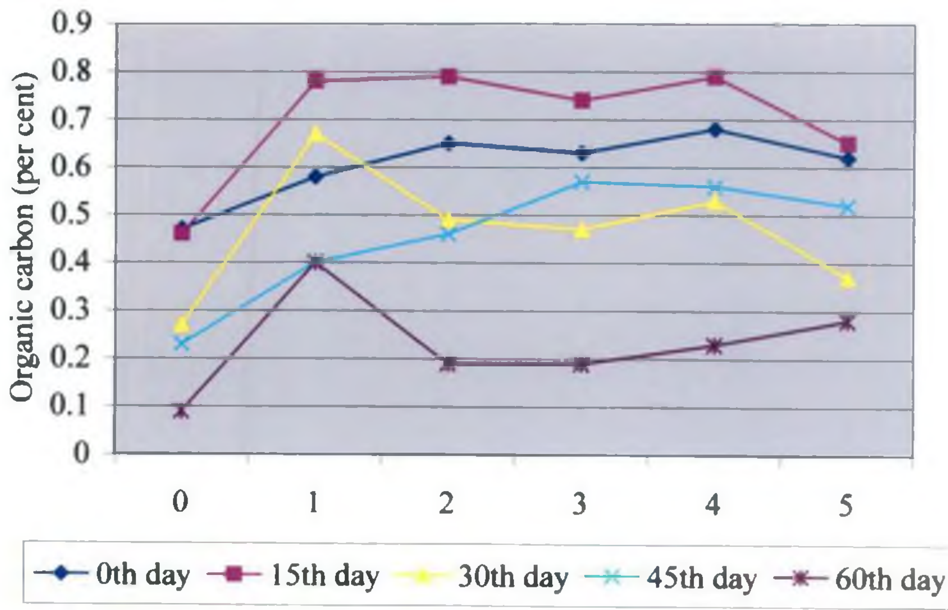


Fig. 7 Influence of different organic sources on organic carbon (per cent) of soil

soil without worms at the same moisture level confirms the positive role of earthworms in influencing this fraction of potassium.

Increased K availability in enriched vermicompost treated pots may be due to the increased potassium in enriched vermicompost. Manjaiah *et al.* (1995) reported that rock phosphate with organic amendments and P solubilisers were effective in making N, P, K and S more available. Potassium availability is more in organic matter treated soil than in control plot. This may be due to high microbial activity that results in increased mineralisation and release of basic cation like K (Ammal and Muthiah, 1994).

Different treatments showed significant variation with respect to organic carbon content of soil (Table 7). Organic carbon content of soil increased upto 15th day of incubation and thereafter declined. The observed decrease in organic carbon content with time after a peak is due to intensive mineralisation and loss of carbon as CO_2. By introducing earth worms and applying organic matter in the red arid soil, the organic carbon content of soil increases from 0.5 to 0.6 per cent (Shuxin *et al.*, 1991). More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon, available N, available P and available K of the soil.

Changes in pH due to incubation indicated that there is an increase in soil pH in all treatments throughout the incubation period with advancement of time. The results (Table 8) indicated that by the addition of organic manures, soil pH found to be increased near to neutral point. The maximum pH of 6.5 was recorded by T_3 which indicated an initial pH of 5.38. All the treatments received organic matter had crossed the pH value by 6.0 on 60th days of incubation except T_5 which attain pH above 6 at 45th day of incubation. This is in agreement with the observation by Datta (1996). Similar changes in pH was reported by Olsen *et al.* (1970).

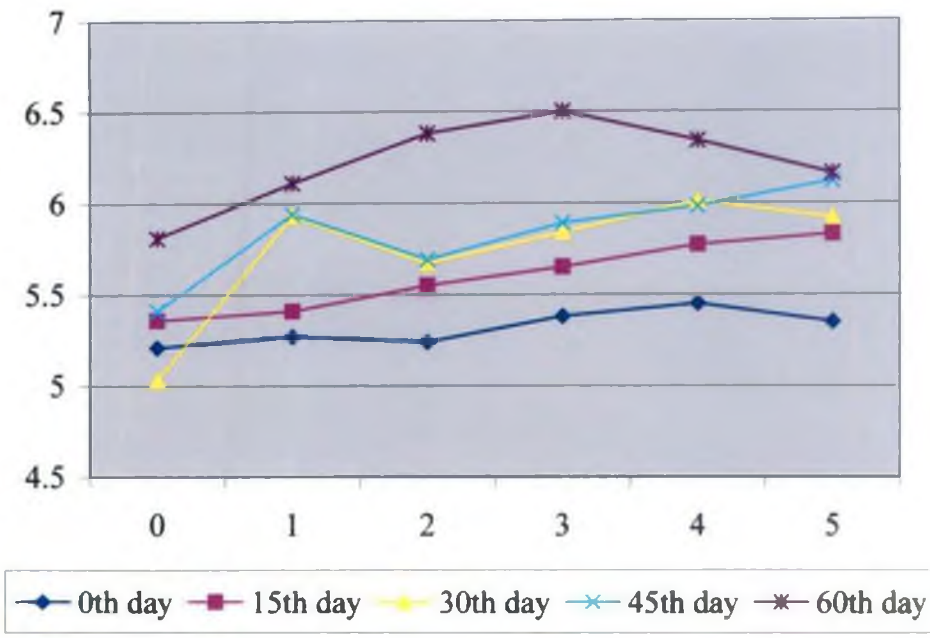


Fig. 8 Influence of different organic sources on pH of soil

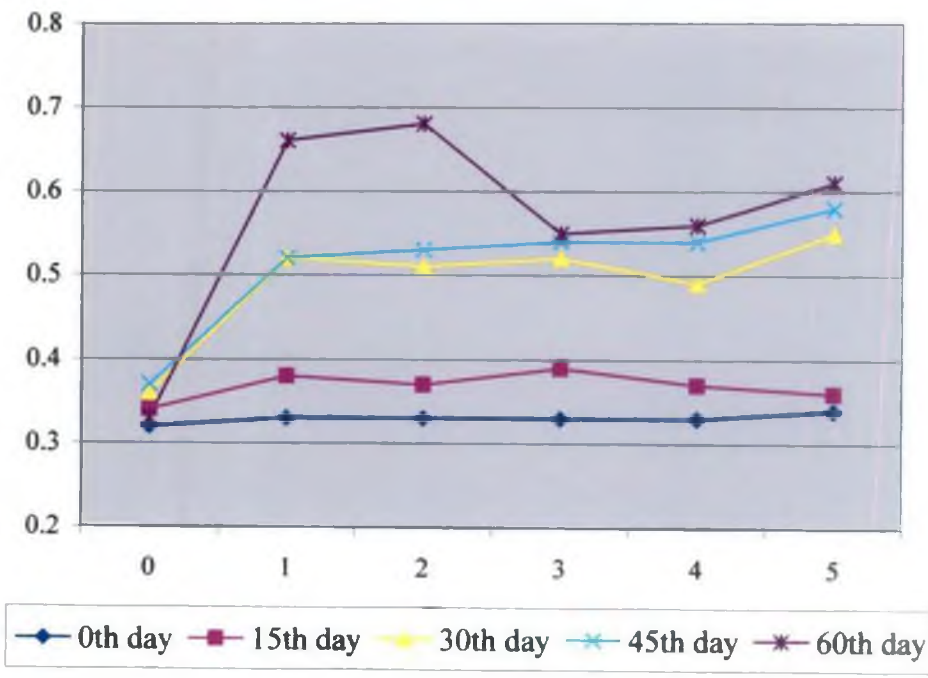


Fig. 9 Influence of different organic sources on electrical conductivity of soil

The increase in pH might be due to increase in bases by active degradation of organic matter and the suppression of activity of Fe and Al oxides and hydroxides which play vital role in protonation and deprotonation mechanisms controlling H^+ ion concentration in soil solution.

Electrical conductivity (EC) of the incubated soil increased by the addition of organic manures. Generally EC increased by application of organic manures throughout the incubation period. This might be due to the faster release of bases and soluble organic fractions to the soil system by mineralisation. This is in agreement with the findings of Thompson *et al.* (1989). They reported that total ionic concentration of system containing organic amendments is increasing leading to higher ionic mobility expressing high EC values. Vermicompost and enriched vermicompost are fully humified and contained large concentration of bases may lead to enhanced EC compared to control (soil alone). By enriching vermicompost with organic additives EC was found to be reduced significantly. This may be due to slow and steady release of ions.

