ORGANIC NUTRITION IN AMARANTHUS (*Amaranthus tricolor* L.)

By
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DECLARATION

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

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CERTIFICATE

Certified that this thesis entitled "Organic nutrition in amaranthus (*Amaranthus tricolor* L.)" is a record of research work done independently by Mr. Arun Kumar K.R. (97-11-04) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS

Al	Aluminium
CD	Critical difference
cm	Centimetre
cv.	Cultivar
DAP	Days after planting
DMP	Dry matter production
et. al.	and others
Fe	Iron
g	Gram
ha	Hectare
K	Potassium
kg	Kilogram
LAI	Leaf area index
lb	Pound
mg	Milligram
mm	Millimetre
N	Nitrogen
NAR	Net assimilation rate
P	Phosphorus
POP	Package of Practices
q	Quintal
RBD	Randomised Block Design
Rs.	Rupees
SE	Standard error
t	Tonnes
@	at the rate of
%	Percentage

INTRODUCTION

INTRODUCTION

Organic matter is an indispensable component of soil and plays an important role in the maintenance of soil productivity and in improving physical conditions of soil for sustaining better plant growth. Continuous use of high analysis chemical fertilizers will lead to decline in soil fertility and productivity, besides causing deficiency and imbalance of secondary and micronutrients.

Vegetables play an important role in human nutrition by providing proteins, carbohydrates, minerals, vitamins and roughages which constitute the essentials of a balanced diet. Indian subcontinent holds unique position as far as vegetable cultivation is considered and can be proud of being the producer of nearly 60 kinds of leafy, fruit and other vegetables. Incidentally India is the second largest producer of vegetables in the world next only to China. But still majority of Indian population has a sub-optimal vegetable intake. Against daily recommended intake of 280 g of vegetables, the availability is only 135.82 g day^{-1} (Ministry of Agriculture, 1994).

Leafy vegetables play an important role in supplying valuable nutrients, particularly minerals and vitamins in human diet. Amaranthus, being rich in protein, vitamin A, vitamin C and iron is the most popular leafy vegetable grown in the homesteads of Kerala. It is capable of producing several crops in a year making it more acceptable to farmers.

For promoting sustainable agriculture, it is essential to minimise application of energy intensive chemical inputs. The development and production of organic manures assumes much importance in view of the increase in fertilizer prices, increased burden of foreign exchange reserves, prevailing fuel shortages and increasing concern for environmental safety. A judicious approach to meet the twin objectives of environmental care and increasing the productivity is therefore needed. In this context organic nutrition gains importance.

Addition of organic manures like farmyard manure, poultry manure, vermicompost and oil cakes improve soil physical, chemical and biological properties and thereby enhance the productivity of soil. Organic manures besides forming stable aggregates in soil, promotes air circulation, root penetration and helps in retention of moisture in soil.

Compost is a good organic supplement to soil. Poultry manure is a good source of nutrients, particularly nitrogen and is useful for vegetable production. Neem cake is not only a good source of organic manure but also has insect repellent action and hence is useful for pest management. Coir pith which is abundantly available in Kerala as a bye product from coir industries, is found to be a good source of organic manure after narrowing down its C : N ratio with *Pleurotus sajor-caju*. Similarly there is wide scope to recycle and use homestead organic wastes after vermicomposting. Vermicompost which is produced by chemical disintegration of organic matter by the enzyme activity in the gut of worms contain higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. Conservation and utilization of native agricultural waste resources, which may otherwise cause environmental pollution is the prime need of the present day agriculture of our country.

Keeping the above views under consideration, the present investigation entitled "Organic Nutrition in Amaranthus (*Amaranthus tricolor* L.)" has been taken up with the objectives of evaluating economically feasible and eco-friendly sources of organic manures with their five different levels to estimate their effect and optimum levels for sustainable productivity of amaranthus.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The organic matter content of the tropical soil is comparatively low due to high temperature favouring intense microbial activity. It is well known that the soil without any supply of organic matter is impoverished and in course of time will lose its productivity. In recent years there has been a welcome awareness for ecofriendly organic products as source of manures. Organic nutrition in vegetables are specially important as they are quality foods and are very important for providing health security to people.

The present study is aimed to find out the effect of different sources of organic manures in sustaining the productivity of amaranthus and to optimise the quantity of these manures for amaranthus. The literature collected pertaining to the above subject are reviewed hereunder.

Organic manures can effectively act as slow release fertilizers and many of the organic amendments bring about pest suppression (Gaur *et al.*, 1984). Sustainable agriculture is a method of farming to produce adequate food without much adverse effect on soil productivity (Kandaswamy, 1992). Regular additions of organic manures in sufficient quantities lead to the maintenance of the organic matter content at optimum levels (Thampan, 1993).

2.1 Effect of organic manures on soil prop‹rties

Addition of organic manures like farmyard manure, poultry manure, green manures, oil cakes, compost etc. improve the physical, chemical and biological properties of soil and thereby enhance the productivity of soil.

Increase in soil moisture retention due to addition of FYM was observed by Salter and Williams (1963). The favourable effect of farmyard manure application on the structural properties of the soil were observed by several investigators (Biswas *et al.*, 1969 and Muthuvel *et al.*, 1982). Loganathan (1990) reported that application of organic amendments viz., saw dust, groundnut shell powder, coir dust and FYM, each @ 2.5 and 5 t ha^{-1} improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil with hard pan. Shinde and Gawade (1992) reported that the application of 100 kg N per ha as FYM increased the structural index (32.3) over the application of NPK (28.5), NP (29) and N alone (25.4).

Olsen *et al.* (1970) reported that addition of manures increased the soil pH. Rabindra and Honnegowda (1986) opined that FYM has greater buffering capacity and helps to maintain soil pH. Lal and Mathur (1988) reported that application of NPK fertilizers reduced pH from 5.5 to 3.8, but FYM application maintained or increased the pH of soil while the combination of fertilizers and manures decreased the pH. Farmyard manure application resulted in lowest acidity due to the decrease in exchangeable and soluble Al in the soil (Nambiar, 1994 and Patiram, 1996).

Sathianathan (1982) found in cassava that neem and mahua cake treatments were efficient in retaining more nitrogen in the ammonical form under field condition. Thus, these oil cakes reduced leaching losses and extended the period of availability of nitrogen to the crop from applied nitrogen.

Maurya and Ghosh (1972) reported an increase in organic carbon content with the addition of FYM. Sharpley and Syres (1977) found increased P availability to plants when vermicasts were used. Mansell *et al.* (1981) suggested that earthworms increased the available phosphorus derived from plant litter by 2-3 folds. This is attributed to greater phosphatase activity in earthworm casts as reported by Satchell *et al.* (1984). Negi *et al.* (1981) observed an increase in the available K content of the soil with the application of K fertilizers and FYM. They also noticed that increase in K was more in FYM treated plots than in K fertilizer treatment. Krishnaswamy *et al.* (1984) observed that application of FYM or compost (15 t ha^{-1}) had a significant effect on increasing the available P from the native and applied sources. Srivastava (1985) observed that the application of organic manures resulted in increased organic carbon content, total N and available P and K status of soil. Gupta *et al.* (1988) observed significant increase in organic carbon, available nitrogen and available phosphorus content of soil with the application of FYM up to 52 days and thereafter it decreased due to crop uptake. Badanur *et al.* (1990) reported that available phosphorus content of soil was significantly increased with the incorporation of subabul, sunhemp loppings and farmyard manure. Kale *et al.* (1992) observed high level of total nitrogen in paddy plots applied with vermicompost and comparatively less quantity of fertilizers. They attributed this due to higher count of nitrogen fixers in the treated plots than that of the control plot. Shinde and Gawade (1992) observed an increase in the available K content of the soil from 235 kg ha^{-1} in control to 258 kg ha^{-1} due to addition of FYM (15 t ha^{-1}) They also noted an increase in available nitrogen with application of 20 t ha^{-1} FYM. Connell *et al.* (1993) found that the composted municipal solid waste application in soil increased the status of available nitrogen content. Balaji (1994) also recorded higher levels of total nitrogen, available phosphorus and potassium in treatments which received either vermicompost alone or in combination with FYM or chemical fertilizers than control. More (1994) reported that addition of farm wastes and organic manures increased available nitrogen and available phosphorus of the soil.

2.2 Effect of organic nitrogen sources on growth, yield and quality of crops with special reference to vegetables

Organic manures are time-tested materials for improving the fertility and productivity of soils. Role of various organic amendments in improving the growth, yield and quality of crops are reviewed here under.

Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches. They yielded 28.18 t h^{-1} which was on par with the recommended dose of FYM and NPK (20 : 100 : 100).

Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984).

Montegu and Gosh (1990) found that fruit colour of tomato was significantly increased as a result of application of organic manure of animal origin. Organic manures like FYM, compost, oilcakes, green leaf, poultry manure etc. improve the yield as well as quality of vegetable crops like tomato, onion, gourds, chillies etc. Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetable crops (Rani *et al.*, 1997).

2.2.1 Effect of farmyard manure on growth, yield and quality of crops

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

Subbiah *et al.* (1983) reported that the yield of brinjal was significantly influenced by levels of FYM (0, 12.5, 25.0 and 37.5 t ha^{-1}) but not by the levels of fertilizer (0, 50, 100 and 150 per cent of recommended dose). Application of 12.5 t ha^{-1} of FYM recorded highest yield of 54.28 t ha^{-1}. In the long-term field experiment for seven years at Jalandhar, Sharma *et al.* (1988) revealed that FYM was more effective in increasing tuber yield of potato than green manuring with dhaincha. Hilaman an Suwandi (1989) found that sheep manure when applied at the rate of 30 t ha^{-1} gave highest yield of 1.05 kg per plant in tomato. From studies at different places it was found that FYM to supply 100 kg P_2O_5 ha^{-1}, about 30 t ha^{-1} not only met P and K needs of the crop but also kept the potato yield level at a higher level than the combined use of P and K fertilizers (Sud and Grewal, 1990). Minhas and Sood (1994) reported that FYM application significantly increased crop yield. Joseph (1988) reported that in snake gourd yield attributing characters viz., length, weight and number of fruits per plant were highest in FYM applied plants as compared to poultry manure or vermicompost applied plants.

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

2.2.2 Effect of poultry manure on growth, yield and quality of crops

A study on optimum level of poultry manure requirement for cauliflower by Singh *et al.* (1970) revealed progressive increase in growth moisture content and yield of cauliflower when the dose was increased from 0 to 169.6 q ha^{-1}. Singh *et al.* (1973) reported that, in potato, application of poultry manure exhibited better response than FYM on yield and growth attributes. Anitha (1997) reported that, in chilli various growth attributes like plant height, number of branches and DMP were better with poultry manure application as compared to FYM or vermicompost.

Morelock and Hall (1980) compared the effects of broiler litter applied at different rates (0-8 t $acre^{-1}$) with preplanting application of commercial fertilizer (N_{10} P_{20} K_{10}) at 280-840 kg ha^{-1} on field grown tomato plants. Marketable fruit yield was found to increase with broiler littter application. Abusaleha (1981) reported that in bhindi, early flowering and highest yield of 18.02 t ha^{-1} were obtained with the application of half nitrogen through ammonium sulphate and half through poultrymanure. In lettuce, poultry manure applied @ 0, 20 and 40 t ha^{-1} either as entire basal dose or in splits increased the yield from 0.66 to 0.81 and 0.90 kg $plant^{-1}$ (Anez and Tavira, 1984). Jose *et al.* (1988) observed that plants supplied with 50 kg N as poultry manure and 50 kg nitrogen as urea recorded the highest yield of brinjal fruits (51 t ha^{-1} followed by plants supplied with 5- kg N as pigmanure and 50 kg as urea.

Studies conducted by James *et al.* (1993) with broiler litter at different levels i.e., 4.8 t ha^{-1}, 9.5 t ha^{-1} and 19 t ha^{-1} to snap beans revealed that broiler litter at the rate of 4.8 t ha^{-1} was as effective as the commercial fertilizer. The broiler litter applied at higher dose did not lower the yield. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost application (Anitha, 1997).

Application of poultry manure showed a slight increase in ascorbic acid content of cauliflower. The highest vitamin C. content was obtained in the plants supplied with 169.6 q ha^{-1} of poultry manure (Singh *et al.*, 1970). He also reported that the protein content of potato gradually increased with higher levels of poultry manure. Anitha (1997) reported that chilli plants treated with poultry manure recorded the maximum ascorbic acid content of fruits as compared to vermicompost and control treatment. Joseph (1998) observed that, in snake gourd, poultry manure treated plants recorded the highest crude protein content and lowest crude fibre content as compared to that of FYM and vermicompost treated plants.

2.2.3 Effect of oilcakes on growth, yield and quality of crops

Increase in plant height of bhindi due to oilcake application was reported by Singh and Sitaramaiah (1963). Chinnaswamy (1967) observed better growth in tomato plants with the application of FYM and groundnut cake in organic mixture. Application of a commercial sea weed concentrate (Kalpak 66) at dilution of 1 : 500 to the foliage at regular interval or once to the soil improved the growth of glass house tomato plants (Featon by Smith and Staden, 1983). Whenever it was applied it brought about significant improvement in root growth due to reduction in root-knot nematode. Jain and Hasan (1986) in a field experiment found that the oilcakes increased the chlorophyll content of leaves and neemcake recorded the maximum chlorophyll content of leaves. Som *et al.* (1992) observed the influence of organic manures on growth and yield of brinjal. The different oilcakes tried were karanj, mahua, mustard and neemcake. The maximum plant height of 70.77 cm was recorded in the treatment receiving neemcake @ 50 q ha^{-1} followed by mustard cake at its higher dose.

Asano (1984) reported that the crops of egg plant, cabbage, tomato, radish and lettuce harvested from the rapeseed cake applied plot produced higher yields than the crop from inorganic fertilizer alone treated plot. Shanmugavelu (1987) observed that application of mahua cake, castor cake, and neemcake @ 500 kg ha^{-1} one day prior to transplanting of tomato, increased the fruit yield by 31.7, 27.8 and 9.0 per cent, respectively over control. Anon (1990) reported that application of neemcake @ 1 t ha^{-1} before planting gave maximum yield in ginger. In the review of soil and fertilizer management for vegetable production in Bangladesh, Islam and Haque (1992) mentioned the application of oilcakes as an organic manure during land preparation to brinjal, chilli and bhindi for getting higher yield. Som *et al.* (1992) while studying the influence of organic manures on growth and yield of brinjal found that maximum fruit length and diameter were recorded by mahua cake and neemcake applied @ 50 q ha^{1} respectively. Mahua cake recorded highest number of fruits of 11.68 per plant. Neem cake @ 50 q ha^{-1} produced the maximum fruit weight of 125.38 g, highest per plant yield of 1.43 kg and highest fruit yield of 22.56 t ha^{-1}. Kadam *et al.* (1993) compared the effect of organic and inorganic sources on the yield of betel vine. Among the various sources tried viz., neem cake, karanj cake, neemcake + urea and urea alone, application of N through neemcake produced significant response in increasing the yield.

Sahrawat and Mukherjee (1997) reported that application of mahua cake improved the grain protein content in rice.

2.2.4 Effect of vermicompost on growth, yield and quality of crops

Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites, particularly gibberellins, cytokinins, auxins and group B vitamins, which can be applied alone or in combination with organic or inorganic fertilizers so as to get better yield and quality of diverse crops (Gavrilov, 1962, Tomati *et al.*, 1983, Bano *et al.*, 1987).

Evangelista (1986) found that application of pure earthworm cast showed significant effect on the weight of roots, nitrogen, phosphorus, calcium and magnesium contents of the lettuce leaves. Plants treated with 50 per cent earthworm cast and 50 per cent soil showed highly significant effect on the fresh weight of plant and dry weight of leaves. Kale and Bano (1986) reported that application of vermicompost as a source of manure increased the growth and yield of paddy. A study on the influence of vermicompost application to six ornamental crops by Kale *et al.* (1991) indicated that vermicompost without any chemical fertilizers was on par with the treatment of FYM and chemical fertilizers. Kale *et al.* (1991) studied the influence of vermicompost application on growth and yield of some vegetable crops also; wherein the results indicated that the level of chemical fertilizer could be brought down to 25 to 50 per cent when applied with vermicompost. They opined that quantity of organic manure can be brought down to 50 per cent when vermicompost is used as the source of organic manure. Puranik (1992) observed improved quality and size of fruits in custard apple due to application of vermicompost. Similarly rose, marigold, sonataka and ixora showed good response to vermicompost application and sonataka continued to bloom even after the season was over, whereas the performance of lawn grass was not good. Stolyarenko *et al.* (1992) reported that application of vermicompost stimulated the root and shoot growth of maize plantlets. In cardamom, Vadiraj *et al.* (1992) observed significant increase in height, number of roots per plant, length of root and fresh and dry weight of seedlings when vermicompost was used as potting mixture.

Desai (1993) observed that the yield of capsicum in vermicompost treated plot was comparable to that of chemical fertilizer application. Gunjal (1993) reported an increase in fruit yield to the tune of 40 per cent and 36 per cent due to the application of chemical fertilizers and vermicompost respectively over the control. Ismail *et al.* (1993) conducted a comparative evaluation of vermicompost, farmyard manure and fertilizers on yields of bhindi and water melon and observed an increase in yield in all the cases with vermicompost.

Balaji (1994) observed that application of vermicompost @ 2.5 or 5.0 t ha^{-1} or FYM @ 20 t per ha or different levels of recommended dose of inorganic fertilizers alone or in combination resulted in increase in growth and dry weight of plants and improved the yield and quality of flowers in China aster. Dharmalingam (1995) got 16 per cent increase in yield in soybean over non pelleted seeds due to vermicompost pelleting. Venkatesh (1995) reported that application of vermicompost @ 5 t per ha alone or in combination with recommended doses and FYM and different levels of inorganic fertiliszers increased the nutrient content of petioles and improved the yield and quality of Thompson seedless grapes. Pushpa (1996) and Rajalekshmi (1996) reported increased uptake of nutrients and higher yields in tomato and chilli by application of vermicompost.

Tomati *et al.* (1990) reported that incorporation of vermicompost increased protein synthesis in lettuce and radish by 24 and 32 per cent. Vermicompost is a potential organic manure that can be prepared in small farm holdings with family labour, its use can reduce the cost of cultivation substantially. Moreover vermicompost has a definite advantage over other organic manures in respect of quality and shelf life of the produce (Khamkar, 1993).

2.2.5 Effect of coirpith compost on growth, yield and quality of crops

Coirpith is a light fluffy refuse obtained during the separation of coir fibre from coconut busk. Normally about 10 000 husks yield one tonne of coir fibre and another one tonne of coirpith as a waste material (Nagarajan *et al.*, 1985). He also observed that coirpith is having about 533 per cent of maximum water holding capacity. The mean water holding capacity of 625 per cent has also been reported (Rajanna, 1988; Ravichandra, 1988). Incorporation of composted coirpith significantly increased the soil moisture content and improved other physical constants of the soil compared to other organic amendments in a highly permeable soil (Subbaraj and Ramaswami, 1992).

