SUSTAINABLE NUTRITIONAL PRACTICES FOR BITTERGOURD – AMARANTHUS INTERCROPPING SYSTEM

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DECLARATION

I hereby declare that this thesis entitled **"Sustainable nutritional practices for bittergourd – amaranthus intercropping system"** 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 to me 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 **"Sustainable nutritional practices for bittergourd – amaranthus intercropping system"** is a record of research work done independently by Mrs. Renu C. Nair under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	-	Per cent
@	-	At the rate of
B	-	Boron
BCR	-	Benefit cost ratio
Ca	-	Calcium
Cu	-	Copper
cv.	-	Cultivar
DAS	-	Days after sowing
DMP	-	Dry matter production
Fig.	-	Figure
FYM	-	Farm yard manure
g	-	gram
ha^{-1}	-	Per hectare
K	-	Potassium
K_2O	-	Potash
kg ha^{-1}	-	Kilogram per hectare
kg	-	Kilogram
km^2	-	Square kilometre
LAI	-	Leaf area index
M	-	metre
m^2	-	Square metre
Mg	-	Magnesium
mg	-	Milligram
ml^{-1}	-	Per millilitre
mm	-	Milli metre
N	-	Nitrogen
^oC	-	Degree Celsius
^oE	-	Degree East
^oN	-	Degree North
P	-	Phosphorus
P_2O_5	-	Phosphate
POP	-	Package of practices
q ha^{-1}	-	Quintal per hectare
S	-	Sulphur
t ha^{-1}	-	Tonnes per hectare
t	-	tones
Zn	-	Zinc

INTRODUCTION

1. INTRODUCTION

A healthy population is a prerequisite for the development of any country. Vegetables are protective quality foods and play a vital part in maintaining the health status of the people. They are rich sources of minerals, vitamins, vegetable fibre and contain fair amounts of carbohydrates and protein. They serve as roughages and improve digestion. Vegetables are realised as one of the components to provide nutritional security to the population.

India ranks second in vegetable crops with an area of 5.3 million hectares and production of 73 million tonnes. But in India, with a large vegetarian population, the vegetable production has not attained self sufficiency. There is a wide gap between the per capita availability of vegetables (135 g day^{-1}) against the minimum requirement (285 g day^{-1}). Hence we must augment the production to meet the requirements of our increasing population.

Even though the soil and climate in Kerala are suitable for growing vegetables, more than 75 per cent of the requirement is procured from our neighbouring states. In a state like Kerala, where the land area is limited, supply of optimum quantity and type of nutrition is most important for improving vegetable production. The increasing trend of abundant use of inorganic fertilizers in the present intensive agricultural system poses a threat to the sustainability of our agro-ecosystem. The continuous indiscriminate use of chemical fertilizers lead to decline in soil fertility and productivity, besides causing health hazards. Proper soil management without impairing soil health is a prerequisite for achieving higher productivity from agricultural lands (Anina, 1995). Since vegetables are mostly consumed fresh or partially cooked, they should be devoid of the residual effect of chemicals. In developing countries, over 50 per cent increase in crop production was brought about by the use of fertilizers. So in the present scenario where the national priority is to feed the increasing population, chemical fertilizer is unavoidable. Further, recent concern is stressing on the reduction of cost of cultivation and improvement in the quality of agricultural produce. Hence a judicious approach to meet the objectives of environmental care, increasing the productivity, improving the quality and reducing the cost of cultivation is needed. One way to achieve sustainability in agricultural production is to substitute chemical fertilizer to the maximum extent possible with organic manures. The use of organic manures along with inorganic fertilizes not only increases but also sustains the production and productivity of the crops as well as soil health.

India has vast potential of manurial resources. Farm yard manure and poultry manure are the most commonly used organic manures by the farmers of Kerala. Poultry manure is a rich source of nutrients especially for vegetable production (Jose *et al.*, 1988). Vermicompost which is produced by chemical disintegration of organic matter by earthworms contain higher amount of nutrients, hormones and enzymes and has stimulatory effect on plant growth. Addition of organic manure improved the physical, chemical and biological properties of soil (Meerabai and Raj, 2001).

Another pathway for Kerala to achieve self sufficiency in vegetable production is to increase the area under vegetables. However in a state like Kerala with a population density of 749 per km^2, due to the scarcity of land there is limited scope to bring additional area under vegetable cultivation. The only way to tackle the problem is to exploit the full potential of the available limited land resources to the maximum possible extent through crop intensification. Intercropping with vegetables is profitable because of yield advantage (Prabhakar and Shukla, 1985). Intercropping is advantageous from the point of view of economy of space, complete utilization of surplus nutrients, better utilization of solar energy, soil moisture reserve and increased gross return from a unit area.

Selection of suitable crop combination, adoption of proper planting geometry and proper nutrient management help greatly in increasing the crop productivity as well as economic return from an intercropping system.

Bittergourd is one of the most important cucurbitaceous vegetables cultivated throughout Kerala for its fruits. It is a rich source of vitamin C and minerals. It has got medicinal uses also and is an essential component in the diet of diabetic patients.

Amaranthus is the most popular leafy vegetable grown in the homesteads of Kerala. It is rich in protein, vitamin A, vitamin C and iron. Amaranthus being a short duration crop with high nutritional value, it can be successfully raised as an intercrop in bittergourd.

With this background the present study was undertaken with the following objectives.

1. To find out sustainable nutritional practice for enhancing the yield, quality and income from bittergourd.

2. To evaluate the economic feasibility of intercropping amaranthus in bittergourd.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Vegetables are universally accepted as protective foods and have been well advocated in solving the problem of food security. The abundant use of inorganic fertilizers in vegetable production has caused a threat not only to soil health but also to human health. Further, reduction in the cost of cultivation and improvement in yield and quality of agricultural produce are to be ensured. Therefore nutrient management strategy must include a proper blend of organic manures and inorganic fertilizers so as to sustain the production and productivity of the crops as well as soil health.

In Kerala, vegetable production is not sufficient to meet the requirement of the growing population. There is little chance to increase the area under vegetable crops due to the scarcity of land. The only way out is through crop intensification which exploits the full potential of the available limited land resources.

An investigation was carried out at the College of Agriculture, Vellayani during the period from October to January 2001-2002 to identify sustainable nutritional practices for enhancing the yield, quality and income from bittergourd and to assess the economics of intercropping amaranthus in bittergourd. The literature collected pertaining to the above subjects are reviewed hereunder. Since literature available on the crop tried in this experiment are meagre, results of similar experiments conducted on other related crops are also cited.

2.1 ORGANIC MANURES

Organic manure serves as slow release source of N, P, S for plant nutrition and microbial growth. It possesses considerable water holding capacity, acts as buffer against changes in pH of the soil and cements clay and silt particles together contributing to the crumb structure of the soils. It also binds micronutrient metal ions in the soil that otherwise might be leached out (Rammohan *et al.*, 2002).

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

Increase in the yield of chilli, bhindi, tomato and brinjal by organic manure application was reported by Gaur *et al.* (1984). Gianquinto and Borin (1990) observed an increase in plant growth and yield of tomato plants by the addition of organic amendments. Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches. They yielded 28.18 t ha^{-1} which was on par with the recommended dose of FYM and NPK (20:100:100). Raj (1999) reported that growth characters like plant height, LAI, DMP, yield attributes like fruit number per plant, fruit weight, fruit length and fruit yield ha^{-1} were higher in organic manure treated okra plants. She also observed that plants treated with organic manures produced fruits with higher crude protein and ascorbic acid contents and lower crude fibre content compared to package of practice recommendation.

Yoshida *et al.* (1984) found that fertilization with bone and rapeseed meals produced firm fruits with most cohesiveness, chewingness and uniform thickness at top and bottom of tomato fruits. Studies conducted at Kerala Agricultural University revealed that in oriental pickling melon, organic manures showed definite advantage over inorganic fertilizers in respect of storability (KAU, 1987). Increased ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds due to the impact of application of organic manures was reported by Rani *et al.* (1997).

2.1.2 Effect of Organic Manures on Soil Properties

Badanur *et al.* (1990) reported that available phosphorous content of soil was significantly increased with the incorporation of subabul, sunhemp loppings and farm yard manure. Srivastava (1985) reported that application of organic manures resulted in increased organic carbon content, total N and available P and K status of soil. Application of organic amendments viz. saw dust, groundnut shell powder, coir dust and FYM each at 2.5 and 5 t ha^{-1} improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of the red soil with hardpan (Loganathan, 1990). Connell *et al.* (1993) observed that the composted municipal solid waste application in soil increased the status of available nitrogen content. Addition of farm wastes and organic manures increased the available N status of the soil (More, 1994). Issac (1995) estimated that available N, P_2O_5 and K_2O contents in the soil after the harvest were highest with the application of 12 tonnes of farm yard manure along with vermicompost as a source of nitrogen in bhindi.

2.1.3 Effect of Organic Manures on Nutrient Uptake

Mishra and Banagar (1986) emphasised that the P enriched compost was comparable to single super phosphate in crop response and P uptake. Abusaleha (1992) observed an increased uptake of N,P,K, Ca and Mg in bhindi when 40 kg N was supplied through poultry manure when compared to the application of same quantity through farm yard manure or ammonium sulfate on equivalent nitrogen basis. Application of farm yard manure was beneficial in enhancing the uptake of phosphorus by potato and maize (Minhas and Sood, 1994). According to Anina (1995) application of Eudrillus compost increased the uptake of nutrients by plants. Pushpa (1996) reported an increased uptake of plant nutrients by tomato when vermicompost was used as a source of organic manure compared to FYM. Anitha (1997) observed the better uptake of N in poultry manure treated chilli plants as compared to control. Raj (1999) noticed that nitrogen and potassium uptake by snakegourd plants was maximum in FYM + neemcake and phosphorus uptake was highest in FYM + poultry manure treatments.

2.1.4 Effect of Organic Manures on Pest and Disease Incidence

The organic manures were reported to work like slow release fertilizers providing balanced nutrition to plants and facilitating balanced growth, finally making them less prone to pest incidence (Gaur, 1984). According to Chindo and Khan (1990), soil nematode population declined drastically during mid season due to poultry manure application. While evaluating the effects of organic manures on the incidence of stemfly in soybean, Kumar *et al.* (1996) observed least incidence of stem tunneling with farm yard manure application alone (6.45 per cent) and highest with inorganic fertiliser alone (14.87 per cent). In a field experiment conducted at Bapatla, Surekha and Rao (2001) noted that vermicompost was significantly more effective in bringing down the population of aphids in bhindi followed by FYM when compared to NPK as inorganic fertilizer.

Seo (1986) opined that the application of poultry manure suppressed the occurrence of *Fusarium* wilt in cucumber (*Cucumis sativus*). Niranjana (1998) reported lowest incidence of leaf blight in amaranthus with the application of vermicompost.

2.1.5 Economics of Using Organic Manures in Vegetable Cultivation

Raj (1999) found that in okra, FYM + neem cake application recorded the maximum profit and highest beneft-cost ratio. According to Manonmani and Anand (2002) vermicompost was cost effective and could be recommended as best fertilizer to farmers for the vegetable crop lady's finger.

2.2 FARM YARD MANURE

Farm yard manure, the most commonly used organic manure is a good source of both macro and micro nutrients. It has both direct and residual effects in plant nutrition. An average dressing of 25 t ha^{-1} of FYM supplies 112 kg N, 56 kg P_2O_5 and 112 kg K_2O (Meerabai and Raj, 2001).

2.2.1 Effect of Farm Yard Manure on Growth Characters

Farm yard manure favourably influenced the growth characters and rate of dry matter increment per unit leaf area of capsicum (Cerna, 1980 and Valsikova and Ivanic, 1982). 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 snakegourd, growth characters viz., weight of the roots $plant^{-1}$ and dry matter production ha^{-1} were highest in FYM treated plants as compared to poultry manure or vermicompsot treated plants.

2.2.2 Effect of Farm Yard Manure on Yield and Yield Attributes

In the long term field experiment for 7 years at Jalandhar, Sharma *et al.* (1988) revealed that FYM was more effective in increasing tuber yield of potato than green manuring with dhaincha. Joseph (1998) reported that in snakegourd yield attributing characters viz., length, weight and number of fruits per plant were highest in FYM treated plants as compared to poultry manure or vermicompost treated plants. Senthilkumar and Sekar (1998) reported that fruit yield $plant^{-1}$ in bhindi was increased markedly by farm yard manure application.

2.2.3 Effect of Farm Yard Manure on Quality Aspects

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

2.2.4 Effect of Farm Yard Manure on Soil Properties

In wheat-maize rotation, available N and P_2O_5 content of the soil increased with continuous use of farm yard manure (Prasad and Singh, 1980). Negi *et* al. (1981) reported on increase in the available K content of the soil in FYM applied plots compared to fertilizer applied plots. The beneficial effect of farm yard manure in increasing the water stable aggregates was reported by Kanwar and Prihar (1982). An increase in available N content of soil upto 20 days after farm yard manure application and a decrease thereafter was noticed in a long-term field experiment with wheat (Gupta *et al.*, 1988). Sarkar *et al.* (1989) suggested that continuous application of farm yard manure increased the water holding capacity due to improvement in porosity and soil aggregation. Dhanokar *et al.* (1994) observed that continuous use of FYM raised the available K_2O content by 1.3 to 5.4 folds over control.

2.3 POULTRY MANURE

Poultry manure with its low C:N ratio and good nutrient value suits well for all crops especially vegetables. Its higher efficiency is due to the large quantities of easily mineralisable nitrogen (Meerabai and Raj, 2001). As the nutrient present in poultry manure is easily available, its effect can be noticed directly on the crop and residual effect can also be seen. Due to high content of NPK it has been proved that one tonne of poultry manure is equivalent to seven tonnes of FYM (Channabasavanna and Biradar, 2002).

2.3.1 Effect of Poultry Manure on Growth Characters

A study on optimum level of poultry manure requirement for cauliflower by Singh *et al.* (1970) revealed progressive increase in growth 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, poultry manure application exhibited better response over FYM on yield and growth attributes. Anitha (1997) remarked that in chilli various growth attributes like plant height, number of branches and dry matter production were better with poultry manure application as compared to FYM or vermicompost.

2.3.2 Effect of Poultry Manure on Yield and Yield Attributes

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 (0, 42.4, 84.4 or 127.2 q ha^{-1}) which supplied 0, 125, 250 and 375 kg N ha^{-1} respectively in cauliflower (Singh *et al.*, 1970). In lettuce, poultry manure applied at 0, 20 and 40 kg 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). Mina (1986) reported that application of poultry manure alone and in combination with 14:14:14 NPK fertilizer mixture irrespective of the rates significantly increased the yield of muskmelon. Julia *et al.* (1993) pointed out the beneficial effect of nitrogen nutrition through poultry manure wherein an increase in the number of large and medium size fruits by applying 15 t ha^{-1} of poultry manure was noticed in tomato. Poultry manure treated chilli plants showed better yield and yield attributing characters as compared to FYM and vermicompost applications (Anitha, 1997).

2.3.3 Effect of Poultry Manure on Quality Aspects

Application of poultry manure showed a slight increase in ascorbic acid content of cauliflower. The highest vitamin C content was obtained in the curds supplied with 169.6 q ha^{-1} of poultry manure (Singh *et al.*, 1970). Anitha (1997) observed that chilli plants treated with poultry manure recorded the maximum ascorbic acid content of fruit as compared to vermicompost and control treatments. Joseph (1998) reported that in snakegourd poultry manure treated plants recorded the highest crude protein content and the lowest crude fibre content as compared to that of FYM and vermicompost treated plants. According to Sharu (2000) poultry manure application registered maximum keeping quality of fruits compared to vermicompost, neemcake and POP recommendation.

2.3.4 Effect of Poultry Manure on Soil Properties

According to Bitzer and Sims (1988) long term increase in soil levels of nutrients like B, Ca, Mg, Cu and Zn could be expected with poultry manure application. Application of poultry manure (15 t ha^{-1}) as source of nitrogen increased the exchangeable K and available K content of soil in a tomato field (Julia *et al.*, 1993). Sharu (2000) reported that highest level of poultry manure recorded highest level of soil N compared to vermicompost, neemcake and POP recommendation. Poultry manure improved the physical structure of the soil (Channabasavanna and Biradar, 2002).

2.4 VERMICOMPOST

Vermicompost plays a vital role in building of nutrients in soil and thereby sustaining the yield. Vermicompost contains various amino acids, minerals and micro organisms which humidify the organic matter in the surrounding soil and acts as a biofertilizer for plants (Shanbhag, 1999). Vermicompost has definite advantage over other organic manures in respect of quality and shelf life of produce (Meerabai and Raj, 2001).

2.4.1 Effect of Vermicompost on Growth Characters

Curry and Boyle (1987) observed enhanced plant growth in the presence of earthworms which was attributed to an increased supply of readily available plant nutrients. The use of vermicompost either as a seed inoculant or as an organic source gives better result in terms of yield as well as growth characters. The quantity of fertilizer can be reduced to half when vermicompost was used as seed inoculant in cowpea (Meera, 1998). In a field experiment conducted at Tiruchirappli, Manonmani and Anand (2002) reported that the growth and yield of lady's finger were found to be maximum in the plot which was supplemented with vermicompost compared to the cultivation in normal soil and cultivation in soil with biofertilizers and biofertilizers + vermicompost.

2.4.2 Effect of Vermicompost on Yield and Yield Attributes

Sacirage and Dzelilovic (1986) obtained higher dry matter yield in leek when grown in vermicompost applied plots compared to inorganic fertilizer. They also found that application of 4, 6 and 8 kg m^{-2} of vermicompost in cabbage increased the dry matter yield from 1 to 66 per cent. Ismail *et al.* (1993) conducted a comparative evaluation of vermicompost, FYM and fertilizer on yield of bhindi and water melon and observed an increase in yield in all the vegetables with vermicompost. Sheshadri *et al.* (1993) studied the comparative effect of vermicompost, farm yard manure and fertilizers on the yield of chilli and observed the superiority of vermicompost over other treatments. Rajalekshmi (1996) observed higher yield in tomato and chilli by the application of vermicompost. Arunkumar (2000) reported highest yield in amaranthus during all harvests when vermicompost was applied @ 25 t ha^{-1} when compared to other organic manures like poultry manure, neem cake and FYM.

2.4.3 Effect of Vermicompost on Quality Aspects

Evangelista (1986) reported that the application of pure earthworm cast showed significant effect on nitrogen, phosphorus, calcium and magnesium content of the lettuce leaves. Tomati *et al.* (1990) observed that incorporation of vermicompost increased protein synthesis in lettuce and radish by 24 and 32 percentage respectively. Alfred and Gunathilagaraj (1996) noticed more N content in amaranthus plants due to introduction of earthworms in to the soil. Joseph (1998) opined that in snakegourd, total soluble solids, vitamin C and total sugars were highest in fruits obtained from vermicompost applied plots. She also reported that shelf life was more in vermicompost applied plots.