Bulk density was significantly influenced by the addition of organic manures(Table10).Treatment T_0 showed highest value. Organic amendments applied treatments showed comparatively lesser value. Decrease in bulk density may be due to increase in soil physical properties like soil aggregation and aeration. Mbagwu (1989) reported that the application of organic waste like poultry manure, compost, saw dust, rice shavings and cashew leaves reduces the bulk density of soil. From a long term field experiment in England, Rose (1990) reported that continuous application of farmyard manure increases the total porosity of soil. In another experiment a decrease in bulk density by the addition of organic matter residues over long time was reported by Rasmussen *et al.* (1991). A decrease in bulk density was reported by Gupta *et al.* (2000) in residue and FYM incorporated treatments. Reduction in bulk density of soil may be due to better soil aggregation and aeration brought about by organic amendments (Kadalli *et al.*, 2000).

Different treatments significantly influenced the water holding capacity (WHC) (Table11). Highest value for WHC was recorded by 45th day and then gradually declined. All the organic manure treated samples recorded high WHC and low values by T_0 (soil alone) throughout the incubation period. Organic matter greatly influences water retention through soil structural changes which in turn influence moisture energy relationship (Brady, 2001).

Mbagwu (1989) reported that the application of organic waste like poultry manure, compost, saw dust, rice shavings and cashew leaves improves the soil structure, total porosity, macro porosity and saturation hydraulic conductivity.

Regarding the microbial count (Table12-Table14) actinomycetes population showed lower values compared to bacteria and fungi. This may be due to competition and actinomycetes are sensitive to acidic soil conditions (Brady, 2001).

During initial period of incubation microbial count was found to be low and subsequently increased upto 45th day of incubation. Lal *et al.* (2002) reported the beneficial effects of organic matter addition on soil microbial population. Lal *et al.* (2000) reported that in an incubation study incorporation of residues of *Lantana camara*, *Ipomea cornea*, water hyacinth, lenthil straw, maize stover and rice straw in acid clay loam soil significantly increased the population of aerobic non-symbiotic nitrogen fixing, phosphorus solubilising and sulphur oxidising microorganisms.

5.3 FIELD EXPERIMENT

Biometric Observations

Important biometric observations recorded are plant height, number of leaves, number of branches, stem girth and leaf stem ratio. All biometric observations were taken at three harvests (30^{th}, 45^{th} and 60^{th} days after transplanting). In general all the growth characters showed significant difference between treatments and maximum crop growth was noticed during second harvest (Table15 to Table 17). This may be due to improved physico-chemical and biological properties of soil as indicated by incubation result (Table 4 – Table 14). The critical evaluation of the data revealed that T_0 received FYM as organics and NPK as inorganics was significantly superior to other treatments with respect to plant height during the first harvest. This may be due to the integrated effect of organics and inorganics and immediate availability of nutrients from soluble inorganic fertilizers. Second highest value for plant height was recorded by T_4 (EVC-NC 2 per cent + Full NPK) for the first cutting. During the second cutting and third cutting maximum plant height was recorded by T_2 (VC + Full NPK) and was on par with T_4 (EVC-NC 2 per cent + Full NPK) and T_0 (FYM + Full NPK). It may be due to enhanced release of nutrients from organics on advancement of time. For all the three cuttings lower values for plant height were recorded by treatments where NPK recommendation was reduced to half. Increased plant height by the addition of vermicompost is in confirmity with the findings of Shuxin *et al.* (1991), Bijulal (1997) and Vadiraj (1993). Plant growth promoting hormones present in the vermicompost can enhance the vegetative growth of the plant.

Different treatments significantly influenced the number of leaves at the first and third cuttings. However maximum number of leaves recorded at the second cutting by all the treatments. Lowest number of leaves were recorded by the treatment T_1 (NPK alone as mineral fertilizer). All the treatments received organic amendments recorded substantial number of leaves, this may be due to the presence of more available nutrients and biologically active metabolites present in the

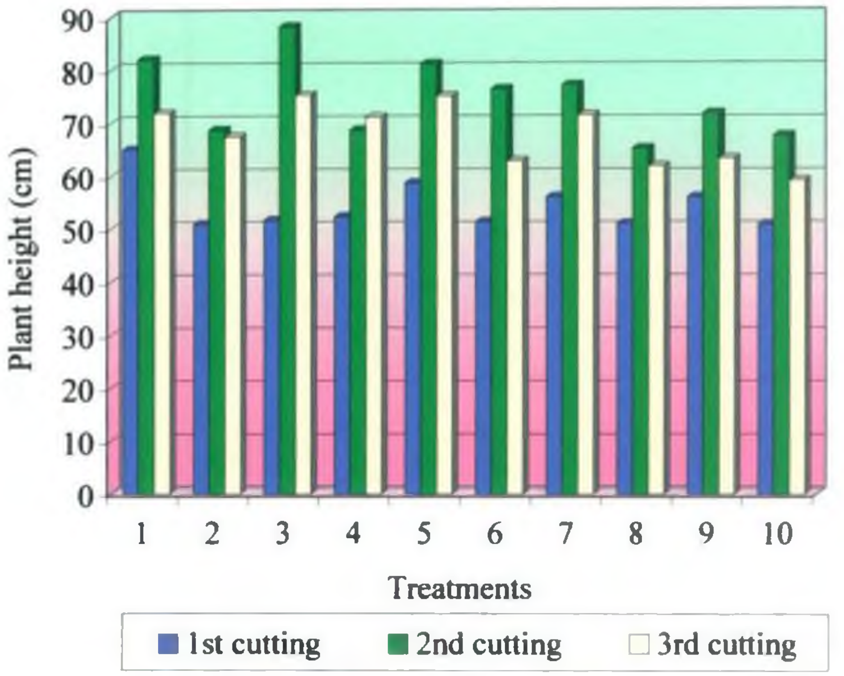


Fig. 10 Effect of different organic sources on plant height

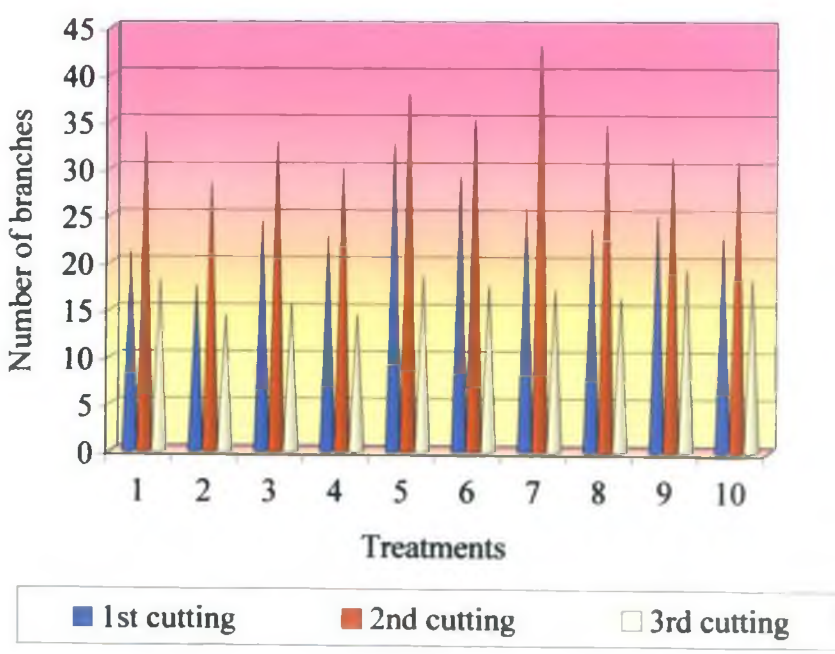


Fig. 11 Effect of different organic sources on number of branches

organics. This was supported by Pushpa (1996), Rajalekshmi (1996) and Meera (1998).

For all the three harvests number of branches were significantly influenced by different treatments. From the data (Table 16) it was revealed that number of branches were more in the case of treatments received vermicompost and enriched vermicompost and it is closely followed by vermicompost enriched with half NPK. Similar trend was observed in the case of vermicompost enriched with bone meal and a combination of bone meal and neem cake. These proved that by enriching vermicompost with organic additives, the NPK requirement can be reduced to half. Sailajakumari (1999) also reported that in cowpea maximum number of branches per plant was produced by treatment which received enriched vermicompost alone. Beneficial effects of organic amendments in increasing growth parameters were reported by Zhang *et al.* (1988), Pushpa (1996) and Anitha (1997) .

