INTEGRATED NUTRIENT MANAGEMENT FOR COLEUS (*Solenostemon rotundifolius* (Poir) Morton)

BY

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THESIS
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DECLARATION

I hereby declare that this thesis entitled **"Integrated nutrient management for coleus (*Solenostemon rotundifolius* (Poir) Morton)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Integrated nutrient management for coleus (*Solenostemon rotundifolius* (Poir) Morton)**" is a record of research work done independently by Ms. Archana. B. 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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To

Achan & Amma

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
^{0}C	Degree Celsius
a.i.	Active ingredient
AMF	Arbuscular mycorrhizal fungi
ANOVA	Analysis of variance
BCR	Benefit-cost ratio
BR	Tuber bulking rate
CCP	Composted coir pith
CD	Critical difference
CGR	Crop growth rate
cm	Centimetre
CTCRI	Central Tuber Crops Research Institute
cv.	Cultivar
DAP	Days after planting
day^{-1}	Per day
DD	Dichloropropene-dichloropropane mixture
DMP	Drymatter production
et. al.	And others
Fig.	Figure
FYM	Farmyard manure
g	Gram

LIST OF ABBREVIATIONS Contd...

ha^{-1}	Per hectare
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram
LAI	Leaf area index
m	Metre
mm	Millimetre
N	Nitrogen
NAR	Net assimilation rate
NC	Neem cake
P	Phosphorus
q	Quintal
RBD	Randomised block design
RD	Recommended dose
RGR	Relative growth rate
Rs.	Rupees
SE	Standard Error
t	Tonne
UI	Utilization index

Introduction

1. INTRODUCTION

The per capita availability of vegetables in India is only about 135 g day^{-1} according to a recent study conducted by ICMR, which is far below the minimum dietary requirement of 280 g vegetables per day. It is estimated that the vegetable production in Kerala is only one third of the vegetable requirement of the state. The production of vegetables can be increased with the use of improved varieties of crops and scientific management practices.

Coleus (*Solenostemon rotundifolius* (Poir) Morton) is grown for its edible tubers which are used as vegetable. It is commonly known as 'koorka' or 'cheevakizhangu' or Chinese potato or country potato. It is a native of Africa. It is a small herbaceous bushy annual with succulent stems and aromatic tubers. It belongs to the family Labiatae. Tubers are preferred for its particular aromatic flavour and sweetness. It has medicinal properties for curing dysentery and certain eye diseases. Tubers are rich in carbohydrates (18-21 %), minerals like Ca and Fe and vitamins like thiamine, riboflavin, niacin and ascorbic acid (CTCRI, 1996). Unlike most other vegetables, coleus tubers possess good keeping quality. It is a short duration crop of 4½ to 5 months duration and hence is best fitted in multiple cropping programmes.

Development of integrated plant nutrient schedule involving an approximate mix of organics, biofertilizers and need based chemical fertilizers would be crucial for sustainability of crop production and soil productivity. The present fertilizer recommendation for coleus is 60 : 60 : 100 kg NPK ha^{-1} along with 10 t of farmyard manure (KAU, 1996 and CTCRI, 1996).

Geetha (1983) found that a fertilizer dose of 60: 30: 120 kg NPK ha^{-1} may be applied for economic production of coleus. It has been estimated that a crop producing 26 t ha^{-1} of tuber removes 106.7, 13.2 and 107.4 kg NPK ha^{-1} (CTCRI. 1997). Hence there is scope for reducing the present recommended dose (RD) of fertilizer phosphorus (P) to coleus.

Use of biofertilizer along with chemical fertilizers offers an opportunity to achieve long term sustainability in crop production systems without land degradation and minimizing environmental pollution. Coleus is reported to be mycorrhiza dependent (Potty, 1990). Mycorrhizal association increases the P availability to plants and thus reduces the rate of application (Patel and Pachal, 1991). In addition, arbuscular mycorrhizal fungi (AMF) has got antagonistic effect on root knot nematode which has been reported as a pest of coleus.

Organic manures like farmyard manure (FYM), oilcakes and compost improve soil physical, chemical and biological properties and thereby enhance the productivity of soil. Inadequate availability of FYM has led us to think of alternate sources of organic manure. Coir pith which is abundantly available in Kerala as a bye product of coir industry is found to be a good source of organic manure after narrowing down its C : N ratio with *Pleurotus* sp. There is also the possibility of reducing the dose of bulky organic manure through the use of concentrated organic manures like neemcake (NC). Besides amending the soil, different oil cakes especially NC was found effective for the control of root knot nematode.

Keeping these views under consideration, the present investigation entitled "Integrated nutrient management for coleus (*Solenostemon rotundifolius* (Poir) Morton)" was undertaken to investigate the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present recommended dose of fertilizer P and to workout the economics of cultivation.

Review of Literature

2. REVIEW OF LITERATURE

Coleus is a minor tuber crop grown mainly in the homesteads as a vegetable. It is a short duration crop which can be best fitted in multiple cropping programmes. The productivity of the crop can be increased by the integrated application of organic manures, fertilizers and biofertilizer. FYM is the commonly used organic manure. Scarcity of it has led us to think of alternate sources like composted coir pith (CCP) and NC which is available in our state. The crop is reported to be mycorrhizal dependent which enhances the P use efficiency. Since the P requirement of the crop is reported to be very low, there is scope for reducing the present RD of P especially with AMF inoculation. The relevant literature on the effect of different organic manures, fertilizer and AMF inoculation on growth characters, yield and yield components, quality of produce and nutrient uptake by the crop are reviewed in this chapter. Wherever information is lacking, pertinent literature on other crops has been included.

2.1 Effect of organic manures

2.1.1 Effect of FYM

2.1.1.1 Growth characters

Application of FYM @ 12.5 t ha^{-1} to cassava gave better response in terms of growth characters (KAU, 1996).

Plant height, number of leaves per plant, sucker number per hill and dry matter production (DMP) was increased by the highest level of FYM tried (20 t ha^{-1}) in arrowroot (Veenavidyadharan, 2000).

Increasing rates of FYM increased plant height but had inconsistent effect on the number of main stem per hill in potato cv. Katela (Wildjajanto and Widodo, 1982). Sahota (1983) found that FYM application increased plant height and number of leaves per plant in potato.

2.1.1.2 Yield and yield components

Experiments conducted in Karnataka to find out the response of sweet potato to FYM showed a 30.6 % increase over control (Gaur, *et al.*, 1984). Studies conducted at CTCRI revealed that basal application of 5 t ha^{-1} of FYM to sweet potato was beneficial in enhancing the yield (Pillai *et al.*, 1987 and Ravindran and Balanambisan, 1987). The presence of FYM enhanced tuber yield both under low land and upland situations indicating that FYM is essential for higher tuber production in sweet potato (Ravindran and Balanambisan, 1987).

Cassava yield was increased over control by 11.8 % when FYM was applied (Gaur *et al.*, 1984). Cassava responds to both bulky and concentrated organic manures (Thampan, 1979). Studies conducted at CTCRI and KAU revealed that basal application of FYM at 12.5 t ha^{-1} enhanced the yield of cassava (Mohankumar *et al.* 1976; Pillai *et al.* 1987; Ravindran and Balanambisan, 1987 and KAU, 1996).

Application of FYM alone resulted in higher yields in elephant foot yam (Patel and Mehta, 1987).

Significantly superior tuber yield of *Dioscorea alata* was obtained by the application of FYM @ 20 t ha^{-1} (CTCRI, 1973). Application of FYM alone or in combination with P and potassium (K) enhanced the tuber yield over control in *Dioscorea alata* (Singh *et al.*, 1973). Mohankumar and Nair (1979) suggested that yield increase obtained by the application of FYM at 20 t ha^{-1} over lower doses (10-15 t ha^{-1}) was not sufficient to compensate the increased cost of FYM and hence 10 t ha^{-1} of FYM is recommended for *D. alata* to obtain economic returns.

FYM had a profound influence on the number of rhizomes per plant and yield of arrowroot. FYM @ 20 t ha^{-1} recorded maximum number of rhizomes per plant and rhizome yield of arrowroot (Veenavidyadharan, 2000).

Higher yields in turmeric was reported by the application of FYM alone to the crop (Balashanmugham *et al.*, 1989).

2.1.1.3 Quality parameters

Ravindran and Balanambisan (1987) observed that the quality of tubers in sweet potato was not much affected by different doses of FYM.

Application of FYM @ 12.5 t ha^{-1} enhanced the quality of cassava tubers as reported by Mohankumar *et al.* (1976) and Pillai *et al.* (1987).

2.1.2 Effect of coir pith compost

Coir pith is abundantly available in Kerala as a bye product of coir industry. It is a light fluffy refuse obtained during the separation of coir fibre from coconut husk. This can be used as an organic manure after narrowing down its C : N ratio with *Pleurotus* sp. Coir pith compost has beneficial effect as an organic manure in increasing the yield of crops like turmeric (Selvakumari *et al.*, 1991).

Suharban *et al.* (1997) reported that in a pot culture experiment with bhindi, plant height was significantly influenced by CCP treatment.

Maximum yield of 5.923 kg per plant was recorded by the treatment with CCP alone followed by treatment with half the RD of nitrogen (N) as coir pith and half as fertilizer.

According to Arunkumar (2000), amaranthus performed inferior with respect to growth characters like number of leaves and number of branches when CCP was used as organic manure but DMP was superior. Also CCP recorded significantly lower yield of amaranthus.

In an on farm trial on groundnut in soils having a pH of 9, the application of gypsum at 400 kg along with 12.5 t of CCP ha^{-1} increased the pod yield appreciably (Ramamoorthy *et al.*, 1991). Lourdraj *et al.* (1996) reported increased yield, net returns and high benefit–cost ratio (BCR) in groundnut when the crop was raised in soil incorporated with CCP. Yield of sesamum could be increased by 63 % with the application of CCP over farmers' practice (Venkatakrishnan and Ravichandran, 1996).

2.1.3 Effect of neem cake

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

2.1.3.1 Growth characters

Arunkumar (2000) reported that when NC was used as an organic manure in amaranthus, an increase in number of leaves was recorded at later growth stages. But the number of branches were on par with package of practices (POP) recommendations of KAU (50 t FYM + 50 : 50 : 50 kg NPK ha^{-1}). In the case of leaf area index (LAI), POP performed better than the highest level of NC (7.2 t ha^{-1}) tried.

In chilli, organic nutrition involving NC did not significantly influence the growth characters. But the growth characters like plant height, number of branches, DMP and LAI were found to be on par with POP (20 t FYM + 75 : 40 : 25 kg NPK ha^{-1}) as observed by Sharu (2000).

2.1.3.2 Yield and yield components

The application of NC @ 1 t ha^{-1} before planting gave maximum yield in ginger (KAU, 1990).

In amaranthus, lower doses of NC recorded lower yield compared to POP. But higher doses of NC was superior to POP (Arunkumar, 2000). Fibre content was superior and protein was on par with NC treated plots compared to POP.

Sharu (2000) reported that mean weight of fruit and keeping quality were maximum when nutrients were supplied to chilli through NC alone. Vitamin C was found to be on par with POP but BCR was the lowest with the NC treatment.

2.1.3.3 Pest and disease incidence

Alam and Khan (1974) observed that NC, mahua cake and mustard cake controlled phytonematodes in the field almost as effective as DD and nemagon. Application of NC greatly reduced the total nematode population in oats and succeeding crop of *Vigna* sp. (Jain and Hasan, 1986).

Amending the soil with different oil cakes especially NC was found effective in reducing the incidence of root-knot nematode *Meloidogyne incognita* in crops like ginger, tomato and brinjal (Goswami and Vijayalekshmi, 1981; Routaray and Sahoo, 1985; Sheela *et al.*, 1995 and Vadhera *et al.*, 1998).

A study conduced by Sheela *et al.* (1995) in ginger revealed that application of NC @ 2.5 t ha^{-1} at the time of planting and carbofuran @ 1 kg a.i. ha^{-1} 45 days after planting (DAP) was effective in reducing the population of *Meloidogyne incognita* in soil and root samples. It also reduced the root-knot index and increased the yield of ginger.

2.1.4 Comparison of different organic manures

Higher efficiency of FYM in producing higher yield of cassava compared to castor oil cake and urea was revealed by Gomes *et al.* (1983). Incorporation of coir waste @ 10 t ha^{-1} recorded significant increase in tuber yield compared to FYM @ 12.5 t ha^{-1} and coir waste @ 5 t ha^{-1}. The positive effect of coir waste on yield might be due to its water holding capacity and better nutrient uptake by the crop (Ayyaswami *et al.*, 1996).

Maheswarappa *et al.* (1997) found that FYM and vermicompost are better than CCP. FYM @ 26-34 t ha^{-1} and vermicompost @ 13.9 to 15.9 t ha^{-1}

recorded significantly higher rhizome yield compared to CCP @ 32 to 42 t ha^{-1}. Application of CCP produced lower values of growth characters, yield components, chlorophyll content, quality parameters like starch and crude protein contents and nutrient uptake compared to application of FYM and vermicompost.

Shanmugavelu *et al.* (1987) reported that the application of mahua cake, castor cake and NC @ 500 kg ha^{-1} one day prior to transplanting to tomato increased the fruit yield by 31.7, 27.8 and 9 % respectively over control. Incorporation of 10 t ha^{-1} of FYM into soil one day prior to transplanting gave the highest fruit yield of tomato (19 t ha^{-1}) followed by 20 t ha^{-1} coir pith (16 t ha^{-1}) and the lowest in the control plot (11 t ha^{-1}) which were treated with neither FYM nor coir pith (Ahmed, 1993).

Som *et al.* (1992) observed the influence of organic manures on growth and yield of brinjal. The different oil cakes tried were karanj, mahua, mustard and NC. The maximum plant height of 70.71 cm was recorded in the treatment receiving NC @ 50 q ha^{-1} followed by mustard cake at its higher dose. Maximum fruit length and diameter were recorded by mahua cake and NC applied @ 50 q ha^{-1} respectively. NC @ 50 q ha^{-1} produced maximum fruit weight, the highest yield per plant and the highest fruit yield.

Asha (1999) observed that maximum number of fruits per plant, maximum yield and keeping quality of bhindi fruits were recorded by FYM + NC treatment. Maximum profit and BCR were also recorded by this treatment.

Among the different organic manures like vermicompost, NC, CCP, FYM and poultry manure tried in amaranthus, FYM and vermicompost performed better in terms of plant height, number of leaves, number of branches and LAI. CCP treatment performed poorly with respect to growth characters. Higher yields were obtained from 100, 125 and 150 % levels of FYM, vermicompost, poultry manure and NC. CCP treatments recorded lower DMP and yield than POP in amaranthus. CCP @ 20 t ha^{-1} recorded maximum fibre content but protein and moisture contents were inferior (Arunkumar, 2000).

2.2 Effect of phosphorus

Phosphorus plays an important role in energy transformations and metabolic processes in plants. Deficiency of P and response to P application are seen in acid soils especially in laterite and red soils which contains high levels of Fe and Al.

There are documented evidences which show that P is required in smaller quantities for tuber crops in general compared to other nutrients. Mohankumar *et al.* (1984) reported P removal of some tropical tuber crops – cassava 22 kg ha^{-1}, sweet potato 5.9 kg ha^{-1}, colocasia 19.2 kg ha^{-1}, amorphophallus 30.5 kg ha^{-1} and dioscorea 26.2 to 30 kg ha^{-1}. It has been estimated that a crop of coleus producing 26 t ha^{-1} of tubers removes 13.2 kg P ha^{-1} (CTCRI, 1997).

2.2.1 Growth characters

In sweet potato, Mc Donald (1963) reported lack of response of P in influencing the vegetative growth. But Spence and Ahmad (1967) reported reduction in size of leaves of sweet potato when the plants are deficient in P. Three was a general increase in LAI values as the level of P was increased from 25 to 75 kg P_2O_5 ha^{-1}. Constantin *et al.* (1977), after his experiment with sweet potato at four locations with varying levels of P application ranging from 0 to 73.9 kg ha^{-1}, observed that P application had no effect on vegetative growth or DMP. Oommen (1989) also observed that different levels of P did not exert any significant effect on vine length of sweet potato. The medium level of P tried (50 kg P_2O_5 ha^{-1}) showed the highest number of branches. LAI was found to increase from 50 DAP onwards at higher levels of P. The highest level of P tried (75 kg P_2O_5 ha^{-1}) increased the leaf, stem, tuber dry matter, BR and crop growth rate (CGR) of sweet potato. But he observed that net assimilation rate (NAR) tended to decrease with increasing levels of P application.

Chadha (1958) reported that P application did not influence the growth attributes of cassava. Plant height was reduced by the application of P alone to cassava (Mohankumar *et al.*, 1976). Even exclusion of P from the manurial schedule of cassava had no significant adverse effect on growth parameters (CTCRI, 1981). Higher rates of P had no significant effect on NAR in cassava (Nayar, 1986).

Application of P fertilizer had no significant effect on plant height, number of leaves per plant and LAI in colocasia as reported by Purewal and Dargen (1957). Pillai (1967) also did not observe any effect on plant height, number of suckers and LAI of colocasia due to graded levels of P application. Levels of P did not show any effect on total DMP as well as CGR in taro (Mohankumar, 1986).

2.2.2 Yield and yield components

Thyagarajan (1969) reported that levels of P (0, 30 and 60 kg P_2O_5 ha^{-1}) had no significant effect on the yield of coleus. Geetha (1983) found that 30 kg P_2O_5 ha^{-1} is sufficient for economic production of coleus.

Samuels (1967) observed that increasing P levels, in the presence of constant supply of N and K, did not appear to cause a marked influence on the yield of sweet potato. Rajput *et al.* (1981) observed significant increase in the yield of sweet potato due to the application of 50 kg P_2O_5 ha^{-1} over no P plots in Maharashtra. Navarro and Padda (1983) and Nicholaides *et al.* (1985) found that applied P had no effect on the yield of sweet potato. However, Oommen (1989) reported that higher levels of P influenced tuber number and length of tuber of sweet potato. Higher doses significantly increased the tuber number and length but did not affect the girth of tuber.