2.4.4 Effect of Vermicompost on Soil Properties

Earthworm increased either directly or indirectly the proportion of mineral N available for plants at any given time, although N was clearly immobilised in the initial stage (Haimi and Huhta, 1990). Hulugalle and Ezumah (1991) reported that pH of the earthworm cast was higher than that of non-ingested soil. Similar result was also reported by Basker *et al.* (1994). By introducing earthworm and applying organic manure in the red arid soil, Shuxin *et al.* (1991) reported that, the organic carbon in the soil increased from 0.5 to 0.6 per cent. Kale *et al.* (1992) noticed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in N fixation and phosphate mobilization, leading to higher nutrient uptake by plants. Vijayalekshmi (1993) reported that soil properties such as porosity, soil aggregation, soil transmission, conductivity and dispersive power of wormcast treated soil were improved when compared with no wormcast amended soil. Higher levels of total N, available P and K in treatments which received either vermicompost alone or in combination with FYM or chemical fertilizer than control (Balaji, 1994). Divya (2001) reported that addition of vermicompost improved the soil physical properties such as porosity, water holding capacity, soil aggregation, hydraulic conductivity and infiltration. It also improved the chemical properties of soil such as pH, available nutrient content and organic carbon content favouring plant growth. According to Senthilkumar and Surendran (2002) vermicompost influenced the physical, chemical and biological properties of the soil. He also opined that it improved the water holding capacity of soil and acted as a mine for various plant essential nutrients such as N, P, K, S and trace elements.

2.5 EFFECT OF COMBINED APPLICATION OF ORGANIC MANURE AND CHEMICAL FERTILIZER

Integrated application of organic manure and chemical fertilizers is needed for the balanced supply of nutrients. Combination of organic manure with inorganic fertilizers had a moderating effect on soil reaction particularly under acidic soil and improvement in sustained availability of N, P, K, S and the micro nutrients particularly zinc (Nambiar and Abrol, 1989). Studies conducted in Kerala Agricultural University revealed that organic and inorganic fertilisers and their combinations had significant influence on vegetable productivity (KAU, 1991). Shelf life of bittergourd fruits at room temperature was more when the nutrient N was supplied through 2:1 ratio of organic-chemical N substitution using farm yard manure or poultry manure as an organic source (Rajasree, 1999). According to Rekha (1999) integrated application of organic and inorganic sources recorded significantly higher values for all the growth characters in brinjal. Sharma (2000) opined that integration of organic and inorganic fertilizer application significantly increased the head yield over inorganic fertilizer alone and also over control in broccoli. Organic sources when applied with mineral fertilizer, improved the efficiency of latter due to their favourable effects on physical and biological properties of soil (Singh, 2001).

2.5.1 Farm Yard Manure and Chemical Fertilizers

2.5.1.1 Effect of Combined Application of Farm Yard Manure and Chemical Fertilizers on Growth Characters

Subbiah *et al.* (1982) reported that in chilli, equal split application of 120 kg nitrogen ha^{-1} along with 25 t of farm yard manure recorded the highest yield of dry chilli pods and stalks. Combined application of organic manure through 12.5 t ha^{-1} FYM, 2 kg in each of Azospirillum and phosphobacteria with inorganic fertilizers favourably influenced the growth parameters like plant height, root length, number of primary branches and leaf area index in brinjal than recommended dose of inorganic NPK alone (Nanthakumar and Veeraragavathatham, 2000).

2.5.1.2 Effect of Combined Application of Farm Yard Manure and Chemical Fertilizer on Yield and Yield Attributes

Katyal (1977) reported that for a successful crop of bittergourd 50 t ha^{-1} FYM and 100 kg ha^{-1} of ammonium sulphate were beneficial. A combination of 12.5 t ha^{-1} of FYM and 50 per cent recommended dose of fertilizer was found to be beneficial for improving the yield in brinjal (Subbiah *et al.*, 1983). Thomas (1984) reported that bittergourd crop responded well to nitrogen application at 60 kg N ha^{-1} along with 18 t ha^{-1} farm yard manure producing maximum yield. According to Mesina (1986) application of 10 t cattle manure ha^{-1} along with 120 kg N ha^{-1} as chemical fertilizer increased the number of fruits per plot in muskmelon. Nair (1988) noticed an increase in the fruit yield in clustered chilli with the application of higher rates of chemical nitrogen together with farm yard manure. Nair and Peter (1990) found that highest yield in chilli was obtained with 15 t FYM + inorganic fertilizers in the three seasons tried when compared to farm yard manure alone or inorganic fertilizers alone. Studies conducted in Kerala Agricultural University revealed that higher rates of N along with FYM induced earliness and increased the fruit yield in clustered chilli (KAU, 1991). Integrated application of fertiliser nitrogen @ 120 kg N ha^{-1} and farm yard manure @ 20 t ha^{-1} increased the yield characters such as head length, girth, number of non-wrapper leaves per head and head weight in cabbage (Dixit, 1997). In an experiment in okra, Issac *et al.* (1998) found that weight of green fruits per plant, weight of mature fruits per plant and total fruit yield per plant were significantly higher in combined application of 12 t farm yard manure or 6 t farm yard manure with chemicals giving on par values. Nanthakumar and Veeraragavathatham (2000) reported that combined application of 12.5 t ha^{-1} FYM, 2 kg each of Azospirillum and phosphobacteria with inorganic fertilizers registered the highest yield of 36.48 t ha^{-1} in brinjal cv. Palur 1 than recommended dose of inorganic NPK alone. Parmar and Sharma (2001) opined that integrated use of farm yard manure and chemical fertilizers had considerable impact in enhancing the yield of vegetables.

2.5.1.3 Effect of Combined Application of Farm Yard Manure and Chemical Fertilizers on Quality Aspects

Shanmugavelu (1989) pointed out that the application of a mixture of farm yard manure and inorganic fertilizer was found to be the best for firmness, storage life and keeping quality of tomato for a long time. Sujatha and Krishnappa (1995) conducted studies in potato to find out the changes in the quality attributes of potato tubers as influenced by different fertilizer levels. They observed highest reducing sugars in treatments with inorganic fertilizer and 50 t ha^{-1} of FYM. According to Nanthakumar and Veeraragavathatham (1999) combined application of organic fertilizers through 12.5 t ha^{-1} of FYM, 2 kg each of Azospirillum and phosphobacteria and inorganic fertilizers favourably influenced the keeping quality in brinjal. The organoleptic test showed that the fruits obtained by the combined application of organic, inorganic and bio-fertilizer were highly acceptable since they recorded good texture, taste and overall acceptability by the consumers.

2.5.1.4 Effect of Combined Application of Farm Yard Manure and Chemical Fertilizers on Soil Properties

Farm yard manure in combination with chemical fertilizer was proved to be beneficial in increasing the water holding capacity of the soil (Prasad and Singh, 1980). Sinha *et al.* (1980) observed a decrease in bulk density of soil with the application of farm yard manure along with lime and inorganic fertilisers, while the continuous use of chemical fertilisers increased the bulk density. Helkiah *et al.* (1981) obtained lowest bulk density and higher porosity with the application of inorganic fertilizer alone. Mahimairaja *et al.* (1986) opined that the soil porosity was improved by application of farm yard manure along with chemical fertilisers. The application of 100 per cent of recommended NPK and 30 t ha^{-1} FYM significantly improved the availability of N, P and K in soil (Parmar and Sharma, 2001).

2.5.2 Poultry Manure and Chemical Fertilizers

2.5.2.1 Effect of Combined Application of Poultry Manure and Chemical Fertilizers on Growth Characters

Jose *et al.* (1988) reported enhanced plant growth in brinjal with the application of poultry manure and inorganic fertiliser. Abusaleha (1992) observed the highest uptake of nutrients in okra with the combined application of nitrogen in the form of poultry manure and ammonium sulfate which was attributed to the increased dry matter accumulation in plants. Sharu (2000) opined that plant height was highest in chilli with the integrated application of chemical fertilizer and poultry manure in the ratio 3:1. She also reported that integrated application of chemical fertilizer and poultry manure at 3:1 ratio recorded maximum number of branches for plant at 35 and 105 DAT.

2.5.2.2 Effect of Combined Application of Poultry Manure and Chemical Fertilizers on Yield and Yield Attributes

Mina (1986) found out that application of poultry manure alone or in combination with chemical fertilizer irrespective of rate significantly increased the diameter of fruits, fruit weight and yield $plot^{-1}$ in muskmelon. Ifenkwe *et al.* (1987) reported that application of 50 per cent of N through chemical source together with the remaining 50 per cent through poultry manure significantly increased the total tuber yield in potato. Plants supplied with 50 kg N as poultry manure and 50 kg N as urea recorded the highest yield of brinjal fruits (Jose *et al.*, 1988). In an experiment in bittergourd, Rajasree (1999) obtained increased fruit yield and number of fruits plant^{-1} with 2:1 ratio of poultry manure - chemical N combination. Rekha (1999) noticed that when 50 per cent of the recommended N was substituted with poultry manure, marketable yield was highest in brinjal when compared to the substitution with neemcake and biogas slurry. Sharu (2000) observed maximum fruiting phase and fruit set in chilli when poultry manure and chemical nitrogen was used in the ratio 3:1. She also opined that poultry manure along with chemical nitrogen in the ratio 1:1 recorded good performance with respect to number of fruits plant^{-1}, harvest interval and total yield.

2.5.2.3 Effect of Combined Application of Poultry Manure and Chemical Fertilizers on Quality Aspects

In a field trial conducted in potato, Singh *et al.* (1973) reported that application of 80 kg ha^{-1} nitrogen through poultry manure along with 80 kg ha^{-1} chemical nitrogen produced higher crude protein content of 2.12 per cent than that obtained with the application of 160 kg nitrogen through poultry manure alone (1.91 per cent). Phosphorus content of tuber was also significantly higher (0.319 per cent) with the above mentioned treatment when compared to the single application of 160 kg nitrogen through poultry manure (0.246 per cent). Rajasree (1999) observed higher iron content in bittergourd fruits when poultry manure and chemical fertilizers were used in the ratio 2:1. Sharu (2000) found that in chilli, vitamin C content was highest for the treatment 25 per cent N as chemical fertilizer + 75 per cent N as poultry manure.

2.5.2.4 Effect of Combined Application of Poultry Manure and Chemical Fertilizer on Soil Properties

Helkiah *et al.* (1981) noticed that when poultry manure was applied at the rate of 30 t ha^{-1} in combination with half the recommended dose of inorganic fertilizers, the bulk density was reduced and porosity was increased, compared with the application of full recommended dose as chemical fertilizers. Budhar *et al.* (1991) obtained increased post harvest nutrient status of soil NPK with the application of 5 t ha^{-1} of poultry manure along with 100 per cent recommended fertilizer. Rajasree (1999) reported that when FYM or poultry manure as organic source was used in equal or higher proportion with chemical N source, it showed moderating effect on the soil acidity. In a field experiment in chilli, Sharu (2000) reported that poultry manure and chemical fertilizer in equal proportion obtained highest value for soil P after the experiment.

2.5.3 Vermicompost and Chemical Fertilizers

2.5.3.1 Effect of Combined Application of Vermicompost and Chemical Fertilizers on Growth Characters

According to Ushakumari *et al.* (1999) combined application of vermicompost and inorganic fertilizer increased plant height and number of leaves $plant^{-1}$ in okra. Application of chemical fertilizer and vermicompost in 3:1 ratio recorded maximum value for shoot-root ratio in chilli (Sharu, 2000).

2.5.3.2 Effect of Combined Application of Vermicompost and Chemical Fertilizers on Yield and Yield Attributes

Pushpa (1996) observed that yield attributes like mean fruit weight, girth of fruits and yield were highest in tomato plants receiving 25 t ha^{-1} vermicompost along with full dose of inorganic fertilizers. Rajalekshmi (1996) found that with regard to the yield and dry matter production of chilli crop, the treatment receiving vermicompost and recommended NPK recorded highest yield. In an experiment conducted in cowpea the treatment vermicompost (20 t ha^{-1}) + lime + fertilizer was found to be superior with a mean grain weight of 10.91 g $plot^{-1}$ (Bijulal, 1997). According to Joseph (1998) integration of vermicompost with chemical fertilizers was beneficial for increasing the yield and improvement in quality in snakegourd. Jiji and Dale (1999) opined that vermicompost with full dose of inorganic fertilisers increased the yield of bittergourd and cowpea by 21 per cent and 19 per cent respectively when compared to the package of practice recommendations. Ushakumari *et al.* (1999) reported that vermicompost + inorganic fertilizer increased the number of fruits per plant and gave more yield in okra. Length of chilli fruit was highest for vermicompost treated plots along with chemical fertilizers in the ratio 1:1 (Sharu, 2000).

2.5.3.3 Effect of Combined Application of Vermicompost and Chemical Fertilizers on Quality Aspects

Pushpa (1996) observed highest protein content in tomato plants receiving 100 t ha^{-1} vermicompost whereas maximum carbohydrate content was found in tomato plants receiving 25 t ha^{-1} vermicompost along with full dose of inorganic fertilizers.

2.5.4 Effect of Combined Application of Organic Manure and Chemical Fertilizer on Uptake of Nutrients

Jose *et al.* (1988) noted that application of half (50 kg) nitrogen as poultry manure along with remaining half (50 kg) as urea increased the uptake of nitrogen, phosphorus, potassium, calcium and magnesium in brinjal. Organic manures applied in conjunction with optimal NPK dose resulted in highest potassium uptake by crops (Sarkar *et al.*, 1989 and Singh and Tomar, 1991). Abusaleha (1992) recorded higher nutrient uptake of 52.53 kg ha^{-1} N, 13.09 kg ha^{-1} P and 55.89 kg ha^{-1} K in okra at 90 days after sowing when 40 kg nitrogen was applied as 20 kg in the form of ammonium sulphate and remaining 20 kg in the form of farm yard manure when compared with the application of 40 kg nitrogen through farm yard manure alone. In long term fertiliser trials, addition of farm yard manure along with inorganic fertiliser increased the uptake of N, P and

K in most of the crops when compared with the application of inorganic fertiliser alone (Nambiar, 1994). In a field experiment in chilli, Sharu (2000) recorded highest value for P uptake and highest value for K uptake by the application of 75 per cent N as poultry manure + 25 per cent N as chemical fertilizer and 25 per cent N as poultry manure + 75 per cent N as chemical fertilizer respectively.

2.5.5 Effect of Combined Application of Organic Manure and Chemical Fertilizer on Pest and Disease Incidence

Dayakar *et al.* (1995) reported that when farm yard manure was applied along with inorganic fertiliser, the population of pigeon pea pod borers was lower than that under the use of straight inorganic fertilisers alone. Application of organic amendments along with 75 per cent dose of nitrogen was found to be better in reducing the population of sucking pests of cotton than with full dose of nitrogen (Balasubramanian and Muralibaskaran, 2000).

Broadbent and Baker (1975) reported that application of fowl manure along with lime and inorganic nutrients, reduced the losses from *Phytophthora* root rot in avacado.

2.5.6 Economics of Combined Application of Organic Manures and Chemical Fertilizer in Vegetable Cultivation

Thomas (1984) opined that the bittergourd crop responded well to N at the rate of 60 kg ha^{-1} along with 18 t ha^{-1} of farm yard manure producing maximum yield and net return. Joseph (1998) observed that in snakegourd, the maximum benefit-cost ratio of 5.5 was obtained by the application of 25 per cent N as vermicompost and 75 per cent N as inorganic fertilizers. According to Rekha (1999) whatever be the type of organic manure used, when it was applied along with chemical source in 1:1 ratio the net returns and benefit-cost ratio were highest in brinjal. Sharma (2000) opined that application of 175 kg N + FYM 12.5 t ha^{-1}

fetched the highest net profit ha^{-1} in broccoli. Sharu (2000) reported that in chilli, combined application of chemical fertilizers and poultry manure in the ratio 1:1 gave maximum net returns and benefit-cost ratio. Parmar and Sharma (2001) reported that application of 100 per cent of recommended NPK and 30 t ha^{-1} FYM generated a net income of Rs.62,800 ha^{-1} in cauliflower.

2.6 ECONOMICS OF INTERCROPPING IN VEGETABLES

According to Irulappan *et al.* (1982) intercropping in vegetables was profitable compared to sole cropping. Shultz *et al.* (1982) opined that polyculture of cucumber and tomato was beneficial over monoculture. Prabhakar *et al.* (1983) observed that the yield of short statured vegetables like beet root, knolkhol, onion and pea were superior when intercropped with okra and capsicum. Rao *et al.* (1983) remarked that vegetable legumes such as lablab bean, cowpea and cluster bean could be remunerative and could form better component crop in intercropping system. Ojeifo and Lucas (1987) found that intercropping two rows of jute with two rows of tomato gave maximum economic return. Prabhakar *et al.* (1989) opined that intercropping capsicum with beetroot was beneficial. Ikeorgu (1990) remarked that amaranthus performed better in mixtures than under sole cropping.

According to Amma and Ramadas (1991) intercropping of amaranthus with bhindi recorded the highest yield for bhindi (10.36 t ha^{-1}) compared to pure crop of bhindi (9.66 t ha^{-1}). He also reported that amaranthus when intercropped with bhindi, fetched an additional income and resulted in higher economic return compared to sole crop of bhindi. Prabhakar and Shukla (1991) reported that okra and radish intercropping system gave higher return than their respective sole crop. According to Singh (1991) tomato-onion combination gave the highest net return and maximum profit and generated additional income when compared with pure crop of tomato. Natarajan (1992) observed that chilli with bhindi as intercrop under normal row system recorded the highest gross income under semi-dry condition. The intercropping of either of arum (*Colocasia esculenta*) with onion or arum with radish proved more remunerative than sole cropping of either of them (Mishra *et al.*, 1993).

Anitha (1995) observed that intercropping was feasible in chilli and by raising amaranthus along with chilli an additional yield as well as profit could be realised compared with pure crops of chilli and amaranthus in summer rice fallows. Kalarani (1995) reported the superiority of bhindi + cowpea intercropping system with respect to gross return and net return over sole cropping Studies conducted at Coimbatore during Rabi and Kharif in chilli had shown that aggregatum onion, black gram and cepa onion could be considered suitable intercrops for chilli (Aravazhi *et al.*, 1996). Intercropping banana with bittergourd and amaranthus is economically feasible and very common among progressive farmers of Kerala (Kerala Horticultural Development Programme, 2000).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The objective of the present investigation was to identify sustainable nutritional practice for enhancing the yield, quality and income from bittergourd and to assess the economics of intercropping amaranthus in bittergourd. The experiment was conducted during the period 01-10-2001 to 31-01-2002 at the Instructional Farm, College of Agriculture, Vellayani. The details of the materials used and methods adopted for the study are presented below.

3.1 MATERIALS

3.1.1 Experimental Site

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani located at 8.5°N latitude and 76.9°E longitude and at an attitude of 29 m above the mean sea level.

3.1.2 Soil

The soil of the experimental site is sandy clay loam, belonging to the taxonomical order Oxisol. The physico-chemical properties of the experimental site are presented in Table 3.1.