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

In an on-farm trial on ground nut in soils having a pH of 9.0, the application of gypsum at 400 kg along with 12.5 ton of composted coirpith per hectare increased the pod yield appreciably (Ramamoorthy *et al.*, 1991). In a sodic soil (pH 10.1) application of composted coirpith, gypsum and fertilizer alone as well as in combination showed 35 per cent increase in grain yield for rice for the application of gypsum and coirpith at 10t ha^{-1} over the treatment which received fertilizers alone. The improvement in the physico-chemical properties was reflected on the nutrition of rice crop (Savithri *et al.*, 1991). According to Selvakumari *et al.* (1991) composted coirpith has beneficial effect as an organic manure in increasing the yield of crops like turmeric. Incorporation of composted coir-pith along with farm yard manure (5t ha^{-1}) into the soil one day prior to transplanting gave the highest fruit yield of tomato (19 t ha^{-1}) followed by 20 t ha^{-1} coirpith (16 t ha^{-1}) and the lowest in control plot (11 t ha^{-1}) which were treated with neither farm yard manure nor coirpith (Ahmed, 1993). Increased panicle length, grains $panicle^{-1}$, grain yield and straw yield in rice were reported following the application of partially decomposed coirpith in the rice field with sandy clay loam soil (Thilagavathi and Mathan, 1995). Lourdraj *et al.* (1996) reported an increased yield net returns and high benefit cost ratio in groundnut when the crop was raised in soil incorporated with composted coirpith. The result of a study conducted by Venkatakrishnan and Ravichandran (1996) on sesame revealed that the yield could be increased by 63 per cent with the application of composted coirpith, over farmer's practice. Suharban *et al.* (1997) in a pot culture experiment with bhindi reported that the treatment with coirpith compost alone gave the maximum yield of 5.923 kg followed by treatment with half recommended dose of coirpith and fertilizer (5.125 kg).

2.3 Effect of organic manures on keeping quality of produce

Considerable scientific data were generated recently to show that the produce obtained from organic farming is nutritionally superior with good taste, lusture and better keeping qualities.

Luchnik (1975) reported that the use of organic manures resulted in high sugar and vitamin C content which resulted in better keeping quality of cabbage. Similarly Kansal *et al.* (1981) reported increased shelf life of spinach leaves due to application of 20 t FYM ha^{-1}. Yoshida *et al.* (1984) found that fertilization with bone meal and rapeseed meal produced firm fruits with most cohesiveness, chewingness and uniform thickness at top and bottom of tomato fruits. In oriental pickling melon the organic form of manures showed definite advantage over inorganic fertilizers in respect of storability, while the degree of rotting increased in treatment which received inorganic form of NPK (Kerala Agricultural University, 1987). Meier-Ploeger and Lehri (1989) studied the quality of tomato plants grown with compost from biogenic waste, NPK fertilizers, composted FYM and commercial organic fertilizers were used for comparison. They found that storage quality and content of desirable nutrients such as vitamin C and sugar of fruits were improved in compost treatments. Shanmugavelu (1989) pointed out that the application of a combination of FYM and inorganic mixture was the best for firmness, storage life and keeping quality of tomatoes for a long time. The better storage life of spinach grown with organic manure was found to be associated with low free amino acid content, lower level of nitrate accumulation and higher protein N to nitrate N (Lampkin, 1990). Joseph (1998) reported that shelf life of snake gourd grown with organic residue is much higher as compared to that grown with fertilizers.

2.4 Effect of organic manures on nutrient uptake

Organic manures play a very important role in enhancing the uptake of nutrients by plants.

Significant increases in crop yield and N uptake in maize were obtained by giving cereal straw and neemcake in the proportion of 3 : 1 (Gaur and Mathur, 1979). Concentration of potassium in seedling tissues of vegetable crops like snap bean, cucumber, radish and tomato increased progressively as the levels of mushroom spent compost increased (Sherry, Hsiao-Lei Wang *et al.*, 1984). Dhanokar *et al.* (1994) reported that continuous use of FYM increased the available K_2O by 1.3 to 5.4 folds over control. Application of FYM was beneficial in enhancing the uptake of phosphorus by potato and maize (Minhas and Sood, 1994). Zachariah (1995) reported that in chilli application of Eudrillus compost inoculated with both Azospirillum and P solubilising organisms increased the uptake of N and P significantly than control. Anitha (1997) observed better uptake of nitrogen in poultry manure treated plants as compared to control.

2.5 Effect of nitrogen levels on the growth, yield and quality of vegetables

2.5.1 Effect on growth characters

Increase in plant height with increasing levels of nitrogen in bhindi was reported by several workers [Singh and Singh (1965), Chauhan and Gupta (1973) and Subramonian (1980)]. Increase in nitrogen levels resulted in a sequential increase in plant height in chilli as noted by Srinivas (1983). Sajitharani (1993) showed that the maximum plant height of 106.75 cm (90 DAS) was at the higher level of nutrients (330 : 110 : 220 kg NPK ha^{-1}) in bhindi. Anitha (1997) reported that plant height of chilli increased significantly with increased levels of nitrogen.

But Singh (1979) observed no significant difference in plant height of bhindi by increasing the nitrogen dose from 75 to 150 kg ha^{-1}.

Increased LAI with increasing levels of nitrogen had been reported by several workers. Subramonian (1980) reported that increasing levels of nitrogen significantly increased the LAI both at 30 and 60 DAS. Thomas and Leong (1984) observed that increase in nitrogen application increased the foliar growth and canopy spread in chilli. Nitrogen enhanced the expansion of leaves which in turn increased the LAI in amaranthus (Rajan, 1991).

Verma *et al.* (1970) observed no effect on the number of leaves in bhindi by increasing fertilizer nitrogen from 90 to 120 kg ha^{-1}.

The significant influence of nitrogen on dry matter production was reported by several workers. Subramonian (1980) observed that in bhindi crop DMP was increased with increasing levels of nitrogen up to 60 kg N ha^{-1} though significance was observed only up to 30 kg N ha^{-1}. Rajendran (1981) reported that the total DMP at 60 DAS and at harvest increased with increasing levels of nitrogen in pumpkin. Hedge (1987) observed that increase in nitrogen application increased the DMP in chilli through higher LAI and crop growth rate. Sajitharani (1993) observed that the dry matter content of plants increased with increasing levels of nutrients, recording the maximum value at 330 : 110 : 220 kg NPK ha^{-1} for bhindi crop. Shirley (1996) observed maximum DMP in chilli with drip irrigation and at higher levels of nutrients.

In general various growth characters showed positive response to increased levels of nitrogen.

2.5.2 Effect on yield attributes and yield

Kamalanathan *et al.* (1970) reported delayed maturity in bhindi with increasing levels of nitrogen. Shrestha (1983) in a study to find out the effect of spacing and nitrogen fertilization in bhindi variety *Pusa sawani* found that nitrogen fertilization advanced the first harvest by 4 to 6 days compared with control receiving no nitrogen. Subhani *et al.* (1990) reported that, 120 kg ha^{-1} nitrogen recorded minimum time for 50 per cent flowering in chilli. Sajitharani (1993) showed that plants supplied with highest level of nutrients (330 : 110 : 220 kg NPK ha^{-1}) took about 42 days for flowering while those supplied with the lowest level of nutrients (50 : 8 : 30 kg NPK ha^{-1}) took only 38 days in the case of bhindi. In general delayed flowering was observed due to nitrogen application.

Verma *et al.* (1970) reported that in bhindi the number of fruits per plant increased with increasing levels of nitrogen up to 90 kg ha^{-1}. Shrestha (1983) found that in bhindi pod yield was highest from plots receiving 60 kg N ha^{-1}. Similar results have been reported by Majanbu *et al.* (1985) and Lenka *et al.* (1989).

But Gupta and Rao (1979) reported that in bhindi application of nitrogen above 100 kg ha^{-1} did not affect the number of fruits per hectare significantly.

Balasubramoni (1988) reported that in bhindi nitrogen application showed significant increase in fruit length with increasing levels. Lenka *et al.* (1989) in a study in bhindi with 4 levels of nitrogen (0, 50, 75 and 100 kg ha^{-1}) observed that all the levels were on par with respect to length of bhindi fruits.

Chandrasekharan (1965) found that highest level of nitrogen showed a decrease in the length of fruits over lower levels.

Saimbhi and Padda (1970) observed increased yield in okra with nitrogen fertilization up to 134 kg N ha^{-1} in sandy loam soils. Tomar and Rathore (1988) found that yield of bhindi was highest in plants which received 75 kg N ha^{-1}. Sajitharani (1993) showed that highest level of nutrients (330 : 110 : 220 kg NPK ha^{-1}) recorded the highest per plant yield of 2.7 kg in bhindi. Anitha (1997) reported that in chilli, yield parameters like number of flowers per plant, fruits per plant, fruit girth, fruit length and total fruit yield were better under higher levels of nitrogen as compared to lower levels.

2.5.3 Effect of nitrogen on quality

Subramonian (1980) found that application of nitrogen at the highest level (60 kg ha^{-1}) increased the protein content of fruits. He also reported that nitrogen at the rate of zero and 30 kg ha^{-1} were on par as far as protein content was concerned.

Chandrasekharan (1965) found that nitrogen at 75 lb and 100 lb per acre increased the crude protein content while 125 lb nitrogen per acre reduced the crude protein.

Singh *et al.* (1986) showed that vitamin C content in chilli was increased with enhanced level of nitrogen and the response was linear up to 90 kg ha^{-1}. Vethamoni (1988) found that in bhindi application of 55 kg N ha^{-1} recorded the highest ascorbic acid content of fruits followed by the decreasing levels of nitrogen. Balasubramoni (1988) reported that the application of 30 kg N ha^{-1} gave highest ascorbic acid content. Sajitharani (1993) showed that the highest level of nutrients (330 : 110 : 220 kg NPK ha^{-1}) recorded the highest ascorbic acid content of 24.48 mg per 100 g^{-1} of fresh weight of bhindi fruit which was on par with 220 : 73 : 146 kg NPK ha^{-1}. She also reported that crude fibre content of fruits significantly decreased and ascorbic acid content increased with higher level of nutrients. Anitha (1997) reported maximum ascorbic acid content in chilli fruit with the highest level of nitrogen.

Mani and Ramanathan (1982) reported that crude fibre content of bhindi fruit was significantly decreased by nitrogen fertilization. Application of 80 kg N ha^{-1} recorded least crude fibre content of 12.91 per cent as against 14.2 per cent with zero level of nitrogen. Balasubramoni (1988) reported least crude fibre content in bhindi fruits with 30 kg ha^{-1} nitrogen.

Effect of nitrogen on nutrient uptake by crops

Singh *et al.* (1970) reported that nitrogen application increased the utilization of phosphorus in cauliflower. Asif and Greig (1972) found that in bhindi application of nitrogen increased nitrogen content but decreased phosphorus content. Joseph (1982) observed that in chilli total uptake of nitrogen was increased significantly by increased levels of nitrogen. The beneficial effect of higher levels of nutrients in increasing the uptake of nitrogen has been reported by Dolkova *et al.* (1986), Hedge (1988), John (1989) and Sajitharani (1993). Anitha (1997) reported that application of higher levels of nitrogen increased the nitrogen and potassium uptake by plants.

MATERIALS AND METHODS

MATERIALS AND METHODS

In the new era of organic farming and sustainable agriculture, organic nutrition of crops has great relevance. The main objective of the present investigation is to find out the effect of different sources of organic manures in sustaining the productivity of amaranthus and to optimise the quantity of these manures for amaranthus. A field experiment was conducted during the period from November 1998 to February 1999 at the Instructional Farm, College of Agriculture, Vellayani. The materials used and methods followed are presented.

3.1 Experimental site

Instructional Farm, Vellayani is located at 8^0 30^l N latitude, 76^0 54^l E longitude and at an altitude of 29 m above MSL. The experimental area was under a bulk crop of amaranthus during the previous season.

3.2 Soil

The experimental soil was red sandy loam (Oxisol, Vellayani series). It was acidic in reaction with a pH of 4.8. It recorded a low available N, high P and medium K contents. The initial data on the mechanical and chemical analysis of the soil are given below.

Soil characteristics of experimental site

A. Mechanical composition

Parameters	Content in soil (per cent)	Method used
Coarse sand	36.35	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	15.00	
Silt	17.50	
Clay	30.00	

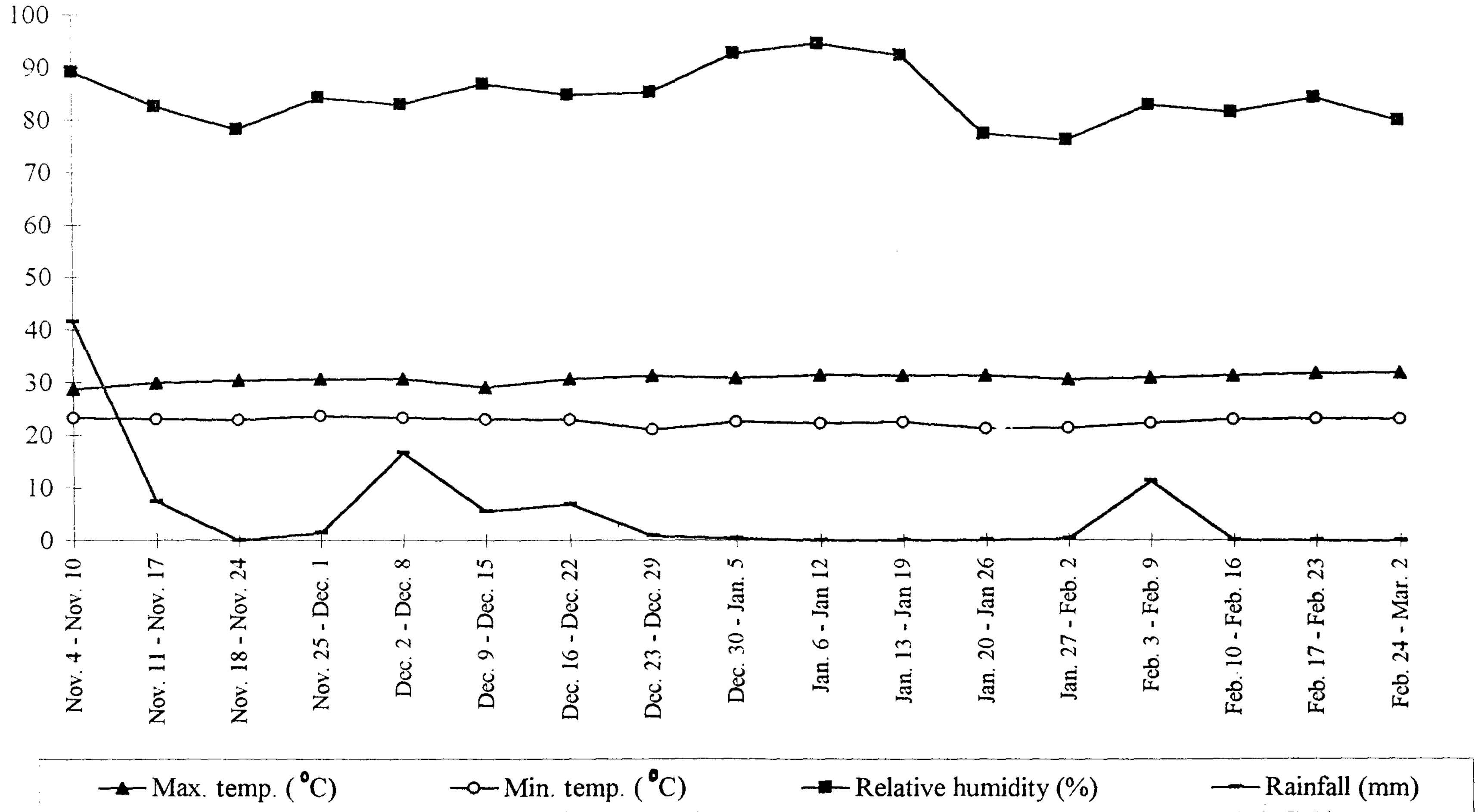
B. Chemical properties

Parameter	Value	Rating	Method
Available N (kg ha^{-1})	238	Low	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	168	High	Bray extraction and klett summerson photoelectric colorimeter (Jackson, 1973)
Available K_2O (kg ha^{-1})	160	Medium	Neutral Normal Ammonium Acetate method (Jackson, 1973)

3.3 Climate and season

A wet tropical climate prevailed in the experimental site. The data on various weather parameters recorded during the cropping period (November 98 to February 99) are given in Appendix - I and graphically presented in Fig. 1. A total rainfall of 32.29 mm was received during the cropping period. Initial stages of crop received moderate showers and in later stages optimum soil moisture status was maintained through irrigation. The mean maximum temperature ranged from 29.2^{0}C to 31.49^{0}C and mean minimum temperature from 21.4^{0}C to 23.76^{0}C.

Fig. 1 Weather conditions during the cropping period (November 1998 to February 1999)



3.4 Variety

The red amaranthus variety viz., Arun which is more popular in homesteads of southern Kerala was used for the experiment. It is a multicut variety with purple coloured leaves evolved by mass selection. It is photo insensitive and is cultivated throughout the year. The seeds were collected from the Instructional Farm, College of Agriculture, Vellayani. The variety has a duration of 90 - 100 days and under ideal conditions grows to a height of about 75 cm.

3.5 Sources of organic manures and chemical fertilizers

Five organic manures used in the experiment with their nutrient content are given below :-

Manure	Nutrient content (%)		
	N	P_2O_5	K_2O
Coir pith compost	1.25	0.06	1.16
Farm yard manure	0.4	0.3	0.2
Neem cake	5.2	1.0	1.4
Poultry manure	1.5	1.6	0.9
Vermicompost	1.5	0.4	1.8

Chemical fertilizers

In the case of the control treatment in which package of practice (POP) recommendation of Kerala Agricultural University was applied, urea (45.8 per cent N), Mussuriphos (20.1 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as nutrient sources.

3.6 Methods

3.6.1 Nursery

A small area adjacent to the experimental site was cleared, dug well, stubbles removed, clods broken and a fine nursery bed was made Amaranthus seeds were sown and Sevin 50 per cent WP was sprinkled round the borders of the bed to prevent the attack of ants. The nursery bed was then covered with coconut fronds. Sprinkling of water was carried out at regular intervals. By third day after sowing complete germination was observed and then coconut fronds were removed. Regular weeding of nursery was also done. After 25 days seedlings were ready for transplanting.

3.6.2 Field culture

The experimental area was dug well, stubbles removed, clods broken and laid out into blocks and plots. A buffer strip of 30 cm width was left all around each plot.

3.6.3 Manures and fertilizers

In the control plot manures and fertilizers as per POP recommendation (50 t FYM ha^{-1} and 50 - 50 - 50 kg N, P_2O_5 and K_2O ha^{-1}) was applied. Entire quantity of P and K and 1/2 N were given as basal, while 1/2 N was top dressed after the harvest. In the rest of the plots FYM, vermicompost, coirpith compost, poultry manure and neem cake at 50 per cent, 75 per cent, 100 per cent, 125 per cent and 150 per cent of POP recommendation were applied on nitrogen equivalent basis. All the organic manures were given as basal dose to respective plots as per the treatment.