Application of 90 kg P_2O_5 ha^{-1} to cassava resulted in 25 % increase in tuber yield over control (Chadha, 1958). Gomes and Howeler (1980) and Gomes *et al.* (1983) reported that the yield of cassava increased significantly with P fertilization. Nair *et al.* (1988) investigated the response of cassava to graded levels of P in acid laterite soil and determined the economic dose as 45 kg P_2O_5 ha^{-1} whereas the optimum dose was 50 kg P_2O_5 ha^{-1}.

Purewal and Dargan (1957) obtained increase in yield of colocasia with the application of P fertilizer. Pillai (1967) reported that application of P at 50 kg ha^{-1} had significant influence on the number and length of corm in colocasia but the girth of corm remained uniform irrespective of the levels of P applied.

According to Sobulo (1972) application of P seemed to increase the yield of yam only in soils very low in P. But Obigbesan and Agboola (1979) and Zaag *et al.* (1980) found that application of P had a positive response on the yield of yams. Kapeglo *et al.* (1980) observed that the weight of marketable tubers of yam was significantly improved by the application of P at 25 kg ha^{-1} in *Dioscorea rotundata.* Lyonga (1982) found that generally there was no response of yam to P application

Tabata and Takase (1968) found that application of high rates of P to potatoes increased the number of tubers but decreased the mean weight of tubers. Perumal (1975) observed that P fertilization initially increased the yield of large and small grades of tubers but further application increased the yield of small tubers in potato. An increase in the yield of potato was noted by Varsheg and Singh (1978) by increasing the quantity of applied P.

2.2.3 Quality parameters

Different levels of P failed to exert any significant influence on the starch and protein contents of sweet potato (Oommen, 1989).

Vijayan and Aiyer (1969) found that application of P upto 100 kg P_2O_5 ha^{-1}enhanced the starch content and reduced the HCN content of cassava. Prema *et al.* (1975) reported increase in the starch and crude protein contents of cassava with higher levels of P application. Kurian *et al.* (1976) observed that there was significant reduction in the HCN content of cassava due to P fertilization. Increased rate of P had an inhibitory effect on the starch content of cassava tubers as reported by Nayar (1986).

In *Dioscorea esculenta* maximum starch content was accorded at 60 kg P_2O_5 ha^{-1} (Nair, 1985). Mohankumar (1986) observed that there was no significant difference in the percentage of starch and protein contents in the taro tuber due to varying levels of P application.

Solle (1980) reported that starch yield in potato increased by 31 % by the application of 120 kg P_2O_5 ha^{-1}.

2.2.4 Nutrient uptake

Uptake of N, P and K by sweet potato was significantly influenced by P application. Higher levels of P showed increased uptake of these nutrients (Oommen, 1989).

According to Nayar (1986), the uptake of N by cassava was not significantly affected by P in the initial stages of plant growth but at later stages, higher levels of P showed increased N uptake. But P application influenced the uptake of P at all stages of growth in the first year only and in the second year influence was seen in the initial growth phases. Higher rates of P application had a tendency to promote the uptake of K.

Levels of P did not exert any significant effect on uptake of N and K in taro whereas increasing P levels increased the uptake of P by the plant (Mohankumar, 1986).

Ramesan (1991) reported that application of P remarkably influenced the uptake of N, P and K by arrowroot. The highest level of P tried showed higher uptake of these nutrients.

Ivanov and Lapa (1980) found that increased rate of P increased its uptake by potato.

2.2.5 Soil nutrient status

Available N and K contents in the soil were not significantly influenced by different levels of P application for sweet potato (Oommen, 1989). But different levels of P significantly influenced the final soil P status. With incremental doses of P, available P in the soil increased significantly.

According to Nayar (1986), the post harvest available N content of the soil showed significant reduction due to enhanced P application for cassava. But soil P content increased with increased rates of P application whereas K status of the soil was not affected.

Mohankumar and Sadanandan (1991) reported that the available N and K status of the soil after a crop of taro was not affected by P levels, but the post harvest soil available P increased with increasing levels of P application. Application of P had no effect on the K status of soil.

The post harvest available N and P status of the soil was significantly increased with the application of increasing levels of P for arrowroot whereas available K status was not influenced by P application (Ramesan, 1991).

2.3 Effect of AMF

Mycorrhizae are symbiotic associations that form between the roots of most plant species and fungi. The most common mycorrhizal association is from the endomycorrhizae, also referred to as AMF, which produces fungal structures (vesicles and arbuscles) in the cortex region of the root.

AMF increase the rate of growth of plants and also influence the partitioning of phytomass between shoot and root (Smith, 1980). Mycorrhizal infection enhances plant growth by increasing nutrient uptake either by increasing the absorbing surface or by mobilizing sparingly available nutrient sources (Bolan *et al.*, 1987). Barea (1991) observed that AMF enhances plant growth as a result of improved nutrition of the host plant. AMF association is known to improve the uptake of P (Gerdemann, 1968; Mosse, 1973; Harley and Smith, 1983) and other nutrients namely Cu, Zn, Ca, K, Fe and Mn (Marschner and Dell, 1994).

The beneficial effects of AMF has been reported in many species of plants including cassava (Howeler *et al.*, 1982). According to Potty (1990), AMF has a definite role in tuber crop production. He observed highly significant difference in cassava dry matter (22 % over uninoculated control) and tuber production (30 %) in natural soil under half the RD of phosphatic fertilizer. Microbial and soil enzyme activity was enhanced in the rhizosphere by mycorrhizal colonization. Mycorrhizal cassava plants had higher P (35-45 %) and micro nutrients like Cu (6-9 %) and Zn (11 %).

In sweet potato, Kabeerathumma *et al.* (1986) observed that tuber yield and P uptake were significantly influenced by AMF inoculation along with FYM application. This combination tended to increase the uptake of other nutrients like Mg, Zn, and Fe. Yield increase of 20-26 % was noticed due to AMF inoculation. The gross returns, net returns and BCR were maximum for the treatment receiving 50 % recommended N and P fertilizer combined with AMF inoculation in sweet potato (Pusphakumari and Geethakumari, 1999). Co-inoculation of AMF and

Phosphobacterium with the addition of P as rock phosphate significantly enhanced the total biomass production, tuber yield and uptake of P in sweet potato (Potty, 2000).

Coleus is also mycorrhiza dependent like other crops and mycorrhizal infection was observed 15 days after inoculation with *Glomus microcarpum* var. *microcarpum* (Potty, 1978). Potty (2000) reported that the percentage of colonization of AMF in coleus was more in low P level compared to high P soils. Microbial activity in the rhizosphere was more under low fertility soil. It was also observed that mycorrhizal infection reduced nematodes in coleus.

2.4 Effect of integrated nutrient management

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

In coleus, Thyagarajan (1969) reported that 60 : 60 : 120 kg NPK ha^{-1} along with 5 t ha^{-1} of FYM may be applied for higher tuber production. But Geetha (1983) found that integrated application of FYM @ 10 t ha^{-1} along with 60 : 30 : 120 kg NPK ha^{-1} may be applied for economic production of coleus. KAU (1996) and CTCRI (1996) recommend 60 : 60 : 100 kg NPK ha^{-1} along with 10 t ha^{-1} of FYM for coleus.

For sweet potato, under low land situation, the combination of FYM @ 10 t ha^{-1} and 75 : 50 : 75 kg NPK ha^{-1} recorded maximum yield (19.6 t ha^{-1}) which was significantly superior to control (8.33 t ha^{-1}) and on par with the combination of 5 t ha^{-1} of FYM + 50 : 25 : 50 kg NPK ha^{-1} which yielded 17.05 t ha^{-1} of tubers (Ravindran and Nair, 1994). There was no significant difference in the tuber yield between FYM doses of 5 and 10 t ha^{-1}.

The highest tuber yield of cassava was obtained with 100 kg each of N, P_2O_5 and K_2O ha^{-1} along with 12.5 t ha^{-1} of FYM. The combined use of NPK and FYM could produce an yield increase of four times higher when FYM or any of the nutrients (N, P or K) applied individually (Mohankumar *et al.*, 2000).

Nutrient management studies on Amorphophallus conducted by CTCRI (1991) revealed that maximum corm yield, the highest DMP as well as the highest nutrient uptake were recorded for the treatment NPK @ 100 : 50 : 150 kg ha^{-1} + FYM @ 25 t ha^{-1} than lower levels of N, P and K with and without FYM.

Maheswarappa *et al.* (1997) opined that combined application of FYM @ 20 t ha^{-1} and 75 : 50 : 50 kg NPK ha^{-1} (17.1 t ha^{-1}) of arrowroot intercropped in coconut garden. Reduction in the yield with FYM applied alone was 16 . 4 to 17.9 %, with NPK alone was 26.9 % and with control was 63.7 % compared to FYM + NPK treatment (Maheswarappa *et al.*, 1999). Increased yield of arrowroot intercropped in the coconut garden due to the combined application of 10 t ha^{-1} of FYM and 120 : 50 : 80 kg NPK ha^{-1} was also reported by Veenavidyadharan (2000).

From the review of literature, it is seen that CCP and NC can be used as organic manures which can solve the problem of scarcity of FYM to some extent. No such studies have been undertaken in coleus so far. NC is also reported to be effective for the control of root-knot nematode *Meloidogyne incognita*. There is also the possibility of reducing the recommended dose of fertilizer P for coleus especially with AMF inoculation. Mycorrhiza do not replace P fertilizer but increase the fertilizer use efficiency thus reducing the rate of application (Patel and Pachal, 1991). Antagonistic effect of AMF on root-knot nematode has also been reported. A scan of literature also indicates the necessity of integrated nutrient management for increasing the crop yield and sustaining soil fertility. Studies on the effect of integrated use of organic manures, chemical fertilizers and AMF inoculation in coleus were lacking. Hence the present investigation was undertaken to find out the feasibility of reducing present recommended dose of fertilizer P with AMF inoculation, to study the combined effect of organic manures, fertilizers and AMF on the productivity and quality of coleus and to workout the economics of cultivation.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation was carried out to study the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present recommended dose of fertilizer P and to workout the economics of cultivation.

3.1 MATERIALS

3.1.1 Experimental site

The experiment was undertaken at the Instructional Farm attached to the College of Agriculture, Vellayani located at 8^0 $30^{\prime}$ N latitude and 76^0 $54^{\prime}$ E longitude at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental site was red loam belonging to Vellayani series which comes under the order oxisol. The initial data on mechanical and chemical properties of the soil and the methods adopted for the analysis are presented in Table 1.

The soil was sandy clay loam in texture and acidic with a pH of 4.8. It was low in available N and medium in available P and K contents.

Table 1 Soil characteristics of the experimental site

Parameter	Unit	Mean value	Method
A. Mechanical composition			
Coarse sand	%	36.35	International pipette method (Piper, 1966)
Fine sand	”	15.00	
Silt	”	17.80	
Clay	”	30.00	
B. Chemical properties			
Available N	Kg ha^{-1}	263.00	Alkaline permanganate method (Subbiah and Asija 1956)
Available P_2O_5	”	40.56	Bray extraction and Klett Summerson photo electric colorimeter (Jackson, 1973)
Available K_2O	”	115.53	Neutral normal ammonium acetate method (Jackson, 1973)
pH	-	4.80	pH meter with glass electrode (Jackson, 1973).

3.1.3 Cropping history of the experimental site

The experimental site was lying fallow for one year prior to the experiment.

3.1.4 Season

The experiment was conducted during October 2000- March 2001. The crop was planted on 20th October 2000 and harvested on 26th March 2001.

3.1.5 Weather conditions

A humid tropical climate prevails in the experimental site. Data on maximum and minimum temperatures, relative humidity and rainfall during the entire crop season are collected and presented as weekly averages in Appendix I and Fig. 1.

3.1.6 Planting material

Coleus var. Sree Dhara released from Central Tuber Crops Research Institute (CTCRI), Sreekariyam, Thiruvananthapuram was the crop used for the experiment. Tubers were obtained from CTCRI, Thiruvananthapuram Uniform sized tubers were used for planting.

3.1.7 Manures and fertilizers

The organic manures used in the experiment were FYM containing 0.4 % N, 0.3 % P_2O_5 and 0.2 % K_2O, CCP containing 1.12 % N, 0.06 % P_2O_5 and 1.16 % K_2O and NC containing 1.12 % N, 1.0 % P_2O_5 and 1.4 % K_2O. On N equivalent basis, 1.78 t of CCP or NC could substitute 5 t of FYM.

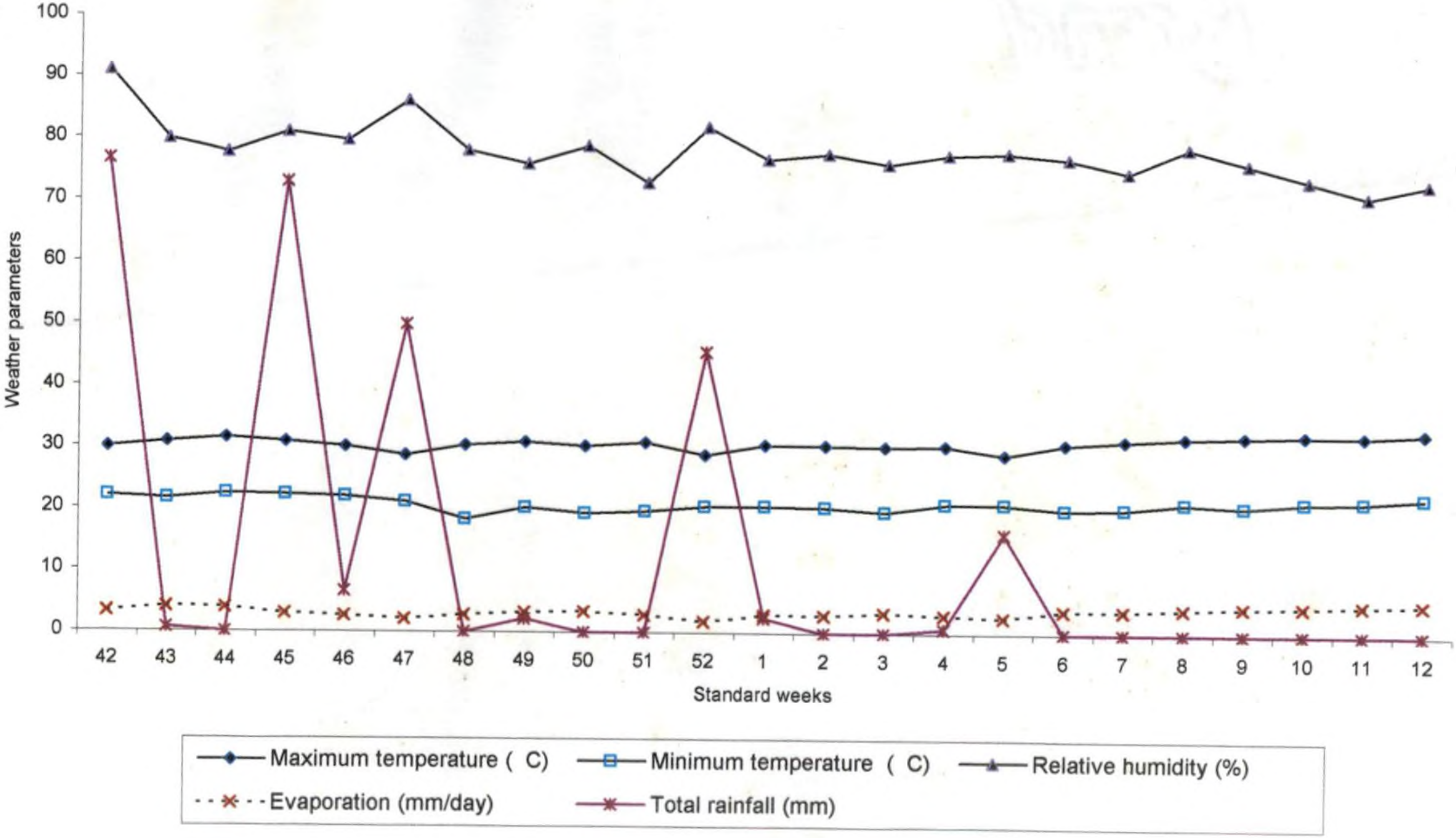

Fig. 1 Weather data for the cropping period

The fertilizers used were urea (46 % N), rajphos (20 % P_2O_5) and muriate of potash (60 % K_2O).

The biofertilizer used was AMF and mixed cultures containing spores of *Glomus* sp. infected sorghum root pieces and infected medium (perlite vermiculite) were collected from the pots maintained at the Department of Plant Pathology, College of Agriculture, Vellayani.

3.2 Methods

3.2.1 Details of treatments

The treatments consisted of factorial combinations of four levels of organic manures and two levels each of P and biofertilizer.

(i) Organic manure (M)

m_1 - Recommended dose (RD) as FYM

m_2 - RD as CCP

m_3 - 1/2 RD as FYM + 1/2 RD as NC

m_4 - 1/2 RD as CCP + 1/2 RD as NC

(ii) P levels (P)

p_1 - 30 kg P_2O_5 ha^{-1}

p_2 - 60 kg P_2O_5 ha^{-1}

(iii) Biofertilizer levels (B)

b_0 - Control (no biofertilizer inoculation)

b_1 - AMF inoculation

A uniform dose of 60 kg N ha^{-1} and 100 kg K_2O ha^{-1} was applied to all plots.

Treatment combinations

$m_1p_1b_0$	$m_2p_1b_0$	$m_3p_1b_0$	$m_4p_1b_0$
$m_1p_1b_1$	$m_2p_1b_1$	$m_3p_1b_1$	$m_4p_1b_1$
$m_1p_2b_0$	$m_2p_2b_0$	$m_3p_2b_0$	$m_4p_2b_0$
$m_1p_2b_1$	$m_2p_2b_1$	$m_3p_2b_1$	$m_4p_2b_1$

3.2.2 Experimental design and layout

The experiment was laid out as a 4 x 2 x 2 asymmetrical confounded factorial design confounding ABC in all replications (Cochran and Cox, 1965). The layout plan is given in Fig 2.