3.1.3 Weather Parameters

The data on various weather parameters like temperature, rainfall, evaporation and relative humidity during the cropping period were obtained from the meteorological observatory, College of Agriculture, Vellayani and are presented in Appendix I and Fig. 1.

Table 3.1 Physico-chemical properties of soil

a. Physical composition

Parameter	Content in soil (%)	Method used
Coarse sand	36.50	Bouyoucos Hydrometer method (Bouyoucos, 1962)
Fine sand	15.40	
Silt	17.55	
Clay	30.55	

b Chemical composition

Parameter	Content	Ranking	Methods used
Available N (kg ha^{-1})	234.00	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P_2O_5 (kg ha^{-1})	33.05	Medium	Bray colorimetric method (Jackson, 1973)
Available K_2O (kg ha^{-1})	160.00	Medium	Ammonium acetate method (Jackson, 1973)
pH	4.8	Acidic	pH meter with glass electrode (Jackson, 1973)

c. Physical properties

Parameter	Content	Method used
Bulk density (g cc^{-1})	1.41	Core method (Gupta and Dakshinamoorthi, 1980)
Water holding capacity (%)	30.87	-do-
Porosity (%)	40.72	-do-

3.1.4 Cropping History of the Field

The field was under bulk crop of snakegourd before the experiment.

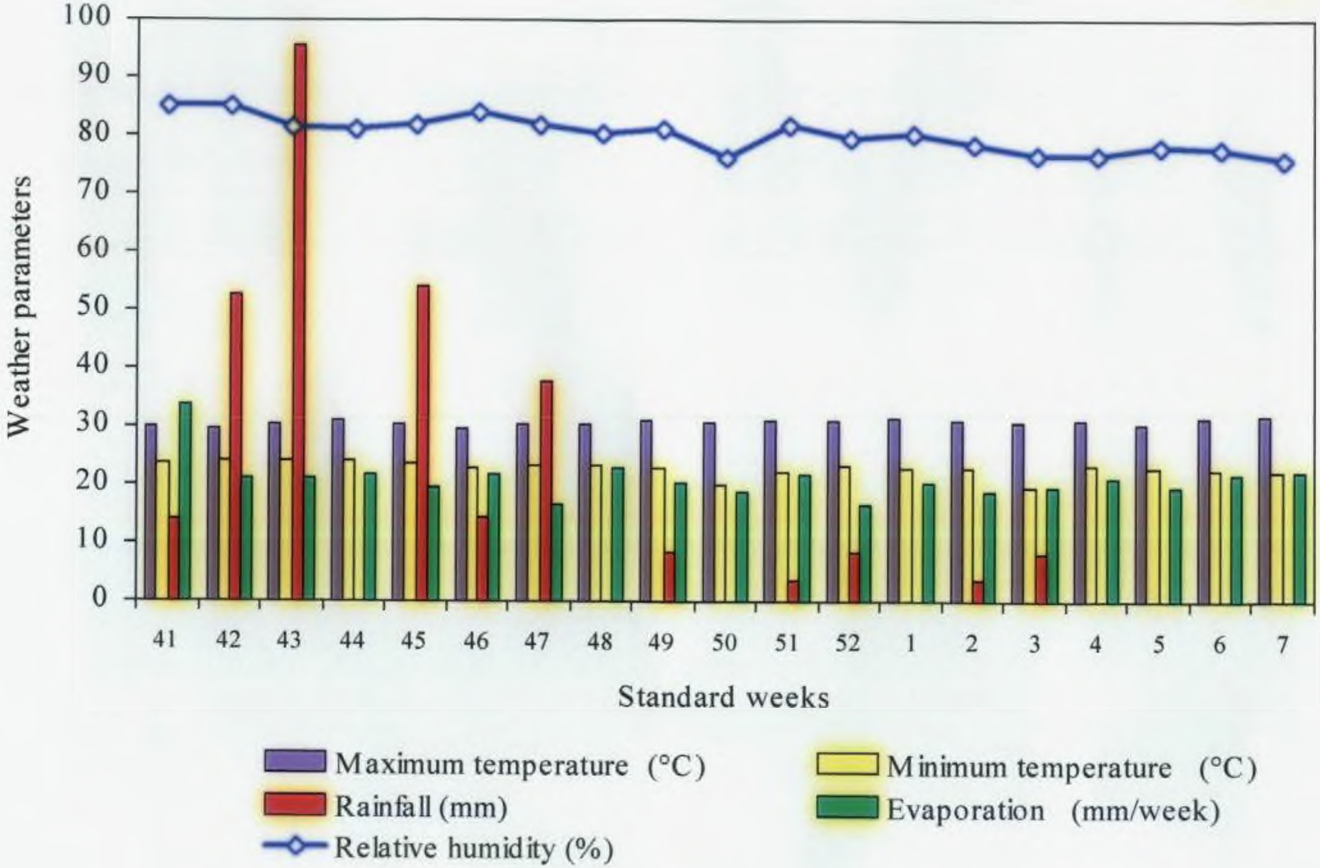

Fig. 1. Weather parameters during the cropping period

3.1.5 Season

The field experiment was conducted during October to January of 2001-2002.

3.1.6 Variety

The variety of bittergourd used for the experiment was Preethi evolved at College of Horticulture, Vellanikkara through selection. The fruits are white, medium long and spiny with good transport quality.

The amaranthus variety used was Arun. It was released from College of Agriculture, Vellayani through mass selection from Palappur local. Photo insensitive purple coloured variety with good quality.

3.1.7 Source of Seed Material

The seeds of bittergourd and amaranthus were obtained from Instructional Farm, College of Agriculture, Vellayani.

3.1.8 Manures and Fertilizers

Farm yard manure (0.5 per cent N), poultry manure (2.6 per cent N) and vermicompost (1.5 per cent N) were used as organic sources.

Urea (46 per cent N), mussoriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as inorganic sources for N, P and K respectively.

3.2 METHODS

3.2.1 Design and Layout

Design	:	7 x 2 factorial experiment in RBD
Treatment combinations	:	14
Number of replications	:	3
Total number of plots	:	42
Plot size	:	3 x 3 m
Spacing	:	2 x 2 m (Bittergourd)
		4 pits/treatment/replication
		Amaranthus seeds were the broadcasted in interspaces immediately after sowing bittergourd

The layout of the experiment is given in Fig. 2. and planting pattern of bittergourd amaranthus intercropping system is given in Fig. 3. An overall view of the experimental plot shown in Plate 1.

3.2.2 Treatments

I. Nutrient sources (on N equivalent basis)

n_1 - 50 per cent N as FYM + 50 per cent N as chemical fertilizer

n_2 - 100 per cent N as FYM

n_3 - 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer

n_4 - 100 per cent N as poultry manure

n_5 - 50 per cent N as vermicompost + 50 per cent N as chemical fertilizer

n_6 - 100 per cent N as vermicompost

n_7 - 100 per cent N as chemical fertilizer (70 kg N ha^{-1})

(Kerala Agricultural University Recommendation, 1996)

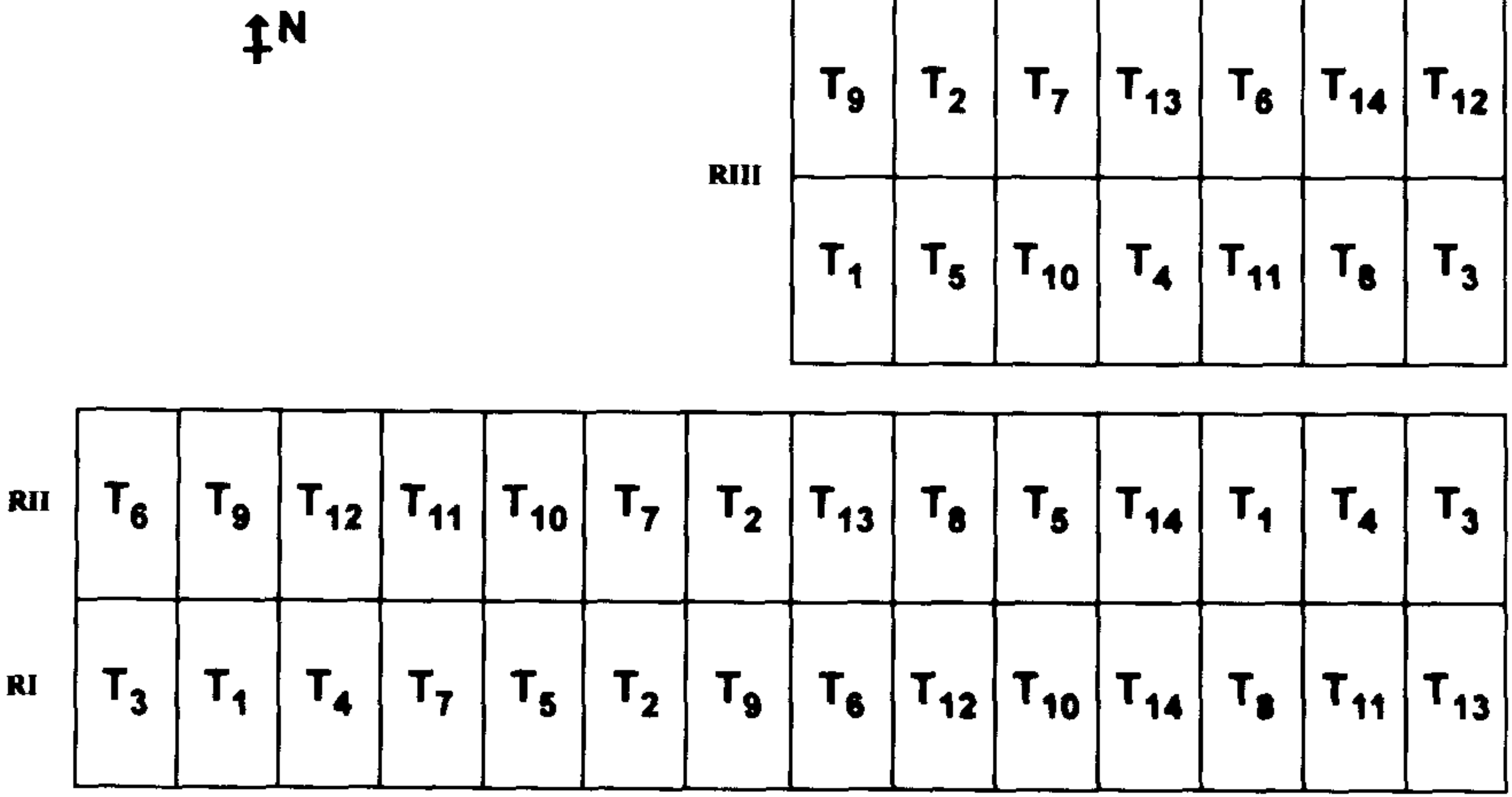

Fig. 2. Layout plan of the experiment

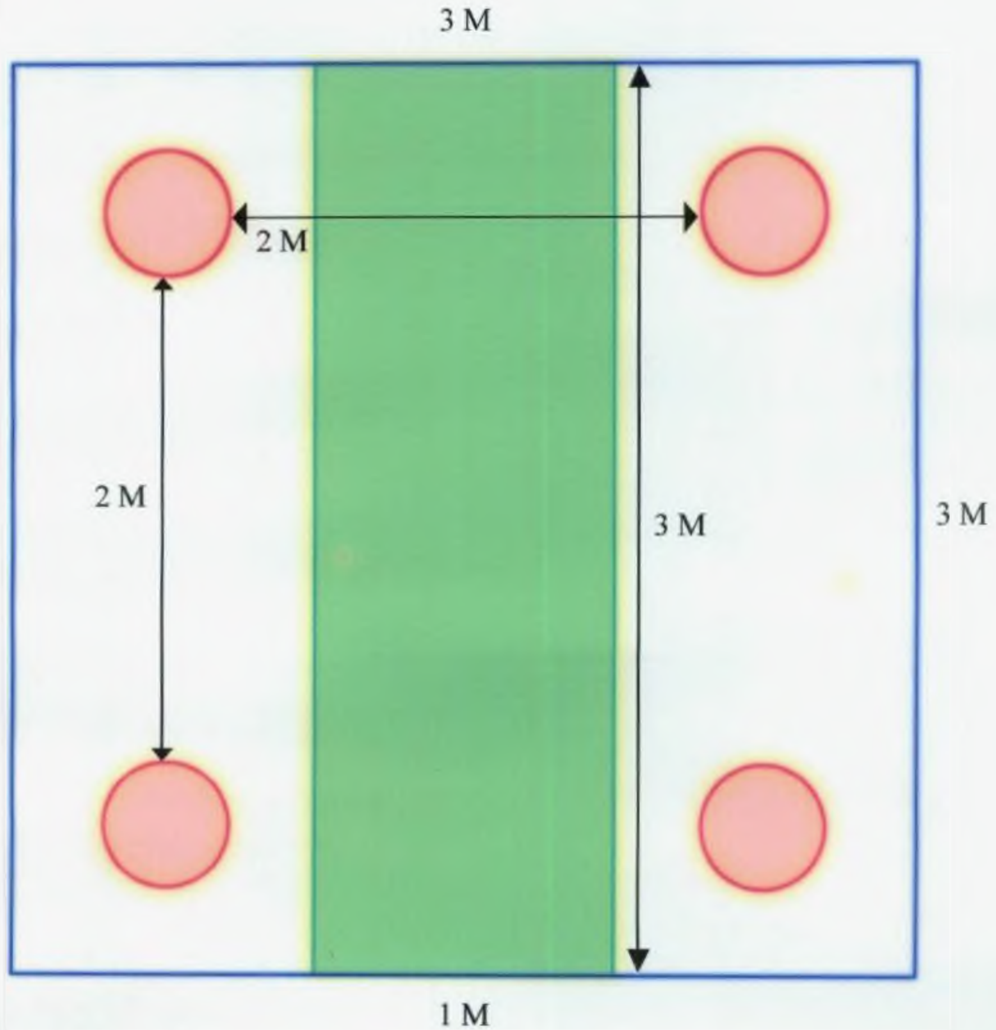

Fig. 3. Planting pattern of bittergourd - amaranthus intercropping system

Plate 1. View of the experimental field

A uniform dose of 20 t ha^{-1} FYM + 25 kg ha^{-1} each of P_2O_5 & K_2O were applied to all the plots.

II. Cropping systems

s_1 - Bittergourd (pure crop)

s_2 - Bittergourd + Amaranthus

3.2.3 Treatment Combinations

T_1 - n_1s_1 - 50 per cent N as FYM + 50 per cent N as chemical fertilizer + bittergourd

T_2 - n_1s_2 - 50 per cent N as FYM + 50 per cent N as chemical fertilizer + bittergourd + amaranthus

T_3 - n_2s_1 - 100 per cent N as FYM + bittergourd

T_4 - n_2s_2 - 100 per cent N as FYM + bittergourd + amaranthus

T_5 - n_3s_1 - 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer + bittergourd

T_6 - n_3s_2 - 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer + bittergourd + amaranthus

T_7 - n_4s_1 - 100 per cent N as poultry manure + bittergourd

T_8 - n_4s_2 - 100 per cent N as poultry manure + bittergourd + amaranthus

T_9 - n_5s_1 - 50 per cent N as vermicompost + 50 per cent N as chemical fertilizer + bittergourd

T_{10} - n_5s_2 - 50 per cent N as vermicompost + 50 per cent N as chemical fertilizer + bittergourd + amaranthus

T_{11} - n_6s_1 - 100 per cent N as vermicompost + bittergourd

T_{12} - n_6s_2 - 100 per cent N as vermicompost + bittergourd + amaranthus

T_{13} - n_7s_1 - 100 per cent N as chemical fertilizer + bittergourd

T_{14} - n_7s_2 - 100 per cent N as chemical fertilizer + bittergourd + amaranthus

3.3 FIELD CULTURE

3.3.1 Land Preparation

The experimental area was first cleaned of weeds and stubbles and laid out as per the design. Initial soil samples were taken for analysis. The individual plots were dug thoroughly and pits of 60 cm diameter and 45 cm depth were taken at 2 x 2 m spacing for sowing seeds of bittergourd. For amaranthus, raised beds (3 x 1 m) were taken in the interspaces of bittergourd.

3.3.2 Sowing

Seeds of bittergourd were soaked in water overnight and 3 seeds were sown per pit. Two healthy seedlings were retained after two weeks. Gap filling was done wherever required.

Amaranthus seeds were mixed with sand and broadcasted on beds taken in the interspaces of bittergourd. The beds were covered with coconut fronds. Sevin 50 per cent WP was sprinkled around the borders of the bed to prevent the attack of ants. Resowing was done wherever required.

3.3.3 Application of Manures and Fertilizers

For bittergourd FYM @ 20 t ha^{-1} was applied uniformly to all the pits as basal. 50 per cent and 100 per cent of recommended dose of N (70 kg ha^{-1}) in the form of FYM, poultry manure and vermicompost on N equivalent basis were applied as basal to respective pits as per the treatment and incorporated well into the soil before sowing. N, P_2O_5 and K_2O were applied in the form of urea, mussoriephos and MOP. 1/2 N was given as basal while 1/4 N was applied at the time of vining and the remaining 1/4 N at the time of full blooming.

For amaranthus, Package of Practices Recommendations of Kerala Agricultural University (1996) was adopted (FYM 50 t ha^{-1} as basal + NPK fertiliser @ 50:50:50 kg ha^{-1}).

3.3.4 After Cultivation

3.3.4.1 Bittergourd

3.3.4.1. Trailing of vines

Thin bamboo splits were fixed in each pit and vines were allowed to trail on them and tied carefully from time to time since one week after germination till they reached the pandal height.

3.3.4.1.2 Pandal making

After 15 days of sowing a pandal with casuarina poles and coir rope was erected over the entire experimental area. The pandal was firmly secured by metal wires from all the four sides.

3.3.4.1.3 Nipping off of lateral buds

Lateral buds were nipped off from time to time to avoid lateral branching till the central vine reached the pandal height.

3.3.4.1.4 Weeding and irrigation

Weeding was done at the time of fertilizer application. During the initial stages of growth, the crop was irrigated at an interval of 3-4 days. Alternate day irrigation was given during flowering and fruiting periods.

3.3.4.1.5 Plant protection

Furadan traps were set up for catching the fruit flies immediately after flowering. After fruit set the fruits were covered with paper as protection from fruit fly attack.

3.3.4.2 Amaranthus

3.3.4.2.1 Weeding and irrigation

The plots were weeded whenever required. Regular irrigation was given excluding the rainy days.

3.3.5 Harvesting

For bittergourd mature fruits were hand picked and 6 pickings were done. For amaranthus uprooting was done at 35 DAS.

3.3.6 Sampling of Plants and Fruits

Four plants were tagged for the purpose of recording biometric observations in the case of bittergourd. After the final harvest, these plants were carefully dug out to determine the plant dry weight. Fruit samples were taken from each plot from the middle harvest, dried, powdered and used to determine the iron content. Fresh fruit samples were used for organoleptic test and to estimate the ascorbic acid content.