3.6.4 Transplanting

Transplanting was done at a spacing of 30 x 20 cm, shade was provided to newly planted area using coconut fronds and light irrigation was given. Coconut fronds from the plots were removed after the establishment of the crop.

3.6.5 After cultivation

Gap filling with healthy seedlings was done from stand by nursery to replace unestsblished seedlings as and when required. Regular irrigation was given to maintain sufficient moisture in the plots. The plots were maintained weed free by hand weeding.

3.6.6 Plant protection

Dithane-M-45 was sprayed at the concentration of 0.4 per cent in cowdung water suspension to prevent the incidence of leaf blight.

3.6.7 Harvesting

First harvest was done at 30 DAT and subsequent harvests at 15 days interval.

Fig. 2 LAYOUT PLAN

N

ORGANIC NUTRITION IN AMARANTHUS (*Amaranthus tricolor* L.)

Replication I	1 T_{20}	2 T_{9}	3 T_{21}	4 T_{11}	5 T_{8}	6 T_{26}	7 T_{6}	8 T_{7}	9 T_{18}	10 T_{5}	11 T_{12}	12 T_{1}	13 T_{24}
	26 T_{3}	25 T_{22}	24 T_{2}	23 T_{16}	22 T_{14}	21 T_{25}	20 T_{15}	19 T_{17}	18 T_{23}	17 T_{10}	16 T_{13}	15 T_{19}	14 T_{4}
Replication II	27 T_{18}	28 T_{15}	29 T_{26}	30 T_{21}	31 T_{16}	32 T_{23}	33 T_{13}	34 T_{25}	35 T_{12}	36 T_{14}	37 T_{17}	38 T_{19}	39 T_{9}
	52 T_{20}	51 T_{10}	50 T_{5}	49 T_{7}	48 T_{1}	47 T_{3}	46 T_{8}	45 T_{11}	44 T_{4}	43 T_{22}	42 T_{2}	41 T_{6}	40 T_{24}
Replication III	53 T_{8}	54 T_{13}	55 T_{4}	56 T_{20}	57 T_{26}	58 T_{3}	59 T_{5}	60 T_{10}	61 T_{15}	62 T_{1}	63 T_{21}	64 T_{7}	65 T_{22}
	78 T_{12}	77 T_{23}	76 T_{18}	75 T_{19}	74 T_{24}	73 T_{6}	72 T_{16}	71 T_{2}	70 T_{14}	69 T_{11}	68 T_{25}	67 T_{17}	66 T_{9}

Design - RBD

Treatments

T_1 - Coir pith compost at 50 per cent of POP (10 t ha^{-1})
T_2 - Coir pith compost at 75 per cent of POP (15 t ha^{-1})
T_3 - Coir pith compost at 100 per cent of POP (20 t ha^{-1})
T_4 - Coir pith compost at 125 per cent of POP (25 t ha^{-1})
T_5 - Coir pith compost at 150 per cent of POP (30 t ha^{-1})
T_6 - FYM at 50 per cent of POP (31.25 t ha^{-1})
T_7 - FYM at 75 per cent of POP (46.88 t ha^{-1})
T_8 - FYM at 100 per cent of POP (62.50 t ha^{-1})
T_9 - FYM at 125 per cent of POP (78.13 t ha^{-1})
T_{10} - FYM at 150 per cent of POP (93.75 t ha^{-1})
T_{11} - Neem cake at 50 per cent of POP (2.4 t ha^{-1})
T_{12} - Neem cake at 75 per cent of POP (3.6 t ha^{-1})
T_{13} - Neem cake at 100 per cent of POP (4.8 t ha^{-1})
T_{14} - Neem cake at 125 per cent of POP (6 t ha^{-1})
T_{15} - Neem cake at 150 per cent of POP (7.2 t ha^{-1})
T_{16} - Poultry manure at 50 per cent of POP (8.34 t ha^{-1})
T_{17} - Poultry manure at 75 per cent of POP (12.5 t ha^{-1})
T_{18} - Poultry manure at 100 per cent of POP (16.67 t ha^{-1})
T_{19} - Poultry manure at 125 per cent of POP (20.84 t ha^{-1})
T_{20} - Poultry manure at 150 per cent of POP (25 t ha^{-1})
T_{21} - Vermicompost at 50 per cent of POP (8.34 t ha^{-1})
T_{22} - Vermicompost at 75 per cent of POP (12.5 t ha^{-1})
T_{23} - Vermicompost at 100 per cent of POP (16.67 t ha^{-1})
T_{24} - Vermicompost at 125 per cent of POP (20.84 t ha^{-1})
T_{25} - Vermicompost at 150 per cent of POP (25 t ha^{-1})
T_{26} - POP recommendation 50 t FYM ha^{-1} and 50 - 50 - 50 kg N. P_2O_5 and K_2O ha^{-1})

3.7 Outline of technical programme

3.7.1 Design and layout

Design	-	RBD
Treatments	-	25 + 1
Replications	-	3
Spacing	-	30 x 20 cm
Gross plot size	-	2.4 x 2.0 m
Net plot size	-	1.8 x 1.2 m

The layout plan of the experiment is given in Fig. 2

3.7.2 Treatments

Organic manures

1) Coir pith compost
2) FYM
3) Neem cake
4) Poultry manure
5) Vermicompost

Control

6) Package of Practices (POP) recommendation of - Kerala Agricultural University

T_1 to T_{25} - FYM, vermicompost, coirpith compost, poultry manure and neem cake at 50 per cent, 75 per cent, 100 per cent, 125 per cent and 150 per cent of POP recommendation on nitrogen equivalent basis as detailed below :

T_1	-	Coir pith compost at 50 per cent of POP (10 t ha^{-1})
T_2	-	Coir pith compost at 75 per cent of POP (15 t ha^{-1})
T_3	-	Coir pith compost at 100 per cent of POP (20 t ha^{-1})
T_4	-	Coir pith compost at 125 per cent of POP (25 t ha^{-1})
T_5	-	Coir pith compost at 150 per cent of POP (30 t ha^{-1})
T_6	-	FYM at 50 per cent of POP (31.25 t ha^{-1})
T_7	-	FYM at 75 per cent of POP (46.88 t ha^{-1})
T_8	-	FYM at 100 per cent of POP (62.50 t ha^{-1})
T9	-	FYM at 125 per cent of POP (78.13 t ha^{-1})
T_{10}	-	FYM at 150 per cent of POP (93.75 t ha^{-1})
T_{11}	-	Neem cake at 50 per cent of POP (2.4 t ha^{-1})
T_{12}	-	Neem cake at 75 per cent of POP (3.6 t ha^{-1})
T_{13}	-	Neem cake at 100 per cent of POP (4.8 t ha^{-1})
T_{14}	-	Neem cake at 125 per cent of POP (6 t ha^{-1})
T_{15}	-	Neem cake at 150 per cent of POP (7.2 t ha^{-1})
T_{16}	-	Poultry manure at 50 per cent of POP (8.34 t ha^{-1})
T_{17}	-	Poultry manure at 75 per cent of POP (12.5 t ha^{-1})
T_{18}	-	Poultry manure at 100 per cent of POP (16.67 t ha^{-1})
T_{19}	-	Poultry manure at 125 per cent of POP (20.84 t ha^{-1})
T_{20}	-	Poultry manure at 150 per cent of POP (25 t ha^{-1})
T_{21}	-	Vermicompost at 50 per cent of POP (8.34 t ha^{-1})
T_{22}	-	Vermicompost at 75 per cent of POP (12.5 t ha^{-1})
T_{23}	-	Vermicompost at 100 per cent of POP (16.67 t ha^{-1})
T_{24}	-	Vermicompost at 125 per cent of POP (20.84 t ha^{-1})
T_{25}	-	Vermicompost at 150 per cent of POP (25 t ha^{-1})
T_{26}	-	POP recommendation (50 t FYM ha^{-1} and 50 - 50 - 50 kg N, P_2O_5 and K_2O ha^{-1})

3.8 Observations

Observations were made on important parameters associated with growth, yield and quality of amaranthus. A destructive row was earmarked at the first outer row of net plot, in each plot uniformly, from which observations like LAI and NAR were estimated. Three plants were selected at random for the purpose of study. Parameters considered and methods followed are briefly described here under.

3.8.1 Growth characters

3.8.1.1 Height of the plant

The height of the plants were recorded from three randomly selected observational plants at three stages of growth *viz.*,15th, 30th and 45th DAT. The height was measured from the ground level to the top most leaf bud (apex). Mean values were computed and expressed in centimetres.

3.8.1.2 Number of leaves

Total number of leaves in each observational plant was counted and the average was recorded for each plant at three growth stages *viz.*, 15th, 30th and 45th DAT.

3.8.1.3 Number of branches

Total number of branches of observational plants were counted and the mean worked out for each plant at three stages of growth *viz.*, 15th, 30th and 45th day of transplant.

3.8.1.4 Leaf area index (LAI)

LAI was measured using LI-300 leaf area meter at three stages of growth *viz.*, 15th, 30th and 45th DAT and expressed in square centimetre. LAI was worked out using the equation.

$$\text{LAI} = \frac{\text{Total leaf area}}{\text{Land area}} \qquad \text{(Watson, 1952)}$$

3.8.2 Yield and yield attributes

3.8.2.1 Number of harvests

There was no difference in the number of harvests between treatments. Therefore the data was not statistically analysed and presented.

3.8.2.2 Yield harvest^{-1}

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

3.8.2.3 Total dry matter production

Dry matter production of whole plant was recorded at the time of harvest.

3.8.2.4 Total marketable green yield

Weight of disease and pest free leaf and stem portion was taken as the marketable green yield. Plants which have flowered were also excluded.

3.8.3 Physiological parameters

3.8.3.1 Biomass

Fresh weight of single whole plant was recorded at each harvest and from this figure the biomass was calculated.

3.8.3.2 NAR

This is the rate of increase in dry weight per unit leaf area per unit time expressed in mg cm^{-2} day^{-1} (William, 1946).

$$NAR = \frac{(W_2 - W_1)\ (l_n\, l_2 - l_n\, l_1)}{(t_2 - t_1)\ (l_2 - l_1)}$$

Where W_1 is the dry weight at time t_1

W_2 is the dry weight at time t_2

l_1 is the leaf area at time t_1

l_2 is the leaf area at time t_2

3.8.3.3 Dry matter production and partitioning

Plants left for destructive sampling were cut close to the ground at 15 days interval. Leaves and stem of the plants were dried separately in shade, oven dried at 70 ± 5^0 C till two constant weight were obtained. The mean weight is presented in kg ha^{-1}.

3.8.4 Leaf quality

3.8.4.1 Moisture content

Plant samples of known fresh weights were first sun dried and then dried to a constant weight in hot air oven at 80^0 C. From the data, moisture content was worked out and expressed as percentage.

3.8.4.2 Ascorbic acid

Estimated by titrimetric method (Paul Gyorgy and Pearson, 1967) and expressed in mg 100 mg^{-1}.

3.8.4.3 Fibre content

Fibre content of plants was determined by A.O.A.C. method (A.O.A.C, 1975) and expressed as percentage.

3.8.4.4 Protein content

The plant nitrogen values were multiplied by the factor 6.25 to obtain the protein content of plants and the values are expressed as percentage (Simpson *et al.*, 1965).

3.8.5 Plant analysis

The plant samples were analysed for nitrogen, phosphorus and potassium at final harvest. The plants were chopped and dried in an air oven at 80 ± 5^0 C till constant weights were obtained. Samples were then ground in a Willey mill to pass through 0.5 mm mesh. The required quantity of samples were then weighed out accurately in a physical balance and analysed.

The nitrogen content in plant was estimated by modified microkjeldahl method (Jackson, 1973) and the uptake of nitrogen was calculated by multiplying the content with the dry matter produced. The phosphorus content in plant was estimated colorimetrically (Jackson, 1973). From the phosphorus content and the dry matter produced at harvest, the uptake was worked out. The potassium content in plants was estimated by the flame photometric method in Perkin-Elmer 3030. The uptake of potassium was calculated based on potassium content in plants and dry matter produced.

3.8.6 Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The air dried soil samples after passing through a 2 mm sieve were analysed for available nitrogen, available phosphorus and available potassium content.

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

3.8.7 Benefit - cost ratio

The economics of cultivation of amaranthus was worked out and benefit cost ratio was calculated as follows.

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

3.9 Statistical analysis

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

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

An investigation was conducted at College of Agriculture, Vellayani to assess the effect of different sources of organic manures on the yield and quality of amaranthus during the period from November 1998 to February 1999. The data collected were statistically analysed and the results of the experiment are presented and discussed in this chapter.

4.1 Growth characters

Observations on growth characters like plant height, number of leaves plant^{-1}, number of branches plant^{-1} and leaf area index were recorded and the results are presented in Tables 1 to 4.

4.1.1 Plant height

The mean plant height from 15 DAP to 45 DAP are presented in Table 1. At 15 DAP treatments T_7, T_{10}, T_{16}, to T_{20} and T_{22} to T_{25} were found to be superior to POP. At initial stages of growth (at 15 DAP), poultry manure treated plants did not show any significant difference in plant height. Poultry manure and vermicompost favourably influenced plant height at 15 DAP. FYM given at 75 per cent (46.88 t ha^{-1}) and 150 per cent (93.75 t ha^{-1}) of POP also registered good response. All other treatments were on par with POP which recorded a plant height of 7.56 cm. At 15 DAP the highest level of vermicompost (T_{25} @ 25 t ha^{-1}) recorded the maximum plant height of 18.61

Table 1 Plant height (cm) of amaranthus as influenced by sources and levels of organic manrues

Treatments	15 DAP	30 DAP	45 DAP
T_1	8.11	15.50	31.00
T_2	5.89	10.28	18.44
T_3	8.33	12.72	22.00
T_4	8.00	11.67	18.44
T_5	6.89	12.28	23.22
T_6	11.39	25.56	39.17
T_7	13.33	35.00	47.56
T_8	11.17	27.06	43.56
T_9	12.11	29.61	52.06
T_{10}	14.11	35.94	67.22
T_{11}	7.61	13.67	31.11
T_{12}	8.50	15.33	32.56
T_{13}	11.94	13.94	37.89
T_{14}	12.44	28.39	42.44
T_{15}	11.11	21.67	31.89
T_{16}	14.78	26.00	35.22
T_{17}	13.44	26.00	40.78
T_{18}	15.56	29.39	42.00
T_{19}	17.28	32.28	44.61
T_{20}	17.06	27.44	43.33
T_{21}	10.50	19.22	33.33
T_{22}	14.11	22.78	28.33
T_{23}	13.44	24.33	34.28
T_{24}	13.50	27.28	40.00
T_{25}	18.61	40.44	62.56
T_{26}	7.56	21.78	35.83
$F_{25, 50}$	3.33**	6.99**	14.01**
SE	2.67	4.42	4.43
CD (0.05 %)	5.36	8.88	8.90

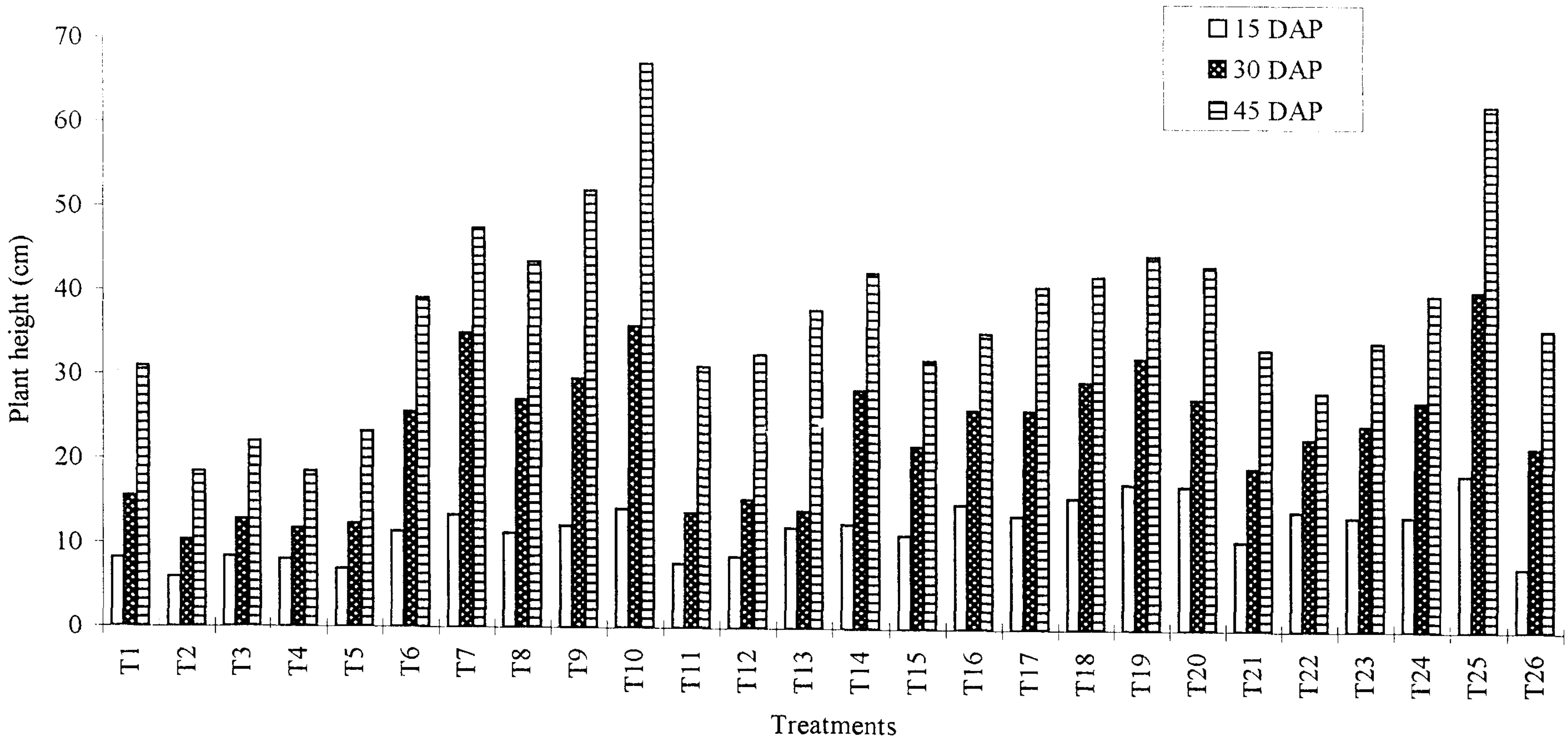
** Significant at 1 per cent level

cm. But it was on par with T_{18}, T_{19} and T_{20} which recorded 15.56, 17.28 and 17.06 cm height respectively. At 30 DAP T_7 (35 cm), T_{10} (35.94 cm), T_{19} (32.28 cm) and T_{25} (40.44 cm) were superior to POP (21.78 cm). Except in the case of T_2 to T_5 and above, all other treatments were on par with POP. T_7 (47.56 cm), T_{10} (67.22 cm) and T_{25} (62.56 cm) maintained its superiority at 45 DAP. T_9 (52.06 cm) also performed well.