With respect to stem girth different treatments showed significant difference and maximum stem girth was recorded by all the treatments at second harvest stage compared to first and third harvest stages (Table16). Statistically equivalent stem girth was registered by treatments T_0 and T_4 during second and third cuttings. This is due to increased availability and utilization of nutrients at four to six weeks of cropping period.

Leaf stem ratio was significantly influenced by different treatments. Highest value was recorded by treatment T_0, lowest value was recorded by plots receiving inorganics alone. Among the enriched vermicompost, enrichment with combination of neem cake and bone meal found to be best with respect to leaf stem ratio. During second cuttings the ratio was found to be increased compared to the first and third cutting. This is because of the increased availability of nutrients and plant metabolites from the organic sources.

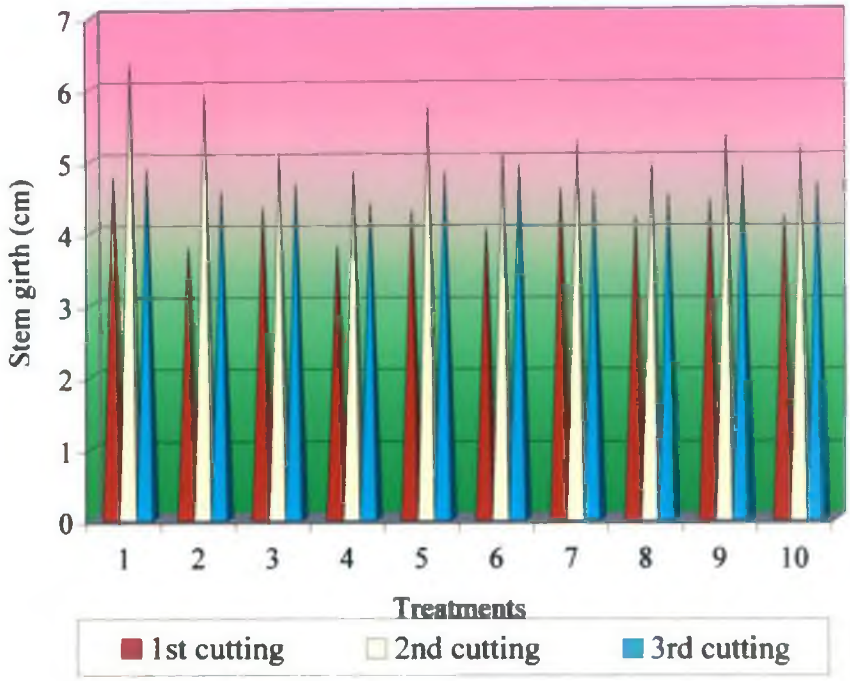


Fig. 12 Effect of different organic sources on stem girth

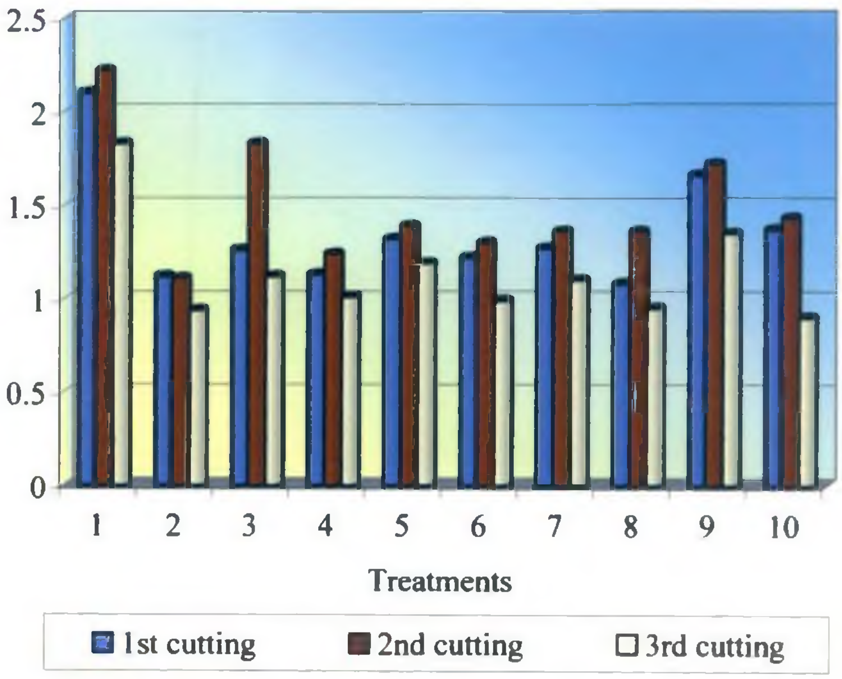


Fig. 13 Effect of different organic sources on leaf : stem ratio

In all the harvest maximum yield was recorded by T_0 and T_4 and lowest value was recorded by the treatment T_1 (NPK alone as inorganics). In the case of inorganic fertilizers nutrient mineralisation occurs very quickly and that are susceptible to leaching losses (Tisdale *et al.*, 1997). This results in low nutrient availability throughout the cropping period in the plots supplied with inorganic fertilizers alone. Hence the nutrients from the chemical fertilizers are not fully available to plants at different stages of crop growth, which results in reduced yield and quality. Organic additives like neem cake and bone meal contained nutrient, which are very slowly available for the plants and less susceptible to leaching. This slow nutrient releasing ability of organic additives would have resulted in increased yield in later stages. In amaranthus, leaf and shoot portions were the economic parts and better manuring gave better growth and yield. The higher yield may be due to better vegetative growth of the plant. This is in confirmity with the experiment conducted by Raj (1999) in bhindi and revealed that neem cake mixed with FYM was superior to all other organic manures. In cowpea application of vermicompost as an organic source enhances the microbial activity and improves nitrogen fixation (Meera, 1998; Parkin and Berry, 1994). The enrichment of soil with nitrogen using vermicompost and enriched vermicompost increased nitrogen uptake and resulted in increased yield. The significant increase in yield as a result of higher nitrogen level was observed by Singh (1984) in amaranthus. Thangavel *et al.* (2003) reported that vermicompost application increased the growth and yield of paddy.

Total yield per plant and total marketable yield were significantly influenced by different treatments (Table 19). The treatment T_0 recorded the maximum value and was found to be on par with T_4. The lowest value was registered by T_1 (NPK alone as inorganics) and this indicates that application of organics along with inorganics is essential to get higher crop yield. Among the enriched vermicompost, vermicompost enriched