In the case of amaranthus observations were taken from five randomly selected plants in each plot.

3.4 OBSERVATIONS

3.4.1 Growth Characters of Bittergourd

3.4.1.1 Plant Height (m)

The length of the vine was measured from the base to the growing tip of each observational plant at the time of harvest. The mean values were recorded and expressed in metre.

3.4.1.2 Number of Main Branches Plant^{-1}

The number of main branches per plant were recorded from four observational plants at the time of final harvest and mean values recorded.

3.4.1.3 Dry Matter Content (g plant^{-1})

At final harvest four sample plants were uprooted from each plot, first dried in shade and then dried in an hot air oven at 70°C. Dry weight was recorded and mean values worked out and expressed as g plant^{-1}.

3.4.2 Yield and Yield Attributes of Bittergourd

3.4.2.1 Fruit Set (%)

Fruit set was calculated by dividing the total number of fruits formed in the plant with the total number of female flowers produced in the same plant. This was worked out in four observational plants in each plot and the mean values worked out.

3.4.2.2 Number of Fruits Plant^{-1}

The per plant fruit number was calculated from the total number of fruits harvested from each of the four observational plants in each plot and mean values worked out.

3.4.2.3 Mean Weight of Single Fruit (g fruit^{-1})

From the observational plants in each plot the weight of four fruits were found out and mean worked out and expressed in g fruit^{-1}.

3.4.2.4 Fruit Yield Plant^{-1} (kg plant^{-1}) and Total Yield (t ha^{-1})

Fruit yield per plant was computed by adding the weights of fruits of each harvest in the observational plants and the mean values worked out and expressed as kg plant^{-1}.

For computing the total yield, the weight of the fruits from total harvests were noted for the observational plants from each plot at the end of the cropping season. The mean values were recorded and converted into per hectare yield.

3.4.2.5 Days to First Harvest

Days taken for the first harvest was noted in the four observational plants in each plot and mean values worked out.

3.4.2.6 Days to Final harvest

Days taken for the last harvest was noted in the observational plants in each plot and mean values were recorded.

3.4.2.7 Number of Harvests

Number of harvests that can be obtained from the observational plants in each plot was found out and the mean values recorded.

3.4.3 Quality Characters of Bittergourd

3.4.3.1 Keeping Quality of Fruit in Ambient Conditions (days)

To determine the number of days the fruits can be stored without damage for culinary purpose, 1 kg of fruit sample with fruits having uniform maturity representing each plot was kept at room temperature. Keeping quality of each lot was assessed by visual observations like change in colour, drying, decay etc.

3.4.3.2 Ascorbic Acid Content (mg 100 ml^{-1})

Fresh fruits were used to determine ascorbic acid content. For this, fruits with uniform maturity were collected from the middle harvest from each plot. The ascorbic acid content was estimated by titrimetric method (Gyorgy and Pearson, 1967).

3.4.3.3 Iron Content (%)

Fruit samples were taken from each plot from the middle harvest, dried and powdered. Iron content of fruit samples was estimated by Atomic Absorption Spectrophotometer after wet digestion of the samples using di-acid mixture as suggested by Perkin-Elmer Corporation (1982).

3.4.3.4 Organoleptic Test

The fruit samples were drawn from different treatments, cooked uniformly and subjected to organoleptic evaluation in which colour, doneness, taste, texture and odour were scored by the 10 panelists giving 1-5 score values (1-very poor, 2-poor, 3-satisfactory, 4-good, 5-excellent) and overall acceptability was computed. The data were subjected to statistical analysis.

3.4.4 Observations Recorded in Amaranthus

3.4.4.1 Plant Height at Harvest (cm)

The height of the plants were recorded from five randomly selected observational plants at harvest. The height was measured from the ground level to the apex and mean values were computed.

3.4.4.2 Number of Leaves Plant^{-1} at Harvest

Total number of leaves in each observational plant was counted at harvest and mean values were recorded.

3.4.4.3 Total Dry Matter Production (g plant^{-1})

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

3.4.4.4 Yield Hectare^{-1} (t ha^{-1})

Total weight of the leaf and stem portion 10 cm above the ground leaving woody portion were recorded for each plot and converted to per hectare basis.

3.4.5 Rooting Pattern of Bittergourd and Amaranthus

Rooting pattern of bittergourd (main crop) and amaranthus (intercrop) was studied separately and in association. The observation plants were uprooted at fortnightly intervals to study the depth of root penetration and root spread.

3.4.5.1 Depth of Root Penetration (cm)

The observation plant was uprooted and the root system was separated and cleaned. The entire length of the tap root was measured by using a thread and scale and the mean for each plot was worked out and expressed in cm.

3.4.5.2 Root Spread (cm)

The root system of the uprooted plant was spread over a plain paper. The length of the longest lateral root on both sides of the tap root was measured using a thread and scale and thus average was found out.

3.4.6 Nutrient Release Pattern of Farm Yard Manure, Poultry Manure and Vermicompost

Incubation studies were carried out to find out the nutrient release pattern of the organic manures used in the study. Three plastic pots without holes of uniform size were cleaned and dried well. 5 kg soil (passed through 2 mm sieve) each with 52 g FYM, poultry manure and vermicompost were filled in the pots. The moisture level was maintained at field capacity. Sampling was done at 0th, 30th, 60th and 90th day after incubation to assess their relative efficiency in releasing NPK from soil. Available N was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956), available P_2O_5 by Bray colorimetric method (Jackson, 1973) and available K_2O by ammonium acetate method (Jackson, 1973).

3.4.7 Plant Analysis (Bittergourd)

Plant samples at the harvest stage were analysed for nitrogen, phosphorus and potassium. The plants were chopped and dried in an air oven at 70°C for 48 hours. Samples were then ground, sieved and the required quantity of samples weighed out accurately in an electronic balance. After acid digestion, samples were analysed for the nutrient contents.

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 by vanadomolybdo phosphoric yellow colour method (Jackson, 1973) and read in a spectronic-2000 spectrophotometer. From the phosphorus content and the dry matter produced at harvest, the uptake was worked out. The potassium content in plants was estimated by using Flame photometer (Jackson, 1973). The uptake of potassium was calculated based on potassium content in plants and dry matter produced.

3.4.8 Soil Analysis

Composite soil samples were collected prior to the conduct of experiment and analysed to determine physical properties, available N, available P_2O_5 and available K_2O. After the final harvest, soil samples were taken from each pit and composited to represent the plot and analysed to determine soil physical properties such as bulk density, water holding capacity and porosity and chemical properties such as available N, available P_2O_5 and available K_2O.

Bulk density, water holding capacity and porosity were determined by the core method as described by Gupta and Dakshinamoorthi (1980). Available N in soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956), available P status by Bray colorimetric method (Jackson, 1973) and available K status by ammonium acetate method (Jackson, 1973).

3.4.9 Economics Analysis

The economics of cultivation using the treatments was worked out considering the total cost of cultivation and the prevailing market price of the produce. The net returns and benefit-cost ratio were computed as follows:

Net returns = Gross income - Cost of cultivation

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

3.4.10 Scoring of Pests and Diseases

Only fruit fly attack was noticed and scoring for the same was done. Number of fruits infested by fruit fly was noted and expressed as percentage of total number of fruits harvested.

3.4.11 Statistical Analysis

Data relating to different characters were analysed statistically by applying the technique of analysis of variance for factorial experiment in Randomised Block Design (Panse and Sukhatme, 1978). Wherever the F value was found significant, critical difference were worked out at five per cent and one per cent probability level.

RESULTS

4. RESULTS

An experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani during the period from October 2001 to January 2002 to identify sustainable nutritional practices for enhancing the yield, quality and income from bittergourd and to assess the economics of intercropping amaranthus in bittergourd. The data pertaining to amaranthus were not statistically analysed. The experimental data concerning bittergourd were subjected to statistical analysis and the results are presented here.

4.1 GROWTH CHARACTERS OF BITTERGOURD (Table 4.1)

4.1.1 Plant Height

The Table 4.1 indicates the variation in plant height due to various treatments. At the final harvest, n_3 (50 % N as poultry manure + 50 % N as chemical fertilizer) recorded the higher plant height (8.63 cm) and was on par with n_4 (8.08 cm) which were significantly superior to all the other treatments. Lowest plant heights were recorded by n_6 and n_7 (4.13 cm and 4.36 cm respectively) and were significantly inferior to all the other treatments.

Considering the two cropping systems, s_1 (pure crop of bittergourd) recorded highest plant height (6.63 cm) and was significantly superior to s_2 (bittergourd + amaranthus intercropping system) (5.77 cm).

Interaction effect of nutrient sources and cropping systems had no significant influence on plant height.

Table 4.1. Effect of nutrient sources and cropping systems on plant height, number of branches per plant and dry matter content at final harvest of bittergourd

Treatments	Plant height, m	Branches plant^{-1}	Dry matter content, g plant^{-1}
Nutrient sources			
n_1	6.14	9.73	512.98
n_2	5.56	9.31	511.41
n_3	8.63	12.41	523.24
n_4	8.08	11.79	522.48
n_5	6.51	10.27	515.67
n_6	4.13	7.28	501.97
n_7	4.36	7.60	503.54
$F_{6,26}$	68.92**	86.42**	47.01**
SE	0.21	0.21	1.21
CD	0.601	0.605	3.531
Cropping systems			
s_1	6.63	10.36	514.90
s_2	5.77	9.17	511.18
$F_{1,26}$	30.95**	57.21**	16.62**
SE	0.11	0.11	0.65
CD	0.321	0.323	1.887

** Significant at 1 per cent level

4.1.2 Number of Branches Plant^{-1}

At final harvest, n_3 recorded highest number of branches (12.41) and was significantly superior to all the other treatments. n_6 (7.28) recorded the lowest number of branches and was on par with n_7 (7.60). These two treatments were significantly inferior to all the other treatments.

Of the two cropping systems, s_1 recorded significantly higher number of branches (10.36) compared to s_2 (9.17).

No interaction effect on number of main branches per plant was observed with nutrient sources and cropping systems.

4.1.3 Dry Matter Content

The data on dry matter content at final harvest is given in the Table 4.1. Among the various nutrient sources, the combined application of poultry manure and chemical fertilizer (n_3) recorded highest dry matter content which was on par with n_4. n_6 (100% N as vermicompost) had the lowest dry matter content and was on par with POP recommendation (n_7).

Pure crop of bittergourd (s_1) recorded the highest dry matter content compared to the dry matter content in bittergourd + amaranthus intercropping system (s_2) (514.90 and 511.18 g plant^{-1} respectively).

Interaction effect of nutrient source with cropping system was not significant.

4.2 YIELD AND YIELD ATTRIBUTES OF BITTERGOURD (Tables 4.2a, 4.2b, 4.2c, 4.2d)

4.2.1 Fruit Set

Fruit setting percentage was significantly influenced by various nutrient sources. n_3 (poultry manure and fertilizer in 1:1 ratio) recorded highest fruit setting percentage and was on par with n_4 (100 % N as poultry manure) and was significantly superior to all the treatments. The lowest fruit setting percentage was recorded by n_6 (100 % N as vermicompost) which was on par with n_1 (FYM and fertilizer in 1:1 ratio) and n_7 (POP).

Table 4.2a Effect of nutrient sources and cropping systems on fruit set, number of fruits and mean weight of single fruit of bittergourd

Treatments	Fruit set, %	No. of fruits $plant^{-1}$	Mean wt. of single fruit, g
Nutrient sources			
n_1	85.44 (9.24)	21.39	189.22
n_2	86.78 (9.32)	20.74	184.19
n_3	92.28 (9.61)	25.02	213.26
n_4	91.46 (9.56)	24.41	208.49
n_5	88.85 (9.43)	22.16	196.37
n_6	83.42 (9.13)	18.14	129.55
n_7	84.91 (9.22)	18.68	145.27
$F_{6, 26}$	18.11**	40.53**	1497.76**
SE	0.04	0.41	0.82
CD	0.123	1.195	2.383
Cropping systems			
s_1	88.69 (9.42)	22.18	190.56
s_2	86.49 (9.30)	20.83	171.25
$F_{1,26}$	13.49**	18.67**	971.96**
SE	0.02	0.22	0.44
CD	0.066	0.639	1.274

** Significant at 1 per cent level ( ) Transformed mean

Table 4.2b Interaction effect of nutrient sources and cropping systems on mean weight of single fruit of bittergourd

Treatments	Mean wt. of single fruit, g
n_1s_1	202.23
n_1s_2	176.21
n_2s_1	197.04
n_2s_2	171.34
n_3s_1	225.95
n_3s_2	200.56
n_4s_1	218.91
n_4s_2	198.07
n_5s_1	202.80
n_5s_2	189.94
n_6s_1	135.73
n_6s_2	123.36
n_7s_1	151.27
n_7s_2	139.27
$F_{6,26}$	16.65**
SE	1.16
CD	3.370

** Significant at 1 per cent level

Table 4.2c Effect of nutrient sources and cropping systems on fruit yield of bittergourd

Treatments	Fruit yield, kg $plant^{-1}$	Total yield, t ha^{-1}
Nutrient sources		
n_1	4.08	10.46
n_2	3.84	9.85
n_3	5.37	13.68
n_4	5.12	13.06
n_5	4.38	11.21
n_6	2.37	6.18
n_7	2.74	6.97
$F_{6,26}$	16.71**	51.80**
SE	0.27	0.39
CD	0.799	1.143
Cropping systems		
s_1	4.33	11.07
s_2	3.64	9.33
$F_{1,26}$	10.77**	34.45**
SE	0.15	0.21
CD	0.427	0.611

** Significant at 1 per cent level

Table 4.2d Effect of nutrient sources and cropping systems on days to first harvest, days to final harvest and number of harvests of bittergourd

Treatments	Days to first harvest	Days to final harvest	Number of harvests
Nutrient sources			
n_1	48.62	97.14	5.52
n_2	49.17	97.44	5.47
n_3	48.11	96.04	5.66
n_4	48.04	96.37	5.61
n_5	48.44	96.45	5.55
n_6	49.10	98.49	5.30
n_7	49.41	98.17	5.35
$F_{6, 26}$	1.06	2.72*	12.22**
SE	0.52	0.57	0.04
CD	-	1.654	0.110
Cropping systems			
s_1	48.26	97.51	5.53
s_2	49.13	96.80	5.45
$F_{1, 26}$	4.88*	2.74	8.28**
SE	0.28	0.30	0.02
CD	0.813	-	0.059

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

Pure crop of bittergourd (s_1) recorded the highest fruit setting percentage and was significantly superior to bittergourd + amaranthus intercropping system (s_2).

No interaction effect was observed with nutrient sources and cropping systems.

4.2.2 Number of Fruits Plant^{-1}

Various nutrient sources had significant influence on number of fruits per plant. It was found that highest number of fruits per plant was obtained from the treatment n_3 (25.02) which was on par with n_4 (24.41). These two nutrient sources were significantly superior to n_1, n_2, n_5, n_6 and n_7. Lowest number of fruits per plant was produced by n_6 (18.14) which was on par with n_7 (18.68).

With the two cropping systems, significant difference in number of fruits per plant was observed. s_1 recorded highest number of fruits per plant of 22.18 and was significantly superior to s_2 (20.83).

Interaction effect of nutrient sources and cropping systems had no significant influence on number of fruits per plant.

4.2.3 Mean Weight of Single Fruit

The different nutrient sources had significant influence on the mean weight of single fruit. n_3 (50 per cent N as poultry manure + 50 per cent N as chemical fertilizer) recorded the highest fruit weight of 213.26 g and was significantly superior to all the other nutrient sources. The lowest fruit weight of 129.55 g was recorded by n_6 (100 per cent N as vermicompost) and was significantly inferior to all the other treatments.

The fruit weight was significantly high when bittergourd was grown as a pure crop (190.56 g). Bittergourd + amaranthus intercropping system recorded a lower fruit weight (171.25 g).

Interaction effect was significant between nutrient sources and cropping systems. n_3s_1 recorded the highest fruit weight (225.95 g) which was significantly superior to all the other treatments. The lowest fruit weight was recorded by n_6s_2 (123.36 g) which was significantly inferior to all the other treatments.

4.2.4 Fruit Yield Plant^{-1}

Fruit yield per plant was markedly high in the treatment n_3 (5.37 kg) and was significantly superior to all the other treatments except n_4 (5.12 kg) which were on par. The fruit yield was lowest for n_6 (2.37 kg) which was on par with n_7 (2.74 kg) and these treatments were significantly inferior to all the other treatments.

In the case of the two cropping systems, s_1 recorded a higher yield (4.33 kg) compared to s_2 (3.64 kg).

Interaction effect of nutrient sources with cropping systems had no significant effect on fruit yield per plant.

4.2.5 Total Yield

Significant difference in yield was noticed with various nutrient sources. Treatment n_3 recorded the highest fruit yield of 13.68 t ha^{-1} and was on par with n_4 (13.06 t ha^{-1}). These two treatments were significantly superior to all the other treatments. The yield was markedly low for n_6 (6.18 t ha^{-1}) and was on par with n_7 (6.97 t ha^{-1}). These treatments were significantly inferior to all the other treatments.

The cropping systems had a significant influence on the yield of bittergourd. Pure crop of bittergourd (s_1) recorded the highest fruit yield (11.07 t ha^{-1}) and was significantly superior to bittergourd + amaranthus intercropping system (s_2).

Interaction effect of nutrient sources with cropping systems was not significant.

4.2.6 Days to First Harvest

There was no significant difference among the various nutrient sources in influencing days to first harvest.

Of the two cropping systems, earliness to first harvest was shown by s_1 (48.26 days) compared to s_2 (49.13 days).

Interaction effect of nutrient source with cropping system was not significant.

4.2.7 Days to Final Harvest

The different nutrient sources had significant influence on days to final harvest of bittergourd. The days to final harvest was more for n_6 (98.49 days) which was on par with n_1 (97.14 days), n_2 (97.44 days) and n_7 (98.17 days).

Days required for the final harvest was not under the influence of cropping systems or interaction effects of nutrient sources and cropping systems.

4.2.8 Number of Harvests

The number of harvests was lowest in n_6 (5.30) closely followed by n_7 (5.35) which were on par and were significantly inferior to all the other treatments. Highest number of harvests was recorded by n_3 (5.66) which was on par with n_4 (5.61) and n_5 (5.55).

In the case of cropping systems, s_1 (5.53) was significantly superior to s_2 (5.45).

Interaction effect of nutrient source with cropping system had no significant influence on number of harvests.

4.3 QUALITY CHARACTERS OF BITTERGOURD (Tables 4.3a and 4.3b)

4.3.1 Keeping Quality of Fruit in Ambient Conditions

The keeping quality was significantly influenced by various nutrient sources. The treatment n_6 recorded the maximum keeping quality (4.69 days) and was on par with n_4 (4.64 days) and n_2 (4.52 days). POP recommendation (n_7) recorded the lowest keeping quality of 3.19 days.

The two cropping systems had no influence on the keeping quality of fruits. Interaction effect of nutrient source and cropping systems had no significant effect on keeping quality.