At 15 DAP and 30 DAP the height recorded by T_2 to T_5 were very less in comparison with that under POP. All the superior treatments were found to respond more or less similarly at 15 DAP and 30 DAP. However, at 45 DAP, a marked increase in plant height was recorded by T_{10} and T_{25} which maintained their superiority at all the stages of growth.

An increasing trend in height was observed with increasing level of organic manures at all stages. One of the main functions of nitrogen in plants is to promote vegetative growth (Tisdale *et al.*, 1990). As the levels of organic manures were increased, the vegetative growth was promoted which naturally increased the height of plants. Similar increase in plant height due to increase in nitrogen fertilization have been reported by Singh *et al.* (1985), Bressani *et al.* (1987) and Ramachandra and Thimmaraju (1983) in amaranthus. The better performance of poultry manure treated plants at early stage (15 DAP) may be due to the better availability of nitrogen. More than 60 per cent of nitrogen in poultry manure is constituted by uric acid which rapidly gets converted to ammonical form and is easily utilised by the plants (Smith, 1950). Singh *et al.* (1973) attributed higher efficiency of poultry manure to its narrow C : N ratio and comparatively higher content of readily mineralisable N.

Fig. 3 Effect of sources and levels of organic manures on plant height in amaranthus



The highest level of nitrogen supplied through various organic manures increased plant height. Similar findings were reported by Prabhakar *et al.* (1987), Belichki (1988),John (1989) and Sajitharani (1993). Increased plant height obtained at higher levels of nitrogen may be attributed to the rapid meristematic activity triggered by plant nutrients especially nitrogen (Crowther, 1935) and the higher rate of metabolic activity coupled with rapid cell division brought about by phosphorus (Bear, 1965).

4.1.2 Number of leaves

Total number of fully opened leaves as influenced by treatments are presented in Table 2. At 15 DAP T_7 (23.22), T_{19} (23.56), T_{20} (23.89) and T_{25} (30.78) were found to be superior to POP. All other treatments were on par with POP which recorded a value of 10.67. As in the case of plant height significant response was noticed with125 per cent N level of poultry manure (20.84 t ha^{-1}) and with 75 per cent N level of FYM (46.88 t ha^{-1}). The number of leaves were maximum for plants treated with highest level of vermicompost (25 t ha^{-1}) at 15 DAP and 45 DAP. At 30 DAP, treatments T_7 (52.67), T_{10} (47.33) and T_{25} (47.78) were significantly superior to POP which recorded the value of 31.22. Plants which received varying levels of coirpith compost were inferior to POP and performed poorly both at 30 DAP and 45 DAP. Barring the above three, all other treatments were on par at 30 DAP. At 45 DAP also T_7 (70.78), T_{10} (97.22) and T_{25} (100.78) maintained its superiority over POP along with T_{14} (62.22). POP recorded a value of 46.78. T_2, T_3 and T_4 were inferior to POP whereas the rest of the treatments were on par with it.

Table 2 Number of leaves per plant of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	7.67	15.11	35.22
T_2	7.56	12.22	18.89
T_3	8.89	13.78	27.33
T_4	9.22	14.44	22.56
T_5	9.56	15.56	38.44
T_6	13.44	27.78	52.67
T_7	23.22	52.67	70.78
T_8	14.33	31.67	49.33
T_9	15.33	39.78	61.67
T_{10}	18.89	47.33	97.22
T_{11}	9.67	15.56	42.11
T_{12}	8.56	20.22	48.22
T_{13}	14.56	28.11	43.44
T_{14}	16.89	40.56	62.22
T_{15}	14.11	26.22	37.22
T_{16}	18.11	25.44	36.11
T_{17}	15.89	27.56	45.44
T_{18}	20.00	39.22	50.56
T_{19}	23.56	40.44	53.11
T_{20}	23.89	38.56	55.56
T_{21}	14.00	21.44	42.67
T_{22}	17.11	31.67	39.67
T_{23}	17.44	27.11	48.67
T_{24}	15.78	30.89	53.11
T_{25}	30.78	47.78	100.78
T_{26}	10.67	31.22	46.78
$F_{25, 50}$	2.34**	4.94**	12.49**
SE	5.30	7.30	7.51
CD (0.05 %)	10.65	14.67	15.09

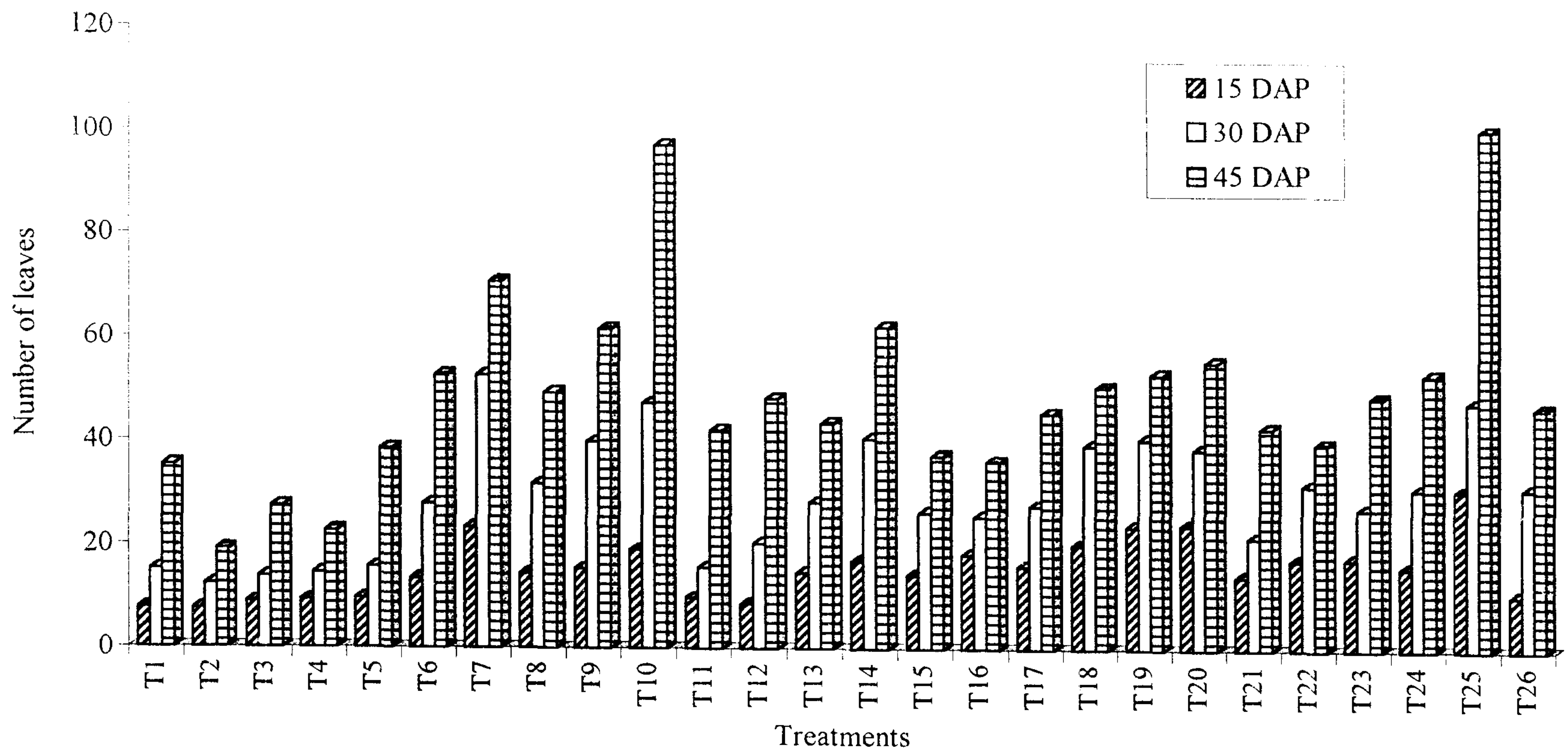
** Significant at 1 per cent level

At 45 DAP, T_{25} (vermicompost @ 25 t ha^{-1}) recorded maximum number of leaves. T_{25} recorded five times more number of leaves than T_2 (coirpith compost @ 15 t ha^{-1}) which recorded the lowest number But T_{25} with a mean value of 100.78 was on par with T_{10} (97.22 leaves). The next best treatment was T_7 (FYM @ 46.88 t ha^{-1}) and it was on par with T_{14} (neem cake @ 6 t ha^{-1}). At 45 DAP a marked increase in number of leaves was noted in T_{25} which received vermicompost at 150 per cent of POP It was also found that the number of leaves increased markedly under neem cake treatments at 45 DAP compared to 30 DAP.

The poor performance of coirpith compost at all the three stages may be due to its wide C:N ratio compared to other organic manures like FYM, neem cake, vermicompost and poultry manure all of which posses narrow C : N ratio of less than 15. The wider C : N ratio of coir pith compost might have resulted in immobilization of nutrients especially nitrogen in the soil. The higher number of leaves recorded by vermicompost treated plants may be due to the effect of significant quantities of available nutrients and biologically active metabolites present in vermicompost. This favourable influence of vermicompost on growth and yield was previously reported by Pushpa (1996), Rajalekshmi (1996) and Shuxin *et al.* (1991). The better performance of higher levels of FYM may be attributed due to increased supply of nutrients and other growth substances along with improvement in the soil properties.

Neem cake is a concentrated organic manure rich in plant nutrients. In addition to nutrients it possesses some alkaloids like nimbin, nimbidin and certain sulphur compounds which have nitrification inhibiting properties. As a

Fig. 4 Effect of sources and levels of organic manures on number of leaves in amaranthus



result neemcake acts like a slow release nitrogenous fertilizer and nutrients are available within a period of 2 - 3 months according to the crop demand. This slow nutrient releasing ability of neemcake would have resulted in increased number of leaves at 45 DAP as shown in table compared to 15 DAP and 30 DAP.

4.1.3 Number of branches

At 15 DAP T_{14} (5.89), T_{18} (5.22), T_{20} (5.56) and T_{25} (7.44) were significantly superior to the control treatment POP (1.44). T_{25} (vermicompost @ 25 t ha^{-1}) performed significantly superior to all other organic manures at this stage. As in the case of other growth characters the performance of coir pith was poor at all the three stages. The control treatment (POP) was on par with the treatment that gave the lowest number of branches. At 15 DAP treatments T_1 to T_5, T_{11} and T_{12} were inferior to POP. The rest of the treatments were on par with POP. But at 30 DAP almost all treatments were on par with POP except T_2 to T_5 which were inferior. At 45 DAP the treatments T_1 to T_5, T_{11} and T_{12} were found to be inferior to POP. The rest of the treatments were on par with POP. Though highest level of vermicompost (25 t ha^{-1}) still recorded maximum number of branches (19.33), it was on par with T_7 (17.22), T_{10} (18.67), T_{18} (15.44) and T_{20} (18.11).

At all the three growth stages the highest level of vermicompost recorded the highest number of branches. At 45 DAP it was noted that treatments with higher levels of organic manures produced more number of branches. The beneficial effect of organic amendments in increasing the growth parameters was reported by Zhang *et al.* (1988), Almazov and

Table 3 Number of branches per plant of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	0.22	3.67	7.67
T_2	0.11	1.44	1.78
T_3	1.44	2.89	3.89
T_4	1.00	3.22	5.56
T_5	0.00	2.00	5.22
T_6	2.67	9.22	12.67
T_7	4.56	12.56	17.22
T_8	3.00	8.56	12.89
T_9	2.67	9.56	14.33
T_{10}	4.44	11.44	18.67
T_{11}	0.33	7.44	7.44
T_{12}	0.56	4.11	9.44
T_{13}	3.44	8.67	11.78
T_{14}	5.89	10.33	13.11
T_{15}	2.89	7.56	11.33
T_{16}	4.11	9.22	11.56
T_{17}	3.78	9.44	11.44
T_{18}	5.22	9.33	15.44
T_{19}	4.89	10.67	12.78
T_{20}	5.56	11.22	18.11
T_{21}	2.44	6.11	12.67
T_{22}	3.44	9.00	10.89
T_{23}	4.00	9.22	12.56
T_{24}	3.44	10.56	13.00
T_{25}	7.44	13.56	19.33
T_{26}	1.44	9.00	15.11
$F_{25, 50}$	2.57**	3.05**	5.46**
SE	1.75	2.67	2.70
CD (0.05 %)	3.52	5.36	5.42

** Significant at 1 per cent level

Kholuyaka (1990), Pushpa (1996) and Anitha (1997). Increase in nitrogen levels might have increased the production, translocation and assimilation of photosynthates to growing points thereby stimulating plants to produce more number of branches and leaves. Similar results were reported by Dolkova *et al.* (1984) and Kaminawar and Rajagopal (1993).

4.1.4 Leaf Area Index

The mean leaf area index recorded at 15, 30 and 45 DAP are presented in Table 4. At 15 DAP a number of treatments performed significantly superior to POP. This include T_7 to T_{10}, T_{16}, T_{18}, T_{19}, T_{22}, T_{24} and T_{25}. The rest of the treatments were on par with POP. No treatment was inferior to POP at this stage. The highest LAI of 0.477 was recorded by T_{10} (FYM @ 93.75 t ha^{-1}) at 15 DAP and it was on par with T_7 (FYM @ 46.88 t ha^{-1}) which recorded 0.409. The control treatment recorded a LAI of 0.112 which was on par with the lowest recorded LAI of 0.055 by T_1 (coirpith compost @ 10 t ha^{-1}). FYM and treatments involving 125 per cent and 150 per cent level of POP as poultry manure and vermicompost also did well.

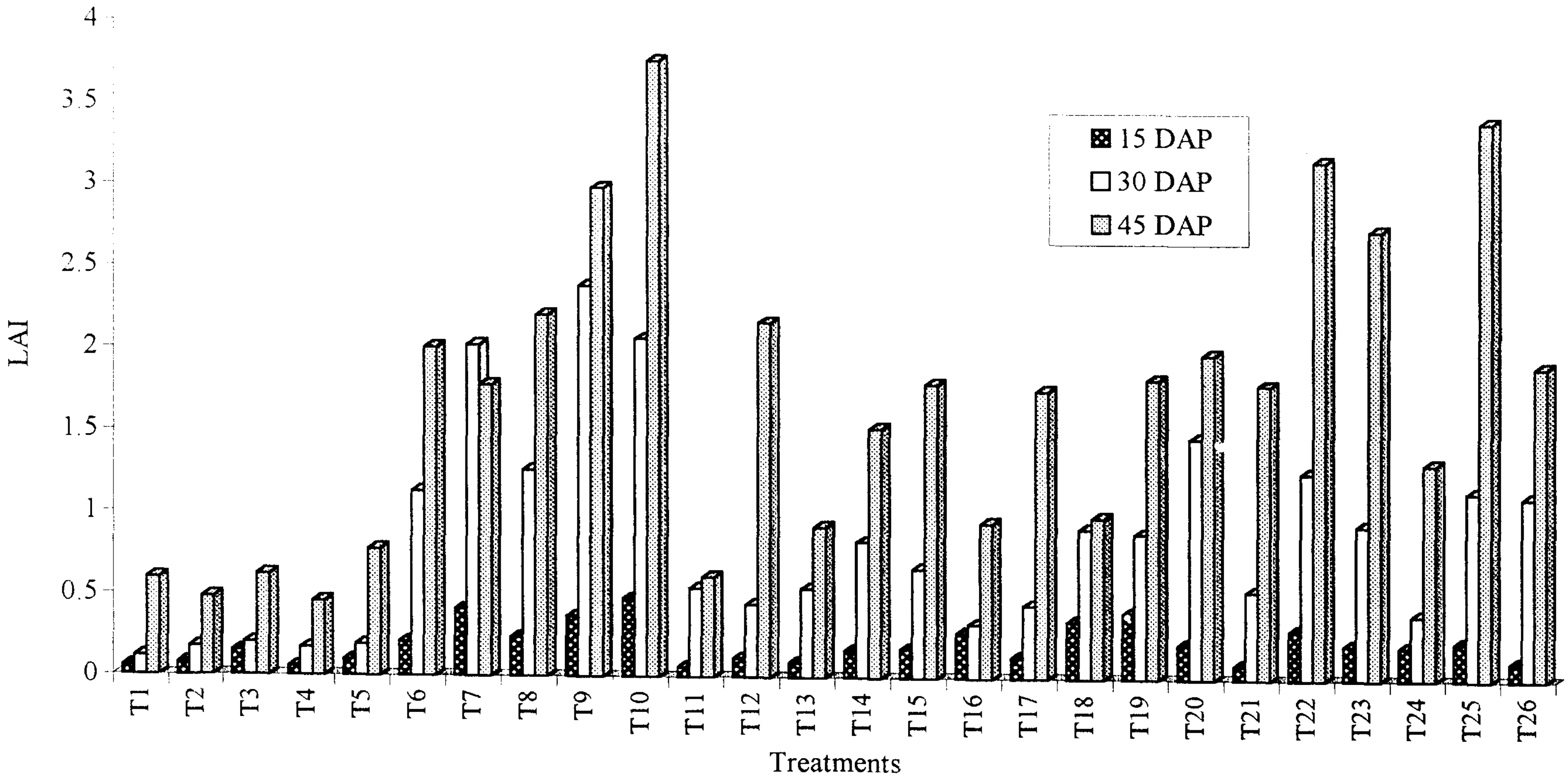
At 30 DAP T_7 (2.024), T_9 (2.391) and T_{10} (2.064) were significantly superior to POP (1.117). Maximum LAI was noted for T_{10} (FYM @ 93.75 t ha^{-1}). These three treatments maintained the same trend as in the case of 15 DAP. All the treatments involving coir pith compost (T_1 to T_5) were significantly inferior to POP. Other inferior treatments include T_{11}, T_{12}, T_{13}, T_{15}, T_{16}, T_{17}, T_{21} and T_{24}. At 30 and 45 DAP POP performed better than highest level of neemcake and vermicompost. At 45 DAP only one treatment

Table 4 Leaf area index of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	0.055	0.116	0.595
T_2	0.079	0.177	0.479
T_3	0.150	0.201	0.618
T_4	0.055	0.171	0.455
T_5	0.098	0.192	0.773
T_6	0.213	1.127	2.005
T_7	0.409	2.024	1.778
T_8	0.241	1.259	2.207
T_9	0.369	2.391	2.989
T_{10}	0.477	2.064	3.767
T_{11}	0.063	0.544	0.611
T_{12}	0.115	0.443	2.167
T_{13}	0.090	0.541	0.917
T_{14}	0.165	0.826	1.521
T_{15}	0.178	0.663	1.793
T_{16}	0.276	0.331	0.946
T_{17}	0.131	0.445	1.752
T_{18}	0.352	0.913	0.982
T_{19}	0.401	0.883	1.826
T_{20}	0.213	1.467	1.981
T_{21}	0.088	0.534	1.794
T_{22}	0.302	1.259	3.168
T_{23}	0.211	0.937	2.750
T_{24}	0.202	0.393	1.314
T_{25}	0.229	1.147	3.415
T_{26}	0.112	1.117	1.913
$F_{25, 50}$	10.72**	15.68**	4.24**
SE	0.052	0.221	0.772
CD (0.05 %)	0.104	0.444	1.551

** Significant at 1 per cent level

Fig. 5 Effect of and levels of organic manures on leaf area index in amaranthus



T_{10} (3.767) was significantly superior to POP (1.913). All the remaining treatments were on par with POP including T_4 (coirpith compost @ 25 t ha^{-1}) which recorded the lowest value of 0.455.