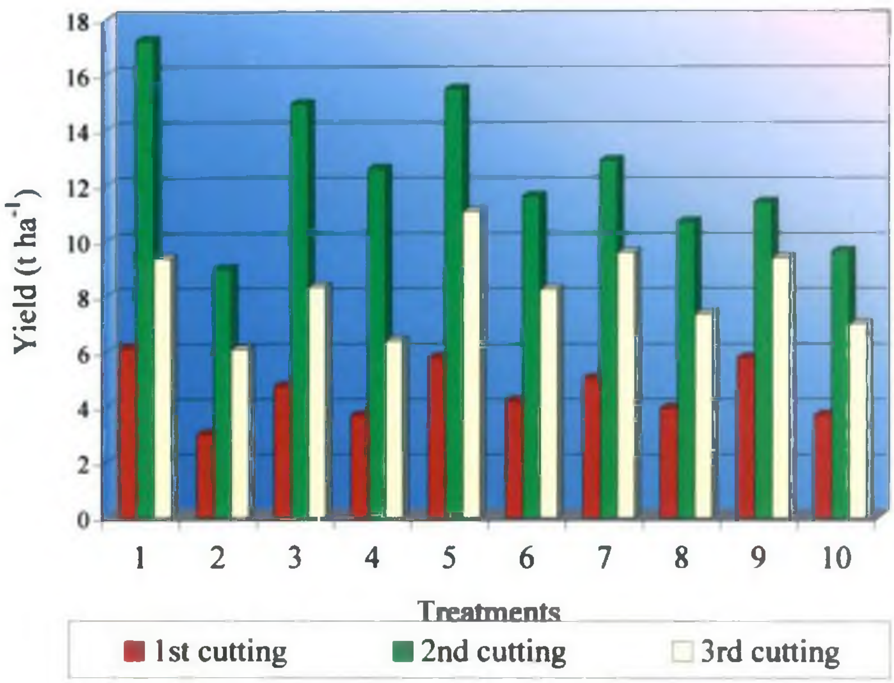


Fig. 14 Effect of different organic sources on yield per cutting

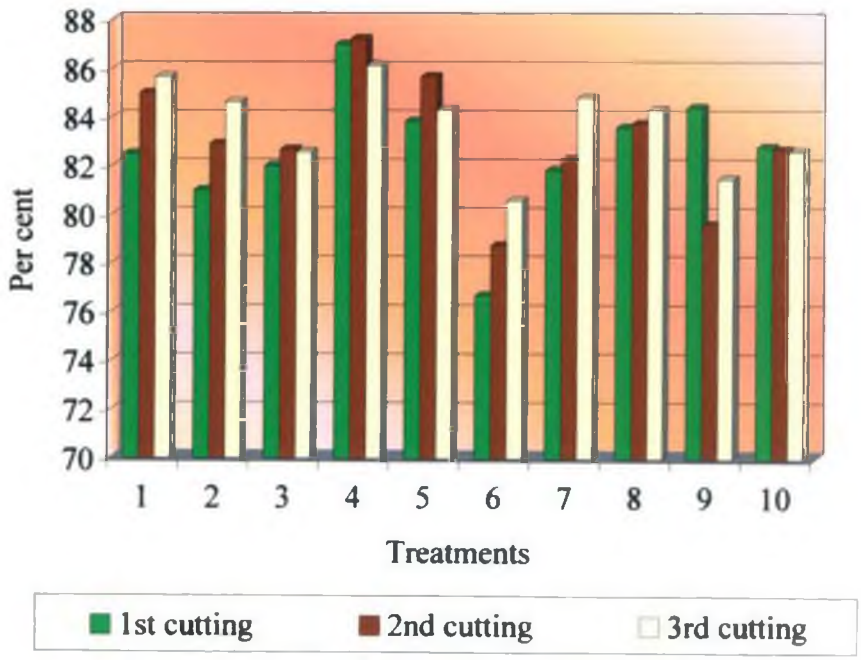


Fig. 15 Effect of different organic sources on moisture content

with neem cake 2 per cent is found to be superior and the superiority is due to the high content of nutrients in it. Similarly integration of organics (FYM) with fertilizer have shown complementary effect. The present observation was supported by findings of Jiji *et al.* (1996) who reported that vermicompost along with full inorganic fertilizer increased the yield of cowpea by 19 per cent.

Total dry matter production varies depending upon the moisture content present in plants. The treatment T_8 (EVC - NC 1 per cent + BM 1 per cent + Full NPK) recorded the maximum value for total dry matter production and it was found to be on par with T_0 (FYM + Full NPK), T_2 (VC + Full NPK) and T_4 (EVC – NC 2 per cent + Full NPK). Moisture content is directly correlated with the vegetative growth and succulence plants which in turn related to the nitrogen content of plant and plants received organic amendments produced maximum vegetative growth compared to inorganics alone which recorded the lowest value (3.03). The increase in plant height and other growth characters due to better assimilation of nutrients at higher levels of organic manure helped to increase the dry matter production. Similar findings were reported by Pandey *et al.* (1992). Farmyard manure application as an organic amendment increasing the dry matter production of bhindi crop was reported by Senthilkumar and Sekar (1998).

5.4 ECONOMICS OF CULTIVATION

Critical evaluation of data in Table 19 shows the economics of cultivation of amaranthus. The result showed that highest BC ratio was recorded by the treatment T_2 (VC+ Full NPK) and lowest by T_9 (EVC- NC 1% + BM 1% + ½ NPK). Next highest value for BC ratio was recorded by T_4 followed by T_3. Higher BC ratio for T_2 is due to higher yield and premium market price for organic produce. In T_4 due to high cost of neem cake the BC ratio is low even though the yield is substantially high. In bone meal enriched compost also due to high cost of bone meal (12 Rs/kg) the BC ratio reduced. Reduced B:C ratio in chilli due to neem cake application was also reported (Sharu,2000)

5.5 PLANT CONTENT OF MAJOR NUTRIENTS

Plant content of major nutrients was greatly influenced by different treatments (Table 20 to Table 22) and there was a general decrease in NPK content with the advancement of plant growth.

For N, the highest mean value for N in all the three cuttings was reported in the treatment T_4 (EVC-NC 2 % + Full NPK). This may be due to the higher content of N in EVC-NC 2% treatment (4%) as compared to other organic sources used in the experiment. Throughout the growth stage T_1 recorded the lowest value for N content and significant enhancement in the uptake of N by all the treatment received organic manures. The results obtained in the present study are in agreement with the findings of Shuxin *et al.* (1991) in soyabean and Sagayaalfred and Gunthilagaraj (1996) in amaranthus who reported increased uptake of N in the respective crops on vermicompost application.

For P the maximum value for P content was reported by treatment T_6 (EVC-BM2 % + Full NPK) for all the three cuttings closely followed by T_8 and T_7. This is due to the high P content of vermicompost enriched with organic P source (Bone meal). In bone meal P is present in organic form. The solubilisation of P by microorganisms was attributed to the excretion of organic acids (Rao, 1983). Microorganisms help in the mineralization of organic P in soluble form. Bijulal(1997) reported that activation of phosphatase leads to higher P availability.

In the case of K content the maximum value was recorded by the treatment T_8 {EVC-NC 1 % + BM 1 % + Full NPK} for all the three cuttings. This is due to the highest concentration of K in vermicompost

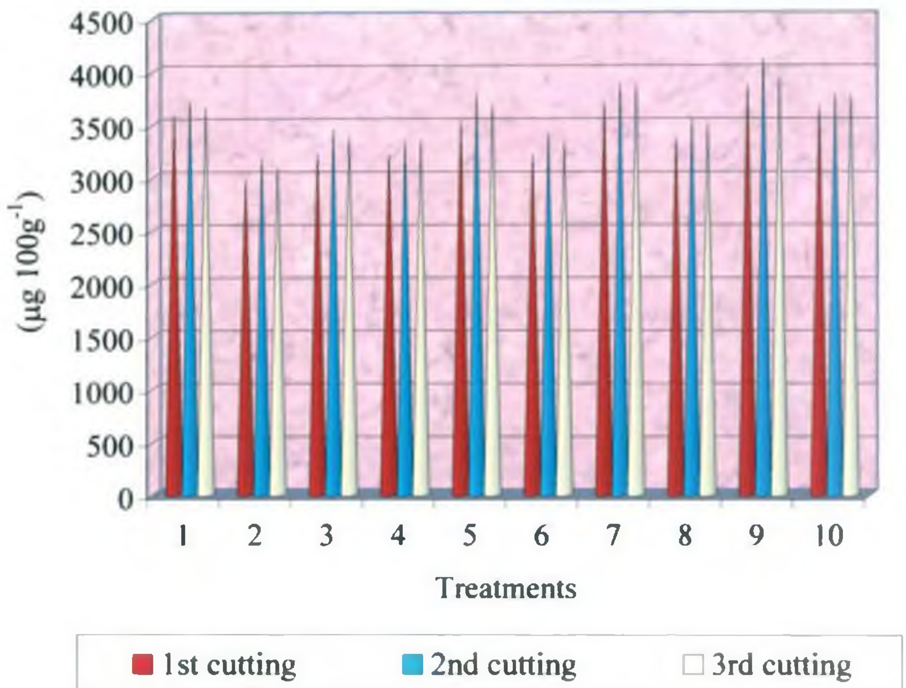


Fig. 16 Effect of different organic sources on β-carotene content

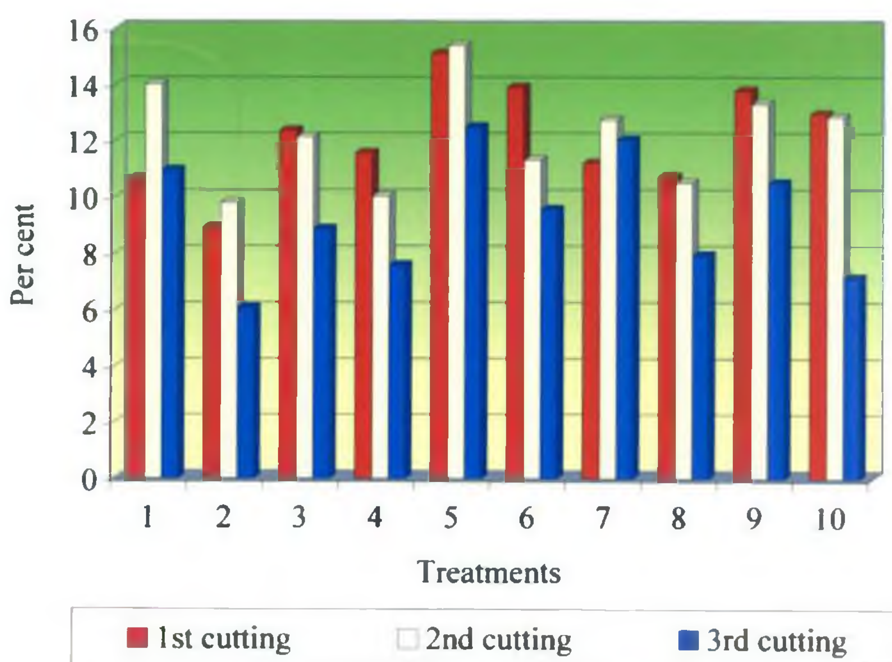


Fig. 17 Effect of different organic sources on crude protein content

photosynthesis are incorporated in the process of amino acid synthesis A.A. which are stored as proteins (Tisdale *et al.*, 1995).