4.3.2 Ascorbic Acid Content

The results on the ascorbic acid content of fruits are presented in Table 4.3.a. There was significant difference among the nutrient sources in influencing the ascorbic acid content of fruits. The highest value was recorded for n_3 (166.97 mg 100 ml^{-1}) which was significantly superior to all the other treatments. The next highest was recorded by the treatment n_4 (164.20 mg 100 ml^{-1}). The lowest content was shown by the treatment n_7 (149.00 mg 100 ml^{-1}) which was significantly inferior to all the other treatments.

Table 4.3a Effect of nutrient sources and cropping systems on keeping quality, ascorbic acid content and iron content of bittergourd fruits

Treatments	Keeping quality, days	Ascorbic acid content, mg 100 ml^{-1}	Iron content, %
Nutrient sources			
n_1	3.92	155.67	0.08
n_2	4.52	152.12	0.07
n_3	4.02	166.97	0.11
n_4	4.64	164.20	0.10
n_5	4.06	162.04	0.09
n_6	4.69	155.17	0.08
n_7	3.19	149.00	0.06
$F_{6,26}$	15.03**	174.11**	5.71**
SE	0.14	0.50	0.01
CD	0.394	1.462	0.021
Cropping systems			
s_1	4.16	157.99	0.08
s_2	4.13	157.77	0.08
$F_{1,26}$	0.07	0.25	0.07
SE	0.07	0.27	0.00
CD	-	-	-

** Significant at 1 per cent level

Table 4.3b Organoleptic test

Treatments	Rank means				
	Appearance	Doneness	Bitterness	Texture	Odour
n_1	22.00	25.95	31.10	28.70	29.35
n_2	15.70	29.40	33.95	38.10	39.70
n_3	46.95	47.90	28.80	31.30	32.80
n_4	33.00	45.95	44.80	44.80	43.15
n_5	50.30	33.25	36.80	28.70	36.25
n_6	30.25	32.80	47.10	45.70	46.60
n_7	50.30	33.25	25.95	31.20	20.65
Kisqr for 6	31.41**	10.67	10.83	9.41	14.78*
Critical value	17.84	17.84	17.84	17.84	17.84

Main effects of cropping systems or the interaction effect of nutrient sources and cropping systems did not influence the ascorbic acid content of bittergourd.

4.3.3 Iron Content

The result revealed that n_3 registered highest iron content (0.11 per cent) which was on par with n_4 and n_5. The lowest iron content of 0.06 per cent was registered by POP recommendation (n_7).

The two cropping systems as well as the interaction effects had little influence on the iron content of bittergourd.

4.3.4 Organoleptic Test

The results on organoleptic test are given in the Table 4.3.b. In the case of appearance the highest rank means were shown by the treatments n_5 (50 per cent N as vermicompost + 50 per cent N as chemical fertilizer) and n_7 (POP recommendation). The lowest rank mean was shown by n_2 (100 per cent N as

FYM). For the character doneness, the highest rank value was shown by the treatment n_3 and the lowest by n_1. In the case of bitterness, texture and odour the highest rank mean was shown by the treatment n_6 (100 per cent N as vermicompost). The lowest rank mean for bitterness and odour was shown by the treatment n_7 and the lowest rank for texture was shown by the treatments n_1 and n_5.

4.4 PLANT ANALYSIS OF BITTERGOURD (Tables 4.4a and 4.4b)

4.4.1 Content of N, P and K

4.4.1.1 Nitrogen Content of Plants

The highest plant nitrogen content was recorded by the treatment n_3 (2.03 per cent) which was significantly superior to all the other treatments. The next highest plant nitrogen content was recorded by the treatment n_5 (1.89 per cent) which was on par with n_1 (1.88 per cent). The lowest plant nitrogen content was recorded by the treatment n_6 (0.99 per cent).

The two cropping system had little effect on the plant nitrogen content. Interaction effects of nutrient sources and cropping systems had no significant effect on plant nitrogen content.

4.4.1.2 Phosphorus Content of Plants

It was found that the P content of plants was highest for n_3 (0.34 per cent) which was on par with n_1, n_2, n_4 and n_5. The lowest P content was shown by the treatment n_6 (0.19 per cent) which was on par with n_7.

Table 4.4a Effect of nutrient sources and cropping systems on plant nutrient content of bittergourd

Treatment	N, %	P, %	K, %
Nutrient sources			
n_1	1.88	0.32	2.37
n_2	1.62	0.30	2.35
n_3	2.03	0.34	2.44
n_4	1.63	0.31	2.41
n_5	1.89	0.32	2.42
n_6	0.99	0.19	1.64
n_7	1.53	0.21	1.82
$F_{6,26}$	66.46**	17.29**	111.06**
SE	0.04	0.01	0.03
CD	0.122	0.041	0.091
Cropping systems			
s_1	1.66	0.28	2.20
s_2	1.64	0.28	2.20
$F_{1,26}$	0.20	0.16	0.01
SE	0.02	0.01	0.02
CD	-	-	-

** Significant at 1 per cent level

Table 4.4b Effect of nutrient sources and cropping systems on plant nutrient uptake of bittergourd

Treatments	N, kg ha^{-1}	P, kg ha^{-1}	K, kg ha^{-1}
Nutrient sources			
n_1	24.11	4.04	30.33
n_2	20.65	3.77	29.98
n_3	26.36	4.38	31.85
n_4	21.23	3.98	31.41
n_5	24.36	4.22	31.13
n_6	12.42	2.39	20.58
n_7	19.26	2.58	22.91
$F_{6,26}$	78.78**	19.41**	142.43**
SE	0.52	0.18	0.38
CD	1.502	0.530	1.116
Cropping systems			
s_1	21.35	3.68	28.41
s_2	21.05	3.57	28.21
$F_{1,26}$	0.58	0.59	0.48
SE	0.28	0.10	0.21
CD	-	-	-

** Significant at 1 per cent level

There was no significant difference between the two cropping systems in influencing the phosphorus content of plants. No interaction effect was noticed.

4.4.1.3 Potassium Content of Plants

The results revealed that highest potassium content was recorded by the treatment n_3 (2.44 per cent) which was on par with n_1, n_2, n_4 and n_5. The lowest potassium content was recorded by the treatment n_6 (1.64 per cent). POP recommendation (n_7) recorded a potassium content of 1.82 per cent.

The effects of cropping systems in influencing the potassium content of plants were found to be non-significant. Interaction effects of nutrient sources with cropping systems in influencing the potassium content of plants were also found to be non-significant.

4.4.2 Uptake of N, P and K

4.4.2.1 Nitrogen Uptake

Nitrogen uptake by plants was profoundly influenced by various nutrient sources. Highest N uptake was noticed for the treatment n_3 (26.36 kg ha^{-1}) and was significantly superior to all other treatments. The lowest N uptake was noticed for the treatment n_6 (12.42 kg ha^{-1}) which was significantly inferior to all other treatments.

The two cropping systems as well as the interaction effects had no significant influence on plant N uptake.

4.4.2.2 Phosphorus Uptake

The phosphorous uptake of plants was significantly influenced by various nutrient sources. It was noted that n_3 recorded highest phosphorus uptake by plants (4.38 kg ha^{-1}) and was on par with n_1, n_4 and n_5. The lowest phosphorus uptake was shown by n_6 (2.39 kg ha^{-1}). POP recommendation (n_7) recorded a phosphorus uptake of 2.58 kg ha^{-1}.

Main effects of cropping systems and the interaction effect of nutrient sources and cropping systems had no influence on the P uptake by plants.

4.4.2.3 Potassium Uptake

Potassium uptake was markedly influenced by the different nutrient sources n_3 recorded highest K uptake (31.85 kg ha^{-1}) closely followed by n_4 (31.41 kg ha^{-1}) and n_5 (31.13 kg ha^{-1}). n_3 was significantly superior to all the treatments except n_4 and n_5 which were on par. The lowest K uptake was recorded by the treatment n_6 (20.58 kg ha^{-1}) which was significantly inferior to all other treatments.

The effects of two cropping systems and the interaction effects did not influence the plant K uptake.

4.5 OBSERVATIONS RECORDED IN AMARANTHUS (Tables 4.5)

Table 4.5 indicates the observations taken in amaranthus viz., plant height, number of leaves for plant, total dry matter production and yield.

4.6 SOIL PHYSICO-CHEMICAL PROPERTIES (Tables 4.6a and 4.6b)

4.6.1 Physical Properties

4.6.1.1 Bulk Density

All the treatments under the nutrient sources recorded a lower bulk density compared to the initial value of 1.41 g cc^{-1}. The lowest bulk density was shown by n_4 n_2 and n_6 (1.31 g cc^{-1}).

Table 4.5 Observations recorded in amaranthus

Treatments	Plant height, cm	No. of leaves per plant	Total DMP, g plant^{-1}	Yield, t ha^{-1}
T_2	52.19	32.15	5.13	18.33
T_4	52.61	32.52	5.39	18.72
T_6	51.95	32.03	4.85	17.78
T_8	52.13	32.10	5.01	17.83
T_{10}	52.32	32.31	5.16	18.33
T_{12}	52.15	32.17	5.13	17.61
T_{14}	51.81	31.96	4.78	17.72

Table 4.6a Effect of nutrient sources and cropping systems on soil physical properties

Treatments	Bulk density, g cc^{-1}	Water holding capacity, %	Porosity, %
Nutrient sources			
n_1	1.33	32.80	42.35
n_2	1.31	35.06	44.21
n_3	1.34	32.79	42.37
n_4	1.31	35.17	44.13
n_5	1.34	32.75	42.25
n_6	1.31	35.18	44.34
n_7	1.40	31.11	41.05
$F_{6,26}$	72.98**	115.33**	50.60**
SE	0.00	0.15	0.18
CD	0.010	0.433	0.519
Cropping systems			
s_1	1.33	33.55	42.95
s_2	1.33	33.55	42.96
$F_{1,26}$	0	0.03	0
SE	0.00	0.08	0.10
CD	-	-	-

** Significant at 1 per cent level

Table 4.6b Effect of nutrient sources and cropping systems on soil NPK status

Treatments	N, kg ha^{-1}	P, kg ha^{-1}	K, kg ha^{-1}
Nutrient sources			
n_1	272.29	49.24	161.41
n_2	279.98	48.82	160.93
n_3	272.38	48.75	160.35
n_4	277.56	49.14	161.25
n_5	268.20	48.18	161.78
n_6	285.72	48.66	170.97
n_7	277.98	48.81	167.53
$F_{6,26}$	4.62**	0.02	16.13**
SE	2.71	2.34	1.02
CD	7.883	-	2.970
Cropping systems			
s_1	276.34	48.66	163.34
s_2	276.27	48.93	163.58
$F_{1,26}$	0	0.02	0.10
SE	1.45	1.25	0.55
CD	-	-	-

** Significant at 1 per cent level

The two cropping systems and the interaction effects of nutrients sources and cropping systems had no significant influence on bulk density of soil.

4.6.1.2 Water Holding Capacity

The different nutrient sources significantly influenced the water holding capacity of the soil wherein it was higher than the initial value of 30.87 per cent. Maximum water holding capacity was recorded with n_6 (35.18 per cent) followed by n_4 (35.17 per cent) and then n_2 (35.06 per cent). However n_6 was on par with n_4 and n_2.

The main effects of two cropping systems and the interaction effect of nutrient source and cropping system did not influence the water holding capacity of soil.

4.6.1.3 Porosity

All the nutrient sources produced h gher porosity as compared to the initial value of 40.72 per cent. The maximum porosity was recorded for the treatment n_6 (44.34 per cent) which was on par with n_2 (44.21 per cent) and n_4 (44.13 per cent).

Neither the main effects of cropping systems nor the interaction effect influence the porosity of the soil.

4.6.2 Chemical Properties

4.6.2.1 Available Nitrogen

With regard to available N status of soil, highest value was obtained for the treatment n_6 (285.72 kg ha^{-1}) which was on par with n_2 and n_7 and these treatments were significantly superior to all other treatments. The lowest value was for n_5 (268.20 kg ha^{-1}) which was on par with n_1 and n_3.

The main effects of two cropping systems had no significant influence on the available N status of soil. Interaction effect of nutrient source and cropping systems also had no influence on available N status of soil.

4.6.2.2 Available Phosphorus

The available P status of the soil was not under the influence of various nutrient sources or cropping systems or their interaction effects.

4.6.2.3 Available Potassium

Available K in soil was highest for the treatment n_6 (170.97 kg ha^{-1}) which was significantly superior to all other treatments. Available K in soil was lowest for the treatment n_3 (160.35 kg ha^{-1}) which was on par with n_1, n_2, n_4 and n_5.

The two cropping systems had little effect on available K of soil. Interaction effects had no significant influence on the available K of soil.

4.7 ROOTING PATTERN OF BITTERGOURD AND AMARANTHUS

4.7.1. Depth of Root Penetration

The results on depth of root penetration is shown on Fig. 4. The depth of root penetration was not affected by intercropping in bittergourd and amaranthus. The root penetration depth were almost same under sole cropping and intercropping situation for both the crops.

4.7.2. Root Spread

The results on root spread is shown on Fig. 5. In the case of bittergourd, root spread was almost same under sole cropping and intercropping. For amaranthus, the root spread was more when grown as an intercrop compared to sole cropping.

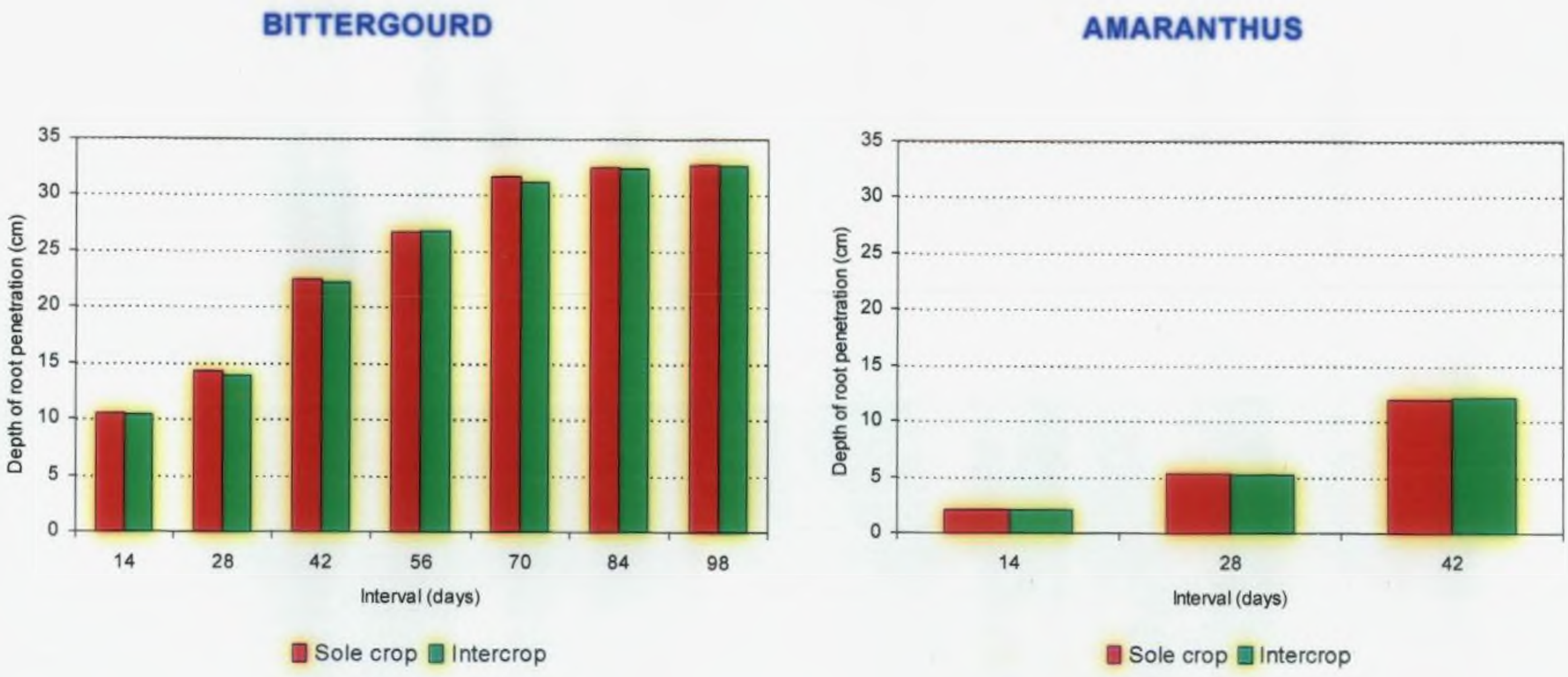

Fig. 4. Depth of root penetration (cm) of bittergourd and amaranthus

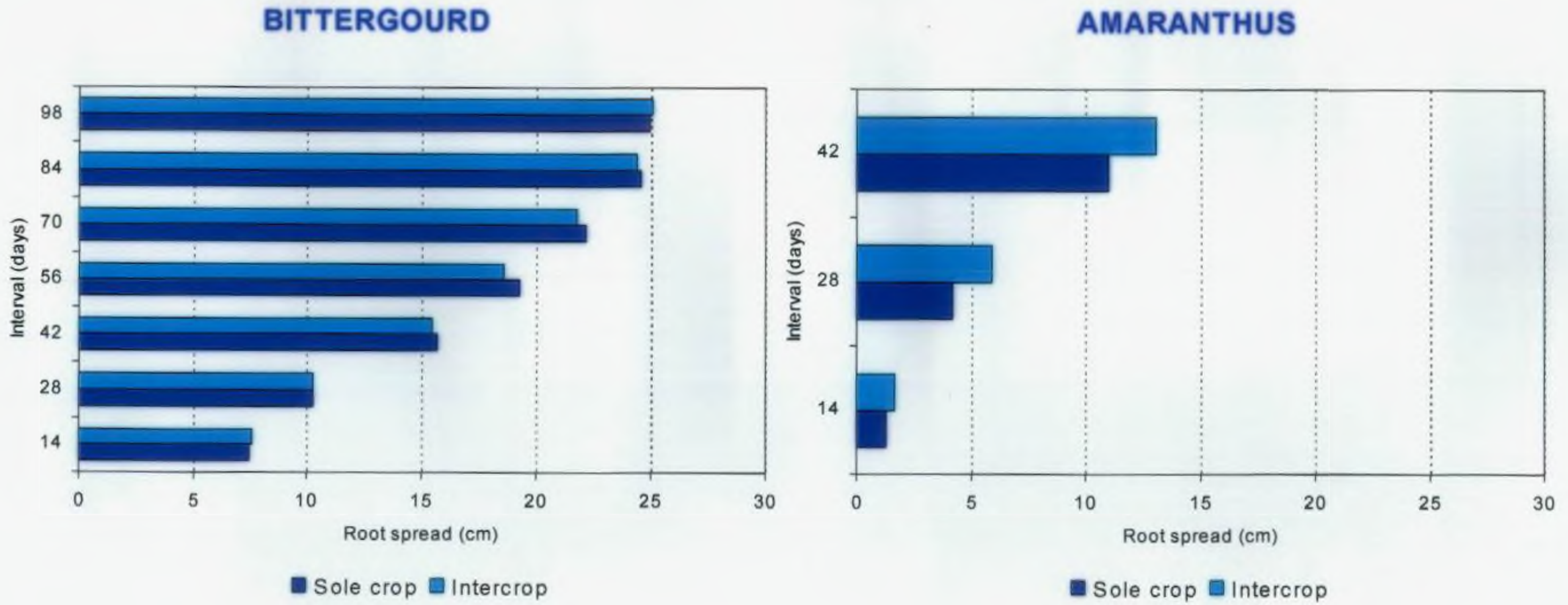

Fig. 5. Root spread (cm) of bittergourd and amaranthus

4.8 NUTRIENT RELEASE PATTERN OF FYM, POULTRY MANURE AND VERMICOMPOST

The results on nutrient release pattern of the organic manures are shown in Fig. 6, Fig. 7 and Fig. 8. In the case of nitrogen there was progressive increase in the availability from 0th to 90th day for FYM, poultry manure and vermicompost. Of the three organic manures, the availability of nitrogen was more for poultry manure. Similar results were obtained for available P_2O_5. In the case of available K_2O for all the three organic manures there was a progressive increase upto the 60 th day and thereafter decreased. However, of the three organic manures poultry manure showed higher availability of K_2O.