The details of the layout are given below:

Treatment combinations	16
Replications	3
Number of blocks per replication	2
Number of plots per block	8
Gross plot size	3 x 3 m
Net plot size	1.8 x 2.4 m
Variety	Sree Dhara
Spacing	30 x 30 cm

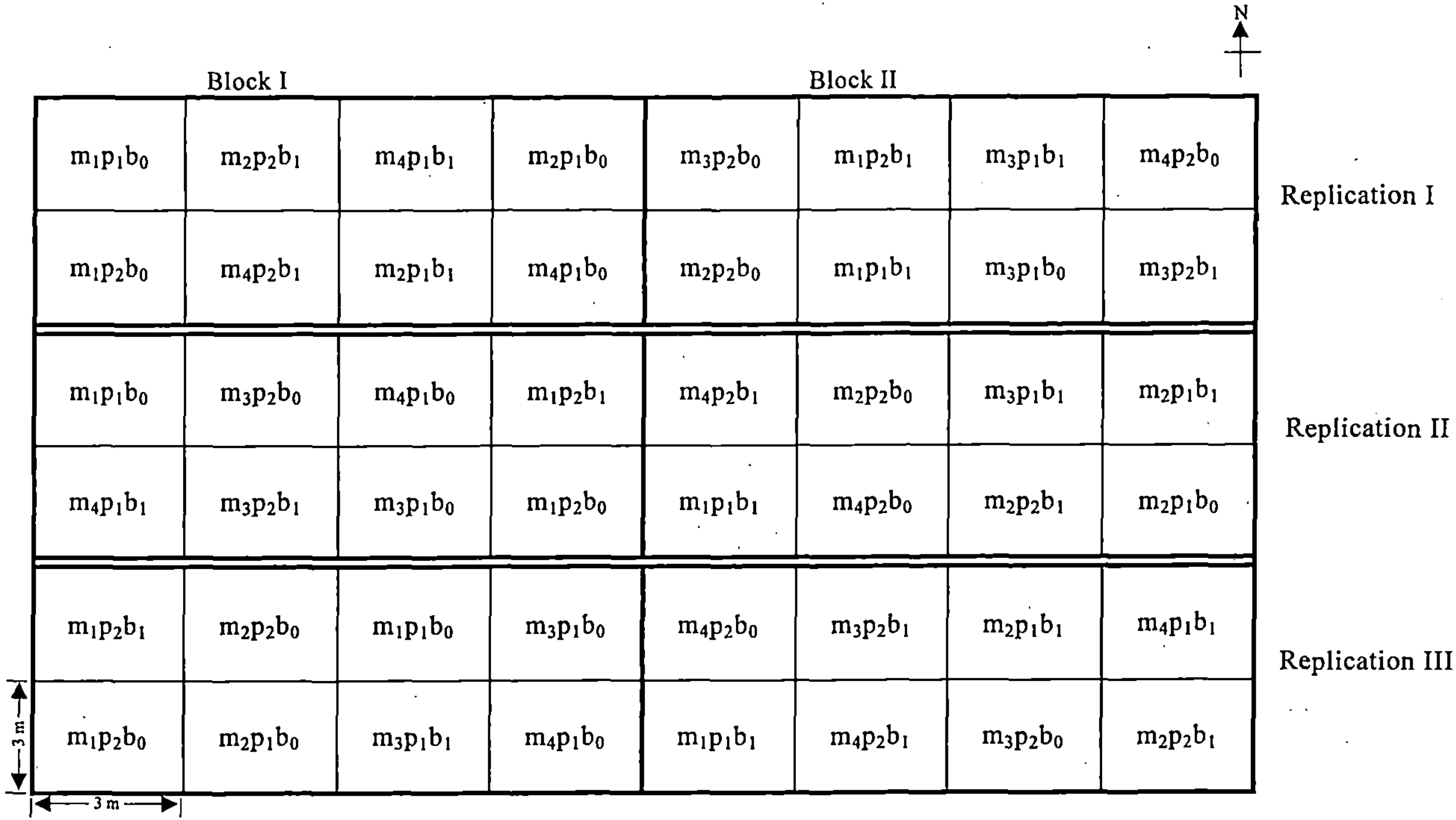

Fig. 2 Layout of the experiment

3.2.3 Details of cultivation

3.2.3.1 Nursery

A small area adjacent to the experimental site was cleared and dug well, stubbles were removed, clods were broken and a raised bed was made. FYM at 1 kg m^{-2} was mixed with the soil. Coleus tubers of uniform size were planted at a spacing of 30 x 15 cm during the first week of September 2000. Healthy and vigorous cuttings of length of 10-15 cm from the apical portions were taken for planting in the main field during the third week of October 2000.

3.2.3.2 Preparation of mainfield

The experimental area was dug twice, stubbles were removed, clods were broken and the field was laid out into blocks and plots and raised beds of 15 cm height was taken in each plot. The beds were levelled and organic manures like FYM, CCP and NC were applied to plots in appropriate quantities as per the treatment schedule and well incorporated into the soil.

3.2.3.3 Fertilizer application

According to the treatment schedule, N, P and K were applied to the plots in the form of urea, rajphos and muriate of potash respectively in appropriate quantities. Full dose of P and half dose of N and K were applied as basal dose. Half of N and K was applied 45 DAP.

3.2.3.4 Biofertilizer application

Culture of AMF @ 2 g per plant was made into a slurry with cowdung and coleus cuttings were dipped in the slurry before planting.

3.2.3.5 Transplanting

Coleus cuttings taken from the nursery were transplanted in the main field at a spacing of 30 cm between rows and 30 cm between plants. Shade was provided immediately after planting and uniform irrigation was given.

3.2.3.6 After cultivation

Gap filling was done a week after planting to have uniform stand of the crop. One hand weeding and earthing up was done 45 DAP along with topdressing of fertilizers. A portion of the vine was covered with soil to promote tuber formation.

3.2.3.7 Harvest

The crop was ready for harvest five months after planting. Harvesting was done by digging out the tubers carefully and the tubers were separated from the shoot portion. The border rows and observational plants were harvested separately from each plot.

3.3 Biometric observations

Single line of plants all round in each plot was left out as border row. A row of plants on the eastern side in each plot was set apart as destructive row for taking plant samples for growth analysis. The subsequent row on that side was again left out as border row, thus making the net plot area to 1.8 x 2.4m. Five plants were randomly selected from the net plot and tagged as observational plants.

3.3.1 Growth characters

Growth characters were recorded from the five observational plants at monthly intervals from planting upto harvest and the averages worked out.

3.3.1.1 Height of the plant

The height of the plant was measured from the base of the plant to the tip of the growing point and expressed in cm.

3.3.1.2 Number of branches per plant

Number of branches per plant were counted and recorded.

3.3.1.3 Plant spread

Spread of the plant was measured from the tip of the largest branch to the tip of the largest branch in the opposite direction.

3.3.1.4 Number of leaves per plant

Number of functional leaves at the time of observation were counted and recorded.

3.3.2 Growth analysis

For growth analysis, two plants were uprooted from the destructive row at 60 DAP, 90 DAP, 120 DAP and harvest.

3.3.2.1 Leaf area index (LAI)

LAI was calculated by adopting punch method. Leaves from the uprooted plants were separated and punched. The discs as well as the leaves were dried in hot air oven at 70^{0}C and their respective dry weights were recorded. From the data leaf area per plant was computed and LAI was worked out using the formula (Watson, 1952).

$$LAI = \frac{\text{Leaf area}}{\text{Land area}}$$

3.3.2.2 Dry matter production (DMP)

The sample plants uprooted were separated into leaves, stem and tubers and were dried in a hot air oven at a temperature of 70^{0}C to constant dry weights. Total DMP was expressed in kg ha^{-1}.

3.3.2.3 Crop growth rate (CGR)

CGR was computed using the formula of Watson (1958) and expressed as g m^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{P\,(t_2 - t_1)}$$

Where W_1 and W_2 - plant dry weights at times t_1 and t_2

t_2-t_1 - time interval in days

P - ground area on which W_1 and W_2 have been estimated.

3.3.2.4 Relative growth rate (RGR)

RGR was determined based on the formula of Williams (1946) and expressed in g $g^{-1}day^{-1}$.

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

Where W_1 and W_2 - plant dry weights at times t_1 and t_2 respectively

t_2-t_1 - time interval in days

3.3.2.5 Net assimilation rate (NAR)

The method proposed by Gregory (1917) and modified by Williams (1946) was employed for calculating the NAR on leaf dry weight basis and the values were expressed as g m^{-2} day^{-1}.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\log_e L_2 - \log_e L_1}{L_2 - L_1}$$

Where W_1 and W_2 - plant dry weights at times t_1 and t_2 respectively

L_1 and L_2 - leaf area at times t_1 and t_2 respectively

t_2-t_1 - time interval in days.

3.3.2.6 Tuber bulking rate (BR)

It is the rate of increase in tuber weight per unit time and is an important measure of tuber growth. It is expressed as g day^{-1} $plant^{-1}$.

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

Where W_1 and W_2 - dry weights of tubers at times t_1 and t_2 respectively

$t_2 - t_1$ - time interval in days

3.3.3 Yield and yield components

3.3.3.1 Numbers of tubers per plant

Total number of tubers from the observational plants were counted and their average worked out.

3.3.3.2 Number of marketable tubers per plant

Marketable tubers were separated based on visual observation and average number recorded.

3.3.3.3 Weight of tubers per plant

Weight of tubers from the observational plants was recorded and average was worked out.

3.3.3.4 Weight of marketable tubers per plant

Weight of marketable tubers from the observational plants were recorded and average worked out.

3.3.3.5 Tuber yield per hectare

Yield of total tubers obtained from each net plot was recorded and expressed in t ha^{-1}.

3.3.3.6 Utilization index (UI)

It is the ratio of the tuber yield to the top yield on fresh weight basis. This was worked out from the tuber weight and top weight of the observational plants.

3.3.4 Quality parameters of tuber

Dried samples of the tubers from the observational plants were used for quality analysis.

3.3.4.1 Starch content

Starch content of tuber was estimated by using potassium ferricyanide method (Ward and Pigman, 1970).

3.3.4.2 Protein content

Protein content of the tuber was calculated by multiplying percentage of N in tuber with the factor 6.25 (Simpson *et al.*, 1965).

3.3.4.3 Shelf life

Samples of tubers weighing 100 g each from all the treatments were spread on floor and observed for the shelf life of tubers. The shrinkage due to weight loss as well as sprouting of tubers were observed once in three days.

3.4 Chemical analysis

3.4.1 Soil analysis

Soil samples were taken from the experimental area before and after the experiment. The composite sample from the experimental area before the experiment was analysed for mechanical composition and chemical properties. After the experiment, composite samples were collected from each plot, air dried, powdered and passed through a 2 mm sieve and analysed for available N, P and K using the standard procedures.

3.4.2 Plant analysis

The observational plants uprooted were used for the analysis of N, P and K contents at harvest. The tubers and the shoot portions were analysed separately. The samples were dried in a hot air oven at 70^0C separately till constant weights were obtained. Samples were then ground to pass through 0.5 mm mesh in a Willey mill.

The N content in plant was estimated by modified micro-kjeldahl method (Jackson, 1973). The P content in plants was estimated colorimetrically (Jackson, 1973) and K content by flame photometric method (Piper, 1966).

3.5 Uptake of nutrients

The total uptake of N, P and K were calculated based on the respective nutrient contents in tubers and shoot portions and their corresponding dry weights. The uptake was expressed in kg ha^{-1}.

3.6 Observations on nematode incidence

Nematodes were extracted from the representative soil samples, collected before and after the experiment, following the modified method of Cobb's sieving and decanting technique (Cobb, 1918). The nematodes thus extracted were counted.

3.7 Economics of cultivation

The economics of cultivation of the crop in terms of net income and BCR was calculated as follows.

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

$$BCR = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.8 Statistical analysis

The experimental data were analysed statistically by applying the technique of analysis of variance (ANOVA) for 4 x 2 x 2 confounded factorial experiment and the significance was tested by F test (Cochran and Cox, 1965). Wherever F test was significant in ANOVA, the critical difference (CD) is provided.

Results

4. RESULTS

The field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from October 2000 to March 2001 to study the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present recommended dose of fertilizer P and to workout the economics of cultivation. The trial was laid out in asymmetrical confounded factorial RBD with 16 treatments in two blocks of eight plots each per replication and three replications. The experimental data were statistically analysed and the results are presented in this chapter.

4.1 Growth characters

4.1.1 Height of the plant

Plant height as influenced by different organic manures, P levels and AMF inoculation as well as their interactions at monthly intervals starting from 30 DAP are presented in Table 4.1.1a and 4.1.1b.

The main effects of organic manure alone was significant, which also at 90 and 120 DAP only. Higher value of 35.75 cm was recorded at 90 DAP when FYM was used as the organic manure (m_1) which was on par with m_4 (1/2 CCP + 1/2 NC) but significantly superior to m_3 (1/2 FYM + 1/2 NC) and m_2 (CCP). At 120 DAP, higher value of 38.08 cm was recorded by the treatment m_3 which was on par with m_1 and m_4. At harvest, the highest value

Table 4.1.1a Effect of different organic manures, P levels and AMF inoculation on plant height (cm)

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)					
m_1	18.04	30.67	35.75	37.42	42.04
m_2	17.75	28.38	30.29	34.08	44.21
m_3	17.38	29.75	31.00	38.08	48.71
m_4	18.17	31.00	33.83	36.33	43.33
$F_{3, 27}$	0.11	2.00	5.66**	3.67*	2.38
SE	1.53	2.12	1.51	1.30	2.66
CD	-	-	3.092	2.656	-
P levels (P)					
p_1	17.88	29.13	32.98	37.17	44.04
p_2	17.79	29.77	32.46	35.79	45.10
$F_{1, 27}$	0.006	0.19	0.24	2.26	0.32
SE	1.08	1.50	1.07	0.92	1.88
Biofertilizer (B)					
b_0	17.42	29.50	32.90	35.75	45.25
b_1	18.25	29.40	32.54	37.21	43.90
$F_{1, 27}$	0.60	0.005	0.11	2.54	0.52
SE	1.08	1.50	1.07	0.92	1.88

*Significant at 5 % level
** Significant at 1 % level

Table 4.1.1b Interaction effect of different organic manures, P levels and AMF inoculation on plant height (cm)

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	18.00	31.33	38.00	39.00	41.75
m_1p_2	18.08	30.00	33.50	35.83	42.33
m_2p_1	18.67	25.17	30.42	35.50	44.17
m_2p_2	16.83	27.58	30.17	32.67	44.25
m_3p_1	17.17	29.08	30.33	37.17	47.08
m_3p_2	17.58	30.42	31.67	39.00	50.33
m_4p_1	17.67	30.92	33.17	37.00	43.17
m_4p_2	18.67	31.08	34.50	35.67	43.50
$F_{3, 27}$	0.32	0.29	1.67	1.56	0.15
SE	2.16	2.99	2.13	1.83	3.76
m_1b_0	17.58	29.92	35.00	35.50	40.58
m_1b_1	18.50	31.42	36.50	39.33	43.50
m_2b_0	16.58	26.83	30.25	32.50	49.17
m_2b_1	18.92	29.92	30.33	35.67	39.25
m_3b_0	17.50	31.08	32.00	37.83	46.83
m_3b_1	17.25	28.42	30.00	38.33	50.58
m_4b_0	18.00	30.17	34.33	37.17	44.42
m_4b_1	18.33	31.83	33.33	35.50	42.25
$F_{3, 27}$	0.26	0.48	0.50	1.91	2.79
SE	2.16	2.99	2.13	1.83	3.76
p_1b_0	17.17	28.42	32.58	36.17	43.58
p_1b_1	18.58	29.83	33.38	38.17	44.50
p_2b_0	17.67	30.58	33.21	35.33	46.92
p_2b_1	17.92	28.96	31.71	36.25	43.29
$F_{1, 27}$	0.29	1.04	1.16	0.35	1.46
SE	1.53	2.12	1.51	1.30	2.66

of 48.71cm was recorded by the treatment m_3. However, no significant difference was observed with m_1, m_2 and m_4.

P levels and AMF inoculation had no significant effect on plant height at any stage of growth.

None of the interaction effects were found to have significant effect on plant height.

4.1.2 Number of branches per plant

Number of branches as influenced by the treatments are presented in Table 4.1.2a and 4.1.2b.

Different organic manures had significant effect on number of branches per plant at 30 DAP only. Higher value of 10.13 was recorded by the treatment m_3 (1/2 FYM + 1/2 NC) which was on par with m_2 (CCP).

P levels and AMF inoculation produced no significant effect on the number of branches at any stage of growth.

The interaction P x B was found to have significant influence on number of branches at all stages except 60 DAP. The highest number of branches was recorded at 30 DAP by the combination p_2 b_0 which was on par with p_1 b_1. At 90 DAP and 120 DAP, higher value was recorded by the treatment combination p_1b_1 which was on par with p_1b_0 and p_2 b_0. At harvest, all the combinations were on par. However, positive response was observed for p_1 with inoculation and negative response for p_2 with inoculation. This response was seen at all stages.

Table 4.1.2a Effect of different organic manures, P levels and AMF inoculation on number of branches per plant

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)					
m_1	8.83	10.88	9.58	8.50	6.46
m_2	9.13	9.88	8.42	8.17	6.13
m_3	10.13	11.17	8.92	9.00	5.67
m_4	7.92	9.63	9.33	8.58	5.88
$F_{3, 27}$	4.88**	1.20	1.20	0.46	0.86
SE	0.58	0.97	0.66	0.71	0.52
CD	1.195	-	-	-	-
P levels (P)					
p_1	8.77	10.46	9.25	8.67	6.00
p_2	9.23	10.31	8.88	8.46	6.06
$F_{1, 27}$	1.24	0.05	0.64	0.17	0.03
SE	0.41	0.69	0.47	0.71	0.37
Biofertilizer (B)					
b_0	9.23	10.46	9.04	8.58	6.17
b_1	8.77	10.31	9.08	8.54	5.90
$F_{1, 27}$	1.24	0.05	0.008	0.007	0.55
SE	0.41	0.69	0.47	0.51	0.37

** Significant at 1 % level

Table 4.1.2b Interaction effect of different organic manures, P levels and AMF inoculation on number of branches per plant

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	9.25	11.33	9.67	8.67	6.58
m_1p_2	8.42	10.42	9.50	8.33	6.33
m_2p_1	9.08	9.58	8.17	8.33	6.67
m_2p_2	9.17	10.17	8.67	8.00	5.58
m_3p_1	9.25	11.33	9.17	9.50	5.42
m_3p_2	11.00	11.00	8.67	8.50	5.92
m_4p_1	7.50	9.58	10.00	8.17	5.33
m_4p_2	8.33	9.67	8.67	9.00	6.42
$F_{3,27}$	1.78	0.22	0.67	0.57	1.64
SE	0.82	1.37	0.94	1.01	0.73
m_1b_0	9.42	11.17	9.33	8.50	6.17
m_1b_1	8.25	10.58	9.83	8.50	6.75
m_2b_0	9.00	9.75	8.17	8.67	6.58
m_2b_1	9.25	10.00	8.67	7.67	5.67
m_3b_0	10.58	12.00	8.83	8.33	5.92
m_3b_1	9.67	10.33	9.00	9.67	5.42
m_4b_0	7.92	8.92	9.83	8.83	6.00
m_4b_1	7.92	10.33	8.83	8.83	5.75
$F_{3,27}$	0.70	0.90	0.58	0.09	0.74
SE	0.82	1.37	0.94	1.01	0.73
p_1b_0	8.38	9.92	8.58	8.00	5.75
p_1b_1	9.17	11.00	9.92	9.33	6.25
p_2b_0	10.08	11.00	9.50	9.17	6.58
p_2b_1	8.38	9.63	8.25	7.75	5.54
$F_{1,27}$	9.22**	3.22	7.65*	7.42*	4.42*
SE	0.58	0.97	0.66	0.71	0.52
CD	1.195	-	1.355	1.465	1.063

*Significant at 5 % level
** Significant at 1 % level

M x P and M x B interactions were absent.