It is clear from the table that higher levels of organic manures gave increased LAI at 15 DAP. Russel (1973) reported that as the nitrogen supply increases, the extra protein produced allows the plant leaves to grow larger and hence resulted in increased surface area available for photosynthesis. Thus increased LAI might be due to the enhanced production of leaves and increased longivity of leaves exhibited by plants receiving higher levels of nutrients. Steineek (1964) reported that more the available nitrogen, the greater the effect of potassium on the growth of shoot and number of leaves and potassium increases longivity of leaves.

4.2 Yield and yield attributes

4.2.1 Yield harvest^{-1}

The mean values of yield obtained at each harvest starting from 30 DAP and subsequently at 15 days interval is presented in Table 5.

First harvest

During first harvest T_9, T_{10}, T_{19}, T_{20}, T_{24}, T_{25} performed significantly superior to POP and recorded 20.35, 23.17, 19.86, 21.67, 20.53 and 23.4 t ha^{-1} respectively. All the coirpith compost treatments were significantly inferior to POP. Other inferior treatments include T_6, T_{11}, T_{12}, T_{16} and T_{21}. All the remaining treatments were on par with POP. The highest yield of 23.4 t ha^{-1} was recorded by T_{25} and it was on par with T_{10}. Lowest yield during first harvest was recorded by T_1 (14.2 t ha^{-1}).

Table 5 Yield (t ha^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	1 CUT	2 CUT	3 CUT	4 CUT
T_1	14.20	11.35	12.92	6.01
T_2	15.07	12.60	14.33	6.98
T_3	15.53	13.67	15.35	8.27
T_4	16.27	13.82	15.19	8.22
T_5	17.27	13.98	16.29	8.90
T_6	17.17	13.27	19.00	8.06
T_7	17.97	14.36	19.00	8.89
T_8	19.21	15.17	19.72	10.35
T_9	20.35	16.92	22.40	10.03
T_{10}	23.17	18.24	23.55	11.35
T_{11}	15.17	12.55	16.33	7.10
T_{12}	16.33	13.57	17.10	8.30
T_{13}	17.92	14.12	18.33	8.13
T_{14}	18.43	15.88	18.59	9.23
T_{15}	18.81	17.15	20.76	10.03
T_{16}	16.56	13.14	17.16	9.34
T_{17}	18.38	14.31	17.32	8.82
T_{18}	18.34	15.57	17.93	10.55
T_{19}	19.86	16.10	17.82	10.20
T_{20}	21.67	17.47	20.20	9.87
T_{21}	17.20	14.65	17.50	8.23
T_{22}	18.02	17.00	17.48	9.03
T_{23}	18.60	16.22	18.27	8.73
T_{24}	20.53	18.03	21.43	10.77
T_{25}	23.40	19.36	23.33	11.93
T_{26}	18.69	14.70	16.71	8.10
$F_{25, 50}$	55.46**	56.07**	73.16**	21.58**
SE	0.434	0.378	0.432	0.419
CD (0.05 %)	0.87	0.76	0.87	0.84

** Significant at 1 per cent level

Second harvest

Those treatments which were superior to POP during first harvest continued the same trend in this harvest also. In addition to those T_{14}, T_{15}, T_{18}, T_{22} and T_{23} performed superior to POP. Here also significantly superior yield of 19.36 t ha^{-1} was recorded by highest level of vermicompost. The next best yield was from T_{10} (18.24 t ha^{-1}). A progressive increase in the yield with increasing levels of organic manures was noted. The significantly inferior treatments noticed during second harvest include T_1 to T_4, T_6, T_{11}, T_{12} and T_{16}. Neem cake treatments started responding to high levels from second harvest onwards. As in first harvest T_1 gave the lowest yield of 11.35 t ha^{-1}.

Third harvest

Compared to second cut yield was higher in third cut in all the treatments. All treatments of FYM and vermicompost (except T_{22}) along with 100, 125 and 150 per cent of neemcake and poultry manure performed superior to POP (16.71 t ha^{-1}). The inferior treatments include T_1 to T_4, T_6, T_{11}, T_{12} and T_{16}. The remaining treatments were on par with POP. The highest yield during 3^{rd} cut was recorded by T_{10} as 23.55 t ha^{-1}. It was on par with T_{25} (23.33 t ha^{-1}), which was the highest dose of vermicompost.

Fourth harvest

Yield from all treatments were found to decrease in the fourth harvest. Higher levels of all the manures (100 per cent level onwards) except coir pith compost performed significantly superior to POP during fourth harvest. In fourth harvest also maximum yield was recorded by vermicompost at 150 per cent level (11.93 t ha^{-1}). Treatments T_1 (6.01 t ha^{-1}), T_2 (6.98 t ha^{-1}) and T_{11} (7.10 t ha^{-1}) were inferior to POP which recorded 8.1 t ha^{-1} during fourth cut. All the other treatments were on par with POP. T_1 recorded the lowest yield. The yield of T_{25} was almost double that from T_1.

Nitrogen promotes vegetative growth. In amaranthus where leaf and shoot portion are the economic plant parts, better manuring gave better growth and yield. The higher yield at higher nutrient level may be due to better plant height, more number of leaves and branches. Amaranthus being a leafy vegetable, the utility of primary nutrient element (NPK) in balanced proportion in recommended quantities is the prime and effective ways for boosting leaf production. The favourable influence of nitrogen on yield attributing characters can also be ascribed to the increased availability and uptake of nutrients required for the growth and development of plants. Significant increase in the yield of vegetative parts as a result of higher nitrogen levels was observed by several workers ; in cabbage (Peck, 1981); in amaranthus (Singh, 1984).

Not only the growth parameters, the yield and yield attributes were also significantly improved by organic manuring. Similar results of increased plant growth and yield of tomato by the application of organic amendments were reported by Gianquinto and Borin (1990). The better expression of growth and yield parameters noticed in the study by some levels of organic manures may be due to the multidynamic role played by organic amendments. Organic manures constitute a dependable source of major and minor nutrient elements.

Apart from this they have a profound influence on soil physical properties resulting in better structure, greater water retention, more favourable environment for root growth and better infiltration of water (Tandon, 1994). Nitrogen fixation and P solubilisation are also improved due to increased microbiological activity in organic matter amended soil. All these factors might have resulted in enhancing nutrient availability and there by more uptake and better performance of amaranthus.

In POP recommendation, a part of the nutrients was supplied through FYM and remaining through chemical fertilizers. In the case of fertilizers especially urea, nutrients mineralise very quickly and are susceptible to leaching losses (Tisdale *et al.*, 1997). Thus quick mineralisation and leaching losses might have resulted in declining nutrient availability through out the crop growth. Thus the nutrients from POP treatment were not fully available to the plants, especially at critical stages of crop growth and reproduction. This might have resulted in decreased crop growth and yield. Unlike chemical fertilizers nutrients in organic manures such as neemcake, FYM etc., are available slowly within 2 to 3 months according to crop demand and are less susceptible to leaching losses. Hence the crop might have utilized the available nutrients more efficiently and resulted in better growth and yield.

Better yield at higher levels of neemcake at later stages of harvest may be due to the reason that neemcake acts as a slow release nitrogenous fertilizer by inhibiting nitrification process in the soil due to the presence of certain alkaloids like nimbin, nimbidin, sulfur compounds etc. and nutrients are available at later stages of cropgrowth according to crop demand.

Fig. 6. Effect of sources and levels of organic manures on marketable yield in amaranthus

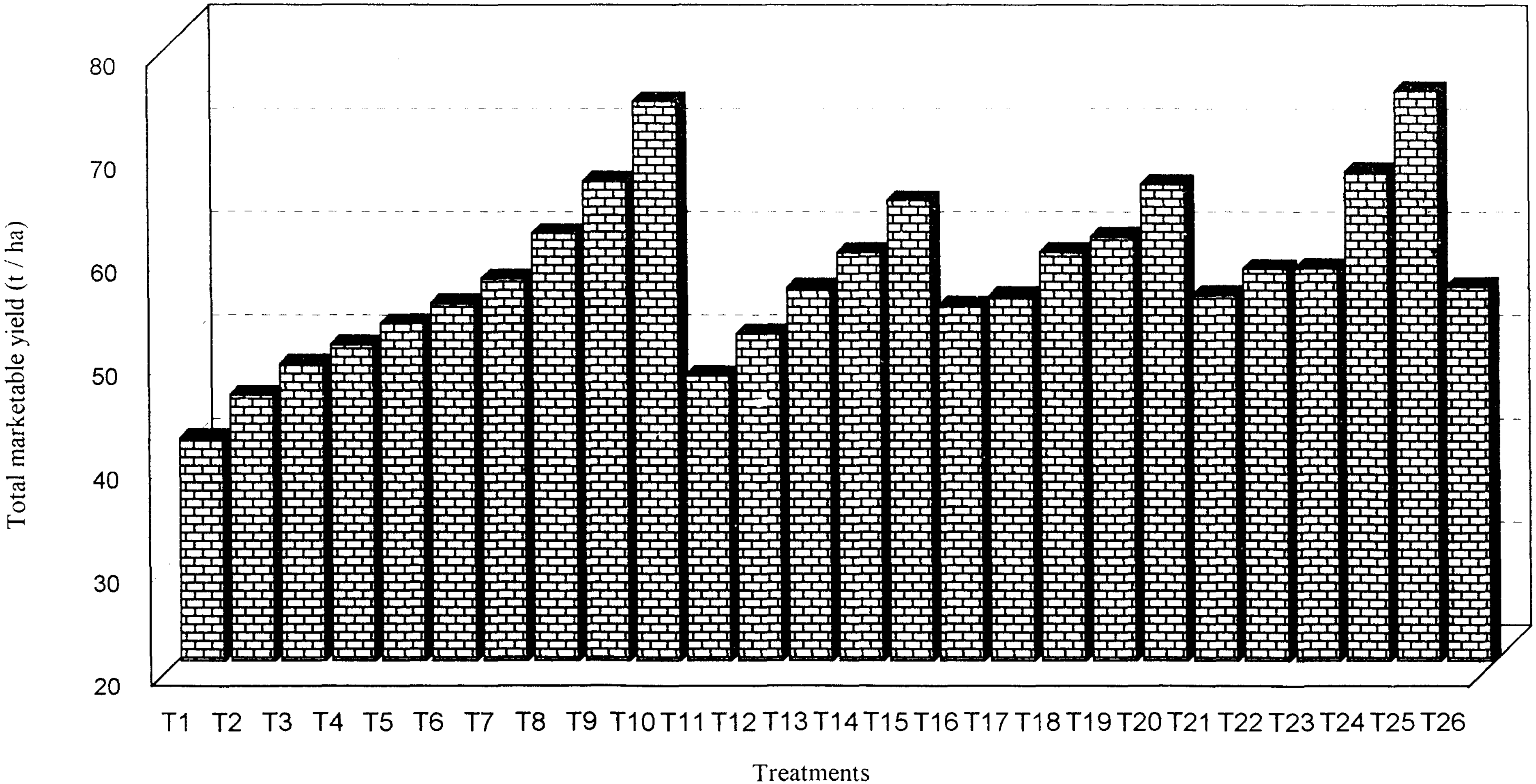


Table 6 Total marketable yield (t ha^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	Total marketable yield (t ha^{-1})
T_1	41.53
T_2	45.68
T_3	48.67
T_4	50.54
T_5	52.60
T_6	54.53
T_7	56.94
T_8	61.34
T_9	66.41
T_{10}	74.12
T_{11}	47.57
T_{12}	51.63
T_{13}	56.07
T_{14}	59.49
T_{15}	64.52
T_{16}	54.30
T_{17}	55.26
T_{18}	59.48
T_{19}	61.02
T_{20}	66.12
T_{21}	55.35
T_{22}	57.91
T_{23}	58.00
T_{24}	67.32
T_{25}	75.15
T_{26}	56.19
$F_{25, 50}$	305.09**
SE	0.654
CD (0.05 %)	1.31

** Significant at 1 per cent level

4.2.2 Number of harvests

There was no significant difference among various treatments with regard to total number of harvests. All the treatments registered more or less same number of harvests (four harvests) eventhough significant variation in yield at all the harvests were noticed.

4.2.3 Total marketable green yield

The fresh plant parts which have not bolted and which were free from disease and pest infection was recorded as marketable green yield.

The same trend in total yield was noticed in the case of marketable yield also. The highest level of vermicompost recorded the highest marketable yield also (75.15 t ha^{-1}). It was on par with T_{10} which yielded 74.12 t ha^{-1}. Treatments T_8 to T_{10}, T_{18} to T_{20}, T_{22} to T_{25}, T_{14} and T_{15} were significantly superior to POP with regard to marketable green yield. All the coir pith compost treatments were inferior to POP along with T_6, T_{11}, T_{12} and T_{16}. Rest of the treatments were on par with POP which recorded 56.19 t ha^{-1}.

The high marketable yield recorded by vermicompost treatments may be due to the reason that it is less prone to the incidence of leaf blight disease.

4.2.4 Total dry matter production

Total dry matter production recorded at various stages are presented in table7. At 15 DAP only a single treatment T_{10} (11.41 g $plant^{-1}$) was found superior to POP (10.52 g $plant^{-1}$). It was on par with T_6, T_7, T_{19} and T_{22}. Treatments T_1, T_3, T_5, T_{11}, T_{12} and T_{21} were significantly inferior to POP.

Rest of the treatments were on par with POP at 15 DAP. Lowest dry matter production was recorded by T_1 (9.5 g plant^{-1}).

Both at 30 DAP and 45 DAP all treatments involving coirpith compost (T_1 to T_5) performed significantly inferior to POP. Other inferior treatments at 30 DAP were T_{11}, T_{15} and T_{16}. T_7, T_9, T_{10} and T_{20} which recorded 25.02, 25.22, 25.70 and 25.25 g plant^{-1} respectively were superior to POP (23.87 g plant^{-1}). At 45 DAP, in addition to coir pith compost treatments only T_{11} performed poorly compared to POP. T_9 and T_{10} performed significantly superior to POP at 30 and 45 DAP. T_9 (24.91 g plant^{-1}), T_{10} (28.27 g plant^{-1}) and T_{22} (24.75 g plant^{-1}) performed superiorily than POP (21.8 g plant^{-1}) at 45 DAP. Generally higher dry matter production was observed with increasing manure levels.

The increase in plant height and LAI due to better assimilation of nutrients at higher levels of organic manure might have helped to increase the DMP. Similar findings were earlier reported by Pandey *et al.* (1980), Singh *et al.* (1986) and Pandey *et al.* (1992). According to Black (1973) an adequate supply of nitrogen is associated with vigorous vegetative growth in plants. Mc Collum and Miller (1971) recorded maximum DMP obtained with the application of 91 kg N ha^{-1} in pickling cucumbers. Similar trend was noticed in pumpkin wherein increasing levels of nitrogen application significantly increased the total dry matter at 60 days after sowing and at harvest (Rajendran, 1981). Farm yard manure application as an organic amendment increasing the dry matter production of bhindi crop was reported

Table 7 Total dry matter production (g plant^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	9.50	22.29	18.98
T_2	9.72	22.43	19.79
T_3	9.42	22.54	19.03
T_4	10.34	22.19	19.00
T_5	9.61	22.23	19.65
T_6	11.01	24.35	21.80
T_7	11.06	25.02	21.67
T_8	10.77	23.75	22.73
T_9	10.96	25.22	24.91
T_{10}	11.41	25.70	28.27
T_{11}	8.75	22.61	19.09
T_{12}	9.35	23.32	21.63
T_{13}	10.50	23.45	20.10
T_{14}	10.83	23.42	20.94
T_{15}	10.64	22.93	21.95
T_{16}	10.84	22.75	20.47
T_{17}	10.85	23.23	20.75
T_{18}	10.56	23.78	20.02
T_{19}	11.04	23.71	21.18
T_{20}	10.17	25.15	21.52
T_{21}	9.24	23.16	22.23
T_{22}	11.00	24.00	24.75
T_{23}	10.88	23.63	21.95
T_{24}	10.81	22.83	21.12
T_{25}	10.95	23.09	21.03
T_{26}	10.92	23.87	21.80
$F_{25, 50}$	5.92**	9.29**	9.72**
SE	0.413	0.449	0.96
CD (0.05 %)	0.83	0.90	1.93

** Significant at 1 per cent level

by Senthil Kumar and Sekar (1998). The poor DMP of coir pith compost treated plants may be due to the poor availability and uptake of nutrients in them. The nitrogen uptake with the highest level of coir pith compost was only 166.93 kg ha^{-1} whereas with the higher levels of FYM, poultry manure and vermicompost it is more than 225 kg ha^{-1} as shown in table 13. P and K uptake of coir pith compost treatments were also much lower compared to other organic manures.

4.3 Physiological parameters

4.3.1 Biomass

The biomass (g $plant^{-1}$) recorded at various stages are presented in table 8. During first harvest T_{10} recorded the maximum biomass of 158.45 g $plant^{-1}$ and it was significantly superior to all other treatments. The second best treatment was T_{25} with a biomass of 135.89 g $plant^{-1}$ and it was on par with T_{20} (129.47 g $plant^{-1}$). In the first cut 125 per cent and 150 per cent levels of FYM, neemcake, poultrymanure and vermicompost performed superior than POP treatment. T_6, T_{13} and T_{18} were also superior. Treatments T_1 to T_4, T_{11} and T_{21} were inferior compared to POP. All the remaining treatments were on par with POP. As in the case of growth characters and yield coir pith compost treatments performed poorly here also.