4.9 ECONOMIC ANALYSIS (Table 4.9)

4.9.1. Net Returns

The data showed that among the various nutrient sources, application of poultry manure and chemical fertilizer in 1:1 ratio (n_3) registered the maximum net profit of Rs. 166499.13 ha^{-1} and was significantly superior to all other treatments.

The two cropping systems had a significant influence on the net return from the system. Intercropping (s_2) gave significantly higher net returns than sole cropping (s_1).

Interaction effect of nutrient sources with cropping systems had no significant effect on net returns from the system.

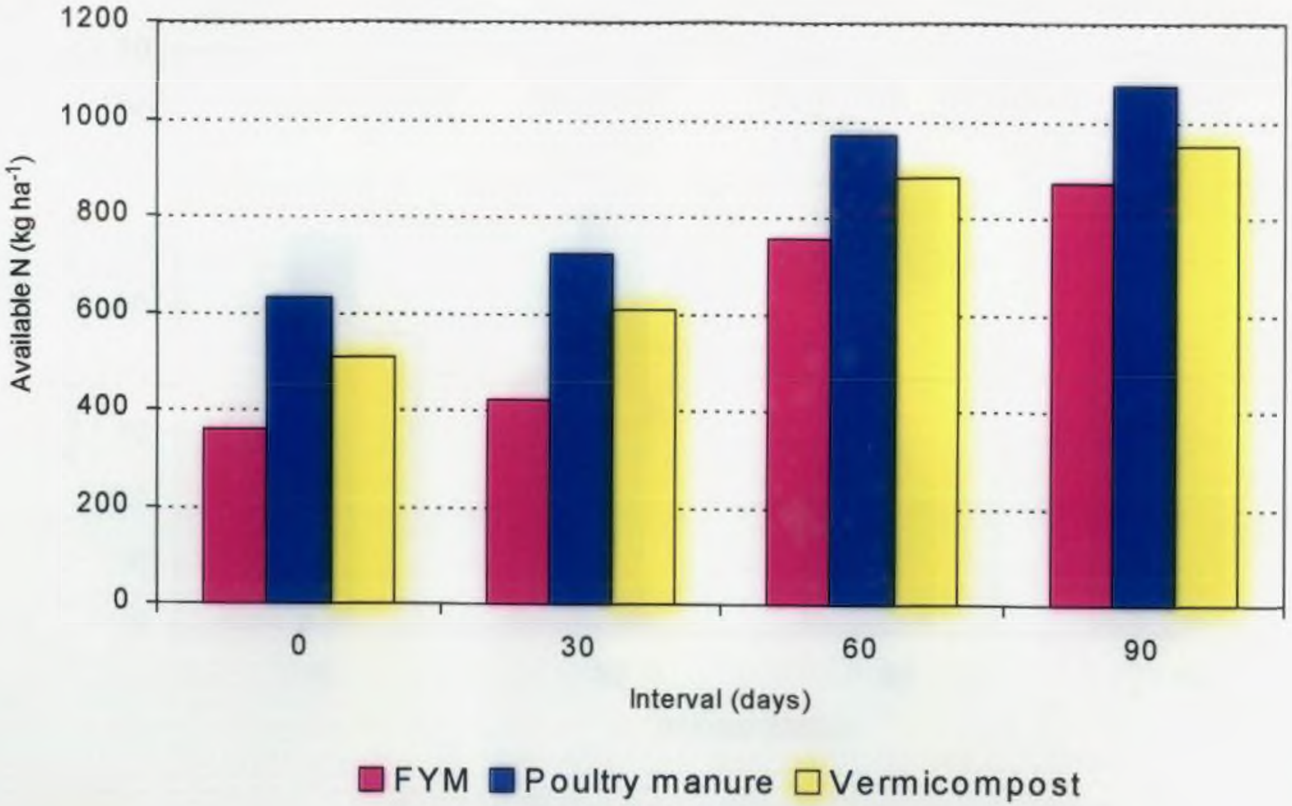

Fig. 6. Nutrient release pattern of FYM, poultry manure and vermicompost - Available N (kg ha^{-1})

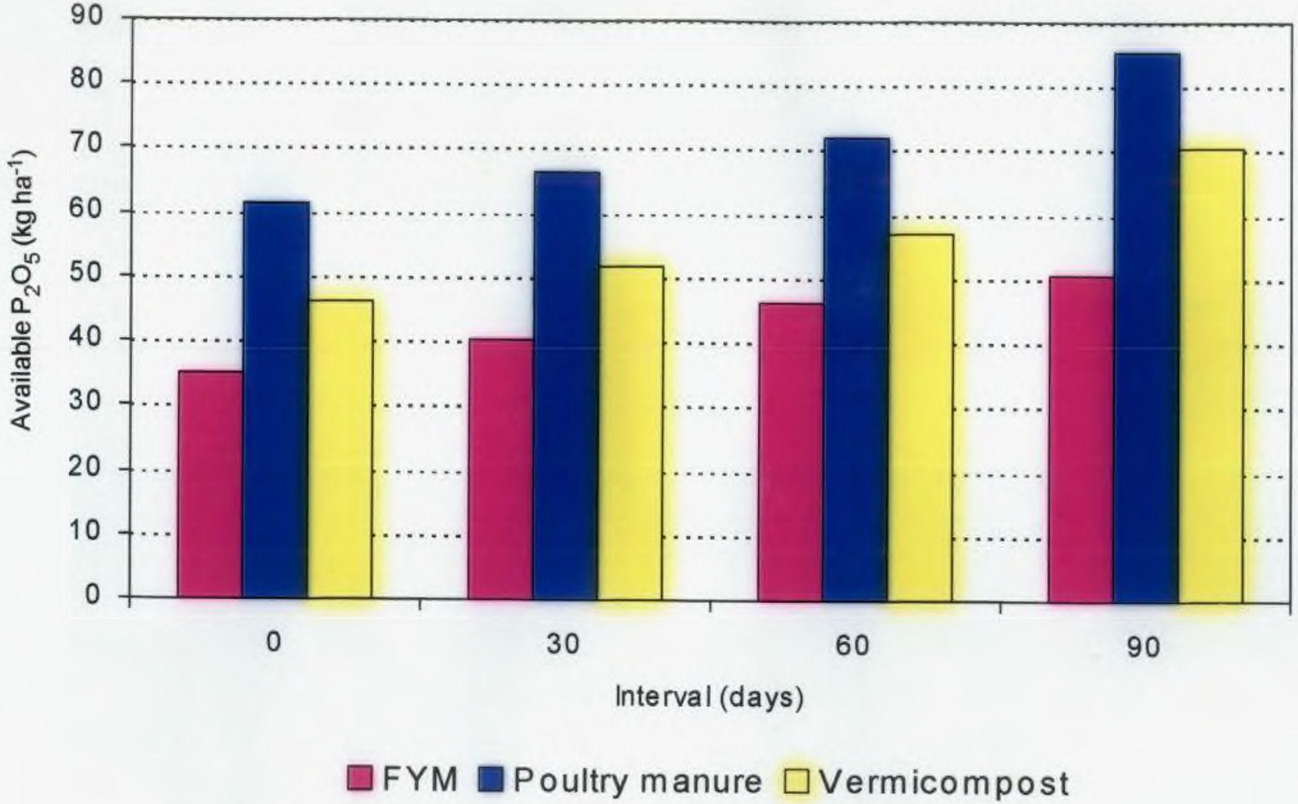

Fig. 7. Nutrient release pattern of FYM, poultry manure and vermicompost - Available P_2O_5 (kg ha^{-1})

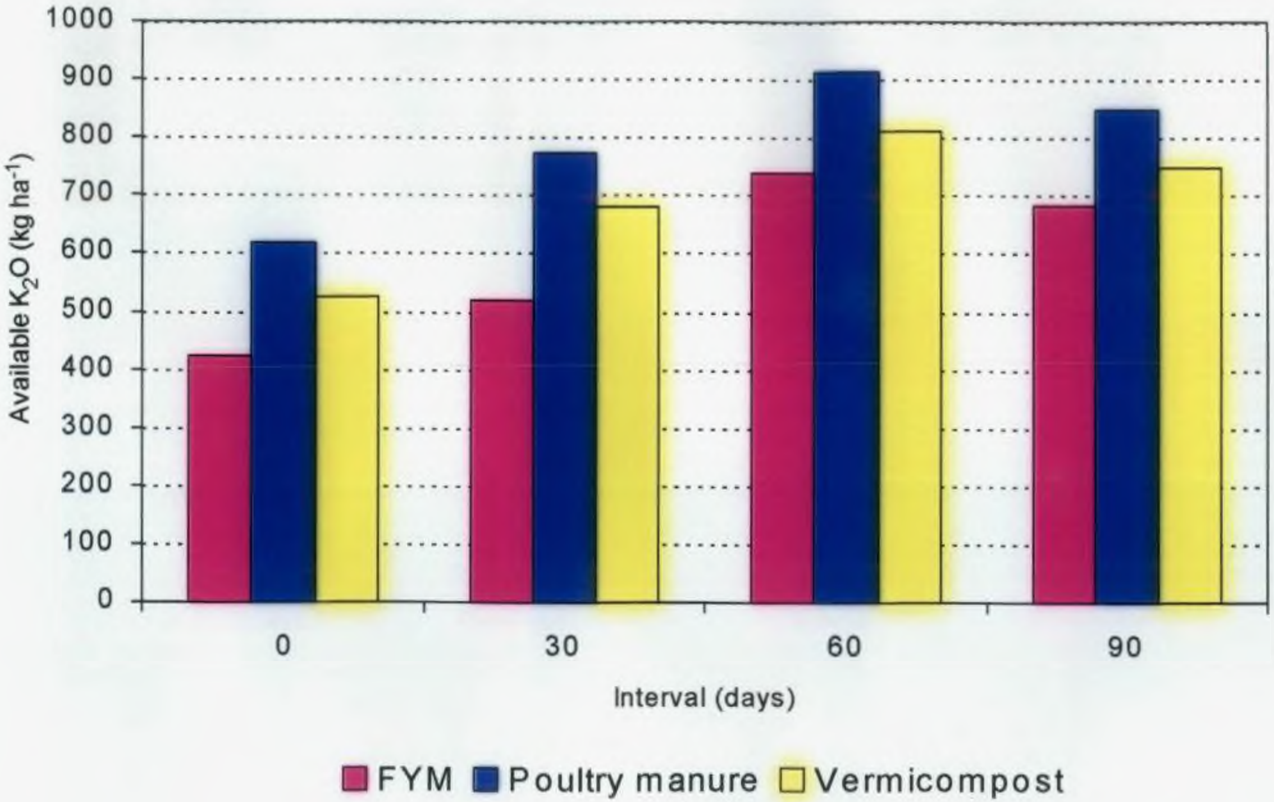

Fig. 8. Nutrient release pattern of FYM, poultry manure and vermicompost - Available K_2O (kg ha^{-1})

Table 4.9 Effect of nutrient sources and cropping systems on net returns and benefit-cost ratio of bittergourd - amaranthus intercropping system

Treatments	Net returns, Rs. ha^{-1}	BCR
Nutrient sources		
n_1	128934.97	3.07
n_2	120874.97	2.86
n_3	166499.13	3.75
n_4	157873.30	3.54
n_5	133384.97	2.99
n_6	64594.97	1.82
n_7	87093.30	2.40
$F_{6,26}$	45.80**	53.88**
SE	5380.41	0.09
CD	15644.201	0.260
Cropping system		
s_1	79964.37	2.55
s_2	165537.23	3.29
$F_{1,26}$	442.67**	120.40**
SE	2875.95	0.05
CD	8362.177	0.139

** Significant at 1 per cent level

Cost of inputs

Cost of nitrogen	=	Rs. 11 kg^{-1}
Cost of phosphorus	=	Rs. 26 kg^{-1}
Cost of potassium	=	Rs. 9.50 kg^{-1}
Cost of FYM	=	Rs.360 t^{-1}
Cost of poultry manure	=	Rs. 1.25 kg^{-1}
Cost of vermicompost	=	Rs. 3 kg^{-1}

Cost of produce

Bittergourd	=	Rs. 12 kg^{-1}
Amaranthus	=	Rs.7 kg^{-1}

4.9.2. Benefit-Cost Ratio

With respect to B:C ratio, application of 50 per cent N as poultry manure and 50 per cent as chemical fertilizer recorded the highest benefit-cost ratio (3.75) and was on par with that recorded by 100 per cent N as poultry manure (3.54) and was significantly superior to all other treatments. Lowest B:C ratio was registered for the treatment 100 per cent N as vermicompost (1.82) which was significantly inferior to all the other treatments.

Of the two cropping systems, intercropping (s_2) gave a higher B:C ratio of 3.29 and was significantly superior to sole cropping (s_1) which gave a B:C ratio of 2.55.

No interaction effect of nutrient sources with cropping systems was noticed.

4.10 SCORING OF FRUIT FLY INFESTATION IN BITTERGOURD (Table 4.10)

Main effects of nutrient sources or cropping systems or their interaction effects could not significantly influence the fruit fly infestation in bittergourd.

Table 4.10 Effect of nutrient sources and cropping systems on fruit fly infestation in bittergourd

Treatments	Fruit fly infestation, %
Nutrient sources	
n_1	15.13 (3.89)
n_2	14.96 (3.87)
n_3	15.00 (3.87)
n_4	14.27 (3.78)
n_5	14.48 (3.81)
n_6	15.05 (3.88)
n_7	15.06 (3.88)
$F_{6,26}$	0.30
SE	0.08
CD	-
Cropping systems	
s_1	14.94 (3.87)
s_2	14.76 (3.84)
$F_{1,26}$	0.14
SE	0.04
CD	-

( ) Transformed mean

DISCUSSION

5. DISCUSSION

The results of the experiment conducted to find out sustainable nutritional practice for enhancing the yield, quality and income from bittergourd and to evaluate the economic feasibility of inter cropping amaranthus in bittergourd are discussed.

5.1 GROWTH CHARACTERS OF BITTERGOURD

The results of the study indicated that there is significant influence of nutrient sources on the growth characters of bittergourd like plant height, number of branches per plant and dry matter content. The maximum height was recorded by the application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer which was on par with the application of 100 per cent N as poultry manure. In the case of dry matter content also same trend was noticed. For number of branches per plant, poultry manure and chemical fertilizer in 1:1 ratio recorded the highest value. By the integrated application of chemical fertilizer and poultry manure, more of nitrogen may be in the readily available form and only a part may be in the slowly available form. Influence of nitrogen in increasing the vegetative growth of the plant is universally accepted. This increased growth characters may be due to the increased availability of nitrogen from chemical fertilizers. Increased nitrogen level increased the growth characters as reported by Joseph (1982). Enhanced plant growth with the combined application of poultry manure and inorganic fertilizer has been observed by Jose *et al.* (1988) in brinjal. Similar result was reported in chilli by Sharu (2000). Poultry manure is a good source of nutrient particularly for vegetable production. In this manure, 60 per cent of N is present as uric acid, 30 per cent as more stable organic nitrogen form and the balance as mineral nitrogen

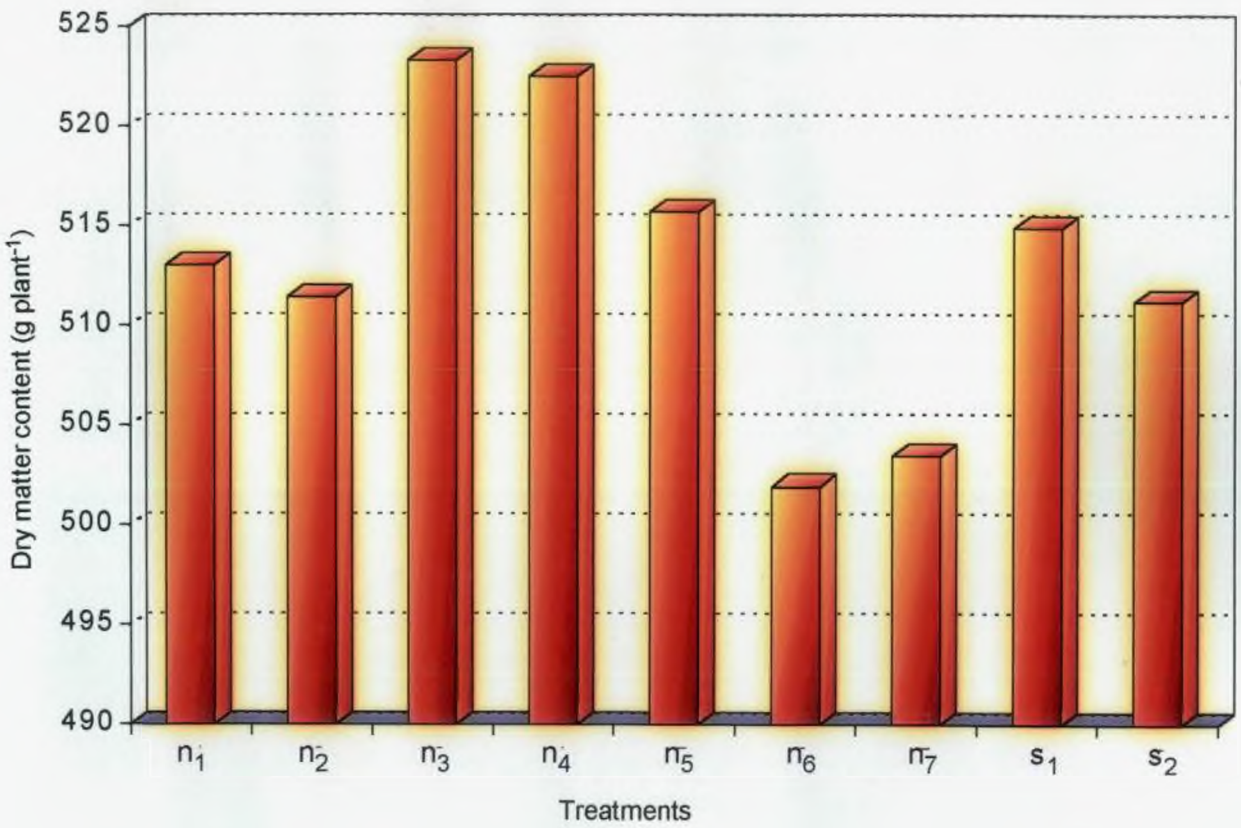

Fig. 9. Dry matter content - main effects of nutrient sources and cropping systems

(Srivastava, 1988). Unlike chemical fertilizers, the nutrients in poultry manure are readily available within a period of 2 to 3 months and are less susceptible to leaching loss. Therefore it could be presumed that these available forms of nitrogen released during the peak nitrogen requirement stages of the crop could have resulted in increased growth characters. Improved growth due to poultry manure application was also reported by Anitha (1997) in chilli, Raj (1999) in bhindi and Arunkumar (2000) in amaranthus.