4.1.3 Plant spread

The results pertaining to plant spread at different stages are furnished in Table 4.1.3a and 4.1.3b.

The effect of different organic manures was not significantly different in plant spread at 30 DAP. But at later stages, significant differences in plant spread were seen. At 60 DAP and 90 DAP, higher plant spread was recorded by the treatment m_1 (FYM) which was on par with m_3 (1/2 FYM + 1/2 NC). At 120 DAP and harvest, m_3 recorded the highest value which was on par with m_2 (CCP) and m_4 (1/2 CCP + 1/2 NC) at both stages.

An increase in applied P and AMF inoculation had no significant influence on plant spread.

No significant difference was observed in plant spread when organic manure treatments, m_1, m_2 and m_3 were combined with p_1 and p_2, but m_4p_2 registered higher plant spread than m_4p_1 at 30 DAP (Table 4.1.3a). At 60 and 90 DAP, such a differential response was not observed. However at 120 DAP, M x P interaction was present. Treatments m_1, m_3 and m_4 combined with p_1 or p_2 did not produce any significant difference in plant spread, but m_2p_1 treated plants registered more spread than m_2p_2 treated plants. At harvest stage also, no interaction was observed.

M x B interaction was absent at all stages while P x B interaction was present at harvest stage. Plants treated with p_1 and AMF inoculation produced

Table 4.1.3a Effect of different organic manures, P levels and AMF inoculation on plant spread (cm)

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)					
m_1	32.43	50.79	52.58	42.92	35.15
m_2	31.75	37.83	42.33	51.17	42.29
m_3	29.54	46.67	47.75	51.67	49.38
m_4	33.67	40.38	44.46	47.00	45.25
$F_{3, 27}$	1.43	3.74*	2.81*	3.22*	7.43**
SE	2.05	4.31	3.77	3.22	3.11
CD	-	8.847	7.726	6.613	6.382
P levels (P)					
p_1	32.56	42.06	44.65	47.54	41.07
p_2	61.13	45.77	48.92	48.83	44.97
$F_{1, 27}$	0.98	1.48	2.57	0.32	3.15
SE	1.45	3.05	2.66	2.28	2.20
Biofertilizer (B)					
b_0	32.07	44.08	46.10	48.00	42.40
b_1	31.63	43.75	47.46	48.68	43.64
$F_{1, 27}$	0.10	0.12	0.26	0.03	0.32
SE	1.45	3.05	2.66	2.28	2.20

*Significant at 5 % level
** Significant at 1 % level

Table 4.1.3b Interaction effect of different organic manures, P levels and AMF inoculation on plant spread (cm)

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	35.25	48.08	50.50	39.17	34.27
m_1p_2	29.62	53.50	54.67	46.67	36.03
m_2p_1	33.58	39.42	39.42	56.83	40.58
m_2p_2	29.92	36.25	45.25	45.50	44.00
m_3p_1	30.83	44.67	46.50	48.33	48.00
m_3p_2	28.25	48.67	49.00	55.00	50.75
m_4p_1	30.58	36.08	42.17	45.83	41.42
m_4p_2	36.75	44.67	46.75	48.17	49.08
$F_{3,27}$	3.25*	0.66	0.07	3.66*	0.35
SE	2.89	6.10	5.33	4.56	4.40
CD	5.940	-	-	9.352	-
m_1b_0	32.03	49.50	49.83	43.17	34.47
m_1b_1	32.83	52.08	55.33	42.67	35.83
m_2b_0	30.67	41.83	42.67	53.50	43.70
m_2b_1	32.83	33.83	42.00	48.83	40.88
m_3b_0	29.92	48.25	47.67	49.17	50.25
m_3b_1	29.17	45.08	47.83	54.17	48.50
m_4b_0	35.67	36.75	44.25	46.17	41.17
m_4b_1	31.67	44.00	44.67	47.83	49.33
$F_{3,27}$	0.84	1.19	0.28	0.79	1.26
SE	2.89	6.10	5.33	4.56	4.40
p_1b_0	32.13	39.75	41.92	46.75	37.88
p_1b_1	33.00	44.38	47.38	48.33	44.26
p_2b_0	32.12	48.42	50.29	49.25	46.92
p_2b_1	30.25	43.12	47.54	48.42	43.02
$F_{1,27}$	0.83	2.65	2.38	0.28	5.47*
SE	2.05	4.31	3.77	3.22	3.11
CD	-	-	-	-	6.382

*Significant at 5 % level

higher spread in comparison with not inoculated ones. But with p_2 treated plants, inoculation did not produce any significant result.

4.1.4 Number of leaves per plant

The data showing the influence of various treatments on number of leaves per plant at monthly intervals from 30 DAP upto harvest are given in Table 4.1.4a and 4.1.4b.

The effect of organic manures on the number of leaves was observed only at 90 DAP and harvest stage. The highest number of leaves was produced by the treatment m_1 (FYM) at 90 DAP which was significantly higher compared to m_2 (CCP), m_3 (1/2 FYM + 1/2 NC) and m_4 (½ CCP + 1/2 NC) only and at harvest by m_4 which was on par with m_1 but superior to m_2 and m_3.

P levels had significant influence on number of leaves at 90 DAP and application of 60 kg P_2O_5 ha^{-1} (p_2) recorded higher number of leaves.

AMF inoculation did not produce any significant influence on the number of leaves per plant at any stage of plant growth.

The interaction P x B influenced the number of leaves per plant at 30 DAP which need not be given any importance as their main effects were not significant at this stage.

Table 4.1.4a Effect of different organic manures, P levels and AMF inoculation on number of leaves per plant

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)					
m_1	126.42	262.42	354.58	174.92	84.83
m_2	128.71	267.75	199.58	195.92	79.00
m_3	129.88	291.42	270.58	202.75	74.58
m_4	120.33	244.79	253.92	218.92	99.42
$F_{3, 27}$	0.26	1.54	12.57**	1.25	3.16*
SE	11.83	21.94	25.61	23.02	8.61
CD	-	-	52.559	-	17.672
P levels (P)					
p_1	122.85	270.44	242.63	204.00	81.50
p_2	129.81	262.75	296.71	189.25	87.42
$F_{1, 27}$	0.69	0.25	8.92**	1.19	0.94
SE	8.36	15.62	18.11	16.28	6.09
CD	-	-	37.164	-	-
Biofertilizer (B)					
b_0	127.92	280.52	264.08	198.17	83.92
b_1	124.75	252.67	275.25	198.08	85.00
$F_{1, 27}$	0.14	8.22	0.38	0.000	0.32
SE	8.36	15.22	18.11	16.28	6.09

*Significant at 5 % level
** Significant at 1 % level

Table 4.1.4b Interaction effect of different organic manures, P levels and AMF inoculation on number of leaves per plant

Treatments	30 DAP	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	124.25	281.17	349.33	167.33	78.33
m_1p_2	128.58	243.67	359.83	182.50	91.33
m_2p_1	124.42	265.50	197.50	203.83	80.83
m_2p_2	133.00	270.00	201.67	188.00	77.17
m_3p_1	133.42	287.83	203.33	214.33	73.17
m_3p_2	126.33	295.00	337.83	191.17	76.00
m_4p_1	109.33	247.25	220.33	242.50	93.67
m_4p_2	131.33	242.33	287.50	195.33	105.17
$F_{3, 27}$	0.52	0.44	2.80	0.62	0.41
SE	16.73	31.03	36.22	32.55	12.81
m_1b_0	133.58	282.42	326.50	157.50	84.67
m_1b_1	119.25	242.42	382.67	192.33	85.00
m_2b_0	125.17	281.00	208.50	200.00	85.83
m_2b_1	132.25	254.50	190.67	191.83	72.17
m_3b_0	128.92	329.33	268.83	225.83	67.00
m_3b_1	130.83	253.50	272.33	179.67	82.17
m_4b_0	124.00	229.33	252.50	209.33	98.17
m_4b_1	116.67	260.25	255.33	228.50	100.67
$F_{3, 27}$	0.33	2.04	0.76	1.11	0.94
SE	16.73	31.03	36.22	32.55	12.18
p_1b_0	114.33	269.21	223.17	198.00	77.00
p_1b_1	131.38	271.67	262.08	216.00	86.00
p_2b_0	141.50	291.83	305.00	198.33	90.83
p_2b_1	118.13	233.67	288.42	180.17	84.00
$F_{1, 27}$	5.84*	3.82	2.35	1.23	1.69
SE	11.83	21.94	25.61	23.02	8.61
CD	24.266	-	-	-	-

*Significant at 5 % level

4.2 Growth analysis

4.2.1 Leaf area index (LAI)

The results on LAI recorded at monthly intervals from 30 DAP upto harvest are given in Table 4.2.1a and 4.2.1b.

Among the treatments, organic manures had significant influence on LAI at 60 DAP, 90 DAP and harvest. FYM (m_1) was superior to all other organic manures at 60 and 90 DAP. But m_3 (1/2 FYM + 1/2 NC) recorded higher LAI at harvest which was on par with m_4 (1/2 CCP + 1/2 NC) but superior to m_1 and m_2 (CCP).

Levels of P and AMF inoculation did not produce any significant result.

The interaction M x B had significant influence on LAI only at 90 DAP and the treatment combination m_1 b_1 was superior to all other combinations. M x P interaction was absent. P x B interaction assumed less importance as the main effects of P and B were not significant.

4.2.2 Total dry matter production

Total dry matter production, as influenced by the treatments, recorded at monthly intervals from 60 DAP upto harvest, is furnished in Table 4.2.2a and 4.2.2b.

In the case of organic manure treatments, the highest value of DMP was registered by FYM (m_1) which was on par with m_3 (1/2 FYM + 1/2 NC) at 60 DAP while FYM was superior to all other treatments at 90 DAP. Treatments

Table 4.2.1a Effect of different organic manures, P levels and AMF inoculation on leaf area index

Treatments	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)				
m_1	3.14	2.64	1.27	0.75
m_2	2.51	1.73	1.11	0.66
m_3	2.41	1.86	1.35	0.94
m_4	2.01	1.83	1.12	0.84
$F_{3, 27}$	17.03**	11.90**	2.02	5.90**
SE	0.16	0.17	0.11	0.07
CD	0.329	0.353	-	0.143
P levels (P)				
p_1	2.49	2.12	1.28	0.80
p_2	2.54	1.92	1.45	0.80
$F_{1, 27}$	0.23	2.76	2.67	0.004
SE	0.11	0.12	0.08	0.05
Biofertilizer (B)				
b_0	2.54	1.95	1.25	0.81
b_1	2.50	2.08	1.18	0.79
$F_{1, 27}$	0.11	1.14	0.65	0.11
SE	0.11	0.12	0.08	0.05

** Significant at 1 % level

Table 4.2.1b Interaction effect of different organic manures, P levels and AMF inoculation on leaf area index

Treatments	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	3.22	2.81	1.41	0.75
m_1p_2	3.07	2.48	1.13	0.76
m_2p_1	2.51	2.00	1.12	0.89
m_2p_2	2.51	1.47	1.10	0.99
m_3p_1	2.38	1.77	1.34	0.71
m_3p_2	2.45	1.96	1.35	0.60
m_4p_1	1.86	1.90	1.24	0.85
m_4p_2	2.16	1.77	1.00	0.83
$F_{3, 27}$	0.68	1.59	0.65	0.77
SE	0.23	0.24	0.16	0.10
m_1b_0	3.10	2.27	1.28	0.79
m_1b_1	3.19	3.02	1.26	0.72
m_2b_0	2.69	1.68	1.22	0.94
m_2b_1	2.33	1.79	1.00	0.95
m_3b_0	2.55	1.95	1.32	0.68
m_3b_1	2.27	1.78	1.38	0.64
m_4b_0	1.81	1.92	1.16	0.84
m_4b_1	2.21	1.75	1.09	0.84
$F_{3, 27}$	2.41	3.20*	0.88	0.15
SE	0.23	0.24	0.16	0.10
CD	-	0.499	-	-
p_1b_0	2.34	1.88	1.22	0.76
p_1b_1	2.64	2.35	1.34	0.84
p_2b_0	2.73	2.02	1.27	0.86
p_2b_1	2.36	1.81	1.02	0.70
$F_{1, 27}$	8.72**	7.84**	0.54	4.98*
SE	0.11	0.17	0.11	0.07
CD	0.329	0.353	0.234	0.143

*Significant at 5 % level
** Significant at 1 % level

Table 4.2.2a Effect of different organic manures, P levels and AMF inoculation on total dry matter production (kg ha^{-1})

Treatments	60 DAP	90 DAP	120 DAP	Harvest
Organic manures (M)				
m_1	3612	4762	5411	6492
m_2	2990	3626	5224	5924
m_3	3468	4014	5098	5955
m_4	3088	3933	4835	6088
$F_{3, 27}$	3.57*	8.56**	2.03	1.65
SE	222.88	232.99	239.48	288.06
CD	457.4	478.1	-	-
P levels (P)				
p_1	3249	3941	5051	6013
p_2	3330	4226	5234	6216
$F_{1, 27}$	0.26	3.01	1.17	0.99
SE	157.60	164.75	169.34	203.68
Biofertilizer (B)				
b_0	3338	4246	5156	6054
b_1	3241	3921	5128	6176
$F_{1, 27}$	0.38	3.91	0.03	0.36
SE	157.60	164.75	169.34	203.68

* Significant at 5 % level
** Significant at 1 % level

Table 4.2.2b Interaction effect of different organic manures, P levels and AMF inoculation on total dry matter production (kg ha^{-1})

Treatments	60 DAP	90 DAP	120 DAP	Harvest
m_1p_1	3686	4400	5238	6518
m_1p_2	3538	5123	5583	6466
m_2p_1	2785	3430	5073	5795
m_2p_2	3195	3822	5375	6053
m_3p_1	3482	3911	4831	5481
m_3p_2	3454	4116	5366	6429
m_4p_1	3045	4021	5060	6260
m_4p_2	3131	3845	4611	5915
$F_{3, 27}$	0.58	1.30	1.64	1.85
SE	315.21	329.49	338.67	407.37
m_1b_0	3687	4902	5374	6465
m_1b_1	3537	4622	5447	6519
m_2b_0	3037	3902	5271	5877
m_2b_1	2943	3349	5177	5970
m_3b_0	3497	4099	5055	5915
m_3b_1	3439	3928	5142	5995
m_4b_0	3130	4083	4925	5957
m_4b_1	3046	3784	4746	6218
$F_{3, 27}$	0.02	0.24	0.15	0.05
SE	315.21	329.49	338.67	407.37
p_1b_0	3257	3950	4810	5788
p_1b_1	3242	3933	5291	6239
p_2b_0	3419	4543	5503	6319
p_2b_1	3241	3910	4965	6112
$F_{1, 27}$	0.27	3.48	9.06**	2.61
SE	222.88	232.99	239.48	288.06
CD	-	-	491.4	-

** Significant at 1 % level

m_2 (CCP), m_3 and m_4 (1/2 CCP + 1/2 NC) were on par at 60 and 90 DAP. At 120 DAP and harvest, no significant variation in total dry matter was observed due to the application of different organic manures.

P application and AMF inoculation failed to produce any significant difference in total dry matter at any stage.

The interaction P x B exerted significant influence on DMP at 120 DAP only, which was not relevant in the present context.

4.2.3 Crop growth rate (CGR)

The average values of CGR as affected by different treatments are presented in Table 4.2.3a and 4.2.3b.

Organic manures significantly influenced CGR at all stages, but different trend in response was observed. Upto 60 DAP, the highest CGR was noticed with FYM (m_1) but was on par with m_3 (1/2 FYM + 1/2 NC) but superior to m_4 (1/2 CCP + 1/2 NC) and m_2 (CCP). At 60-90 DAP, m_1 treated plots recorded the highest CGR. Treatment m_4 was superior to m_3 but on par with m_2. At 90-120 DAP, m_3 treated plots registered the highest CGR which was on par with m_2 but superior to m_4 and m_1. At harvest stage, m_1 treated plots showed higher CGR value than m_3 and m_2 but on par with m_4.

Application of P at 60 kg P_2O_5 ha^{-1} registered higher CGR at harvest in comparison with P at the rate of 30 kg P_2O_5.

The effect of AMF inoculation on CGR was seen only at harvest stage.