For all the three cuttings highest value for fibre content was recorded by the treatment T_1 (NPK alone) and least value was reported by T_2 (VC + Full NPK) for first cutting. T_2 was found to be on par with T_4 and T_4.

Arunkumar (2000) reported that vermicompost treatments recorded lower fibre content. Presence of growth hormones and enzymes in vermicompost may decrease the crude fibre content. Higher levels of neem cake and poultry manure recorded lower crude fibre content. Increased nitrogen uptake might have resulted in increasing the succulence and thereby decreasing the crude fibre content.

Oxalate is an important antinutrient factor present in amaranthus. For first cutting and third cuttings highest mean value for oxalate content was reported by the treatment T_6 (EVC – BM 2 per cent + Full NPK). For second cutting T_1 (NPK alone) recorded highest mean value.

5.6 PLANT CONTENT OF MAJOR NUTRIENTS

Plant content of major nutrients was greatly influenced by different treatments (Table 20 to Table 22) and there was a general decrease in NPK content with the advancement of plant growth.

For N, the highest mean value for N in all the three cuttings was reported in the treatment T_4 (EVC-NC 2 % + Full NPK). This may be due to the higher content of N in EVC-NC 2% treatment (4%) as compared to other organic sources used in the experiment. Throughout the growth stage T_1 recorded the lowest value for N content and significant enhancement in the uptake of N by all the treatment received organic manures. The results obtained in the present study are in agreement with the findings of Shuxin *et al.* (1991) in soyabean and Sagayaalfred and Gunthilagaraj (1996) in