During second cut treatments T_8 to T_{10}, T_{14}, T_{15}, T_{20}, T_{22} to T_{25} were superior to POP treatment. FYM and vermicompost were found to respond well with the growth of the plant and produced higher biomass. The general trend observed was that with increasing levels of organic manures the biomass

Table 8 Biomass (g plant[-1]) of amaranthus as influenced by different sources and levels of organic manures

Treatments	1 CUT	2 CUT	3 CUT	4 CUT
T_1	86.40	65.36	75.04	33.87
T_2	95.68	72.37	79.63	37.88
T_3	98.04	78.12	93.16	51.51
T_4	98.55	84.18	87.15	53.35
T_5	101.83	82.28	102.34	59.81
T_6	114.28	77.81	114.97	49.49
T_7	101.70	88.98	115.20	52.71
T_8	110.30	96.66	119.50	64.76
T_9	127.21	101.03	128.08	69.42
T_{10}	158.45	112.08	145.11	76.70
T_{11}	91.05	71.79	105.04	47.83
T_{12}	104.33	74.13	106.49	51.19
T_{13}	114.72	87.88	119.21	49.48
T_{14}	119.96	100.93	116.70	68.58
T_{15}	117.17	95.56	126.26	75.00
T_{16}	103.03	78.81	109.34	58.72
T_{17}	101.50	81.93	102.99	58.90
T_{18}	111.50	71.52	104.48	62.59
T_{19}	115.70	93.77	108.56	66.79
T_{20}	129.47	101.40	121.00	69.25
T_{21}	95.54	87.19	99.22	49.99
T_{22}	109.36	96.79	111.94	50.55
T_{23}	108.58	97.50	102.93	58.41
T_{24}	121.00	108.09	119.41	67.64
T_{25}	135.89	119.33	127.83	77.94
T_{26}	107.31	88.11	97.85	51.60
$F_{25, 50}$	45.56**	44.84**	40.69**	62.49**
SE	3.23	2.88	3.45	2.02
CD (0.05 %)	6.48	5.79	6.93	4.05

** Significant at 1 per cent level

production also increased. During second cut the treatment with 150 per cent level of POP in vermicompost recorded highest biomass of 119.33 g plant^{-1} and no other treatment was on par with it.

In the third harvest also the general trend remained the same. Here treatments T_6 to T_{16}, T_{18}, T_{19}, T_{22}, T_{24} and T_{25} were significantly superior to POP (97.85 g plant^{-1}). Only three treatments T_1 (75.04 g plant^{-1}), T_2(79.63 g plant^{-1}) and T_4 (87.15 g plant^{-1}) were found inferior to POP. All the other treatments were on par with POP. All the FYM and neemcake treatments performed superior to POP at this stage. Unlike in second cut the maximum biomass was produced by T_{10} (145.11 g plant^{-1}) and no other treatment was on par with it.

During fourth cut also T_1 (33.87 g plant^{-1}) and T_2 (37.88 g plant^{-1}) remained inferior to POP (51.60 g plant^{-1}). These two were the only treatments inferior to POP at fourth harvest. In the fourth harvest T_{25} recorded the highest biomass of 77.94 g plant^{-1}. It was on par with T_{10} (76.70 g plant^{-1}) and T_{15} (75 g plant^{-1}). T_5 (coirpith compost at 150 per cent of POP) was found superior to POP at this stage. Other superior treatments include T_8 to T_{10}, T_{14} to T_{20} and T_{23} to T_{25}. T_{25} recorded maximum biomass during second and fourth harvests.

More availability and uptake of nutrients at higher levels of organic manures might have resulted in consistent higher biomass production at higher levels. High manurial levels always recorded higher weight of fresh plant and variation was significant within same treatments which received different levels. Higher fertilizer levels have reported better plant height, number of leaves, (Table 1 and 2) which have contributed to higher biomass. This is evident in yield too.

Vermicompost treatments recorded maximum biomass at three stages. This confirms the findings of Kale and Bano (1988). Bhawalkar *et al.* (1993) reported better soil biology and better nutrition due to vermicompost. The poor biomass production by coirpith compost treatments may be due to poor availability of nutrients due to high C : N ratio, low biodegradability and the presence of some tannin related phenolic compounds.

Biomass production in poultrymanure applied treatments were superior at 4^{th} cut. This is in confirmity with the findings of other workers. In a field investigation, application of 169.6 q ha^{-1} poultry manure which supplied 500 kg N ha^{-1} on equivalent nitrogen basis produced the highest marketable yield, maximum size of curd and weight of curd compared to lower rates of poultry manure application in cauliflower (Singh *et al.*, 1970). Later in 1980, Shukla and Gupta observed that increasing levels of nitrogen fertilization increased the fruit size, fruit number and fruit yield per unit area in squash. Ravikrishnan (1989) reported that bitter gourd responded linearly to increasing levels of nitrogen from 0 to 50, 70 and 90 kg N ha^{-1} in terms of fruit yield. Senthilkumar and Sekar (1998) reported that fruit yield $plant^{-1}$ in bhindi was increased markedly by FYM application.

4.3.2 Stem dry weight

Data on stem dry weight at different growth stages of various treatments are presented in the table 9. At 15 DAP no treatment was significantly

Table 9 Stem dry weight (g plant^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	4.56	11.13	9.43
T_2	5.16	11.17	9.42
T_3	4.04	11.28	9.58
T_4	5.16	11.04	9.46
T_5	4.55	11.07	9.82
T_6	5.38	12.28	10.64
T_7	5.26	12.20	10.96
T_8	5.26	11.69	11.27
T_9	5.40	12.55	12.84
T_{10}	5.63	12.67	14.56
T_{11}	4.14	11.10	9.53
T_{12}	4.33	11.35	10.46
T_{13}	5.19	11.82	10.49
T_{14}	5.28	11.53	10.63
T_{15}	5.32	11.63	11.45
T_{16}	5.44	11.33	10.46
T_{17}	5.39	11.50	10.63
T_{18}	5.34	11.71	10.20
T_{19}	5.37	11.62	10.77
T_{20}	5.28	12.76	10.88
T_{21}	4.67	11.54	11.43
T_{22}	5.32	11.77	13.17
T_{23}	5.34	11.66	10.78
T_{24}	5.24	11.26	10.74
T_{25}	5.32	11.33	10.75
T_{26}	5.10	11.91	10.76
$F_{25, 50}$	4.36**	8.70**	7.52**
SE	0.289	0.240	0.612
CD (0.05 %)	0.58	0.47	1.23

** Significant at 1 per cent level

superior to POP (5.1 g $plant^{-1}$). T_3, T_{11} and T_{12} were significantly inferior to POP at this stage. All the remaining treatments were on par with POP. At 30 DAP coir pith compost was inferior to POP. T_{11}, T_{12}, T_{16}, T_{24} and T_{25} also recorded values which are inferior to POP treatments. Three treatments T_9 (12.55 g $plant^{-1}$), T_{10} (12.67 g $plant^{-1}$) and T_{20} (12.76 g $plant^{-1}$) were significantly superior to POP (11.91 g $plant^{-1}$) at 30 DAP. The rest of the treatments were on par. At 45 DAP only T_9, T_{10} and T_{22} which recorded 12.84, 14.56 and 13.17 g $plant^{-1}$ respectively were found superior to POP (10.76 g $plant^{-1}$). Coir pith compost treatments registered poor dry weights. T_1, T_2 and T_4 were inferior whereas all others are on par with POP at 45 DAP. T_9 and T_{10} gave consistently higher dry weight at all the three stages. At 15 DAP maximum dry weight was recorded by T_{10} which was on par with T_9, T_{16} and T_{17}. Variation was much less with regard to stem dry weight at all the three stages.

4.3.3 Leaf dry weight

As in the case of stem dry weight at 15 DAP no treatment was found significantly superior to POP (5.42 g $plant^{-1}$). T_2, T_{11}, T_{20} and T_{21} were found inferior to POP whereas rest of the treatments were on par with it at 15 DAP. At 30 DAP, T_7 (12.83 g $plant^{-1}$), T_9 (12.67 g $plant^{-1}$) and T_{10} (13.04 g $plant^{-1}$) performed significantly superior to POP (11.96 g $plant^{-1}$). All the coirpith compost treatments were significantly inferior to POP at 30 DAP and 45 DAP. T_{11} and T_{15} were inferior to POP at 30 DAP. At 45 DAP T_9 (12.07 g $plant^{-1}$) and T_{10} (13.72 g $plant^{-1}$) continued their superior trend. T_{11}, T_{13}, T_{16} and T_{18}

Table 10 Leaf dry weight (g plant^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	15 DAP	30 DAP	45 DAP
T_1	4.94	11.16	9.56
T_2	4.56	11.25	9.37
T_3	5.38	11.27	9.46
T_4	5.18	11.15	9.55
T_5	5.07	11.16	9.82
T_6	5.64	12.07	11.16
T_7	5.80	12.83	10.71
T_8	5.52	12.05	11.46
T_9	5.57	12.67	12.07
T_{10}	5.78	13.04	13.72
T_{11}	4.61	11.51	9.57
T_{12}	5.02	11.97	11.16
T_{13}	5.31	11.63	9.61
T_{14}	5.55	11.89	10.31
T_{15}	5.32	11.30	10.50
T_{16}	5.40	11.42	10.01
T_{17}	5.46	11.73	10.12
T_{18}	5.41	12.07	9.82
T_{19}	5.67	12.08	10.41
T_{20}	4.90	12.39	10.64
T_{21}	4.57	11.62	10.79
T_{22}	5.68	12.23	11.58
T_{23}	5.54	11.97	11.17
T_{24}	5.57	11.57	10.38
T_{25}	5.63	11.76	10.28
T_{26}	5.42	11.96	11.04
$F_{25, 50}$	4.17**	5.91**	8.35**
SE	0.254	0.30	0.48
CD (0.05 %)	0.51	0.60	0.96

** Significant at 1 per cent level

performed inferiority at 45 DAP. All the remaining treatments were on par with POP. At 30 and 45 DAP maximum leaf dry weight was recorded for T_{10}. No other treatments were on par with them at these two stages.

The better performance of T_9 and T_{10} at 30 and 45 DAP may be due to the high leaf area. Higher manurial levels recorded better dry weights. Photosynthesis is the basic process for the build up of organic substances by the plants. The quantity of dry matter production therefore depends on the effectiveness of photosynthesis and further more on crops whose vital activities are functioning efficiently (Arnon, 1975). The LAI recorded in the present study also showed similar pattern. Greater leaf area allowed more photosynthesis and this might have resulted in increased dry weight.

4.3.4 NAR

From the data presented in table 11 it is clear that at 30 DAP, treatments T_9, T_{10}, T_{19}, T_{20} and T_{25} were significantly superior to POP. All other treatments were on par with POP. Maximum NAR of 0.0335 mg cm^{-2} day^{-1} was recorded by the highest level of FYM (T_{10}). No other treatment was on par with it. The next best treatment was T_{25} which recorded 0.0253 mg cm^{-2} day^{-1}. It was on par with T_{19} and T_9.

At 45 DAP T_9, T_{10}, T_{20} and T_{25} maintained the same trend and were significantly superior to POP. Maximum NAR was recorded by T_{10} as in 30 DAP. No other treatment was on par with it. The second best treatment T_{25} was on par wtih T_{20}, T_9, T_{24} and T_{19}. All treatments except T_9, T_{10}, T_{20} and T_{25} were on par with POP.

Table 11 NAR (mg cm^{-2} day^{-1}) of amaranthus as influenced by sources and levels of organic manures

Treatments	30 DAP	45 DAP
T_1	0.0027	0.00001
T_2	0.0046	-0.00008
T_3	0.0026	-0.00005
T_4	0.0047	0.00015
T_5	0.0061	0.00024
T_6	0.0058	0.00007
T_7	0.0084	0.00054
T_8	0.0070	0.00048
T_9	0.0179	0.00126
T_{10}	0.0335	0.00276
T_{11}	0.0081	0.00018
T_{12}	0.0090	0.00021
T_{13}	0.0114	0.00026
T_{14}	0.0043	0.00034
T_{15}	0.0136	0.00042
T_{16}	0.0050	0.00016
T_{17}	0.0051	0.00018
T_{18}	0.0102	0.00028
T_{19}	0.0152	0.00075
T_{20}	0.0249	0.00133
T_{21}	0.0028	0.00028
T_{22}	0.0042	0.00029
T_{23}	0.0110	0.00046
T_{24}	0.0131	0.00099
T_{25}	0.0253	0.00143
T_{26}	0.0065	0.00016
$F_{25, 50}$	8.22**	2.65**
SE	0.0038	0.0005
CD (0.05 %)	0.0076	0.00104

** Significant at 1 per cent level

High NAR recorded by T_9, T_{10}, T_{20} and T_{25} at both the stages may be due to the increased dry weight produced by these treatments and also it indicated the benefiical effect of these manures on incresing the leaf growth. In an experiment in pumpkin higher DMP was noticed with incresing levels of nitrogen application at 60 days after sowing and at harvest by Rajendran (1981). A significant increase in total DMP of Snake gourd was reported by Haris (1989) with higher doses of nitrogen (50, 70 or 90 kg N ha^{-1}) applied.

4.4 Leaf quality

4.4.1 Moisture content

Moisture content (in percentage) in the leaves is given in table 12. With regard to moisture content the organic manure treated plants remained more or less the same. Not a single treatment was found superior to POP with respect to moisture content. In a number of treatments, including all coir pith compost treatments moisture content was significantly less than that in POP (83.4 per cent). The maximum moisture content is recorded by T_{10} (83.94 per cent). Higher levels of poultry manure recorded higher moisture levels. Similar result was obtained by Singh *et al.* (1970) who estimated a slight increase in moisture content of curd in cauliflower with increasing levels of poultry manure and highest moisture content was recorded for highest level of poultry manure. The highest moisture content was recorded here for highest dose of FYM which was on par with T_{15} (83.7 per cent).

4.4.2 Ascorbic acid

Vitamin C content in the leafy vegetable is an important quality parameter. It is presented in table 12. Organic manure treatments in general performed significantly superior to POP which recorded an ascorbic acid content of 60.93 mg $100g^{-1}$. It is interesting to note that all the vermicompost treatments (T_{21} to T_{25}) were significantly superior to POP in ascorbic acid content. Other superior treatments include T_1, T_2, T_5, T_9, T_{10}, T_{14}, T_{15}, T_{17}, T_{19} and T_{20}. The highest vitamin C content of 65.57 mg $100g^{-1}$ was registered by the highest dose of vermicompost. Only one treatment T_{11} (59.33 mg $100g^{-1}$) was found inferior to POP. All the other treatments were on par with POP.

It is clear from the table that with increasing levels of organic manures the ascorbic acid content also increased. Ascorbic acid content is promoted by nitrogen nutrition in spinach, kohlrabi, cauliflower and radish (Fritz and Habben, 1972). Pandita and Bhatnagar (1981) observed high ascorbic acid content in tomato fruits from plants receiving high rate of nitrogen (120 kg ha^{-1}). In a trial on cucumber, Maurya (1987) noticed an increase in the vitamin C content of fruits with increasing levels of application of nitrogen up to 80 kg ha^{-1}. Similar results were also reported by Dod *et al.* (1992) in chilli, Singh and Singh (1992) in tomato.

High vitamin C content was recorded by all the vermicompost treatments. The significant quantities of available nutrients, biologically active metabolites, particularly gibberellins, cytokinins, auxins and group B vitamins might have contributed to better yield and quality due to vermicompost treatments. Similar results of increased quality of vermicompost treatments

Table 12 Leaf quality of amaranthus as influenced by sources and levels of organic manures

Treatments	Moisture (per cent)	Vitamin C. (mg $100g^{-1}$)	Fibre on dry weight basis (per cent)	Protein on dry weight basis (per cent)
T_1	80.52	63.23	12.47	12.77
T_2	81.17	64.40	12.41	11.42
T_3	81.57	61.67	12.77	13.50
T_4	80.99	61.97	12.53	14.23
T_5	81.57	62.90	12.32	14.30
T_6	82.37	61.97	12.49	12.83
T_7	82.63	60.50	12.47	14.84
T_8	81.05	62.03	14.08	16.86
T_9	82.05	63.67	13.22	18.78
T_{10}	83.94	64.93	14.27	20.58
T_{11}	82.40	59.33	13.27	12.47
T_{12}	82.67	60.73	14.47	13.44
T_{13}	80.90	61.57	14.50	15.32
T_{14}	83.18	62.43	12.50	16.37
T_{15}	83.70	63.67	12.81	17.66
T_{16}	82.80	61.33	13.90	13.76
T_{17}	82.23	63.13	13.23	15.09
T_{18}	81.73	61.97	12.60	16.82
T_{19}	82.67	64.13	12.73	20.41
T_{20}	83.05	63.80	12.82	21.69
T_{21}	81.85	62.53	11.97	14.45
T_{22}	80.60	62.90	12.28	16.03
T_{23}	82.07	64.07	12.57	16.69
T_{24}	82.50	64.97	12.33	18.60
T_{25}	83.37	65.57	11.93	21.50
T_{26}	83.40	60.93	12.05	17.43
$F_{25, 50}$	5.50**	9.55**	21.22**	23.87**
SE	0.579	0.692	0.234	0.833
CD (0.05 %)	1.16	1.39	0.47	1.67

** Significant at 1 per cent level

were also reported by Gavrilov (1962), Tomati *et al.* (1983) and Bano *et al.* (1987).