Table 4.2.3a Effect of different organic manures, P levels and AMF inoculation on crop growth rate (g m^{-2} day^{-1})

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
Organic manures (M)				
m_1	6.39	2.90	2.42	3.11
m_2	5.00	2.17	3.36	2.08
m_3	5.78	1.96	3.77	2.65
m_4	5.15	2.48	3.01	3.01
$F_{3,27}$	7.02**	5.35**	8.10**	9.40**
SE	0.34	0.25	0.28	0.22
CD	0.695	0.514	0.584	0.450
P levels (P)				
p_1	5.58	2.21	3.24	2.44
p_2	5.58	2.55	3.04	2.97
$F_{1,27}$	0.001	3.60	0.92	11.72**
SE	0.24	0.18	0.20	0.16
CD	-	-	-	0.318
Biofertilizer (B)				
b_0	5.59	2.34	2.95	2.54
b_1	5.57	2.43	3.33	2.87
$F_{1,27}$	0.009	0.26	3.57	4.37*
SE	0.24	0.18	0.20	0.16
CD	-	-	-	0.318

*Significant at 5 % level
** Significant at 1 % level

Table 4.2.3b Interaction effect of different organic manures, P levels and AMF inoculation on crop growth rate (g m^{-2} day^{-1})

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
m_1p_1	6.87	2.21	2.63	3.27
m_1p_2	5.90	3.60	2.21	2.95
m_2p_1	4.64	2.16	3.48	1.57
m_2p_2	5.36	2.18	3.25	2.54
m_3p_1	5.73	1.89	3.38	2.09
m_3p_2	5.82	2.04	4.17	3.21
m_4p_1	5.08	2.59	3.47	2.84
m_4p_2	5.22	2.38	2.55	3.18
$F_{3, 27}$	2.16	4.06	3.16	4.49*
SE	0.48	0.36	0.40	0.31
CD	-	-	-	0.636
m_1b_0	6.15	2.70	2.09	2.98
m_1b_1	6.63	3.11	2.75	3.24
m_2b_0	5.10	2.38	3.06	2.30
m_2b_1	4.91	1.96	3.66	1.81
m_3b_0	5.89	1.93	3.85	2.29
m_3b_1	5.66	2.00	3.70	3.01
m_4b_0	5.22	2.34	2.81	2.61
m_4b_1	5.08	2.63	3.21	3.41
$F_{3, 27}$	0.48	1.07	0.85	3.67*
SE	0.48	0.36	0.40	0.31
CD	-	-	-	0.636
p_1b_0	5.43	1.94	2.86	2.30
p_1b_1	5.73	2.49	3.61	2.58
p_2b_0	5.75	2.73	3.04	2.78
p_2b_1	5.40	2.36	3.05	3.16
$F_{1, 27}$	1.81	6.77	3.35	0.11
SE	0.34	0.25	0.28	0.22

*Significant at 5 % level

The interaction M x P and M x B was present from 120 DAP upto harvest. In the case of M x P interaction, the treatment combination m_1p_1 produced the highest CGR which was on par with m_1p_2, m_3p_2, m_4p_1 and m_4p_2. Treatments m_1 and m_4 combined with p_1 or p_2 produced no significant difference in CGR. But m_2 and m_3 combined with p_2 exhibited higher CGR at harvest stage.

With regard to M x B interaction, the highest value was recorded by the combination m_4b_1 which was on par with m_1b_0, m_1b_1 and m_3b_1. Plants which were inoculated and treated with m_3 and m_4 showed higher CGR values in comparison with those not inoculated. Treatments m_1 and m_2 whether inoculated or not did not produce any positive result.

4.2.4 Relative growth rate (RGR)

The monthly averages of RGR from 60 DAP upto harvest are furnished in Table 4.2.4a and 4.2.4b.

Only organic manures provided any significant effect on RGR, that also during the period from 90 to 120 DAP. During that stage, the effect of all the sources of organic manure were on par but superior to CCP (m_2) alone.

RGR was not appreciably influenced by P levels and AMF inoculation at all stages.

None of the interactions were significant in their effects on RGR.

Table 4.2.4a Effect of different organic manures, P levels and AMF inoculation on relative growth rate (g $g^{-1}day^{-1}$)

Treatments	60-90 DAP	90-120 DAP	120 DAP - Harvest
Organic manures (M)			
m_1	0.009	0.010	0.006
m_2	0.007	0.005	0.005
m_3	0.005	0.008	0.007
m_4	0.008	0.007	0.007
$F_{3, 27}$	1.76	3.44*	1.58
SE	0.002	0.001	0.001
CD	-	0.0031	-
P levels (P)			
p_1	0.007	0.008	0.006
p_2	0.008	0.007	0.007
$F_{1, 27}$	0.80	1.11	1.00
SE	0.001	0.001	0.001
Biofertilizer (B)			
b_0	0.008	0.007	0.006
b_1	0.007	0.008	0.006
$F_{1, 27}$	0.31	1.79	0.47
SE	0.001	0.001	0.001

*Significant at 5 % level

Table 4.2.4b Interaction effect of different organic manures, P levels and AMF inoculation on relative growth rate (g g^{-1} day^{-1})

Treatments	60-90 DAP	90-120 DAP	120 DAP - Harvest
m_1p_1	0.006	0.006	0.007
m_1p_2	0.001	0.004	0.005
m_2p_1	0.007	0.011	0.004
m_2p_2	0.007	0.008	0.005
m_3p_1	0.005	0.008	0.006
m_3p_2	0.006	0.008	0.007
m_4p_1	0.009	0.007	0.005
m_4p_2	0.007	0.007	0.009
$F_{3, 27}$	2.32	0.56	1.98
SE	0.002	0.002	0.001
m_1b_0	0.009	0.004	0.006
m_1b_1	0.010	0.006	0.006
m_2b_0	0.008	0.008	0.005
m_2b_1	0.006	0.001	0.005
m_3b_0	0.005	0.007	0.007
m_3b_1	0.006	0.009	0.006
m_4b_0	0.009	0.007	0.006
m_4b_1	0.007	0.007	0.008
$F_{3, 27}$	0.29	0.25	0.600
SE	0.002	0.002	0.001
p_1b_0	0.007	0.007	0.006
p_1b_1	0.007	0.009	0.005
p_2b_0	0.009	0.006	0.006
p_2b_1	0.007	0.007	0.008
$F_{1, 27}$	1.21	0.11	3.27
SE	0.002	0.001	0.001

4.2.5 Net assimilation rate (NAR)

The influence of treatments on NAR during different stages are given in Table 4.2.5a and 4.2.5b.

Organic manures had profound influence on NAR at all stages. Upto 60 DAP, the highest NAR was noticed with the treatment m_4 (1/2 CCP + 1/2 NC) which was on par with m_3 (1/2 FYM + 1/2 NC) and superior to m_2 (CCP) and m_1 (FYM). From 60 to 90 DAP, the highest NAR was recorded by the treatment m_4 which was superior to m_2 and m_3 while at 90 to 120 DAP, m_2 (CCP) which was on par with m_3 was superior to m_1. NAR was more or less similar at harvest stage with respect to m_4, m_1 and m_3 but superior to m_2.

P application had significant effect on NAR from 60 to 90 DAP and 120 DAP upto harvest. NAR increased with increase in P level during both the stages.

AMF inoculation had significantly increased the NAR from 90 DAP upto harvest.

The interactions M x P and M x B were found to have significant influence on NAR. Regarding M x P interaction, m_1p_2 treated plots recorded higher NAR than m_1p_1 treated plots at 60-90 DAP while m_2, m_3 and m_4 combined with p_1 or p_2 produced no significant difference in NAR. But at harvest, the treatment m_1 in combination with p_1 or p_2 did not show any significant difference in NAR but m_2, m_3 and m_4 combined with p_2 registered significantly higher NAR values in comparison with m_4 combined with p_1.

Table 4.2.5a Effect of different organic manures, P levels and AMF inoculation on net assimilation rate (g m^{-2} day^{-1})

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
Organic manures (M)				
m_1	1.94	1.10	1.19	2.92
m_2	2.01	1.00	2.50	2.14
m_3	2.38	0.91	2.23	2.77
m_4	2.56	1.26	2.04	3.07
$F_{3, 27}$	4.44*	4.70**	16.81**	5.40**
SE	0.20	0.10	0.19	0.25
CD	0.407	0.199	0.402	0.512
P levels (P)				
p_1	2.19	0.96	1.94	2.34
p_2	2.26	1.18	2.04	3.11
$F_{1, 27}$	0.25	10.87**	0.49	19.11**
SE	0.14	0.07	0.14	0.18
CD	-	0.140	-	0.362
Biofertilizer (B)				
b_0	2.19	1.06	1.83	2.54
b_1	2.25	1.08	2.15	2.91
$F_{1, 27}$	0.19	0.09	5.49*	4.43*
SE	0.14	0.07	0.14	0.18
CD	-	-	0.284	0.362

*Significant at 5 % level
** Significant at 1 % level

Table 4.2.5b Interaction effect of different organic manures, P levels and AMF inoculation on net assimilation rate (g m^{-2} day^{-1})

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
m_1p_1	1.92	0.72	1.11	3.02
m_1p_2	1.96	1.48	1.26	2.82
m_2p_1	1.75	0.94	2.27	1.59
m_2p_2	2.27	1.07	2.72	2.68
m_3p_1	2.46	0.87	2.20	2.04
m_3p_2	2.29	0.96	2.27	3.50
m_4p_1	2.61	1.30	2.18	2.69
m_4p_2	2.51	1.22	1.90	3.44
$F_{3, 27}$	1.26	7.32**	1.19	4.06*
SE	0.28	0.14	0.28	0.35
CD	-	0.281	-	0.724
m_1b_0	2.01	1.02	1.06	2.86
m_1b_1	1.87	1.19	1.31	2.98
m_2b_0	1.81	1.07	2.24	2.34
m_2b_1	2.22	0.94	2.75	1.93
m_3b_0	2.19	0.88	2.09	2.31
m_3b_1	2.56	0.94	2.38	3.23
m_4b_0	2.76	1.27	1.92	2.64
m_4b_1	2.36	1.24	2.16	3.49
$F_{3, 27}$	2.01	0.89	0.49	3.25*
SE	0.28	0.14	0.28	0.35
CD	-	-	-	0.724
p_1b_0	2.30	0.97	1.87	2.33
p_1b_1	2.08	0.94	2.01	2.35
p_2b_0	2.09	1.15	1.79	2.75
p_2b_1	2.43	1.21	2.29	3.47
$F_{1, 27}$	4.04	0.58	5.49*	3.88*
SE	0.20	0.10	0.19	0.25

*Significant at 5 % level
** Significant at 1 % level

M x B interaction was present during the period from 120 DAP upto harvest. Treatments m_3 and m_4 combined with inoculation produced higher NAR as against m_1 and m_2.

4.2.6 Tuber bulking rate

Tuber bulking rate as influenced by the treatments are presented in Table 4.2.6a and 4.2.6b.

Organic manures had profound influence on BR at all stages except at 90-120 DAP. At all stages, FYM recorded higher values except at 60-90 DAP. Upto 60 DAP, m_1 and m_3 were superior and were on par with each other in their effects. The treatment m_2 recorded the lowest value. At 60-90 DAP, all other organic manures except FYM were on par. Although the effect was not significant, FYM recorded higher BR at 90-120 DAP. FYM was superior to other treatments at harvest stage. All other treatments were similar in their effects.

P levels had no significant effect on BR at all stages except 60-90 DAP. At 60-90 DAP, p_2 showed higher BR which was on par with p_1. AMF had no effect on BR at any stage of plant growth.

Among the interactions, the interaction M x P was significant at all growth stages except at harvest. The interaction m_1p_1 recorded the highest BR which was on par with m_2p_2 and m_4p_2 during the initial growth stage. At 60-90 DAP, m_3p_1 recorded the highest BR which was on par with m_2p_2, m_3p_2 and m_4p_2. The combination m_1p_1 recorded the least value. At 90-120 DAP, the

Table 4.2.6a Effect of different organic manures, P levels and AMF inoculation on tuber bulking rate (g day^{-1} $plant^{-1}$)

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
Organic manures (M)				
m_1	0.24	0.83	0.58	1.66
m_2	0.19	0.40	0.56	1.04
m_3	0.23	0.41	0.51	1.03
m_4	0.21	0.40	0.53	0.95
$F_{3,27}$	3.040*	6.36**	1.71	3.55
SE	16.08	20.37	34.11	67.74
CD	0.033	0.042	-	0.139
P levels (P)				
p_1	0.22	0.37	0.54	1.05
p_2	0.22	0.40	0.55	1.04
$F_{1,27}$	0.001	5.74*	0.15	0.13
SE	11.50	14.42	24.12	48.00
CD	-	0.030	-	-
Biofertilizer (B)				
b_0	0.21	0.38	0.53	1.03
b_1	0.22	0.39	0.56	1.06
$F_{1,27}$	0.66	0.84	1.40	0.34
SE	11.50	14.42	24.12	48.00

*Significant at 5 % level
** Significant at 1 % level

Table 4.2.6b Interaction effect of different organic manures, P levels and AMF inoculation on tuber bulking rate (g day^{-1} $plant^{-1}$)

Treatments	Up to 60 DAP	60-90 DAP	90-120 DAP	120 DAP - Harvest
m_1p_1	0.267	0.299	0.505	1.121
m_1p_2	0.212	0.366	0.660	1.211
m_2p_1	0.203	0.364	0.652	1.115
m_2p_2	0.185	0.434	0.475	0.965
m_3p_1	0.201	0.436	0.477	1.026
m_3p_2	0.249	0.391	0.545	1.037
m_4p_1	0.194	0.377	0.538	0.956
m_4p_2	0.221	0.422	0.531	0.937
$F_{3, 27}$	4.007*	3.515*	8.510**	1.083
SE	23.00	28.75	48.25	96.00
CD	0.0472	0.0591	0.0990	-
m_1b_0	0.219	0.361	0.490	1.011
m_1b_1	0.261	0.304	0.675	1.321
m_2b_0	0.187	0.405	0.558	1.102
m_2b_1	0.202	0.393	0.568	0.978
m_3b_0	0.216	0.400	0.536	1.095
m_3b_1	0.234	0.427	0.485	0.969
m_4b_0	0.226	0.352	0.549	0.921
m_4b_1	0.189	0.447	0.52	0.972
$F_{3, 27}$	0.089	5.088**	8.511**	4.584*
SE	23.00	28.75	48.25	96.00
CD	-	0.0591	-	0.197
p_1b_0	0.200	0.350	0.525	1.043
p_1b_1	0.233	0.388	0.561	0.066
p_2b_0	0.224	0.409	0.542	0.021
p_2b_1	0.210	0.398	0.563	0.054
$F_{1, 27}$	4.191	2.932	0.108	0.009
SE	16.08	20.37	34.11	67.74

*Significant at 5 % level
** Significant at 1 % level

treatment combination m_1p_2 recorded maximum BR compared to other combinations which was on par with m_2p_1.

The effect of the interaction M x B was not relevant as the main effect of the biofertilizer was not significant.

4.3 Yield components

The average values of yield components as influenced by the treatments are presented in Table 4.3a and 4.3b.

4.3.1 Number of tubers per plant

Different organic manures significantly influenced the number of tubers per plant. The RD of organic manure as FYM (m_1) or half the dose as FYM and half as NC (m_3) produced more number of tubers per plant, the m_4 (1/2 CCP + 1/2 NC) and m_2 (CCP) which were on par and no significant difference was observed between m_1 and m_3.

Neither P applied at different levels nor AMF inoculation produced any significant influence on number of tubers per plant.

The interaction M x P appreciably influenced the number of tubers per plant. No significant difference was observed when the treatments m_1, m_3 and m_4 were combined with p_1 or p_2. But m_2p_2 recorded a significant reduction in the number of tubers in comparison with m_2p_1 and all other treatment combinations.

Table 4.3a Effect of different organic manures, P levels and AMF inoculation on yield components

Treatments	Number of tubers per plant	Number of marketable tubers per plant	Weight of tubers per plant (g)	Weight of marketable tubers per plant (g)
Organic manures (M)				
m_1	21.58	13.04	252.08	220.92
m_2	18.00	12.79	166.67	152.75
m_3	22.17	12.33	210.42	182.58
m_4	18.58	12.71	192.50	169.00
$F_{3, 27}$	4.38*	0.16	16.67**	11.08**
SE	1.41	1.05	12.44	12.35
CD	2.905	-	25.531	25.352
P levels (P)				
p_1	20.33	12.79	211.79	184.42
p_2	19.83	12.65	199.04	178.21
$F_{1, 27}$	0.25	0.04	2.10	0.51
SE	1.00	0.74	8.80	8.74
CD	-	-	-	-
Biofertilizer (B)				
b_0	20.71	13.69	208.33	186.58
b_1	19.46	11.75	202.50	176.04
$F_{1, 27}$	1.56	6.85*	0.44	1.46
SE	1.00	0.74	8.80	8.74
CD	-	1.519	-	-

*Significant at 5 % level
** Significant at 1 % level

Table 4.3b Interaction effect of different organic manures, P levels and AMF inoculation on yield components

Treatments	Number of tubers per plant	Number of marketable tubers per plant	Weight of tubers per plant (g)	Weight of marketable tubers per plant (g)
m_1p_1	21.17	12.67	254.17	221.00
m_1p_2	22.00	13.42	250.00	220.83
m_2p_1	22.50	15.17	188.33	167.17
m_2p_2	13.50	10.42	145.00	138.33
m_3p_1	20.67	12.00	208.83	176.50
m_3p_2	23.67	12.67	212.00	188.67
m_4p_1	17.00	11.33	195.83	173.00
m_4p_2	20.17	14.08	189.17	165.00
$F_{3, 27}$	8.29**	4.72**	1.40	0.97
SE	1.20	1.48	17.60	17.47
CD	4.108	3.038	-	-
m_1b_0	21.17	12.92	260.00	232.00
m_1b_1	22.00	12.17	244.17	209.83
m_2b_0	48.17	14.67	172.50	168.33
m_2b_1	17.83	10.92	160.85	137.17
m_3b_0	23.50	13.00	217.50	186.83
m_3b_1	20.83	11.67	203.33	178.33
m_4b_0	20.00	14.17	183.33	159.17
m_4b_1	17.17	11.25	201.67	178.83
$F_{3, 27}$	0.81	1.43	0.85	1.61
SE	1.20	1.48	17.60	17.47
CD	-	-	-	-
p_1b_0	20.08	12.54	207.33	184.67
p_1b_1	20.58	13.04	216.25	184.17
p_2b_0	21.33	14.83	209.33	188.50
p_2b_1	18.33	10.46	188.75	167.92
$F_{1, 27}$	3.06	10.84**	2.81	1.32
SE	1.41	1.05	12.44	12.35
CD	-	2.149	-	-

** Significant at 1 % level

4.3.2 Number of marketable tubers per plant

Organic manures and P levels could not produce any appreciable effect on number of marketable tubers per plant. But the number of marketable tubers per plant decreased significantly due to AMF inoculation.