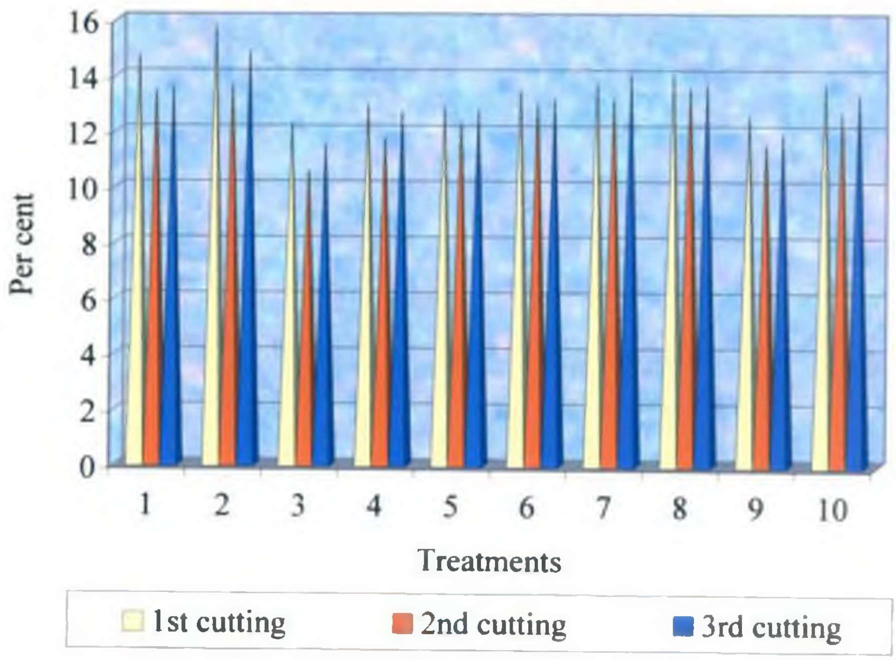


Fig. 18 Effect of different organic sources on fibre content

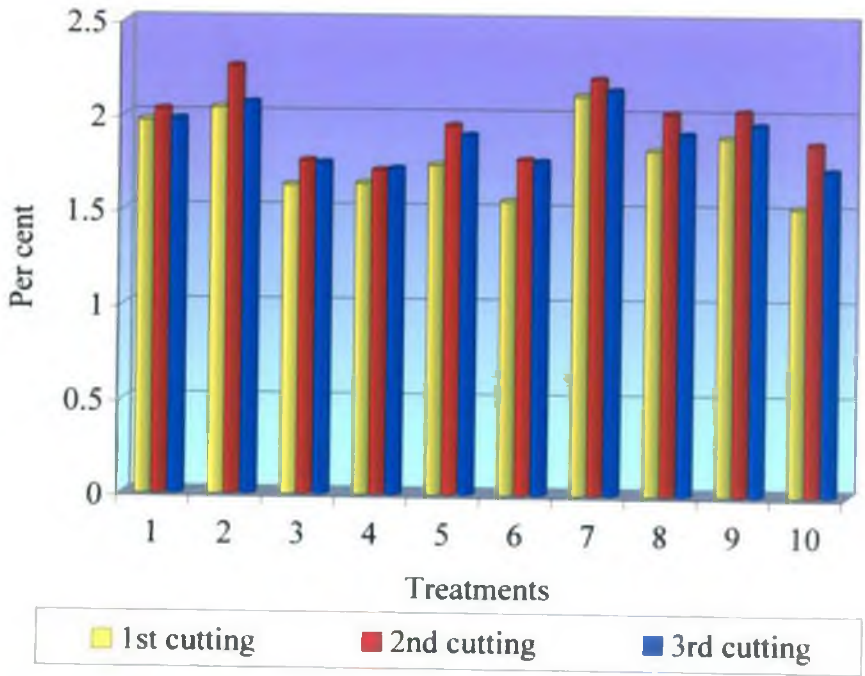


Fig. 19 Effect of different organic sources on oxalate content

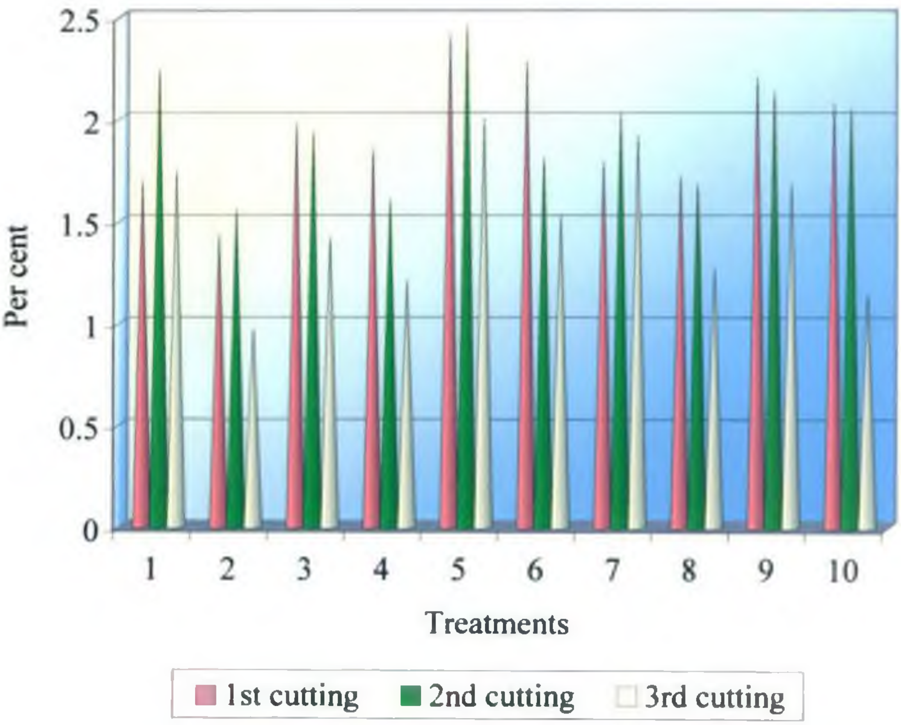


Fig. 20 Effect of different organic sources on nitrogen content

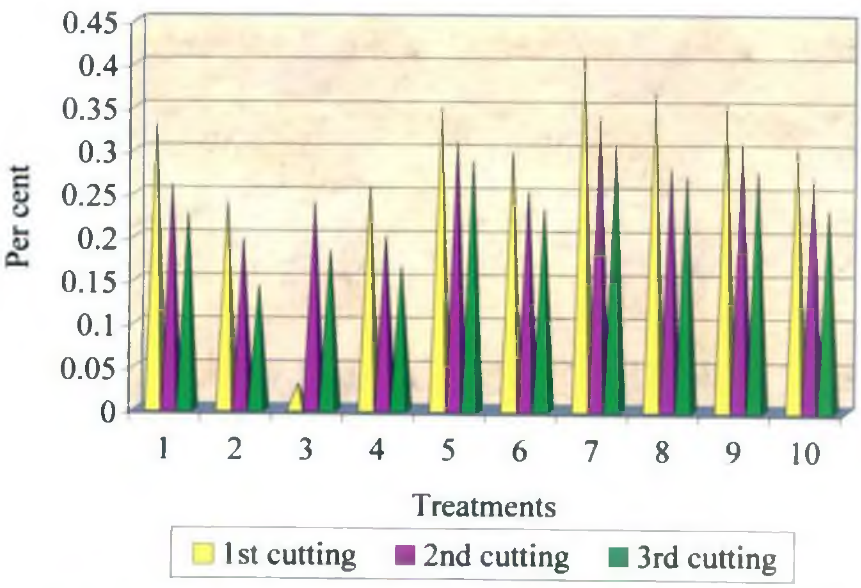


Fig. 21 Effect of different organic sources on phosphorus content

present in organic matter could be made available to plants through vermicomposting and microbial activity. Also it can be attributed to small increase in N input from biological N fixation, increased nitrate reductase activity with the enhancement in uptake of NO_3 and NH_4^+. Zacharia (1995) have also reported the superiority of vermicompost in enhancing N uptake in chilli. The higher rate of metabolic activity with rapid cell division brought about by vermicompost application resulted in high uptake of nutrients. Earthworms stimulate P uptake by redistribution of organic matter and by increasing enzymatic activation of phosphatase (Mackay *et al.*, 1983; Bijulal 1997). The increased mineralization of soil P and added P as a result of production of organic acid during decomposition of organic matter is one reason for high P uptake.

5.8 POST HARVEST ANALYSIS OF SOIL

The available nutrient status of soil is greatly enhanced by the application of vermicompost as an organic source. Earthworm casts are enriched with nutrients essential for the growth of plants (Edwards and Lofty, 1977). The worm cast have been reported to contain more exchangeable cations and organic carbon (Cook *et al.*, 1980; Tiwari *et al.*, 1989. and Hullugale and Ezumath, 1991). Earthworms increased the amount of extractable N by feeding on microbial biomass and increasing the turnover and mineralization of microbial tissue (Bohlen and Edwards, 1995).

Except organic carbon application of organic manure significantly affects content of nutrients in the soil. Application of organic matter in the form of vermicompost increased the availability of N, P, K, Ca and Mg in soil.(Rajalekshmi,1996;Bijulal,1997) In the case of organic carbon even though there is no significant difference between the treatments, the maximum value was recorded by the treatment T_2 (VC + Full NPK). For N highest value for available N was recorded by the treatment T_4 (EVC-

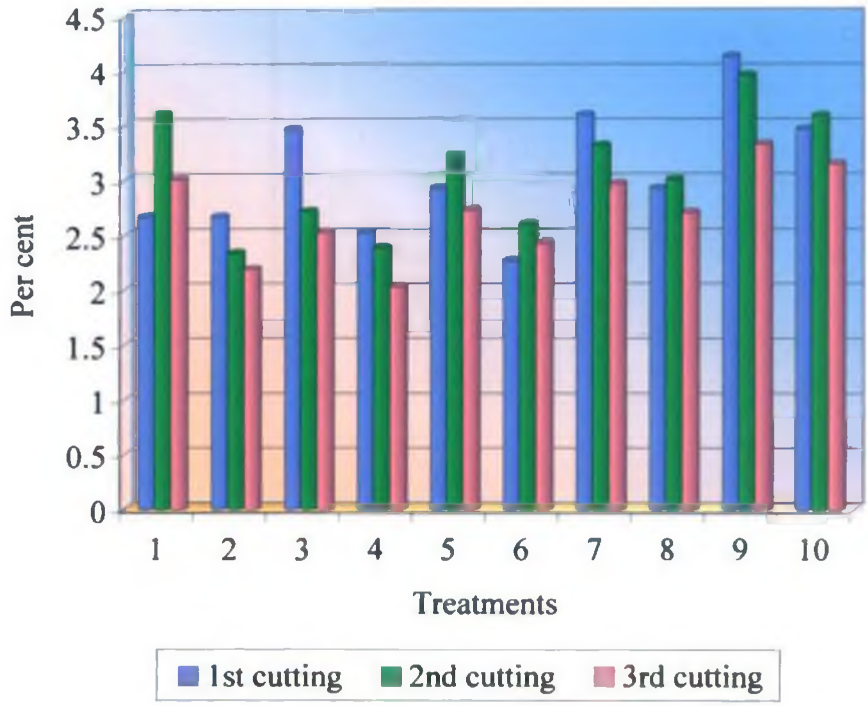


Fig. 22 Effect of different organic sources on potassium content

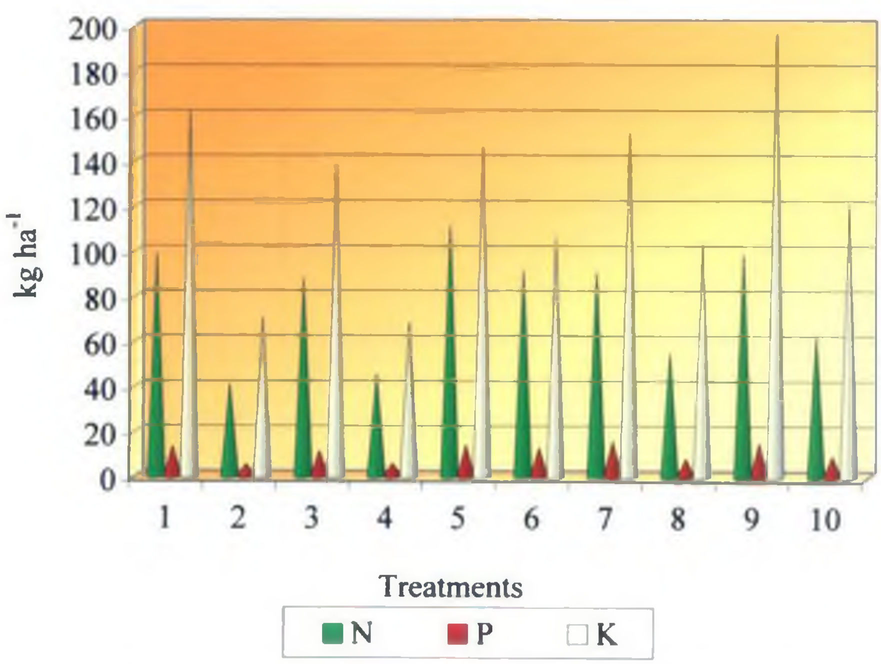


Fig. 23 Effect of different organic sources on plant uptake of major nutrients

NC 2 % + Full NPK) followed by the treatment T_8 (EVC- NC1 % + BM 1% + Full NPK), presence of neem cake may extended the period of availability of N and reduced the leaching loss. This is in conformity with the findings of Sathianathan (1982). Increased availability of N in worm cast treated plots may be due to release of nitrogenous products of earthworm metabolism to the soil through the cast and urine Increased availability of N in soil and increased N recovery due to the application of vermicompost as an organic source has been reported by several workers. (Kale *et al.*, 1992; Parkin and Berry, 1994 Vasanthi and Kumaraswamy, 1996). For P treatment T_6 (EVC-BM2 per cent + Full NPK) shows highest mean value for uptake and this treatment is found to be superior to all other treatments. When vermicompost is enriched with bone meal its P content is found to be increased, bone meal contains about 24 per cent P_2O_5.