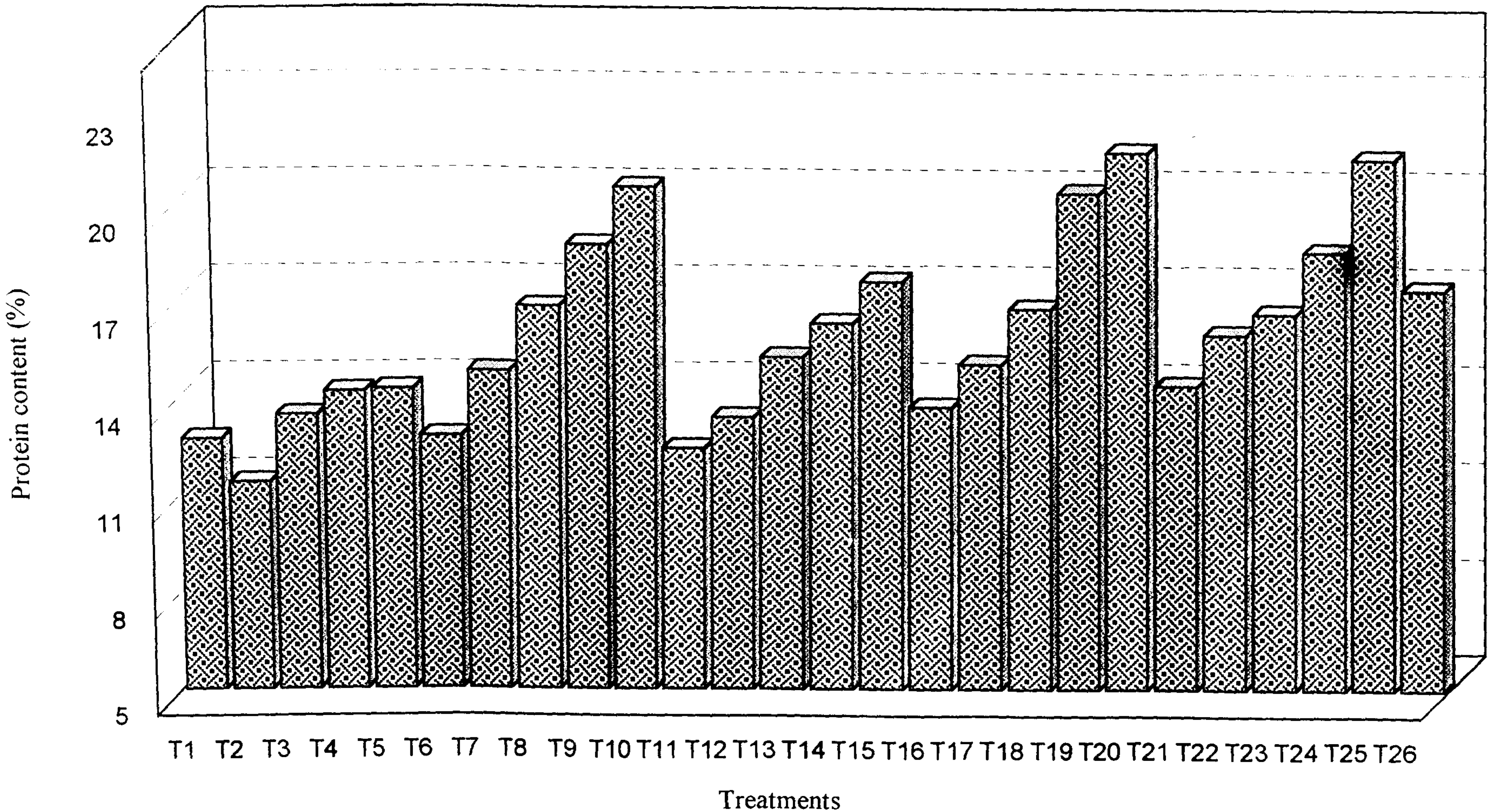
4.4.3 Fibre content

Treatments T_3, T_4, T_8 to T_{13}, T_{15} to T20 and T_{23} were significantly superior to POP with regard to fibre content. Rest of the treatments were on par with POP which recorded a fibre content of 12.05 per cent. Maximum fibre content was recorded by T_{13} (14.5 per cent) which was on par with T_{12} (14.47 per cent). The lowest fibre content was recorded by the highest level of vermicompost, T_{25} (11.93 per cent). It is interesting to note that all poultry manure treatments recorded superior fibre content. In general vermicompost treatments recorded lower fibre content. Presence of growth hormones and enzymes in vermicompost might have decreased the crude fibre content. Higher levels of neemcake and poultry manure recorded lower crude fibre content compared to 50 per cent and 75 per cent levels. This might be due to the reason that increased nitrogen uptake might have resulted in increasing the succulence and thereby decreasing the crude fibre content.

4.4.4 Protein content

From the table it is clear that four treatments performed significantly superior to POP. T_{10}, T_{19}, T_{20} and T_{25} recorded 20.58, 20.41, 21.69 and 21.50 per cent respectively and were superior to POP (17.43 per cent). This include highest dose of FYM, poultry manure and vermicompost. The highest dose of neem cake was on par with POP. Treatments T_1 to T_7, T_{11} to T_{13}, T_{16}, T_{17} and

Fig. 7 Effect of sources and levels of organic manures on protein content in amaranthus



T_{21} were significantly inferior to POP. Rest of the treatments were on par with POP. The highest protein content was recorded for the highest dose of poultry manure.

A general trend was noticed from the table that protein content in amaranthus increased with increasing levels of organic manures irrespective of the type of organic manure. With increasing levels of manures more and more nitrogen is available to the plants. Nitrogen thus obtained is metabolised via ammonium ions into glutamic acid. Carbon skeletons (carbohydrates) provided by photosynthesis are incorporated in this process of aminoacid synthesis. Glutamic acid is further converted to other aminoacids which are stored as proteins (Tisdale *et al.*, 1995). Therefore higher levels of N nutrition would have favourably influenced the crude protein content of leaves on account of increased assimilation. N application promoting the crude protein content was previously reported by Fritz and Habben (1972) in spinach, Maurya (1987) in cucumber and Haris (1989) in snake gourd. Application of higher levels of organic sources as FYM in improving the N content in economic plant parts was earlier reported by Singh *et al.* (1996).

4.5 Soil Analysis

Final NPK status of soil

Soil samples analysed after the experiment to assess the available nutrient status of soil with different sources and levels of organic manures are presented in the table 13.

Table 13 Soil NPK (kg ha^{-1}) as influenced by sources and levels of organic manures

Treatments	N	P	K
T_1	301.52	143.55	90.66
T_2	292.55	163.69	89.67
T_3	313.55	202.21	91.19
T_4	289.85	119.75	91.85
T_5	304.38	194.83	97.16
T_6	268.24	162.11	101.75
T_7	249.65	183.38	77.09
T_8	238.33	220.27	76.78
T_9	311.35	198.47	90.16
T_{10}	317.31	168.91	102.26
T_{11}	222.93	127.48	90.73
T_{12}	222.84	76.91	90.71
T_{13}	293.47	112.84	90.68
T_{14}	280.45	138.67	90.66
T_{15}	265.77	142.54	90.63
T_{16}	272.34	192.37	90.61
T_{17}	211.60	127.10	90.59
T_{18}	301.28	165.59	90.56
T_{19}	341.99	150.41	90.54
T_{20}	213.71	218.93	90.52
T_{21}	353.47	156.43	90.49
T_{22}	333.42	184.15	90.47
T_{23}	259.06	178.97	90.45
T_{24}	290.00	157.15	90.42
T_{25}	373.82	186.88	90.40
T_{26}	235.43	210.43	90.38
$F_{25, 50}$	14.93**	1.77*	0.94^{NS}
SE	15.92	37.45	7.61
CD (0.05 %)	31.98	75.24	-

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

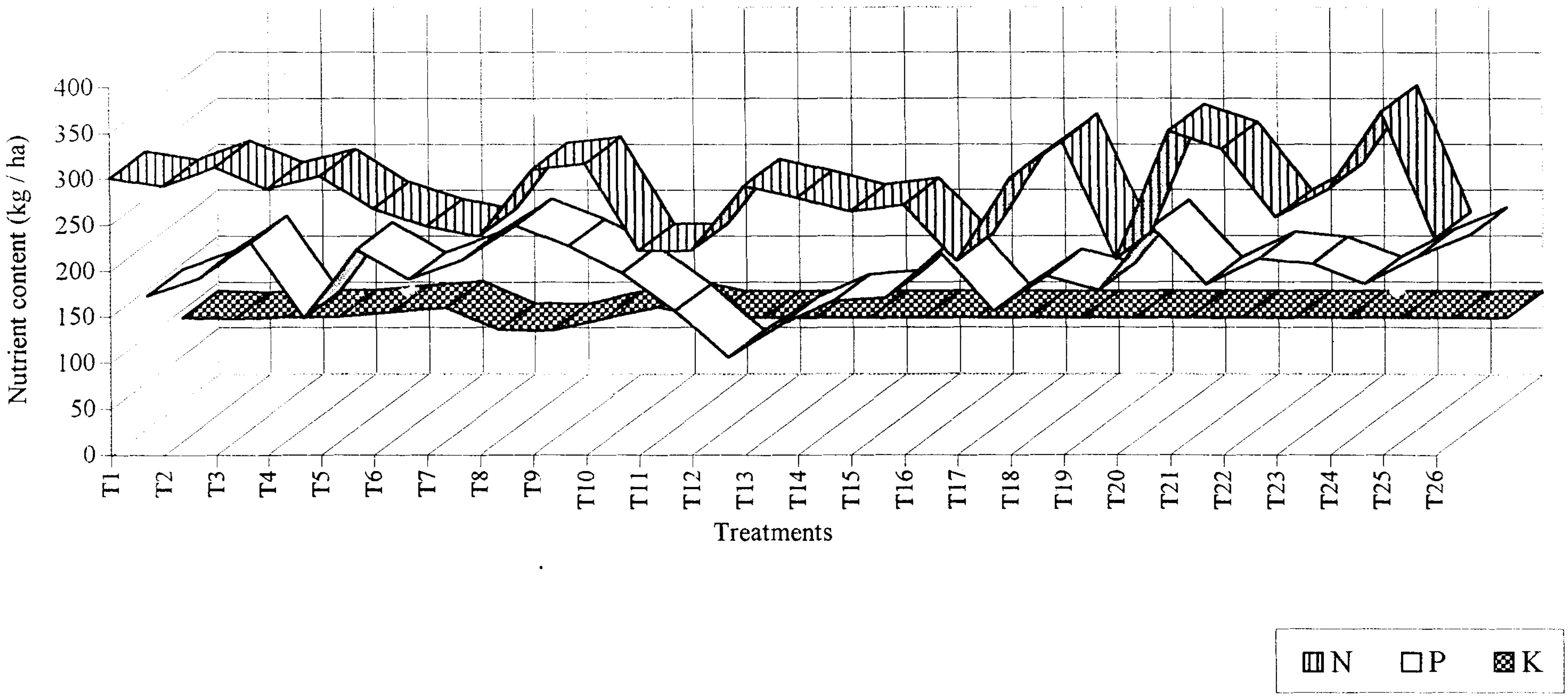
With respect to nitrogen content, no treatment was inferior to POP which recorded a value of 235.43 kg ha^{-1}. High soil N was found in treatments T_1 to T_6, T_9, T_{10}, T_{13}, T_{14}, T_{16}, T_{18}, T_{19}, T_{21}, T_{22}, T_{24} and T_{25}. i.e., all the coir pith compost treatments and 125 and 150 per cent levels of FYM, poultry manure and vermicompost recorded high soil N status. Barring the above treatments, others were on par with POP. Highest soil N was recorded by highest dose of vermicompost (373.82 kg ha^{-1}). It was on par with T_{21} (353.47 kg ha^{-1} and T_{19} (341.99 kg ha^{-1}).

The high soil nitrogen content recorded in most of the organic manure treatments might be because of better retention of nutrients in soil due to slow mineralisation and reduced leaching losses of nutrients in the case of organic manures as compared to fertilizers. Application of higher levels of N increased the actual N balance or available N content of soil was reported by Haris (1989) and Ravikrishnan (1989).

In the case of final P status of soil T_4, T_{11}, T_{12}, T_{13} and T_{17} were found significantly inferior to POP (210.43 kg ha^{-1}). The rest of the treatments were on par with POP. No treatment was significantly superior to POP. The highest value of soil P was recorded by T_8 (220.27 kg ha-1) but it was on par with a number of treatments.

In the case of soil K, no significant variation was noted among different sources and levels of organic manures. Highest soil K was recorded for T_{10} (102.26 kg ha^{-1}).

Fig. 8 Effect of sources and levels of organic manures on residual soil nutrient status

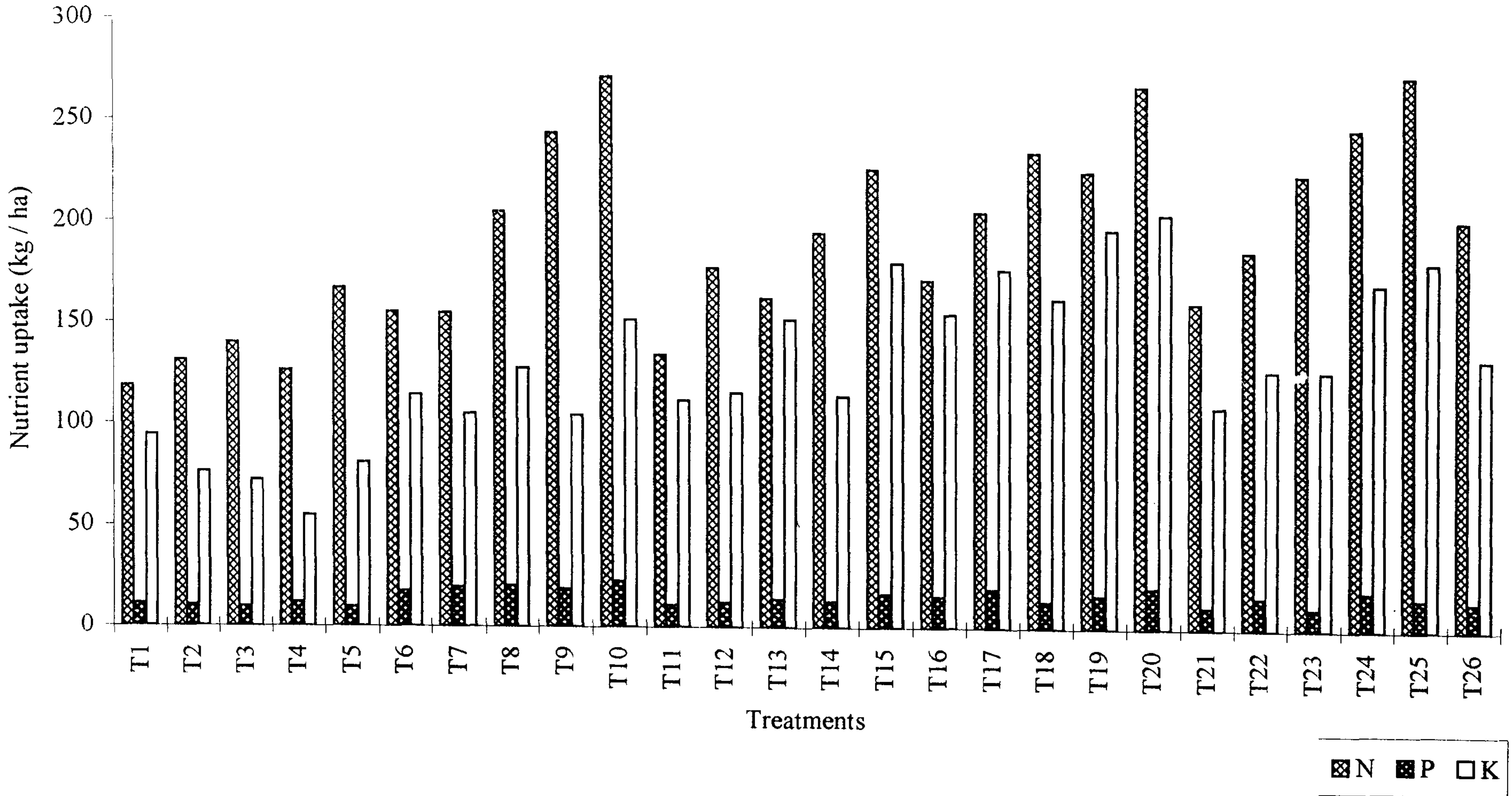


4.6 Uptake of nutrients

Examination of data on plant nutrient uptake revealed that treatments T_9, T_{10}, T_{15} and 100 per cent, 125 per cent and 150 per cent of POP levels of poultry manure and vermicompost treatments registered significantly superior uptake compared to control treatment POP. Treatments T_1 to T_7, T_{11} to T_{13}, T_{16} and T_{21} were inferior in N uptake compared to POP. Rest of the treatments were on par with POP (202.22 kg ha^{-1}). The highest N uptake was recorded by T_{25} (273.76 kg ha^{-1}) and it was on par with T_{10} (271.88 kg ha^{-1}) and T_{20} (268.18 kg ha^{-1}) which were the highest doses of FYM and poultry manure respectively. Application of organic manures at higher doses improved the uptake of nitrogen. The uptake of nitrogen in all the coirpith compost treatments were poor. This also supports the poor yield obtained from coir pith compost treatments.

The N uptake was found to have increased in proportion to the quantities of applied N except in the case of coir pith compost. Application of higher levels of N in enhancing the N uptake was previously reported by Hegde (1987) in water melon, Haris (1989) in snake gourd and Ravikrishnan (1989) in bittergourd. According to Tisdale *et al.* (1995), one of the beneficial effects of organic manure is its warming effect o1 soil. The enhanced root zone temperature resulting from this warming effect might have enhanced the N uptake when organic manures like FYM was applied in higher proportion. In this context, Mooby and Graves (1980) and Nkansah and Ito (1995) reported higher uptake of N due to the warming up of root zone area. Higher quantity of FYM application promoting the N uptake was reported earlier by Subbiah *et al.*

Fig. 9 Effect of sources and levels of organic manures on plant nutrient uptake in amaranthus



(1983) in brinjal. Favourable influence of poultry manure application on N uptake was indicated by Heathman *et al.* (1995).

Tisdale *et al.* (1995) pointed out chances of immobilisation of N when organic manure with low N content was applied in higher proportion, since the microorganisms which need N in C : N ratio of about 8 : 1 utilise the inorganic N in soil for their activities which lower the available N content of soil. The same reason might be applicable with coir pith compost which has a higher C : N ratio.

In the case of uptake of P treatments T_6 to T_{10}, T_{17}, T_{20} and T_{24} were significantly superior to POP. So it is clear that all FYM treatments had substantial P uptake. Maximum uptake was for T_{10} (22.67 kg ha^{-1}). No treatments were on par with it. The second highest uptake was noted for T_8 (20.35 kg ha^{-1}) and it was on par with T_{20} (20.26 kg ha^{-1}) and T_7 (19.56 kg ha^{-1}). T_1 to T_3, T_5, T_{11}, T_{21} and T_{23} recorded values which are inferior to POP (14.19 kg ha^{-1}). All the remaining treatments were on par with POP.