The interaction M x P assumed no importance since the main effects were not significant. In the case of P x B interaction, p_2 without inoculation was superior to p_2 with inoculation while p_1 with and without inoculation did not produce any significant effect.

4.3.3 Weight of tubers per plant

Organic manures had exerted positive influence on the weight of tubers per plant. FYM alone as the source of organic manure (m_1) recorded the highest value (258.08g) of tuber weight per plant. The treatment m_3 in which half the dose of FYM was substituted with NC, could produce 210.42 g of tubers per plant on par with m_4 (1/2 CCP + 1/2 NC). The lowest value was recorded by CCP (m_2).

P levels and AMF inoculation did not produce any significant change on tuber weight per plant.

None of the interaction effects were significant with respect to this character.

4.3.4 Weight of marketable tubers per plant

Sources of organic manure varied significantly with respect to weight of marketable tubers per plant. The RD of organic manure as FYM (m_1) registered the highest value of 220.92g. The treatment m_3 (1/2 FYM + 1/2 NC) registered the next higher value of (182.58g) which was on par with m_4 (1/2 CCP + 1/2 NC). CCP (m_2) recorded the lowest value.

P levels and AMF inoculation failed to produce significant change in the weight of marketable tubers per plant.

The effects of interactions were also not significant.

4.4 Tuber yield per hectare

The tuber yield per hectare as influenced by different organic manures, P levels and AMF inoculation as well as their interactions are presented in Table 4.4a and 4.4b.

Among the treatments, different organic manures exerted noticeable difference in tuber yield. The RD of organic manure as FYM (m_1) recorded the highest tuber yield (28 t ha^{-1}) which was superior to all other sources. The next best treatment was m_3 (1/2 FYM + 1/2 NC) which produced 23.4 t ha^{-1} of tubers but was on par with m_4 (1/2 CCP + 1/2 NC). CCP (m_2) was inferior to other sources in its effect on tuber yield.

Table 4.4a Effect of different organic manures, P levels and AMF inoculation on tuber yield and utilization index

Treatments	Tuber yield (t ha^{-1})	Utilization index
Organic manures (M)		
m_1	28.0	2.40
m_2	18.4	2.24
m_3	23.4	2.10
m_4	21.4	2.34
$F_{3, 27}$	17.79**	1.78
SE	1.36	0.14
CD	2.79	-
P levels (P)		
p_1	23.5	2.31
p_2	22.1	2.23
$F_{1, 27}$	1.93	0.60
SE	0.96	0.10
Biofertilizer (B)		
b_0	23.1	2.33
b_1	22.5	2.21
$F_{1, 27}$	0.35	1.52
SE	0.96	0.10

** Significant at 1 % level

Table 4.4b Interaction effect of different organic manures, P levels and AMF inoculation on tuber yield and utilization index

Treatments	Tuber yield (t ha^{-1})	Utilization index
m_1p_1	28.2	2.46
m_1p_2	27.8	2.34
m_2p_1	20.6	2.30
m_2p_2	16.1	1.90
m_3p_1	23.2	2.09
m_3p_2	23.6	2.39
m_4p_1	21.7	2.38
m_4p_2	21.0	2.30
$F_{3,27}$	1.25	2.12
SE	1.92	0.20
m_1b_0	28.9	2.34
m_1b_1	27.1	2.46
m_2b_0	18.8	2.14
m_2b_1	17.9	2.06
m_3b_0	24.2	2.34
m_3b_1	22.6	2.15
m_4b_0	20.4	2.51
m_4b_1	22.4	2.17
$F_{3,27}$	0.84	0.98
SE	1.92	0.20
p_1b_0	22.8	2.35
p_1b_1	24.0	2.27
p_2b_0	23.3	2.32
p_2b_1	21.0	2.15
$F_{1,27}$	3.23	0.25
SE	1.36	0.14

Enhancement of P or AMF inoculation did not help in increasing the tuber yield.

The effects of interactions on tuber yield were not significant.

4.4.1 Utilization index (UI)

Utilization index was not influenced by any of the factors M, P or B tested.

4.5 Quality parameters of tuber

The average values of starch and protein contents of tuber as affected by the treatments are furnished in Table 4.5a and 4.5b.

Neither the starch content nor the protein content of the tuber was affected by the treatments.

4.5.1 Shelf life

Number of days taken from harvest of tubers to the stage at which tubers become shrunken or decayed or sprouted was recorded. No loss in weight was observed even when the samples were kept till the day on which sprouting of 50 % of tubers was observed. Sprouting of 50 % of samples was observed in all the treatments within 30 to 40 days after storage. No decay of tubers due to microbial attack was observed even when the tubers were kept for more than two months.

4.6 Uptake of nutrients

The data pertaining to the effect of different organic manures, P levels and AMF inoculation on the uptake of N, P and K (kg ha^{-1}) are furnished in Table 4.6a and 4.6b.

Table 4.5a Effect of different organic manures, P levels and AMF inoculation on quality parameters of tuber

Treatments	Starch %	Protein %
Organic manures (M)		
m_1	17.60	8.14
m_2	17.01	7.92
m_3	17.37	8.66
m_4	17.16	8.85
$F_{3, 27}$	0.72	2.26
SE	0.43	0.41
P levels (P)		
p_1	17.31	8.60
p_2	17.26	8.19
$F_{1, 27}$	0.02	2.03
SE	0.30	0.29
Biofertilizer (B)		
b_0	17.48	8.49
b_1	17.09	8.29
$F_{1, 27}$	1.59	0.50
SE	0.30	0.29

Table 4.5b Interaction effect of different organic manures, P levels and AMF inoculation on quality parameters of tuber

Treatments	Starch %	Protein %
m_1p_1	17.63	8.52
m_1p_2	17.57	7.76
m_2p_1	17.27	8.23
m_2p_2	16.75	7.60
m_3p_1	16.68	8.70
m_3p_2	18.07	8.63
m_4p_1	17.66	8.94
m_4p_2	16.67	8.75
$F_{3, 27}$	2.88	2.26
SE	0.60	0.58
m_1b_0	17.64	8.16
m_1b_1	17.57	8.12
m_2b_0	17.95	7.96
m_2b_1	16.07	7.88
m_3b_0	17.17	8.93
m_3b_1	17.57	8.40
m_4b_0	17.16	8.93
m_4b_1	17.17	8.76
$F_{3, 27}$	2.82	2.03
SE	0.60	0.58
p_1b_0	17.15	8.75
p_1b_1	17.46	8.44
p_2b_0	17.80	8.24
p_2b_1	16.73	8.14
$F_{1, 27}$	5.21*	0.50
SE	0.43	0.41
CD	0.880	-

*Significant at 5 % level

Table 4.6a Effect of different organic manures, P levels and AMF inoculation on uptake of nutrients (kg ha^{-1}) at harvest

Treatments	N uptake	P uptake	K uptake
Organic manures (M)			
m_1	143.68	34.74	241.60
m_2	111.51	26.38	187.79
m_3	140.57	32.37	224.74
m_4	126.63	29.13	202.32
$F_{3,27}$	3.54*	5.03**	3.32*
SE	11.07	2.31	18.48
CD	22.711	4.738	37.928
P levels (P)			
p_1	125.91	28.68	216.10
p_2	135.28	32.63	212.12
$F_{1,27}$	1.43	5.85*	0.09
SE	7.83	1.63	13.07
CD	-	3.350	-
Biofertilizer (B)			
b_0	132.52	30.54	215.24
b_1	128.68	30.77	212.98
$F_{1,27}$	0.24	0.02	0.03
SE	7.83	1.63	13.07

*Significant at 5 % level
** Significant at 1 % level

Table 4.6b Interaction effect of different organic manures, P levels and AMF inoculation on uptake of nutrients (kg ha^{-1}) at harvest

Treatments	N uptake	P uptake	K uptake
m_1p_1	131.18	28.19	234.69
m_1p_2	156.18	41.30	248.51
m_2p_1	124.90	28.73	223.64
m_2p_2	98.12	24.03	151.95
m_3p_1	131.92	31.62	220.85
m_3p_2	149.22	33.11	228.62
m_4p_1	115.65	26.18	185.23
m_4p_2	137.60	32.09	219.41
$F_{3,27}$	2.41	5.27**	3.17*
SE	15.65	3.27	26.14
CD	-	6.700	53.638
m_1b_0	140.01	32.99	244.23
m_1b_1	147.35	36.50	238.96
m_2b_0	113.00	26.81	194.66
m_2b_1	110.02	25.95	130.92
m_3b_0	151.84	32.40	228.22
m_3b_1	129.30	32.34	221.25
m_4b_0	125.23	29.97	193.84
m_4b_1	128.03	28.30	210.80
$F_{3,27}$	0.71	0.49	0.26
SE	15.65	3.27	26.14
p_1b_0	121.14	26.77	208.56
p_1b_1	130.68	30.60	223.64
p_2b_0	143.90	34.31	221.92
p_2b_1	126.67	30.95	202.32
$F_{1,27}$	2.92	4.85*	1.76
SE	11.07	2.31	18.48
CD	-	4.738	-

*Significant at 5 % level
** Significant at 1 % level

The treatment m_1 (FYM) registered higher N, P and K uptake compared to m_4 (1/2 CCP + 1/2 NC) and m_2 (CCP) which were on par. But m_1 and m_3 were on par in their effects.

Uptake of P increased significantly with increase in the level of P but the uptake of N and K were not influenced by P levels.

AMF inoculation did not produce any significant effect on nutrient uptake.

Among the interactions, only M x P was relevant that too with P uptake only and the treatment combination m_1p_2 was significantly superior to all other combinations.

4.7 Soil nutrient status after the experiment

The mean values of nutrient status of the soil (kg ha^{-1}) after the experiment are summarised in Table 4.7a and 4.7b.

Available N, P and K contents of the soil after the experiment were not influenced by organic manures, P levels or AMF inoculation. So their interactions did not assume any importance.

4.8 Observation on nematode incidence

The initial population of the nematode in the soil ranged from zero to 12 per 100 g of soil which was far below the threshold level (100 larvae per 100 g soil). No symptom of attack of the nematode was observed in the crop. The population of the nematode was less than the infective level in the soil samples collected after the experiment.

Table 4.7a Effect of different organic manures, P levels and AMF inoculation on soil nutrient status (kg ha^{-1}) after the experiment

Treatments	Available N	Available P_2O_5	Available K_2O
Organic manures (M)			
m_1	232.55	50.28	148.49
m_2	226.32	51.32	180.41
m_3	222.93	53.65	177.46
m_4	225.76	54.25	154.00
$F_{3,27}$	0.51	0.80	2.91
SE	8.07	2.97	3.43
P levels (P)			
p_1	224.14	53.86	162.26
p_2	229.65	50.88	167.92
$F_{1,27}$	0.94	2.01	0.36
SE	5.70	2.10	9.49
Biofertilizer (B)			
b_0	224.33	50.23	165.85
b_1	229.46	54.52	164.33
$F_{1,27}$	0.81	4.17	0.03
SE	5.70	2.10	9.49

Table 4.7b Interaction effect of different organic manures, P levels and AMF inoculation on soil nutrient status (kg ha^{-1}) after the experiment

Treatments	Available N	Available P_2O_5	Available K_2O
m_1p_1	218.4	49.85	161.65
m_1p_2	246.70	50.71	135.33
m_2p_1	228.42	58.31	187.79
m_2p_2	224.22	44.34	173.03
m_3p_1	236.48	49.72	172.67
m_3p_2	209.39	57.57	182.25
m_4p_1	213.25	57.57	126.93
m_4p_2	238.28	50.93	181.07
$F_{3, 27}$	5.27**	5.03**	3.52*
SE	11.40	4.20	18.99
CD	23.403	8.616	38.970
m_1b_0	227.87	46.54	146.53
m_1b_1	237.23	54.02	150.45
m_2b_0	228.42	50.07	188.90
m_2b_1	224.22	52.57	171.92
m_3b_0	221.04	50.07	166.50
m_3b_1	224.83	57.22	188.41
m_4b_0	219.99	54.24	161.47
m_4b_1	231.54	54.26	146.53
$F_{3, 27}$	0.38	0.75	0.92
SE	11.40	4.20	18.99
p_1b_0	216.50	52.50	144.67
p_1b_1	231.77	55.23	179.85
p_2b_0	232.16	47.96	187.03
p_2b_1	227.14	53.81	148.81
$F_{1, 27}$	3.16	0.55	14.94**
SE	8.07	2.97	13.43
CD	-	-	27.556

*Significant at 5 % level
** Significant at 1 % level

4.9 Economics of cultivation

The results on economics of cultivation are presented in Table 4.9a and 4.9b.

Maximum net income was recorded when FYM was used on the organic manure (m_1). This was significantly superior to all other organic manure treatments. The treatments m_3 (1/2 FYM + 1/2 NC) and m_4 (1/2 CCP + 1/2 NC) were on par with each other. CCP recorded the lowest net income.

Different organic manures had significantly influenced the BCR. Maximum BCR of 3.49 was recorded by FYM (m_1) which was superior to all the other treatments. The treatment m_3 (1/2 FYM + 1/2 NC) and m_2 (CCP) were on par with each other. The lowest BCR was recorded by m_4 (1/2 CCP + 1/2 NC) but was on par with m_2.

P levels and AMF inoculation had no significant effect on BCR.

Net income was not affected either by P levels nor AMF inoculation. Among the treatment combinations (Table 4.9c), all the FYM treatments resulted in higher net income and BCR. FYM along with 60 kg P_2O_5 ha^{-1} or with 30 kg P_2O_5 ha^{-1} + AMF inoculation produced higher net income and BCR. Lower values of net income and BCR was recorded by CCP or 1/2 CCP + 1/2 NC along with 60 kg P_2O_5 ha^{-1} with or without inoculation.

Table 4.9a Effect of different organic manures, P levels and AMF inoculation on economics of cultivation

Treatments	Net income (Rs. ha^{-1})	BCR
Organic manures (M)		
m_1	99900	3.49
m_2	46153	1.95
m_3	64281	2.22
m_4	50733	1.75
$F_{3, 27}$	25.65**	38.17**
SE	178.75	6.80
CD	13945.2	0.367
P levels (P)		
p_1	69308	2.48
p_2	61225	2.23
$F_{1, 27}$	2.83	3.86
SE	126.22	4.81
Biofertilizer (B)		
b_0	67091	2.39
b_1	63442	2.32
$F_{1, 27}$	0.58	0.34
SE	126.22	4.81

** Significant at 1 % level

Cost of cultivation per ha excluding the treatments	=	Rs. 35654.00	
Cost of 1 t FYM	=	Rs. 360.00	FYM-0.4 % N
Cost of 1 t CCP	=	Rs. 3000.00	CCP – 1.12 % N
Cost of 1 t NC	=	Rs. 8000.00	NC – 1.12 % N
Cost of 1 kg P_2O_5	=	Rs. 20.00	
Cost of 1 kg tuber	=	Rs. 5.00	

5 t FYM ≡ 1.78 t NC / CCP

Table 4.9b Interaction effect of different organic manures, P levels and AMF inoculation on economics of cultivation

Treatments	Net income (Rs. ha^{-1})	BCR
m_1p_1	11354	3.54
m_1p_2	98446	3.43
m_2p_1	59281	2.20
m_2p_2	33024	1.70
m_3p_1	63714	2.22
m_3p_2	64848	2.23
m_4p_1	52883	1.95
m_4p_2	48583	1.56
$F_{3, 27}$	1.647	0.872
SE	9.61	252.92
m_1b_0	104296	3.60
m_1b_1	95504	3.38
m_2b_0	50181	1.20
m_2b_1	42124	1.90
m_3b_0	68231	2.30
m_3b_1	60331	2.15
m_4b_0	45658	1.67
m_4b_1	55808	1.84
$F_{3, 27}$	0.918	0.438
SE	9.61	252.92
p_1b_0	67220.16	2.41
p_1b_1	71396.00	2.54
p_2b_0	66962.66	2.37
p_2b_1	55487.67	2.09
$F_{1, 27}$	2.652	2.483
SE	6.80	178.75

Discussion

5. DISCUSSION

The results of the experiment conducted to study the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present RD of fertilizer P and to workout the economics of cultivation are discussed in this chapter.

5.1 Growth characters

Results of the study indicated that different organic manures had a positive influence on the growth characters of the plant. Phosphorus levels and AMF inoculation had no influence on different growth characters except that P levels had a positive influence on the number of leaves per plant at 90 DAP.

The influence of organic manures was pronounced during the later stage of growth with respect to growth characters like plant height, plant spread and number of leaves per plant (Table 4.1.1a, 4.1.3a and 4.1.4a). But in the case of number of branches per plant, significant influence was noticed only at 30 DAP (Table 4.1.2a). There was not much improvement in the number of branches at 60 DAP. If there is scarcity of FYM, half the dose of it can be substituted with NC (m_3) for obtaining positive influence on the growth characters of coleus. In general, CCP (m_2) was inferior to other sources of organic manure which is in agreement with the findings of Maheswarappa *et al.* (1997) and Arunkumar (2000). The poor performance of CCP compared to other organic manures like FYM and NC may be due to its wide C : N ratio compared to others. The wide C : N ratio of CCP might have resulted in immobilization of nutrients especially N in soil. Instead of substituting the full dose of FYM with CCP, a combination of half the dose as CCP and half the dose as NC (m_4) was found better.

Application of P failed to exert any significant influence on growth characters except number of leaves per plant, that too at 90 DAP only. Number of leaves produced per plant was maximum with 60 kg P_2O_5 ha^{-1} (p_2) at 90 DAP.

Inoculation with AMF culture did not produce any appreciable influence on growth characters. In general, inoculation at lower P level (p_1) performed well than at higher P level (p_2). The acidic nature of soil and medium status of P in the soil might have contributed for the poor response of AMF inoculation as observed by Abbott and Robinson (1984) and Mathew (1999).