The two cropping systems also had a significant influence on the growth characters of bittergourd. The growth characters like plant height, number of branches per plant and dry matter content were higher for sole cropped bittergourd compared to bittergourd - amaranthus intercropping system. This may be due to the competition for water and nutrients between bittergourd and amaranthus. It could be also due to the dominant nature of amaranthus as suggested by Ikeorgu (1990). The influence of intercrops in suppressing the growth of main crop was reported by Olasantan (1991) in bhindi + cowpea intercropping system and Anitha (1995) in chilli + amaranthus intercropping system.

5.2 YIELD AND YIELD ATTRIBUTES OF BITTERGOURD

The scanning of the data presented in Tables 4.2.a and 4.2.c revealed the superiority of the treatment poultry manure and chemical fertilizer in 1:1 ratio on fruit setting percentage, number of fruits per plant, fruit yield per plant and total yield. This treatment was on par with the application of 100 per cent N as poultry manure. In the case of integrated application of chemical fertilizer and poultry manure, there is increased supply of nitrogen to the plants. In poultry manure, the nitrogen mineralised during the first two-three months of the application, 80 per cent is converted to NO^-_3 at the end of first three weeks (Tisdale *et al.*, 1995). This might have resulted in better availability and uptake of nutrients which might have resulted in increased yield and yield attributes. The beneficial effect of the combination of chemical fertilizer and poultry manure in the ratio 1:1 in

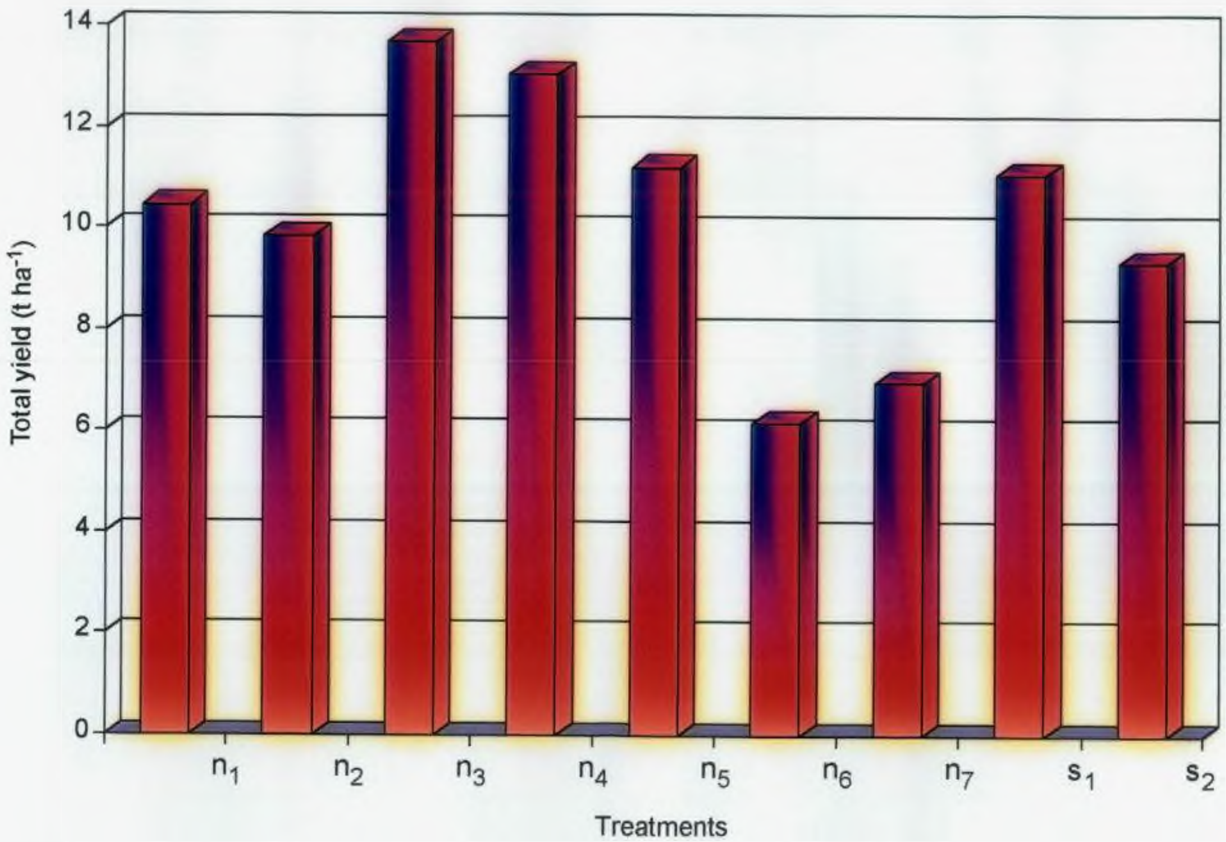

Fig. 10. Total yield - main effects of nutrient soucres and cropping systems

increasing yield parameters in brinjal were reported by Rekha (1999). This is in agreement with the findings of Singh *et al.* (1973), Ifenkwe *et al.* (1987) in potato and Jose *et al.* (1988) in brinjal. Singh *et al.* (1973) attributed higher efficiency of poultry manure due to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen. Rapid conversion of uric acid present in poultry manure may be one of the reason for higher yield recorded by poultry manure (Smith, 1950). Therefore poultry manure which contains more nitrogen in a utilizable form could have resulted in better utilisation of this nutrient and improvement in soil properties which might have contributed to the increase in yield and yield attributes. Superiority of poultry manure in producing higher number of fruits and fruit yield per plot was opined by Mina (1986) in musk melon.

The mean weight of fruit, was also found to be highest for the integrated application of poultry manure and chemical fertilizer. This may be due to the higher number of seeds per fruit in this treatment. This is in conformity with the findings of Raj (1999) in bhindi and Sharu (2000) in chilli. Due to the increased nitrogen availability by the combined application of chemical fertilizer and poultry manure, the P uptake might have improved which might have increased the P content in plants. Synergistic influence of N nutrition on P content was reported by Singh *et al.* (1970) in cauliflower. Another factor contributing to it may be its high P_2O_5 content.

The lowest number of days to final harvest and highest number of harvests was noticed by the integrated application of poultry manure and chemical fertilizer in 1:1 ratio. This treatment was on par with 100 per cent N as poultry manure and 50 per cent N as vermicompost and chemical fertilizer in 1:1 ratio. Organic sources when applied with mineral fertilizer, improve the efficiency of latter due to their favourable effects on physical and biological properties of soil (Singh, 2001). This might have resulted in better availability and uptake of nutrients and this might have resulted in increased yield attributes like number of harvests. The beneficial effect of the integrated application of chemical fertilizer and poultry manures in reducing the harvesting interval in chilli was observed (Sharu, 2000). The rapid release of nutrients from poultry manure might have improved the nutrient availability, nutrient uptake and nutrient content of plants, which in turn might have resulted in increased yield characters. The higher availability of plant nutrients created due to the improved physical environment brought about by vermicompost can be cited as the major reason for higher number of harvests by the integrated application of chemical fertilizer and vermicompost. This is in conformity with the findings of Rajalekshmi (1996) in chilli.

Remarkable positive increase in yield attributes of bittergourd like fruit set percentage, number of fruits per plant, mean weight of single fruit, days to first harvest, number of harvests, fruit yield per plant and total yield were noticed under sole cropping. The better performance of pure crop of bittergourd can be due to the better growth and yield attributes and better nutrient uptake of sole cropped bittergourd compared to intercropped bittergourd. According to Kadali *et al.* (1988) and Natarajan (1992) chilli yield was higher when grown as a pure crop compared to intercrop yield for chilli. Higher yield of bhindi when grown as sole crop compared to bhindi + cowpea intercropping system was found by Kalarani (1995).

Interaction effect of nutrient sources with cropping system had a significant influence on mean weight of bittergourd fruit. The highest fruit weight was recorded when bittergourd was grown as a sole crop and when 50 per cent N was given as poultry manure + 50 per cent N as chemical fertilizer. The beneficial effect of the combination of chemical fertilizer and poultry manure in the ratio 1:1 in increasing the yield parameters were reported by Rekha (1999). Better performance of pure crop of bittergourd may be due to the less competition for the resources when compared to intercropping system. This is in conformity with the findings of Anitha (1995) in chilli-amaranthus intercropping system.

5.3. QUALITY CHARACTERS OF BITTERGOURD

Perusal of the data presented in Table 4.3.a revealed the significant and positive influence of different nutrient sources on the keeping quality of fruits. There was significant increase in keeping quality when organic sources of N alone were applied. The maximum keeping quality was obtained when 100 per cent N was given as vermicompost. This treatment was on par with 100 per cent N as FYM and 100 per cent N as poultry manure. Beneficial effect of organic sources of nitrogen on keeping quality of fruits is well known. Asano *et al.* (1981) reported on decreased hardening of fruit surface, decreased browning and discolouration in brinjal and cucumber consequent to the application of organic sources of nitrogen compared to the application of fertilizer nitrogen. This beneficial effect could be the result of slow or delayed activity of organic nitrogen contained in the organic sources. The significant quantities of available nutrients, biologically active metabolites particularly gibberellines, cytokinins, auxins and group B vitamins might have contributed to better quality of vermicompost treatment. Similar results of increased quality with vermicompost treatment was reported by Bano *et al.* (1987) and Meerabai and Raj (2001). While considering the influence of FYM as an organic source, its application has profound influence on soil properties as it enriches the soil organic matter and release micronutrients, organic acids and other growth substances through chelation (Tisdale *et al.*, 1995). The production of these organic constituents and availability of micronutrients would have indirectly contributed to the higher keeping quality when farm yard manure was applied. Application of poultry manure seemed to have a favourable influence in keeping quality of fruits when compared to the application of fertilizer source. According to Bitzer and Sims (1988), when poultry manure is applied, long term increase in soil levels of nutrients like B, Ca, Mg, Cu and Zn can be expected. Importance of micronutrients like boron in keeping quality of fruits and tubers was indicated by Tisdale *et al.* (1995) wherein it was pointed out that boron deficiency causes cracking or rotting of fruits and tubers thereby reducing the storage life.

Ascorbic acid content which is an important quality parameter was found to be highest in the treatment in which dual application of poultry manure and chemical fertilizer was practiced. The combined application of chemical fertilizer and poultry manure might have increased the availability of nutrients throughout the growing period. Increased ascorbic acid content might be due to the increase in protein synthesis and enhancement of enzymatic activities for amino acid synthesis at higher level of nutrient which was instrumental in improving the quality (Kaminwar and Rajagopal, 1993). Increased vitamin C content with poultry manure application has been reported by Sharu (2000) in chilli.

The integrated application of chemical fertilizer and poultry manure registered the highest iron content which was on par with application of poultry manure alone and integrated application of vermicompost and chemical fertilizer. Chemical analysis of poultry manure revealed that it is primarily composed of NH4-N (Bitzer and Sims, 1988). According to Tisdale *et al.* (1995), Fe solubility and availability are favoured by the acidity that develops when NH4+ is utilised by the plant. Hence it could be presumed that application of poultry manure would have increased the Fe availability, uptake and accumulation in plants. Vermicompost influences the availability of micronutrients by chelating them as complexes (Senthilkumar and Surendran, 2002). Therefore by the application of vermicompost the Fe availability to the plants might have increased.

5.4 NUTRIENT CONTENT AND NUTRIENT UPTAKE OF BITTERGOURD

Among the various nutrient sources, application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer recorded the highest N content in plants. According to Tisdale *et al.* (1995), of the N mineralized during the first 2 or 3 months of application of poultry manure, 80% is converted to NO3- at the end of first three months which is readily utilised by the plant. Therefore chances of mineralization of poultry manure and release of plant available forms of nitrogen and its utilization would have resulted in an enhanced uptake and higher

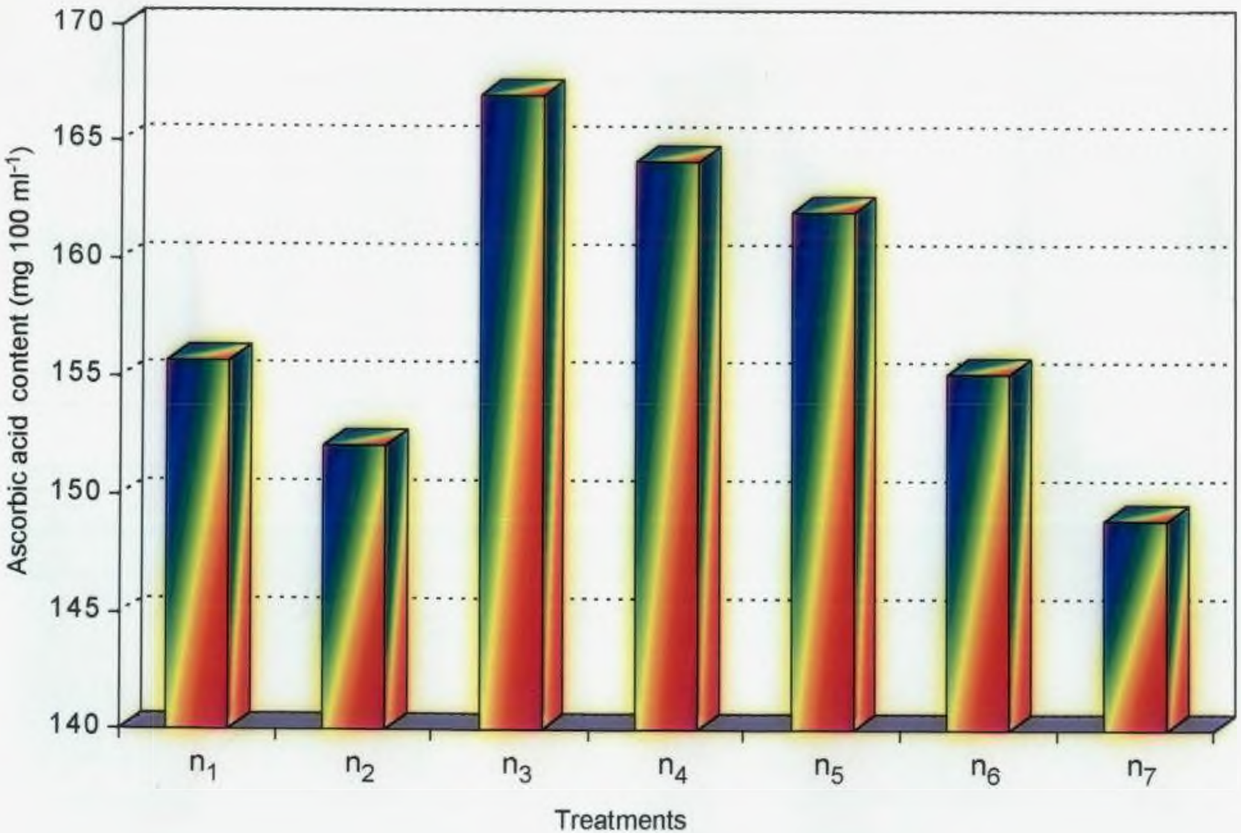

Fig. 11. Ascorbic acid content - main effect of nutrient soucres

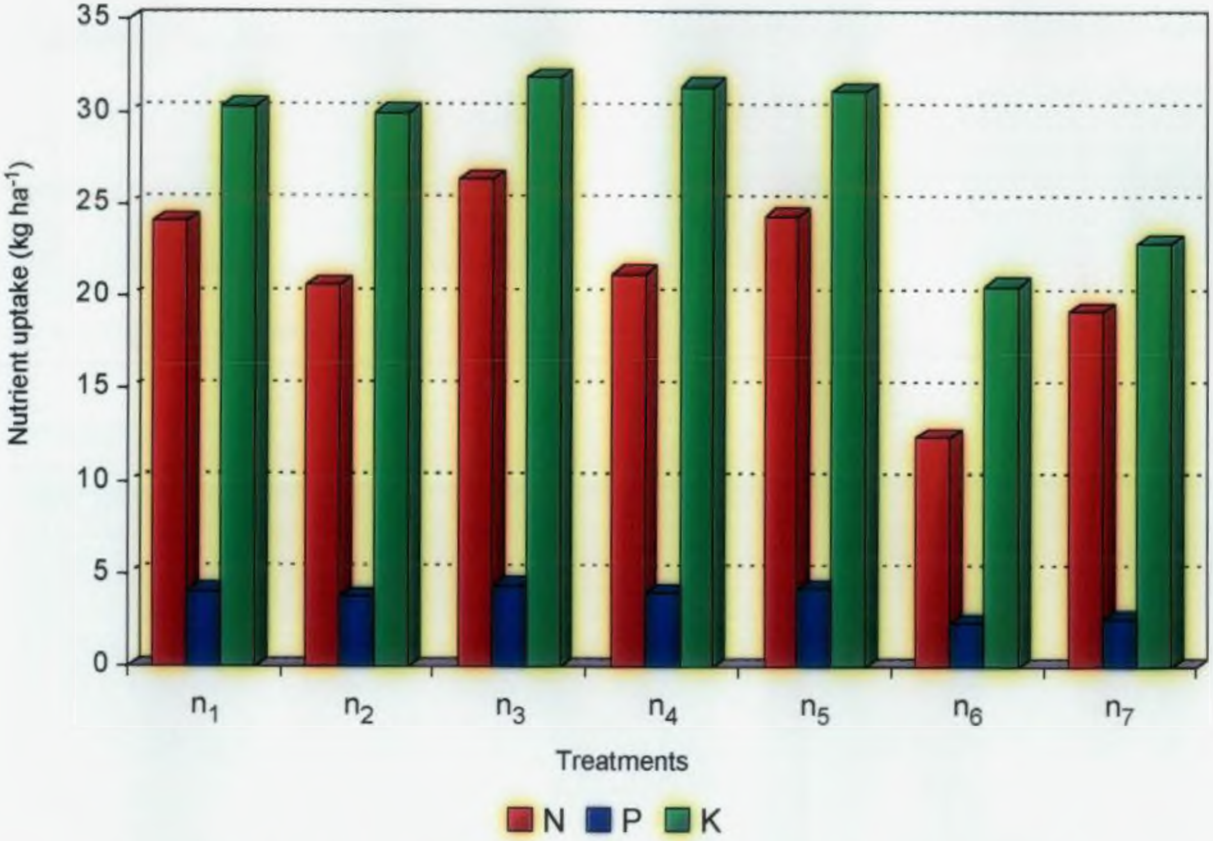

Fig. 12. Effect of nutrient sources and cropping systems on plant nutrient uptake

total plant N content. The highest P and K content of plants was recorded for the combined application of poultry manure and chemical fertilizer. This treatment was on par with the application of FYM + chemical fertilizer, FYM alone, poultry manure alone and vermicompost + chemical fertilizer. P is an important structural component of the wide variety of biochemicals including nucleic acid, coenzymes, nucleotides, phosphoproteins, phospholipids and sugarphosphates. Therefore it could be presumed that by the integrated application of poultry manure and chemical fertilizer the N supply might have increased which increased the production of P containing biochemicals under non-limited conditions of P supply which would have contributed to improved P content in plant. Synergistic influence of N nutrition on P content was previously reported by Singh *et al.* (1970) in cauliflower. Another factor contributing to it may be the high P2O5 content in poultry manure. Organic manure like FYM application would have resulted in vigorous root growth thereby increasing the P uptake and P contents in plants. When vermicompost is applied, the earthworms stimulate the P uptake by the redistribution of organic matter and by increasing the enzymatic activation of phosphatase (Mackay *et al.*, 1982). The increased mineralisation of soil P as a result of production of organic acids during decomposition of organic matter may also be one of the reason for increased P uptake and P content of the plants. One of the advantage of organic manure application is that it increases the moisture retention capacity of the soil. Increasing moisture content and retention in soil likely to have accelerated K+ diffusion to roots as pointed out by Tisdale *et al.* (1995), which would have resulted in better uptake and higher K concentration in plants.