When organic source of nitrogen was applied in higher proportion, especially using FYM, it would have improved the P uptake through increased P availability in soil. According to Tisdale *et al.* (1995), organic matter increased the P availability and uptake through formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of $H_2PO^-_4$ on adsorption sites and reducing P adsorption by coating with a protective cover on Fe and Al particles by humus. Application of higher quantities of FYM promoting the P uptake was observed earlier by Subbiah *et al.* (1983) and Bagavathiammal and Muthiah (1995). The favourable effect

Table 14 Plant nutrient uptake (kg ha^{-1}) and B : C ratio of amaranthus as influenced by sources and levels of organic manures

Treatments	N	P	K	BC ratio
T_1	118.50	11.09	94.20	0.78
T_2	131.17	10.52	75.85	0.86
T_3	139.71	9.60	72.08	0.91
T_4	126.16	11.78	54.51	0.98
T_5	166.93	9.57	80.67	1.14
T_6	155.28	17.30	114.20	1.36
T_7	154.67	19.56	105.03	1.45
T_8	204.93	20.35	127.59	1.63
T_9	243.89	18.76	104.26	1.76
T_{10}	271.88	22.67	151.47	1.89
T_{11}	134.59	11.05	111.70	1.20
T_{12}	177.29	12.29	115.65	1.28
T_{13}	162.36	13.88	151.75	1.35
T_{14}	194.73	12.79	113.95	1.41
T_{15}	226.51	16.54	179.98	1.52
T_{16}	171.58	15.60	154.83	1.50
T_{17}	205.04	19.15	176.80	1.44
T_{18}	234.85	13.26	162.44	1.63
T_{19}	225.34	16.24	196.82	1.74
T_{20}	268.18	20.26	204.40	1.88
T_{21}	160.74	11.08	109.39	1.40
T_{22}	186.16	15.78	127.52	1.57
T_{23}	224.25	10.38	127.14	1.56
T_{24}	247.51	19.01	170.61	1.80
T_{25}	273.76	15.74	181.29	1.93
T_{26}	202.22	14.19	133.64	1.33
$F_{25, 50}$	84.87**	19.87**	57.16**	424.92**
SE	7.24	1.22	7.49	0.022
CD (0.05 %)	14.55	2.44	15.04	0.04

** Significant at 1 per cent level

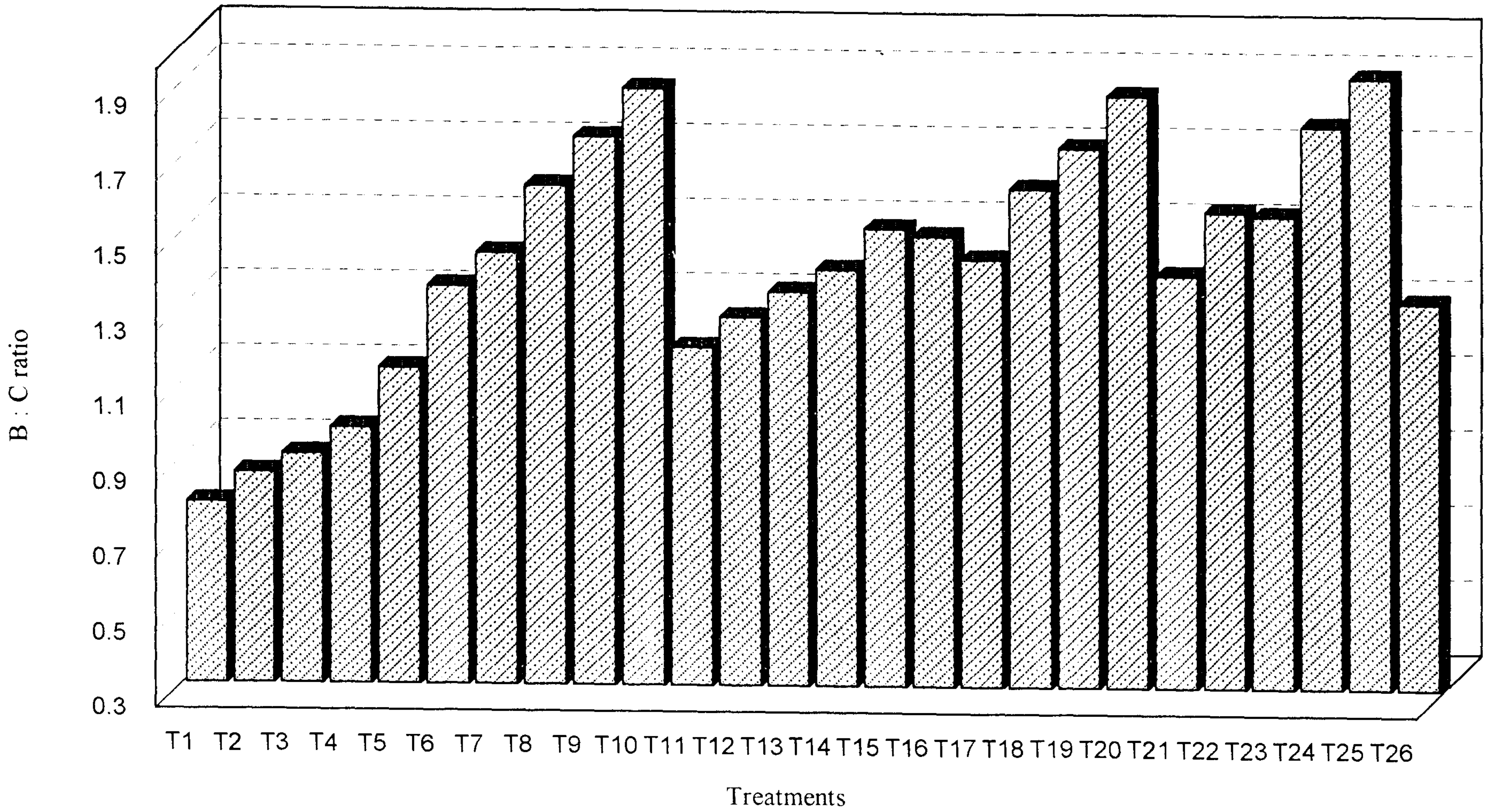
of poultry manure application on P uptake was reported by Warneke and Siregar (1994).

K uptake was significantly superior in treatments T_{10}, T_{13}, T_{15} to T_{20}, T_{24} and T_{25}. Interestingly all levels of poultry manure registered significantly substantial K uptake compared to POP (133.64 kg ha^{-1}). Though highest level of poultry manure recorded the highest K uptake (204.4 kg ha^{-1}) it was on par with T_{19} (196.82 kg ha^{-1}). All the coir pith compost treatments (T_1 to T_5) registered inferior K uptake on comparison with control. Other inferior treatments include T_6, T_7, T_9, T_{11}, T_{12}, T_{14} and T_{21}. Remaining treatments are on par with POP. Higher doses of FYM also recorded substantial K uptake.

Increase in levels of N significantly increased total K content of plant. As pointed out by Tisdale *et al.* (1995), uptake of K largely depends on the supply of other nutrients and therefore when nutrient nitrogen was supplied in higher levels, the requirement of K also would have increased which in turn resulted in increased K uptake and K accumulation in plants. Higher levels of nitrogen nutrition favouring the plant K content was previously reported by Singh *et al.* (1970) and Haris (1989).

Poultry manure treatments registered increased K uptake. Application of higher levels of poultry manure might have enhanced the root zone temperature which would have favourably influenced the K uptake by plant. Role of organic manures in increasing the soil temperature which inturn enhances the K uptake was suggested by Tisdale *et al.* (1995). Nkansah and Ito (1995) observed increased K uptake due to higher root zone temperature. Favourable influence of poultry manure on K uptake was earlier reported by Abusaleha (1992).

Fig. 10 Effect of different sources and levels of organic manures on B : C ratio of amaranthus



4.7 B C ratio

From the table 14 it is clear that coirpith compost treatments performed significantly inferior to POP (1.33) along with T_{11} (1.2) and T_{12} (1.28). T_6 and T_{13} are on par with POP with regard to BC ratio. All the remaining treatments were significantly superior to POP. Highest BC ratio was recorded by T_{25} (1.93) which received highest dose of vermicompost. It in fact gave the highest marketable yield of 75.15 t ha^{-1}. But it was on par with T_{10} (1.89), the highest level of FYM. BC ratio was less than one for all coir pith compost treatments except its highest level T_5 (1.14). But the highest level also was inferior to POP or control. It is clear from the table that poultry manure treatments performed very well along with FYM and vermicompost treatments.

SUMMARY

SUMMARY

The study entitled "Organic Nutrition in Amaranthus (*Amaranthus tricolor* L.)" has been carried out as a field experiment at Instructional Farm attached to the College of Agriculture, Vellayani, Thiruvananthapuram during 1998-99. The main objectives of the study were to find out the effect of different sources and levels of organic manures for sustaining the productivity of amaranthus and to assess the optimum quantity of these sources.

The trial was conducted in Randomised Block Design (RBD) with twenty six treatments and three replications. The control treatment was Package of Practices Recommendation of Kerala Agricultural University (50 t FYM ha^{-1} and 50 - 50 - 50 kg N, P_2O_5 and K_2O ha^{-1}). Remaining twenty five treatments were five sources of organic manures each tried at five different levels. The organic manures consisted of coirpith compost, FYM, neem cake, poultry manure and vermicompost. Five levels of these organic manures (50, 75, 100, 125 and 150 per cent of POP) were tried on nitrogen equivalent basis. The findings of this investigation are summerised below.

1. Effect of various nitrogen sources on growth, yield and quality of amaranthus was significant. At 15 DAP and 30 DAP maximum plant height of 18.61 cm and 40.44 cm respectively were recorded for the application of highest dose of vermicompost (@ 25 t ha^{-1}). Vermicompost, poultry manure and FYM treatments gave good performance through out different growth stages. At all stages coir pith compost was inferior to vermicompost,

poultry manure, neem cake and FYM with respect to plant height. Highest level of FYM and vermicompost maintained their superiority at all the growth stages. An increasing trend in height was noted with increasing levels of organic manures which were statistically significant in the case of FYM and vermicompost.

2. The number of leaves were maximum for plants treated with 150 per cent level (25 t ha^{-1}) of vermicompost at all the stages. FYM at 75 per cent level (46.88 t ha^{-1}) and 150 per cent level (93.75 t ha^{-1}), alongwith similar levels of vermicompost were superior to POP at 30 DAP and 45 DAP. At later stages of growth (45 DAP) the number of leaves in neem cake treated plots recorded substantial increase and neem cake @ 6 t ha^{-1} (150 per cent level) was superior to POP at this stage. Coir pith compost treatments performed poorly as in the case of other growth characters.
3. At all the stages of growth highest level of vermicompost (25 t ha^{-1}) recorded the highest number of branches. At later stages of growth (45 DAP), treatments with higher levels of organic manures gave more number of branches.
4. In the case of LAI, FYM treated plots gave good results at all the three stages of growth. T_{10} (FYM @ 93.75 t ha^{-1}) recorded maximum LAI of 2.064 and 3.567 at 15 and 45 DAP respectively. All coir pith compost treatments, lower levels of neem cake and poultry manure were inferior to POP at 30 DAP. FYM at 150 per cent (93.75 t ha^{-1}) was superior to POP at all the three stages.

5. High yield was noted for higher levels (100, 125 and 150 per cent of POP) of FYM, poultry manure, neem cake and vermicompost. First and third harvest recorded higher yield than second and fourth harvests. Fourth harvest recorded lowest yield in all treatments. Coir pith compost was the least effective treatment during all harvests. Yield was high from FYM and vermicompost treated plots compared to other organic manures. Higher levels of these two manures were always superior to POP. Generally with increase in nutrient level yield was found to increase. Maximum yield was recorded for vermicompost @ 25 t ha^{-1} during all harvests except the third where it was second to FYM @ 93.75 t ha^{-1}.
6. The same trend in the total yield continued in the case of marketable yield also. Three higher levels (100 per cent, 125 per cent and 150 per cent of POP) of FYM, poultry manure and vermicompost were significantly superior to POP. Highest marketable yield of 75.15 t ha^{-1} was recorded for vermicompost @ 25 t ha^{-1} (150 per cent of POP). The treatments supplying 125 and 150 per cent of neem cake were also superior to POP. All coir pith compost treatments were inferior to POP. Remaining treatments gave yields comparable to POP.
7. Higher dry matter production was observed with increasing manure levels. FYM at 150 per cent of POP (93.75 t ha^{-1}) recorded maximum dry matter at all the three growth stages. Lowest dry matter was always recorded by T_1, the lowest dose of coir pith compost. All coir pith compost treatments were inferior to POP at 30 and 45 DAP.

8. Not much variation was found among the treatments regarding NAR and dry matter partitioning. But biomass production was significantly influenced by different levels and sources of organic manures. Throughout the growth period 125 and 150 per cent levels of all manures except coir pith compost recorded superior biomass on comparison with POP. During first, second and fourth harvests maximum biomass was produced by highest level of vermicompost (25 t ha^{-1}) and during third harvest by FYM @ 93.75 t ha^{-1} (150 per cent of POP).
9. Various organic manures showed definite advantage in qualities except moisture content. All the vermicompost treatments recorded significantly high ascorbic acid content compared to POP. The ascorbic acid content increased with increasing level of organic manures. Highest level of vermicompost was found best for the production of maximum vitamin C (65.57 mg 100 g^{-1}).
10. The lowest fibre content was recorded by the highest level of vermicompost (@ 25 t ha^{-1}). In general vermicompost recorded low fibre content compared to other manures. Maximum fibre content was noted for neem cake @ 4.8 t ha (100 per cent level). Higher levels of neem cake and poultry manure recorded lower crude fibre content compared to 50 per cent and 75 per cent N levels.
11. The highest level (150 per cent) of FYM, vermicompost and poultry manure recorded significantly higher protein content on comparison with POP. Protein content increased with increasing levels of organic manures irrespective of the source of organic manure.

12. Regarding residual nutrients, high soil nitrogen was recorded for treatments which received high levels of organic manures. No treatment was found inferior to POP with respect to soil nitrogen content. Highest soil nitrogen of 373.82 kg ha^{-1} was recorded by the treatment which received vermicompost @ 25 t ha^{-1}. High soil NPK values were registered for high levels of organic manures. All the coir pith compost treatments recorded high soil nitrogen values indicating poor uptake of nitrogen. In the case of soil K, no significant variation was noted among different sources and levels of organic manures.
13. Uptake of nitrogen in all coir pith compost treatments were poor. The highest nitrogen uptake of 273.76 kg ha^{-1} was noted for vermicompost at 150 per cent level. Uptake of nitrogen increased with increasing level of organic manure. The 100, 125 and 150 per cent levels of FYM, poultry manure and vermicompost also recorded substantial nitrogen uptake. P uptake was high in all FYM treatments. Maximum P uptake was for maximum dose of FYM (93.75 t ha^{-1}). All levels of poultry manure registered significantly substantial K uptake compared to POP, along with higher doses of FYM. All the coir pith compost treatments registered very low K uptake on comparison with POP.
14. B : C ratio was maximum for highest dose of vermicompost. Most of the treatments fetched good profit except coir pith compost and lower levels of neem cake.

Study revealed that amaranthus responded well to various organic manures. Yield, yield attributes and growth characters are influenced to a greater extent by vermicompost and FYM. Higher levels of poultry manure and neem cake also performed well. It is found that quality aspects are significantly influenced by organic manures, especially vermicompost on comparison with POP. Study also pointed out the suitability of these organic manures at higher levels for getting increased yield and profit. It also revealed that coir pith compost is not suited as an organic manure for high yield and improved quality of amaranthus.

Future line of work

Considering the over all beneficial influence of organic sources on soil and plant environment, it would be more appropriate to initiate studies on the various combinations of organic manures, unlike in this experiment where no combination was tried. Since the residual soil nutrient values were high in this experiment, the possibility of a second crop can be verified without further addition of any manures. Also instead of trying coir pith compost alone, it can be blended with inorganic fertilizers to find out its beneficial effect. Similar experiments may be tried using coir pith enriched by poultry droppings after its use as a bedding material in poultry farms. From the present study it is clearly seen that vermicompost is a very promising manure for amaranthus. Similar study with vermicompost on other crops will explore the importance of this manure in augmenting the vegetable production of the state.

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* Original not seen

APPENDIX - I

Weather data for the crop period - Weekly averages
(November 1998 - February 1999)

Period	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)	Rainfall (mm)	Evaporation (mm)
1998					
Nov. 4 - Nov. 10	28.77	23.39	89.14	41.57	2.20
Nov. 11 - Nov. 17	30.07	23.10	82.71	7.43	3.30
Nov. 18 - Nov. 24	30.57	23.07	78.36	-	3.57
Nov. 25 - Dec. 1	30.74	23.76	84.36	1.51	2.94
Dec. 2 - Dec. 8	30.9	23.43	83.07	16.77	2.60
Dec. 9 - Dec. 15	29.20	23.11	87.09	5.54	1.90
Dec. 16 - Dec. 22	30.79	23.08	85.00	6.86	2.87
Dec. 23 - Dec. 29	31.34	21.14	85.50	0.86	2.79
Dec. 30 - Jan. 5	30.93	22.63	92.93	0.46	2.11
1999					
Jan. 6 - Jan 12	31.49	22.27	94.71	-	3.19
Jan. 13 - Jan 19	31.34	22.53	92.50	-	3.59
Jan. 20 - Jan 26	31.36	21.27	77.43	-	2.27
Jan. 27 - Feb. 2	30.63	21.37	76.29	0.29	3.53
Feb. 3 - Feb. 9	30.94	22.27	83.00	11.23	3.97
Feb. 10 - Feb. 16	31.40	23.06	81.64	-	3.77
Feb. 17 - Feb. 23	31.80	23.14	84.39	-	3.77
Feb. 24 - Mar. 2	31.93	23.11	80.00	-	3.96

Date of planting : 19-10-1998

ORGANIC NUTRITION IN AMARANTHUS (*Amaranthus tricolor* L.)

By
ARUNKUMAR K.R.

ABSTRACT OF THESIS
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FACULTY OF AGRICULTURE
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DEPARTMENT OF AGRONOMY
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THIRUVANANTHAPURAM

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ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, during November 1998 to February 1999 with objectives to find out the effect of different sources and levels of organic manures on the yield and quality of amaranthus and to assess the optimum quantity of these sources in sustaining the productivity of amaranthus. The experiment consisted of twenty six treatments and three replications laid out in RBD. The organic manures used were coir pith compost, FYM, neem cake, poultry manure and vermicompost. Five levels of these organic manures (50, 75, 100, 125 and 150 per cent of POP) were tried on nitrogen equivalent basis.

The results of the study revealed that the growth characters as well as yield were significantly influenced by different levels and sources of organic manures. Regarding growth characters vermicompost, FYM and poultry manure performed well throughout the growth period. Highest level of FYM and vermicompost (150 per cent POP) maintained their superiority at all growth stages regarding plant height, number of leaves, number of branches and LAI. Maximum plant height of 67.22 cm was recorded at 45 DAP by highest level of FYM. Vermicompost @ 25 t ha^{-1} (150 per cent of POP) recorded maximum number of leaves (100.78) at 45 DAP but it was on par with highest dose of FYM. Maximum LAI was noted in the highest dose of FYM and no other treatment was on par with it.

High yield was obtained from 100, 125 and 150 per cent levels of FYM, vermicompost, poultry manure and neem cake. All the coir pith compost treatments recorded lower yield than POP. The lowest yield was recorded by

lowest dose of coirpith compost. The same trend was obtained in the case of marketable yield also. Higher levels gave better yield in general. Total dry matter production showed an increasing trend with increasing dose of manure. Highest dose of FYM recorded maximum DMP of 11.41, 25.7 and 28.27 g respectively at 15, 30 and 45 DAP.

Variation among different organic manures was significant in the case of biomass production also. Through out the growth stages 125 and 150 per cent levels of all manures except coir pith compost recorded superior biomass compared to POP. Vermicompost at highest level (25 t ha^{-1}) recorded maximum biomass during three harvests. Variation was less in the case of NAR and dry matter partitioning at different stages.

Quality of amaranthus improved with various organic manures. Maximum vitamin C content was recorded by highest level of vermicompost. Maximum fibre content was registered by neemcake at 100 per cent level of POP (4.8 t ha^{-1}). Highest dose of poultry manure (25 t ha^{-1}) gave highest protein content. Vitamin C and protein contents increased with increasing doses of manure. Highest moisture content was noted by highest dose of FYM.

In the case of residual nutrients high soil NPK values were registered by higher levels of organic manures irrespective of source. No treatment was inferior to POP with respect to nitrogen content. Uptake of nutrient was poor from all coir pith compost treatments. Uptake of N increased with increasing levels of manures. P uptake was more for FYM treatments. Vermicompost at highest dose (37.5 t ha^{-1}) gave maximum B: C ratio.