5.2 Growth analysis

A general observation about LAI (Table 4.2.1a and 4.2.1b) is that LAI was maximum at 60 DAP for all the treatments and afterwards it showed a declining trend. This might be due to shedding of leaves and production of small sized leaves during later stages. Organic manures had significant influence on LAI at different growth stages. In the early growth stages of the plant, the RD of organic manure as FYM (m_1) produced the highest LAI whereas in the later stages, 1/2 FYM + 1/2 NC (m_3) recorded the highest value but on par with 1/2 CCP + 1/2 NC (m_4). In general, CCP was inferior in its effects. The better performance of FYM in early stages might be due to the increased supply of nutrients and other growth substances along with the improvement of the soil properties. Neem cake acts like a slow release nitrogenous fertilizer and nutrients are available to the crop slowly. This would have resulted in higher LAI in later stages. Application of P had no effect on LAI which is in agreement with the findings of Purewal and Dargen (1957) and Pillai (1967) in colocasia. LAI was also not influenced by AMF inoculation. The interaction M x B had significant influence only at 90 DAP. Application of FYM along with AMF inoculation recorded maximum value of LAI at 90 DAP.

The results given in Table 4.2.2a and 4.2.2b revealed that FYM (m_1) is the best source of organic manure for maximum DMP irrespective of growth stages. The performance of CCP (m_2) was poor during the initial stages while improvement was seen during the later stages. No significant variation in DMP was observed due to application of different organic manures during the later stages. So it can be inferred that FYM can be substituted partly with NC (m_3) or fully with half CCP and half NC (m_4) for higher DMP. The treatments m_3 and m_4 had positive influence on growth characters which might have resulted in favourable DMP also. Application of P could not produce significant increase in total drymatter. This result corroborated with the works of Constantin *et al.* (1977) wherein P application from zero to 73.9 kg ha^{-1} had no effect on DMP in sweet potato. Mohankumar (1986) also reported that total DMP was not affected by P levels in taro. AMF inoculation had no influence on DMP at any stage of growth. The acidic nature of the experimental soil and its medium P status might have contributed for the poor response of AMF.

Organic manures had significant influence on CGR at all stages (Table 4.2.3a). FYM (m_1) recorded superior values at all stages except at 90-120 DAP. At 90-120 DAP, the highest rate of crop growth was recorded by 1/2 FYM + 1/2 NC (m_3). The results also revealed that FYM (m_1) could be substituted partly with NC (m_3) or fully with CCP and NC (m_4). Application of P at higher level produced higher CGR at harvest stage. Similar results were obtained by Oommen (1989) in sweet potato. Although the effect of AMF inoculation was significant only at harvest stage, inoculation registered enhanced CGR at all stages. The interaction M x P and M x B had significant influence on CGR during later stage of plant growth (Table 4.2.3b). The additive effect of the individual nutrients might have resulted in the significant effects of the interactions.

It is evident from Table 4.2.4a and 4.2.4b that only organic manures had significant influence on RGR. Levels of P and AMF had no effects. Organic manures influenced RGR from 90 to 120 DAP. At that stage, all the sources of organic manure were similar in their effects except CCP. The poor performance of CCP at all stages may be due to its wide C : N ratio compared to other organic sources like FYM and NC.

The results on NAR during different stages (Table 4.2.5a) clearly indicated that organic manures had profound influence on NAR at all stages. On the whole, the treatments m_3 (1/2 FYM + 1/2 NC) and m_4 (1/2 CCP + 1/2 NC) were found to be superior in their effects on NAR. At harvest, CCP recorded the lowest NAR. Poor NAR of CCP treated plants may be due to low availability and uptake of nutrients from them. NAR increased with increase in P level during 60 to 90 DAP and 120 DAP to harvest stage. During other stages, P had no effect on NAR. High rates of P had significant effect on NAR in cassava as reported by Nayar (1986). AMF inoculation significantly increased the NAR during the later stages of plant growth. The interaction with P levels and AMF inoculation were found to have significant influence on NAR (Table 4.2.5b). At 60-90 DAP, FYM (m_1) with 60 kg P_2O_5 ha^{-1} (p_2) recorded increased NAR while at harvest CCP (m_2), 1/2 FYM + 1/2 NC (m_3) and 1/2 CCP + 1/2 NC (m_3) combined with 60 kg P_2O_5 ha^{-1} (p_2) recorded higher NAR. Hence it may be inferred that organic manures in combination with higher levels of P gave higher NAR. This may be due to the additive effect of the factors. Positive response to inoculation with AMF was observed with m_3 (1/2 FYM + 1/2 NC) and m_4 (1/2 CCP + 1/2 NC) treated plants than with m_1 (FYM) and m_2 (CCP) treated plants. FYM recorded superior values of BR of tubers at all stages except at 60-90 DAP (Table 4.2.6a). This might be due to the significant effect of FYM on growth characters. There was not much variation in the BR due to different organic manures during later stages of growth. Increased rate of P application did not produce any significant variation in the BR which is in agreement with the findings of Mohankumar (1986) in taro. No significant variation in BR was observed due to inoculation with AMF.

5.3 Yield components

Different organic manures significantly influenced the yield components such as number of tubers per plant, weight of tubers per plant and weight of marketable tubers per plant as observed from Table 4.3a. The highest number of tubers per plant was recorded by the treatment m_1 (FYM) which was on par with m_3 (1/2 FYM + 1/2 NC). These treatments exerted positive influence on growth characters. Improvement in the growth characters might have resulted in higher values of yield components recorded by these treatments. Increase in rhizome number per plant in arrowroot due to application of FYM has been reported by Maheswarappa *et al.* (1997) and Veenavidhyadharan (2000). According to Asha (1999), FYM + NC treatment recorded maximum number of fruits per plant in brinjal. No significant effect of organic manures on number of marketable tubers per plant could be observed which also indicates the possibility of substitution of FYM with CCP and NC. Significant increase in tuber weight per plant was recorded with FYM (m_1) treated plants. The least weight was recorded by CCP (m_2) treated plants. Maheswarappa *et al.* (1997) also observed that application of CCP alone produced lower values of yield components of arrowroot. No significant difference in tuber weight per plant was observed with m_3 (1/2 FYM + 1/2 NC) and m_4 (1/2 CCP + 1/2 NC) treated plants indicating the possibility of substituting FYM with NC and CCP in different proportions. The same trend was observed in the case of weight of marketable tubers per plant also.

Neither P application nor AMF inoculation could produce any appreciable influence on the yield components. The same trend was noticed in various growth characters also. Actually, the values of yield components slightly decreased due to increase in P level from 30 to 60 kg P_2O_5 ha^{-1}. This reflects the low P requirement of the crop. Poor response of AMF inoculation might be due to the acidic nature and medium P status of the soil as observed by Mathew (1999).

5.4 Tuber yield per hectare

When per ha yield data was analysed (Fig. 3), the highest tuber yield (28 t ha^{-1}) was obtained from FYM (m_1) treated plants and the lowest (18.4 t ha^{-1}) from CCP (m_2) treated plants. No significant difference was observed between the treatments, 1/2 FYM + 1/2 NC (m_3) and 1/2 CCP + 1/2 NC (m_4) which produced tuber yields of 23.4 and 21.3 t ha^{-1} respectively. The favourable effect of FYM application for enhanced yields of tuber crops has been reported by Pillai *et al.* (1987) and Ravindaran and Balanambisan (1987) in sweet potato; Mohankumar *et al.* (1976), Pillai *et al.* (1987) and KAU (1996) in cassava; Patel and Mehta (1987) in elephant foot yam; CTCRI (1973) in *Dioscorea alata* and Veenavidyadharan (2000) in arrowroot. Poor yield of amaranthus due to CCP treatment alone has been reported by Arunkumar (2000). The poor response of CCP might be due to wide C : N ratio as compared to other organic manures. NC is a concentrated organic manure. It is also a nitrification inhibitor due to the presence of the alkaloids, nimbin and nimbidin. Hence it acts as a slow release nitrogenous fertilizer. So nutrients are available slowly according to the crop demand. Therefore, when NC is combined with FYM, higher tuber yield was obtained. Due to the high cost of NC, FYM cannot be completely substituted with the NC but partly with NC as done in the present experiment. Asha (1999) also obtained maximum yield of bhindi due to FYM + NC treatment. Although CCP was found to be an inferior organic source, it can be used to substitute half the dose of FYM along with half the dose as NC (m_4) as evident from the present study. Increase in yield of tomato due to combined application of CCP and

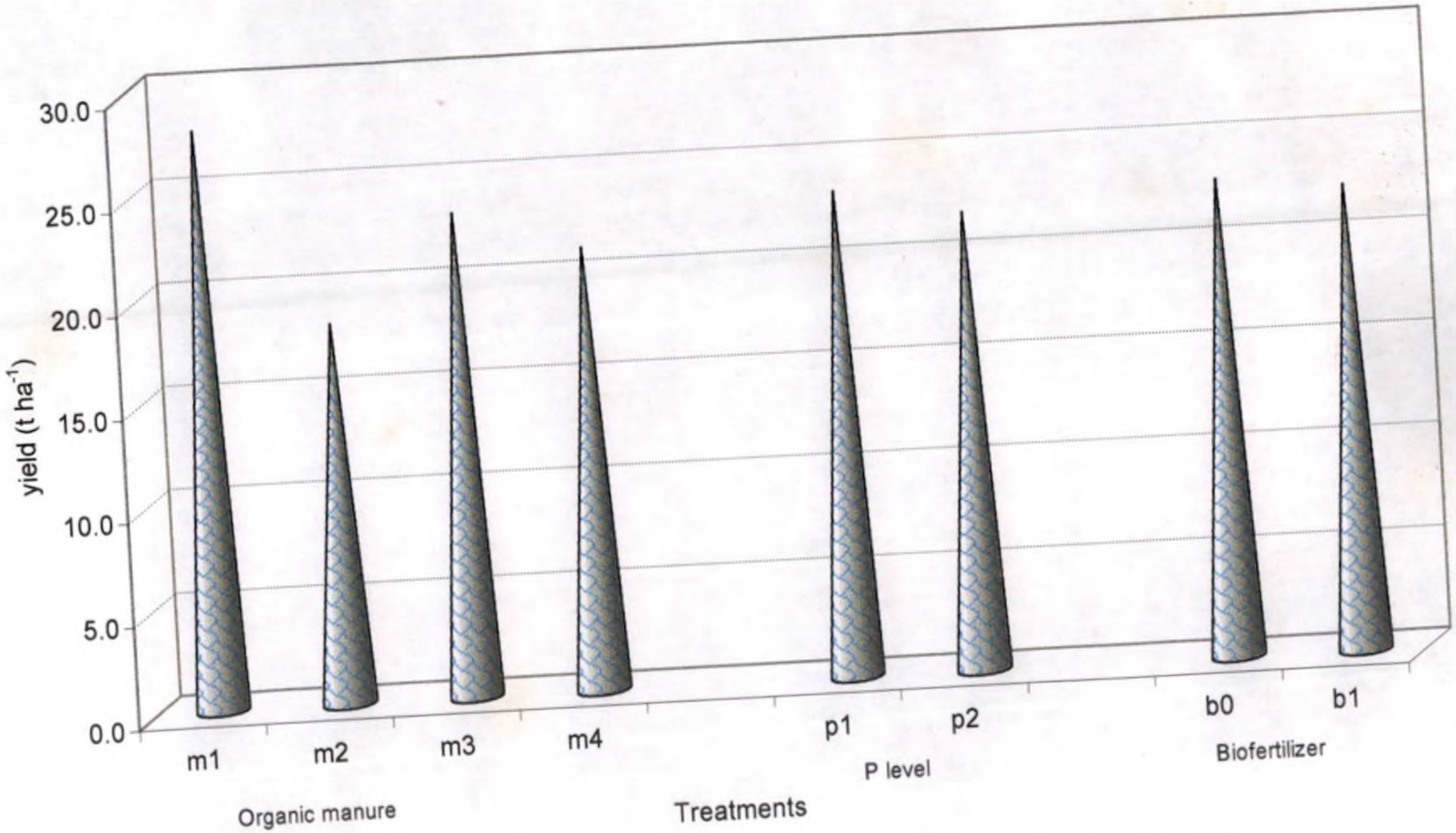

Fig. 3 Effect of different organic manures, P levels and AMF inoculation on tuber yield

FYM as compared to application of CCP alone has been reported by Ahmed (1993).

Levels of P had no significant effect on the tuber yield (Fig. 3). The results corroborates with the findings of Thyagarajan (1969) who reported that levels of P had no significant effect on the yield of coleus. Applied P had no effect on the yield of other tuber crops also as evident from the studies of Samules (1967), Navarro and Padda (1983) and Nicholaides *et al.* (1985) in sweet potato and Lyonga (1982) in yam. An increase in applied P from 30 to 60 kg P_2O_5 ha^{-1} did not register any increase in tuber yield but showed a slight decline indicating low P requirement of the crop. CTCRI (1997) also estimated that coleus removes only 13.2 kg P ha^{-1} for producing 26 t ha^{-1} of tubers. Geetha (1983) also found that a lower dose of P (30 kg P_2O_5 ha^{-1}) along with 10 t FYM was sufficient for economic production of the crop. Several studies conducted by Howeler (1981), CTCRI (1983), Mohankumar *et al.* (1984), Kabeerathumma *et al.* (1988) and Nair *et al.* (1988) in other tuber crops also revealed the sufficiency of a lower dose of P for these crops. Hence the present RD of P (60 kg P_2O_5 ha^{-1}) for coleus can be reduced to 30 kg P_2O_5 ha^{-1}.

Inoculation with AMF culture failed to register any impact on the tuber yield (Fig. 3). The poor response expressed by AMF in the growth characters and yield components of the crop was also reflected in the tuber yield (Fig. 3). The infection of mycorrhizae seems to be inhibited by medium status of P and lower pH of the soil. Earlier reports have shown that the percentage of colonization of AMF was more at low P level compared to high P soils (Potty, 2000). The preference of fungi at low P concentration is because of that at low levels the exudates from plants stimulate the hyphal elongation of AMF (Elias and Safir, 1987). Probably the method of inoculation was not appropriate under field condition. There is the need for standardizing dose as well as method of application in vegetatively propagated crops like coleus under field condition.

Different organic manures, P levels and AMF inoculation did not produce any significant effect on UI (Table 4.4a) but higher values of UI were recorded by FYM (m_1) treatment and lower level of P (30 kg P_2O_5 ha^{-1}) application.

5.5 Quality characters of tuber

The results presented (Table 4.5a) revealed that organic manures, P levels and AMF inoculation did not have any impact on the starch and protein contents of the tuber. Hence it can be inferred that there won't be any loss in quality of tuber if FYM is substituted partly with NC (m_3) or wholly with CCP and NC (m_4). CCP (m_2) treated plants produced lower values of starch and protein contents. Maheswarappa *et al.* (1997) also obtained lower values of quality characters of arrowroot treated with CCP alone. Comparable results on the effect of P application on the quality of tuber have been reported by Mohankumar (1986) in taro and Oommen (1989) in sweet potato. Hence the present recommended dose of P can be reduced to 30 kg P_2O_5 ha^{-1}.

Poor keeping quality of tubers is one of the disadvantage of tuber crops. But coleus is seen to possess good keeping quality as evident from the present study. There was not much variation in the keeping quality depending upon the treatments. The tubers could be stored for a month without any loss in weight, decay or sprouting. Within 30 – 40 days after storage, sprouting of 50 % of tubers was observed. But no decay of tubers was observed even after two months of storage.

5.6 Uptake of nutrients

Significant variation in the uptake of nutrients was observed depending upon the sources of organic manure (Table 4.6a). Full dose of organic manure as FYM (m_1) or half the dose as FYM and half as NC (m_3) registered higher uptake of N, P and K. Lower values of nutrient uptake were recorded by the CCP (m_2) treated plants. This is in agreement with the observations of Maheswarappa *et al.* (1997). The treatments, m_1 and m_3 recorded higher DMP during different stages of plant growth. Increased DMP might have resulted in higher uptake of nutrients by m_1 and m_3 treated plants.

Levels of P did not exert any significant influence on the uptake of N and K but the uptake of P was increased when its level was increased from 30 to 60 kg P_2O_5 ha^{-1}. Similar results were reported by Mohankumar (1986) in taro. Also Ivano and Lappa (1980) found that increased rate of P increased its uptake by potato.

Inoculation with AMF failed to register any significant effect on nutrient uptake. Values of P uptake in the control and treated plots remained same. This might be due to poor colonization of AMF or acidic nature and medium P status of the soil. The interaction between organic manure and P level influenced the uptake of P by the plant. The effect might be due to the additive effect of the individual nutrients. FYM along with 60 kg P_2O_5 ha^{-1} was the best among different treatment combinationsfor higher P uptake.

5.7 Soil nutrient status after the experiment

Available N, P and K contents of the soil after the experiment given in Table 4.7a, were not influenced by organic manures or P levels or AMF inoculation. Available N and K contents of the soil were not significantly influenced by different levels of P application as reported by Oommen (1989) in sweet potato and Mohankumar and Sadanandan (1991) in taro. Arunkumar (2000) also reported that the different sources of organic manure produced no significant variation in the P and K status of the soil after the experiment on amaranthus. It is also seen that the available P and K status of the soil after the experiment increased over their initial status whereas there was a slight decline in the status of available N than its initial content. In short, there was no depletion of soil nutrients if organic manure is applied to coleus at the recommended dose irrespective of the source of organic manure. The results also revealed the sufficiency of 30 kg P_2O_5 ha^{-1} to the crop to maintain the soil nutrient status.

5.8 Observations on nematode incidence

Coleus is generally infected with the root-knot nematode *Meloidogyne incognita* when planted as intercrop or in rotation with vegetables. The initial nematode population in the experimental site was only upto 12 larvae per 100 g of soil which was far below the threshold level of 100 larvae per 100 g soil. Hence the multiplication of this negligible population did not become injurious. The population of the nematode after the experiment was also less than the infective level of zero to six larvae per 100 g soil. Thus this population level was not able to cause any damage on the crop.

5.9 Economics of cultivation

The economics of cultivation was worked out in terms of net income and BCR (Table 4.9a). Maximum net income of Rs. 99900 and the highest BCR of 3.49 were obtained when FYM (m_1-10 t ha^{-1}) was used as the source of organic manure (Fig. 4 and 5). CCP recorded the lowest net income (Rs. 46153) and lower BCR (1.95). Substitution of FYM partly with NC (m_3- 5t ha^{-1} of FYM + 1.78 t ha^{-1} of NC) was the second best option which registered a net income of Rs. 64281 and BCR of 2.22. Since coir pith is available in plenty in our state, effort should be taken for its full utilization avoiding environmental pollution. So substitution of FYM with 1/2 CCP + 1/2 NC (m_4-1.78t ha^{-1} each of CCP and NC) can be done if situation warrants. The effect of organic manures on tuber yield was reflected in the economics of cultivation. Besides, per unit cost of FYM (Re. 0.36 kg^{-1}) is less than that of CCP (Rs. 3 kg^{-1}) and NC (Rs. 8 kg^{-1}). Although the tuber yield was the lowest with CCP (m_2), CCP recorded slightly higher BCR (1.95) than 1/2 CCP +1/2 NC (m_4) which recorded a BCR of 1.75. The reason may be the low cost of CCP compared to NC.