Increase in total and available P_2O_5 content due to vermicompost application was reported by Gaur (1990). The higher P content of vermicompost might have reflected in high P status of soil. This may be due to greater mineralization of organic matter with the aid of microorganisms associated with earthworms. The presence of P solubilising organisms in vermicompost may be enhancing the biological solubilisation of P there by increasing the available P_2O_5 status of soil. Sharpley and Syers (1997) concluded that most of the additional P present in casts must be held in physically sorbed rather than chemically stabilized form and would consequently be readily available to plants. The increase in P^H of worm cast might have resulted in higher solubility of P in casts. Also the greater release of P from casts was due to a shift in the P sorption isotherm relative to that in the undisturbed soil.

For K the treatment T_8 (EVC- NC 1 % + BM 1% + Full NPK} shows highest value for available K content in soil. The soil organic matter because of its high absorptive capacity usually carries substantial amount of exchangeable K. The increase in available K content of soil where vermicompost is applied as organic manure is due to the increased concentration of available and exchangeable K content in casts compared to surrounding soil. The increase in available K status of soil especially in vermicompost treated plots can be attributed to the ability of earthworms to increase K availability by shifting the equilibrium from relatively unavailable forms to available form (Basker *et al.*, 1992). Vasanthi and Kumaraswamy (1996) reported increased availability of K by earthworm activity.

Generally by the application of organic manures pH of the soil is found to be increased. The highest value for P^H was shown by the treatment T_2 (VC + Full NPK) and it was found to be on par with T_4 (EVC-NC 2% + Full NPK), T_6 (EVC-BM2 % + Full NPK) and T_8 (EVC-NC 1 per cent + BM 1 per cent + Full NPK). Haimi and Huhta (1990) observed that earthworms significantly raised the PH of the humus and reported that part of the effect of earthworm on soil PH was probably an increase in the ammoniacal nitrogen. VC&EVC treated samples showed a marked change in soil reaction buffering it near neutrality and thus assuring conducive conditions for better plant growth.

Electrical conductivity of the soil was affected by the application of different types of organic manures. Highest value for EC was shown by the treatment T_6 (EVC-BM2%+FullNPK) followed by T_8 (EVC-BM 1 % + NC 1 % + Full NPK) and T_7 (EVC-BM 2 % + ½ NPK).Lowest value is reported by the treatment T_1 (NPK alone).Generally by the application of organic manures electrical conductivity is found to be increased.

The treatment T_1 (NPK alone) registered the maximum value for bulk density and the minimum value was recorded by the treatment T_2 (VC + Full NPK). Generally by the addition of organic manures bulk density of the soil was found to be decreased. Mbagwu (1989) also obtained the same result. Application of FYM has favourable effects on soil aggregation compared to chemical fertilizers (Rabindra *et al.*, 1985). In another experiment a decrease in bulk density by the addition of organic matter residues over long time was reported by Rasmussen *et al.* (1991).

Table 29 denote the microbial population of soil after the harvest of crop, where fungal and bacterial population were significant influenced by different treatments. For fungus highest mean value for population was recorded by T_8 (EVC-NC 1 % + BM 1 % + Full NPK) (22.67). In the case of bacteria, the treatment T_4 (EVC –NC 2% + Full NPK) (31.67) recorded the highest value. Even though the actinomycete population was not influenced by different treatment, the treatment T_4 recorded the highest mean value. Reddy and Mahesh (1995) found that microbial population was high when vermicompost was applied in the soil. In another experiment Kale *et al.* (1989) reported that when earth worms are introduced into the plot the population of nitrogen fixing fungi and bacteria were found to be increased. Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers, P solublilizers and mycorrhizal fungi. Devliegher and Verstrete (1995) found that nutrient enrichment process are responsible for the increased number of microorganisms reported in the presence of earthworms. Many workers reported that application of organic manures usually increases the soil microbial biomass (Goyal *et al.*, 1993; Sakamoto and Oba, 1991).

SUMMARY

6. SUMMARY

An investigation was carried out at Instructional Farm, College of Agriculture, Vellayani during 2002-2004. Main objective of the study was to assess the effect of vermicompost enriched with organic additives on physico-chemical and biological properties of soil, to study its impact on crop performance and the feasibility of substituting FYM and inorganic fertilizers. The study consist of three parts (1) preparation of vermicompost and enriched vermicompost (2) incubation experiment (3) field experiment.

Preparation and analysis of enriched vermicompost

Neem cake and bone meal were used as additives for the preparation of enriched vermicompost. Neem cake two per cent, bone meal two per cent and combination of neem cake one per cent and bone meal one per cent were used separately for enrichment on the basis of total weight of biowaste and cowdung mixture. Analysis of different compost samples showed that by enriching biowastes with organic additives like neem cake and bone meal the nutrient content as well as microbial count enhanced. C : N ratio of enriched vermicompost was lower than ordinary vermicompost

Incubation experiment

Incubation experiment was laid out in completely randomised design and it was carried out in laboratory condition for a period of 60 days. The experiment consisted of six treatments and three replications. The treatment consist of T_0 – absolute control (soil alone), T_1 – soil + FYM, T_2 – soil + ordinary vermicompost, T_3 – soil + enriched vermicompost (neem cake 2 per cent), T_4 – soil + enriched vermicompost (bone meal 2 per cent), T_5 – soil + enriched vermicompost (bone meal 1 per cent + neem cake 1 per cent). Soil sampling was done at 15 days interval for analysing physico-chemical and biological properties of soil.

The results of the incubation experiment are summarised below.

* It was revealed from the incubation experiment that available nitrogen, phosphorus and potassium content of soil increased upto 45 days of incubation, then the availability slowly decreases. Highest availability for available nitrogen and phosphorus is for treatments T_3 and T_4 respectively. For available potassium maximum value was registered by treatment received vermicompost enriched with bone meal.

* In the case of organic carbon, due to the application of vermicompost organic carbon content of soil suddenly increased, then it showed declining tendency. Enriched vermicompost treatment showed highest values for organic carbon.

* The treatments produced significant variation in the pH, EC and BD of soil. pH of the soil generally increased by the addition of organic manures. EC of the soil also increased. But bulk density of the soil decreased by the application of organic manures. During initial stages BD values are high, then it shows a declining tendency. For all the treatments highest mean values for BD was shown by T_0 (soil alone).

* In the case of WHC also, it increased upto 45 days of incubation, then it decreased. Initially WHC is low, it was increased by the application of organic manures.

* Different treatments significantly influenced the microbial population of incubated soil. Both fungal and bacterial population increased upto 45 days of incubation, then the count slowly decreased. The result indicated that different treatments did not show any significant effect on

actinomycete count. Generally by the addition of organic manures the microbial population increased.

Field experiment

Third part of investigation was field experiment using amaranthus var. Arun as test crop and it was laid out in randomised block design with ten treatments and three replications. The treatment details are T_0 – FYM + full NPK, T_1 – full NPK, T_2 – VC + full NPK, T_3 – VC + ½ NPK, T_4 – (EVC - NC 2 per cent) + full NPK, T_5 - (EVC - NC 2 per cent) +1/2NPK, T_6- (EVC - BM 2 per cent)+ full NPK, T_7 – (EVC - BM 2 per cent)+ ½ NPK, T_8 –(EVC - NC 1 per cent + BM 1 per cent)+ full NPK, T_9 – (EVC NC 1 per cent+ BM 1 per cent) + ½ NPK. From T_2 to T_8 nitrogen will be supplemented through organic manures additional requirement of P and K will be supplied through RP and ash. The salient findings of the experiment are listed below.

* Biometric characters like height of the plant, number of leaves, number of branches, stem girth, leaf stem ratio at different intervals of plant growth (30th day, 45th day and 60th day after transplanting) were significantly influenced by different treatments.

* For plant height highest mean value for plant height during first cutting was recorded by T_0 (FYM + NPK). In the second and third cutting treatment T_2 (VC + full NPK) recorded the highest value. Lowest value was recorded by the treatment T_1 (NPK alone) in all the three cuttings.

* Number of leaves in the plant is also significantly influenced by different treatments during first and third cutting. For the first and third cutting highest values for number of leaves was recorded by the treatments T_8 and T_4 respectively. During second cutting eventhough there is no significant variation between treatments, highest value was recorded by T_6.