5.5 SOIL PHYSICO-CHEMICAL PROPERTIES

5.5.1 Physical Properties

An appraisal of the data on Table 4.6a revealed that the nutrient sources had a significant influence on the physical properties of the soil. The lowest bulk density, maximum water holding capacity and higher porosity was shown by the application of 100% N as poultry manure which was on par with the application of 100% N as FYM and 100% N as vermicompost. The organic sources would have promoted the granulation of soil which might have lowered the bulk density. Ability of organic amendments in improving the soil physical characters was reported by Loganathan (1990). The influence of FYM application in lowering the soil bulk density was reported by Helkiah *et al.* (1981) and Nambiar (1994). The role of poultry manure application in lowering the soil bulk density was corroborated by Hafez (1974) and Aravind (1987). The influence of vermicompost in improving the physical properties of the soil was reported by Senthilkumar and Surendran (2002). According to Brady (1996), organic matter binds mineral particles into granules that are largely responsible for the loose, easily managed condition of productive soil and increases the quantity of water a soil can hold. Influence of organic source in improving the water holding capacity was reported by Bhadoria (1987). When nutrient N was supplied through organic source, there is a favourable influence on total pore spaces in soil and porosity of soil. According to Brady (1996), organic matter is a major agent that stimulates the formation and stabilisation of granular and crumb type aggregates. As organic residues decompose, jels and other viscous microbial products are evolved which along with associated fungi and bacteria encourage the crumb formation and the net effect of these activities would have increased the soil granulation, aggregation and porosity as reported by Helkiah *et al.* (1981) and Loganathan (1990). According to Channabasavanna and Biradar (2002) poultry manure is a good source of fertilizer and it improves the physical structure of soil. Effect of vermicompost in improving the soil physical properties such as porosity was reported by Divya (2001).

5.5.2 Chemical Properties

The various nutrient sources had a significant influence on the available nitrogen and available potassium content of the soil. The highest value for available N status of the soil was obtained for the treatment in which 100% N was given as vermicompost. This treatment was on par with the application of 100% N as FYM and POP recommendation. The higher degree of decomposition and mineralisation in vermicompost may be one of the reasons for high N content and this might have finally contributed to the available N status of soil. Higher levels of total N in treatments which received vermicompst was reported by Balaji (1994). The increase in available N content of the soil and increased N recovery due to the use of organic source of N has been reported by Srivastava (1985). According to Prasad and Singh (1980) available N content of the soil increased with the continuous use of FYM. In POP recommendation, nutrients are supplied mainly through chemical fertilizer and only a part through FYM. So this might have resulted in lower uptake of N and subsequently increased the soil N status.

Available K in soil was highest for the treatment where 100% N was given as vermicompost. The increased availability of K due to the addition of vermicompost may be due to the increased concentration of available and exchangeable K content in wormcast compared to surrounding soil. Basker *et al.* (1994) inferred that earthworms increases the availability of K by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms.

5.6 ROOT STUDIES IN BITTERGOURD AND AMARANTHUS

It can be deciphered from the results that the depth of root penetration was almost same under sole cropping and intercropping situations. In the case of bittergourd, root spread was almost same under sole cropping and intercropping. However, for amaranthus the root spread was more under intercropping situation than sole cropping. This is in conformity with the findings of Ikeorgu (1990) in amaranthus. In the active growth phase for utilising the resources to the maximum, the crops spread their roots extensively. Kalarani (1995) reported that root spread was more when bhindi was intercropped compared to sole cropped.

5.7 NUTRIENT RELEASE PATTERN OF FYM, POULTRY MANURE AND VERMICOMPOST

Scrutiny of the data on nutrient release pattern of three organic manures, FYM, poultry manure and vermicompost indicated that there was progressive increase in the availability of N and P_2O_5 from the 0th to the 90th day. But in the case of available K_2O, for all the three organic manures there was a progressive increase upto the 60th day and there after decreased. Similar result was reported by Bijulal (1997). Of the three organic manures, poultry manure showed higher availability for N, P_2O_5 and K_2O. This may be due to the higher nutrient content in poultry manure.

5.8 ECONOMIC ANALYSIS

Results of the economic analysis revealed that integrated application of poultry manure and chemical fertilizer in the ratio 1:1 gave the best performance with respect to net returns. This higher returns may be due to the best performance of the crop with respect to yield and fertilizer use efficiency. According to Rekha (1999) net return from brinjal was highest when organic manure was applied along with chemical fertilizer.

With respect to the B:C ratio also, the same trend was noticed. Application of poultry manure and chemical fertilizer in the ratio 1:1 recorded the highest B:C ratio and was on par with 100% N as poultry manure. This result is in confirmity with the finding of Sharu (2000) in chilli. The role of poultry manure in reducing the cost of cultivation and thus increasing the benefit-cost ratio was suggested by Channabasavanna and Biradar (2002). The suitability of poultry manure as organic source for bittergourd cultivation was also established by Rajasree (1999).

A perusal of the data shown in Table 4.9 revealed that bittergourd - amaranthus intercropping system is feasible because by raising amaranthus along

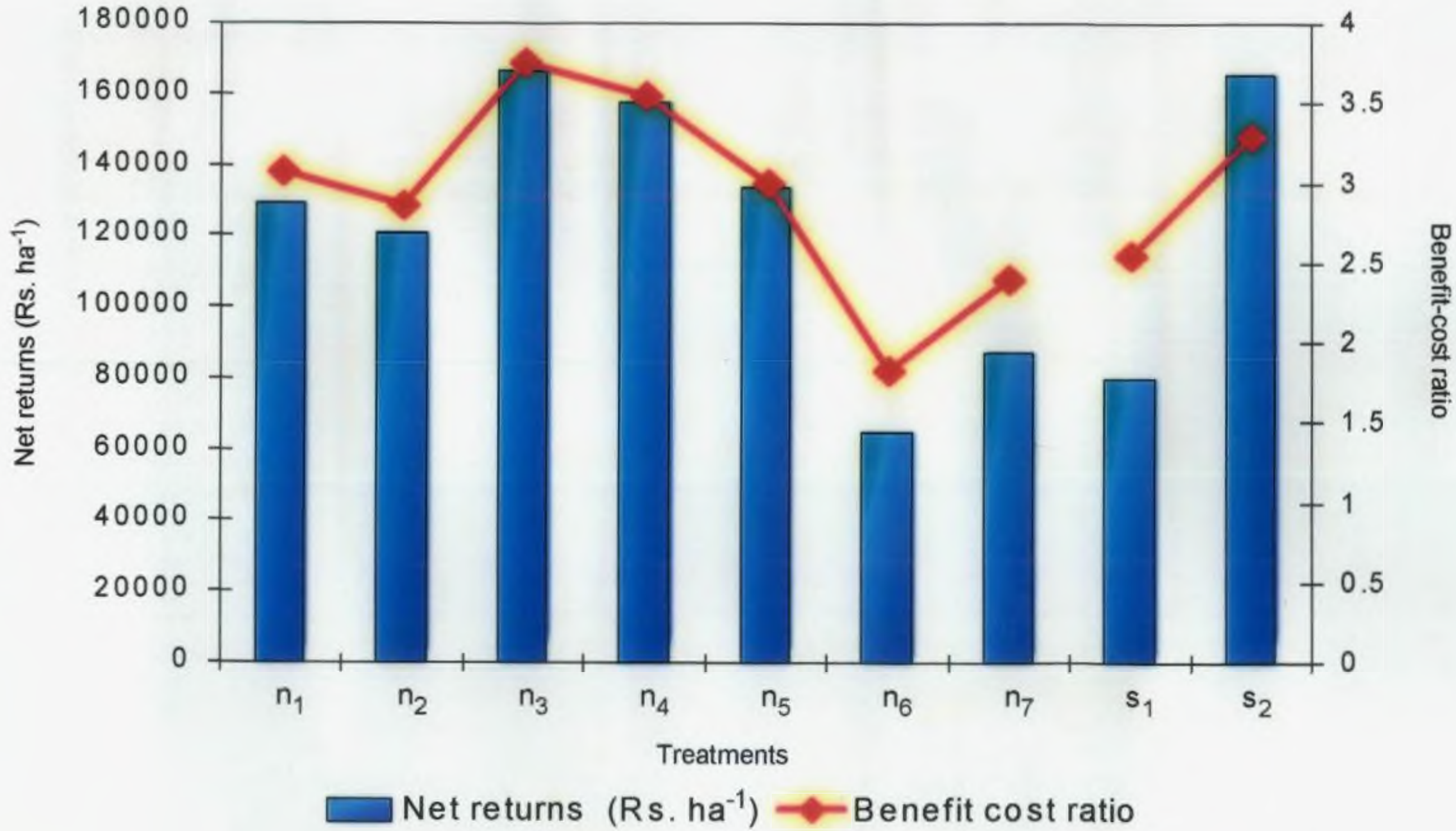

Fig. 13. Effect of nutrient sources and cropping systems on net returns (Rs. ha^{-1}) and benefit-cost ratio

with bittergourd an additional yield as well as profit can be realised compared to pure crop of bittergourd. Similar results were obtained by Anitha (1995) with chilli - amaranthus system and Kalarani (1995) in bhindi - cowpea system. Though there was a slight reduction by 15.72 per cent in bittergourd yield under intercropping system compared to pure crop yield, net returns and B:C ratio was significantly higher in intercropping system. In this study a saving of Rs. 165537.23 was obtained with bittergourd - amaranthus intercropping system as against Rs. 79964.37 for pure crop of bittergourd. Thus this finding has considerable practical significance for the vegetable growers in Kerala. Application of poultry manure in combination with chemical fertilizer is a remunerative and sustainable nutritional practice for bittergourd - amaranthus intercropping system.

SUMMARY

6. SUMMARY

The investigation entitled "Sustainable nutritional practices for bittergourd-amaranthus intercropping system" was carried out at the Instructional Farm, College of Agriculture, Vellayani during the period from October 2001 to January 2002. The main objectives of the study were to identify sustainable nutritional practices for enhancing the yield, quality and income from bittergourd and to assess the economics of intercropping amaranthus in bittergourd.

The experiment consisted of seven nutrient sources and two cropping systems. There were altogether 14 treatment combinations. The experiment was laid out in factorial Randomised Block Design with three replications. The salient findings of the experiment are summarised below.

Significant difference in plant height due to various nutrient sources were noticed at final harvest. Application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer recorded the maximum plant height. The same treatment gave the highest number of branches at final harvest. The two cropping systems also had a significant influence on growth characters of bittergourd. Pure crop of bittergourd recorded the highest plant height and higher number of branches.

At final harvest, the combined application of poultry manure and chemical fertilizer gave maximum dry matter content. The dry matter content was highest when bittergourd was grown as pure crop.

Highest fruit setting percentage was observed with the integrated application of poultry manure and chemical fertilizer. Fruit setting percentage was highest for pure crop of bittergourd.

Number of fruits per plant was highest when chemical source of nitrogen was substituted with poultry manure in 1:1 ratio. Pure crop of bittergourd registered the highest number of fruits per plant.

Application of poultry manure along with chemical fertilizer recorded the highest fruit weight. The fruit weight was significantly high when bittergourd was grown as a pure crop. Interaction effect of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer and bittergourd raised as pure crop increased the fruit weight.

Fruit yield per plant and total yield were markedly high for the combined application of poultry manure and chemical fertilizer. Pure crop of bittergourd recorded the highest fruit yield.

Integrated application of chemical fertilizer and poultry manure in 1:1 ratio gave best performance with regard to days to final harvest and number of harvests. Earliness to first harvest and higher number of harvests were shown by bittergourd when grown as pure crop.

Vermicompost application registered maximum keeping quality of fruits. Ascorbic acid content and iron content were highest when chemical fertilizer was substituted with poultry manure in 1:1 ratio.

For appearance, the highest rank mean was shown by the combined application of vermicompost and chemical fertilizer and POP recommendation. The highest rank value for doneness was shown by the integrated application of poultry manure and chemical fertilizers. In the case of bitterness, texture and odour the highest rank mean was shown by the application of 100 per cent N as vermicompost.

Application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer obtained highest value for NPK content of plants. The same treatment recorded highest value for N, P and K uptake.

Use of organic manures alone improved the soil physical properties such as bulk density, water holding capacity and porosity.

Vermicompost application alone gave highest level of soil N and soil K.

The depth of root penetration was not affected by intercropping in bittergourd and amaranthus. In the case of bittergourd, root spread was almost same under sole cropping and intercropping. For amaranthus, the root spread was more when grown as an intercrop compared to sole cropping.

Of the three organic manures used in the study, poultry manure showed higher availability for N, P_2O_5 and K_2O. The nutrient release pattern had shown that there was progressive increase in the availability of N and P_2O_5 upto the 90^{th} day. In the case of available K_2O, there was a progressive increase upto 60th day and thereafter decreased.

The highest net profit and B:C ratio were registered by the treatment receiving equal proportion of poultry manure and chemical fertilizer. Of the two cropping systems, intercropping gave significantly higher net returns, and B:C ratio.

Future Line of Work

The results of the present investigation point towards the beneficial effects of integrated application of chemical fertilizer and organic manure on soil and plant environment. So it would be appropriate to initiate studies on the various combinations of other organic manures with chemical fertilizer in vegetable based cropping system. The extent to which the costly chemical fertilizers can be substituted by locally available organic sources of nutrients for vegetable cultivation also needs immediate attention. The study also pointed out the suitability of poultry manure as a promising organic manure for bittergourd. Similar studies with poultry manure on other vegetable crops will explore the use of this organic source for commercial vegetable cultivation in Kerala. From the present study it is evident that bittergourd amaranthus intercropping system is more economical than sole cropping of bittergourd. The finding of this work can be experimented with other vegetables also. In the light of this study, in a state like Kerala where there is scarcity of land in order to augment vegetable production intercropping with vegetables could be undertaken.

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SUSTAINABLE NUTRITIONAL PRACTICES FOR BITTERGOURD – AMARANTHUS INTERCROPPING SYSTEM

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Abstract of the
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8. ABSTRACT

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani during 2001-2002 to identify sustainable nutritional practices for enhancing the yield, quality and income from bittergourd and to assess the economics of intercropping amaranthus in bittergourd. The experiment consisted of seven nutrient sources and two cropping systems and was laid out in factorial RBD with three replications.

The various nutrient sources as well as cropping system exerted significant influence on growth parameters and yield attributing characters of bittergourd. Application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer significantly increased the growth, yield attributes and the total yield. Bittergourd grown as pure crop showed increase in growth parameters, yield attributes and yield.

The nutrient sources influenced the quality characters of bittergourd. Keeping quality was higher for vermicompost treatment while ascorbic acid content and iron content were higher for the integrated application of poultry manure and chemical fertilizer.

Highest value for NPK content of plants and NPK uptake was obtained when chemical sources of nitrogen was substituted with poultry manure in 1:1 ratio.

The soil physical properties were improved significantly by the application of organic manures alone. Soil available nitrogen and potassium were higher for the treatment in which 100 per cent N was applied as vermicompost.

The depth of root penetration was not affected by intercropping in bittergourd and amaranthus. The root spread was more in amaranthus when grown as an intercrop compared to sole cropping.

The nutrient release pattern of organic manures had shown that there is a progressive increase in the availability of N and P_2O_5 till the 90th day and for available K_2O there was a progressive increase upto 60th day and thereafter decreased. Among the three organic manures, poultry manure showed higher availability of the three nutrients.

The economics of cultivation revealed that application of 50 per cent N as poultry manure + 50 per cent N as chemical fertilizer gave the maximum net returns and benefit-cost ratio. The net returns and B:C ratio were higher under bittergourd-amaranthus intercropping system compared to sole crop of bittergourd.

APPENDIX

APPENDIX I

Weather data during the entire crop growth period - weekly averages

Standard week	41	42	43	44	45	46	47	48	49	50	51	52	1	2	3	4	5	6	7
Maximum temperature (°C)	30.0	29.5	30.3	31.0	30.4	29.7	30.5	30.5	31.0	30.6	31	31	31.4	31	30.7	31	30.2	31.5	32.0
Minimum temperature (°C)	23.7	24.0	24.0	24.2	23.7	23.1	23.4	23.2	22.9	20.0	22.3	23.5	23.0	22.9	19.5	23.5	23.0	22.5	22.4
Rainfall (mm)	14.2	52.6	95.7	Nil	54.2	14.6	37.9	Nil	8.6	Nil	3.7	8.6	Nil	3.7	8.3	Nil	Nil	Nil	Nil
Relative humidity (%)	85.3	85.1	81.4	81.1	81.8	84.1	81.9	80.3	81.1	76.2	82	79.5	80.3	78.4	76.6	76.6	78.3	77.9	75.8
Evaporation (mm/week)	33.6	21.0	21.0	21.7	19.6	21.7	16.8	23.1	20.3	18.9	21.7	16.8	20.3	18.9	19.6	21.0	19.6	21.7	22.4