* Number of branches per plant at three harvest were significantly influenced by different treatments. For the first, second and third cutting highest mean values for number of branches were recoded by the treatment T_4, T_6 and T_8 respectively.

* For stem girth, treatment T_0 (FYM + full NPK) recorded the highest mean values during the first and second cutting. During third cutting T_5 (EVC – NC 2 per cent + ½ NPK) was found to be best.

* In the case of leaf stem ratio highest value was registered by T_0 (FYM + full NPK) in all three harvests.

* Generally T_1 (NPK alone as inorganics) recorded lower values for all biometric observation.

* Quality parameters of the produce like moisture content, protein content β-carotene content, fibre content and oxalate content were also influenced by various treatments in all the three cuttings. T_3 (VC + ½ NPK) recorded highest value for moisture content in all the three cuttings. In the case of β-carotene content treatment T_8 (EVC - NC 1 per cent + BM 1 per cent) + full NPK) recorded the maximum value in all cuttings. In the case of protein treatment T_4 (EVC – NC 2 per cent + full NPK) recorded the maximum value.

* Fibre content, treatment T_2 (VC + full NPK) recorded the minimum value, but maximum value was recorded by treatment T_1 (NPK alone).

* For oxalate content treatment T_6 (EVC-BM 2 per cent + full NPK) recorded highest mean value in the first and third cutting but in the second cutting maximum value was recorded by the treatment T_1.

Soil analysis after the field experiment for major nutrients, organic carbon, pH, EC and bulk density revealed that they were significantly influenced by the treatment. Organic carbon, available P, EC and pH increased. But for available nitrogen and potassium the values were slightly decreased in comparison with initial soil test values and for bulk density, the values decreased favourably.

Yield per cutting, total yield per plant, total marketable yield and total dry matter production showed significant response to different treatments. In the case of yield per cutting (except third cutting), total yield per plant and total marketable yield, highest value was reported by the treatment T_0 (FYM + full NPK). For total dry matter production highest mean value was recorded by T_8 and was found to be on par with T_0, T_2 and T_4.

Plant analysis at three harvest indicated significant response to different macronutrients. For nitrogen, treatment T_4 (EVC – NC 2 per cent + full NPK) recorded the highest mean value in all the three cuttings. In the case of phosphorus, treatment T_6 (EVC – BM 2 per cent + full NPK) recorded the highest value. For K, treatment T_8 (EVC – NC 1 per cent + BM 1 per cent + full NPK) recorded the highest value.

Uptake of major nutrients at harvest was studied. Data indicated that different treatments significantly influenced the uptake of nutrients. The treatments T_4, T_6 and T_8 recorded maximum value for N, P and K uptake respectively. For N and P lowest value is recorded by the treatment T_1 (NPK alone), but for K it was recorded by the treatment T_3 (VC + ½ NPK). T_3 was on par with T_1.

Considering the salient findings in perspectives different organics favorably influenced the soil physico-chemical and biological properties, which in turn resulted in increased yield and quality of amaranthus. The study also revealed that substitution of inorganic fertilizers and FYM with enriched vermicompost was possible for increasing yield and improving the quality of amaranthus.

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*Original not seen

VERMICOMPOST ENRICHED WITH ORGANIC ADDITIVES FOR SUSTAINABLE SOIL HEALTH

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ABSTRACT

An investigation was carried out at the Instructional Farm, attached to the College of Agriculture, Vellayani to evaluate the effect of vermicompost enriched with organic additives *viz.*, neem cake and bone meal on physico-chemical and biological properties of soil, to evaluate its impact on crop performance and the feasibility of substituting farmyard manure and inorganic fertilizer using amaranthus as test crop. The study consist of three parts 1) Preparation and analysis of vermicompost and enriched vermicompost 2) laboratory incubation experiment 3) Field experiment.

On enriching biowastes with neem cake and bone meal, improved the manurial value of vermicompost produced using earthworm species *Eudrillus eugeniae*. C/N ratio was reduced by enrichment. Microbial population also increased considerably by enriching vermicompost with organic additives.

Second part of our investigation was an incubation study and it was conducted to evaluate relative efficiency of enriched vermicompost to release nutrients from soil and its influence on physico-chemical and biological properties of soil. The results revealed that available nitrogen, phosphorus and potassium content of the soil increased upto 45 days of incubation then the availability slowly declined. Organic carbon, pH and EC increased whereas bulk density reduced due to the effects of various organic sources. Application of organic matter had a positive effect on microbial count also.

Third part of the study was field experiment, and it was laid out in RBD with 10 treatments and three replications. The biometric

observations *viz.*, plant height, number of leaves, number of branches, stem girth, leaf stem ratio all were significantly influenced by different treatments. Significant differences were observed among yield attributing characters like yield per cutting (t ha^{-1}), total yield per plant (g $plant^{-1}$), total marketable yield (t ha^{-1}), and total dry matter production (t ha^{-1}). Highest yield per cutting was recorded by the treatments T_0 (FYM + full NPK), T_4 (EVC – NC two per cent + full NPK) and T_8 (EVC – NC 1 per cent + BM 1 per cent + full NPK]. With respect to plant contents of nutrients, for nitrogen, highest value was recorded by the treatment T_4 (EVC – NC two per cent + full NPK), for P, highest value was recorded by T_6 (EVC – BM two per cent + full NPK) and for K, highest value was recorded by the treatment T_8 (EVC – NC 1 per cent + BM 1 per cent + full NPK). For plant uptake highest values were registered by the treatments T_4, T_6 and T_8 for N, P and K respectively.

With respect to quality characters, treatments with organic sources of plant nutrients *viz.*, T_8 [EVC- NC 1 per cent + BM 1 per cent + full NPK) recorded highest value for β-carotene content in all the three cuttings, for moisture content T_3 (VC+1/2NPK) recorded the highest value in all cuttings, for protein T_4 (EVC – NC two per cent + full NPK) recorded the highest value in all cuttings. For fibre content treatment T_1(Full NPK as mineral fertilizer) recorded the highest value and T_2 (VC + full NPK) recorded the lowest value. Oxalate content is also influenced by different treatments. Vermicompost enriched with bone meal and treatment received NPK alone recorded highest oxalate content. Post harvest analysis of the soil indicated that organic carbon, available phosphorus, pH, EC and microbial count were increased by applying enriched vermicompost. But available nitrogen and available potassium were slightly decreased. Bulk density was found to be influenced favourably.

From the investigation it was proved that enriched vermicompost established its superiority over other organic sources and POP recommendation with respect to yield and quality of amaranthus and soil properties. Study also revealed the feasibility of substituting FYM and inorganic fertilizer with enriched vermicompost.

APPENDICES

APPENDIX – I

Composition of media used for isolation of microorganisms

Fungi – Martins rose bengal streptomycin agar (Martin, 1950)

Composition

Dextrose	–	10 g
Peptone	–	5 g
$KH_2 PO_4$	–	1 g
Rose Bengal	–	(1 part in 30,000 parts of the medium)– 20 µg
Agar	–	20 g
$Mg SO_4$	–	0.5 g
Streptomycin	–	30 mg
Distilled water	–	1000 ml.

Bacteria – Soil extract agar

Soil extract	–	100 ml
Glucose	–	1 g
Dipotassium phosphate	–	0.5 g
Agar	–	15 g
Tap water	–	90 ml
PH	–	7 - 7.2

Actinomycetes – Kenknight's medium

Dextrose	–	1 g
K_2HPO_4	–	0.1 g
$NaNO_3$	–	0.1 g
KCl	–	0.1 g
$Mg SO_2$	–	0.1 g
Agar	–	15 g
Distilled water	–	1 lit.

APPENDIX - II

Weather parameters during the cropping period

(October 2003 to January 2004)

Standard week	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)
40	29.90	23.80	93.60	222.80
41	30.60	23.50	92.10	19.20
42	30.50	24.00	93.20	72.80
43	30.20	23.00	93.90	201.10
44	30.60	23.00	91.70	24.00
45	30.00	22.90	93.90	49.70
46	30.90	23.50	93.70	23.20
47	0.09	23.40	93.60	1.70
48	30.70	23.50	94.00	0.80
49	31.30	21.30	92.60	0.00
50	31.00	20.70	95.10	0.00
51	31.10	22.10	92.00	0.00
52	31.40	22.10	95.00	0.00
53	31.70	22.30	94.00	0.00
54	31.50	20.90	93.30	0.00
55	30.80	20.50	95.60	0.00
56	31.80	22.30	94.10	0.00
57	32.00	22.90	95.30	7.20