An increase in applied P or inoculation with AMF did not produce any increase in net income and BCR (Fig. 4 and 5). This might be due to the absence of any significant effect of P levels or AMF inoculation on tuber yield.

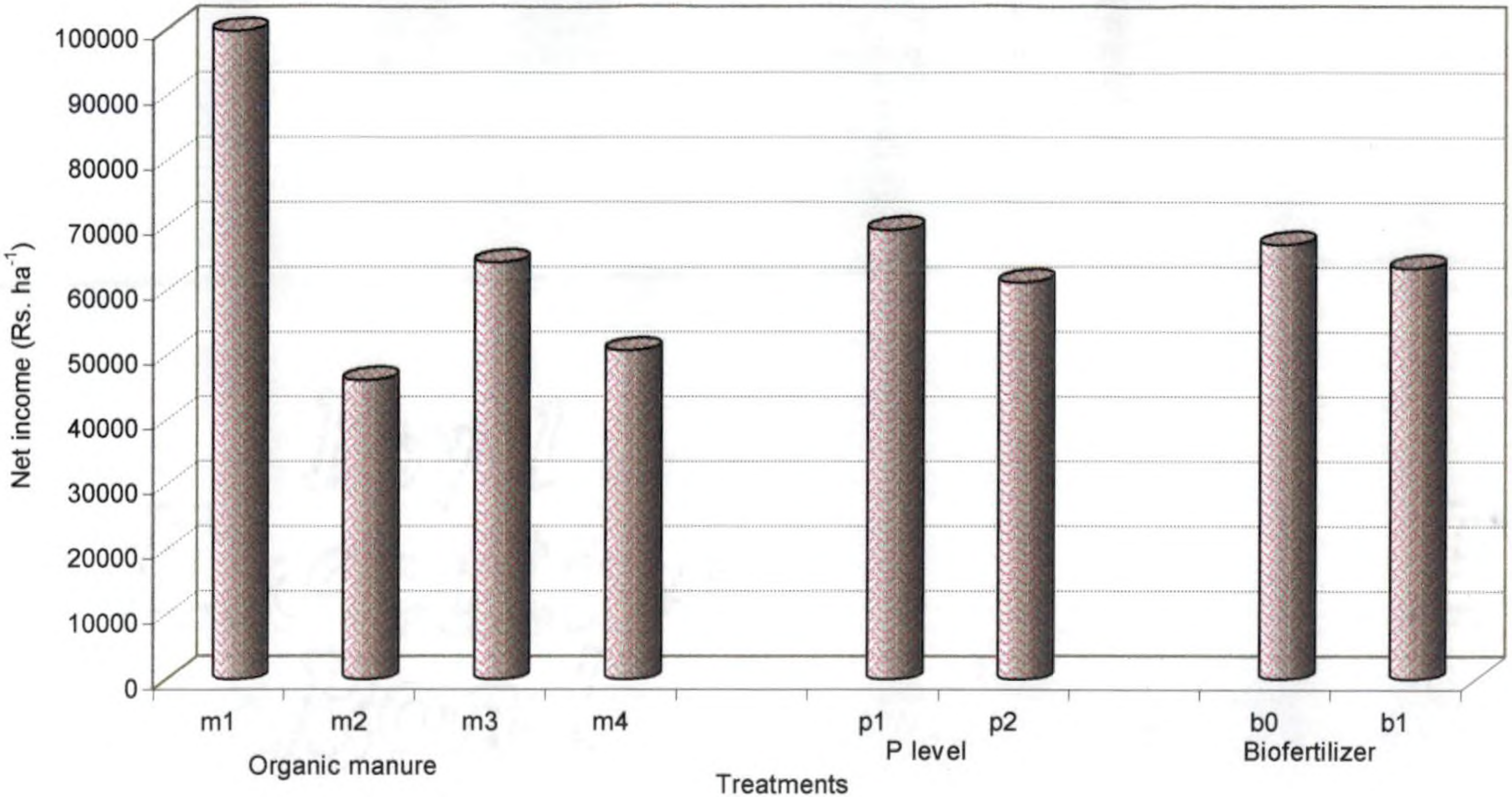

Fig. 4 Effect of different organic manures, P levels and AMF inoculation on net income

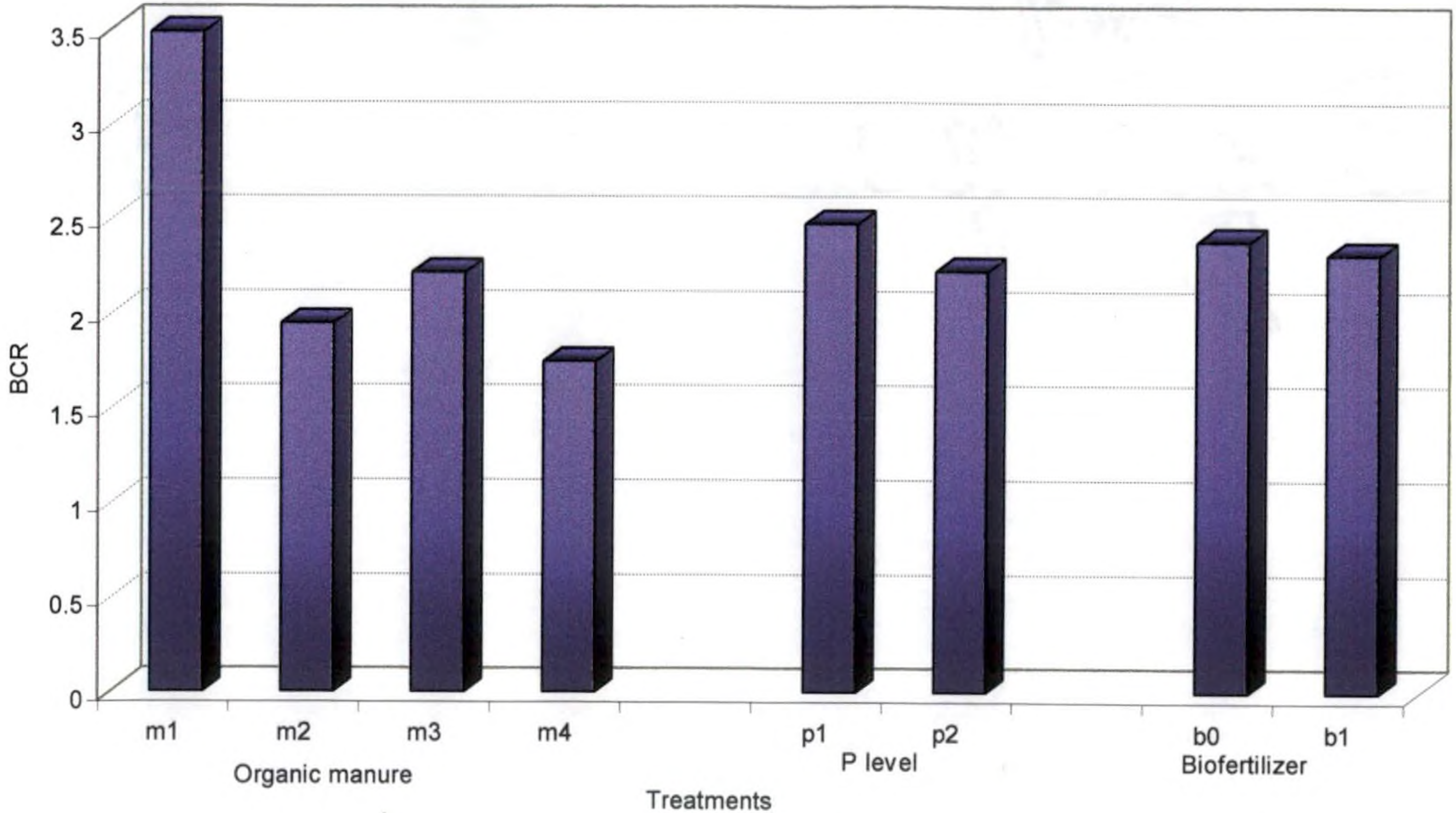

Fig. 5 Effect of different organic manures, P levels and AMF inoculation on BCR

Among the treatment combinations (Fig. 6 and 7), the combination with FYM as the organic manure resulted in higher net income (Rs. 81779 to 115113) and BCR (3.02 to 3.84). FYM along with 60 kg P_2O_5 ha^{-1} or with 30 kg P_2O_5 ha^{-1} + AMF inoculation were found economically superior. The quantities of CCP and NC were fixed on N equivalent basis with FYM. The economics of cultivation also revealed that half the dose of FYM could be substituted with NC (m_3) recording higher net income (Rs. 58806 to 68622) and BCR (2.13 to 2.32) compared to CCP (m_2) or 1/2 CCP + 1/2 NC (m_4). Although the treatments involving NC as the organic manure produced a decrease of about 4.6 to 6.6 t ha^{-1} in tuber yield than FYM, they registered drastic reduction in the net income and BCR. Low N content of NC than expected and its high cost were the reasons for the remarkable reduction in the net income and BCR of the NC treatments compared to FYM treatments. Generally it is assumed that NC contains 5 % N (Gaur *et al.*, 1984; Sankaran and Mudaliar, 1991; KAU, 1996; Reddy, 1999; FIB, 2001). But the sample of NC procured from the market and used for the present study contained only 1.12% N. This might be due to adulteration in the commercially available product.

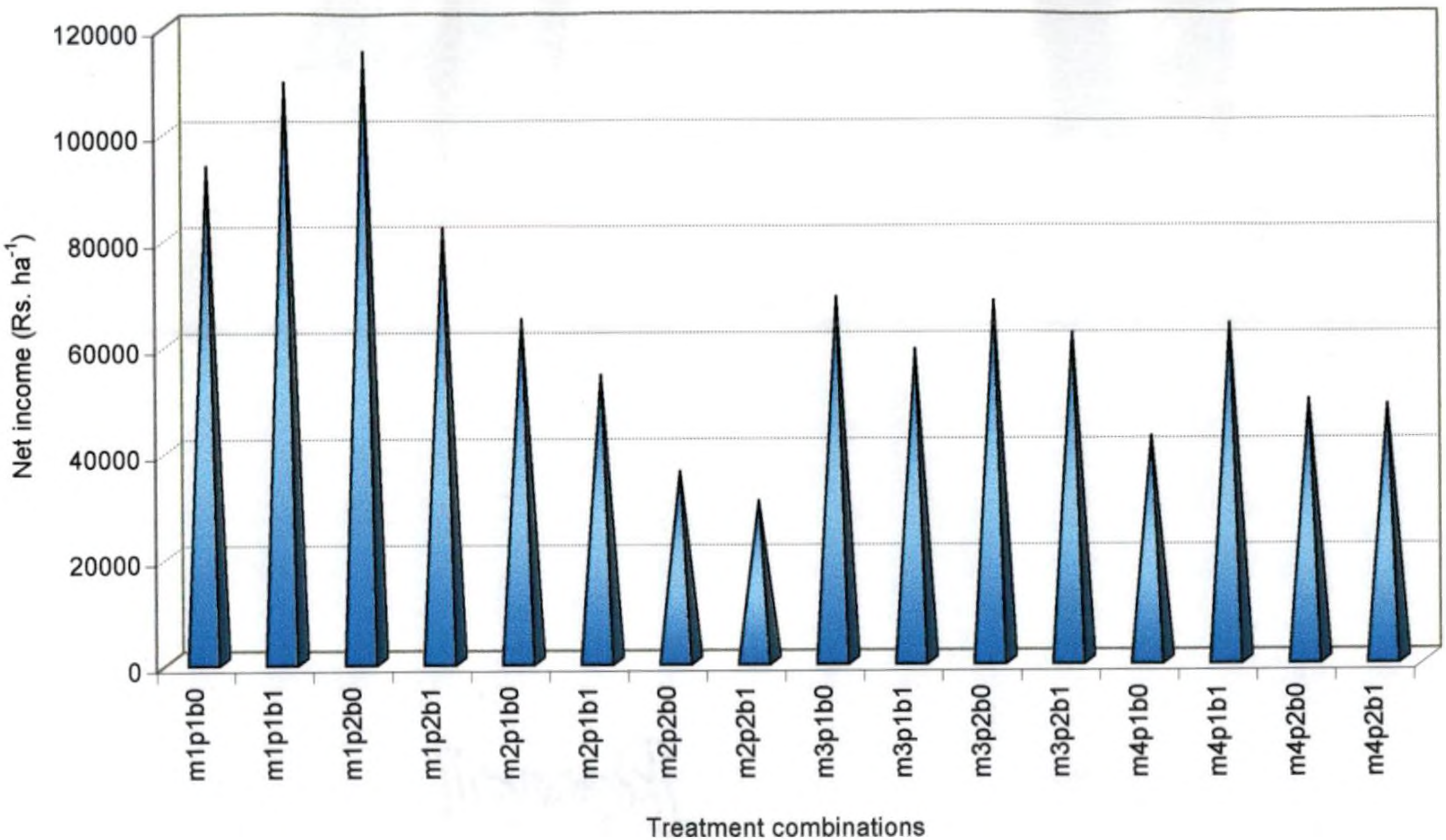

Fig. 6 Interaction effect of different organic manures, P levels and AMF inoculation on net income

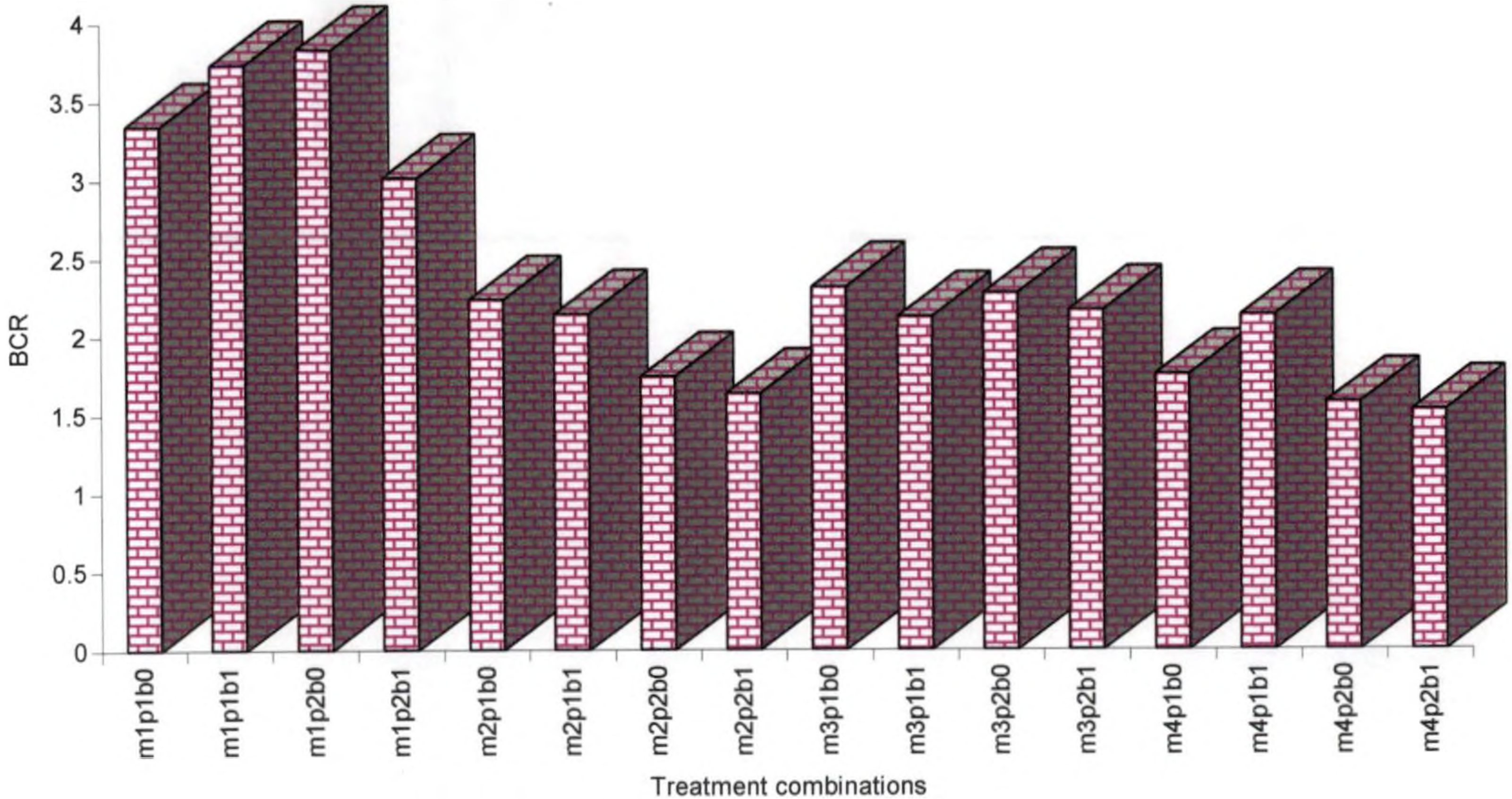

Fig. 7 Interaction effect of different organic manures, P levels and AMF inoculation on BCR

Summary

6. SUMMARY

A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani from October 2000 to March 2001 to study the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present recommended dose (RD) of fertilizer P and to workout the economics of cultivation. The treatments consisted of different sources of organic manure, levels of P and AMF inoculation. The organic manure treatments included RD as FYM, RD as composted coir pith (CCP), 1/2 RD as FYM + 1/2 RD as neem cake (NC) and 1/2 RD as CCP + 1/2 RD as NC on N equivalent basis. Two levels of P, 30 and 60 kg P_2O_5 ha^{-1} were also tried along with and without AMF inoculation. The trial was conducted as a 4 x 2 x 2 asymmetrical confounded factorial experiment with three replications, confounding ABC in all replications. A uniform dose of 60 kg N ha^{-1} and 100 kg K_2O ha^{-1} was applied to all the plots. The results of the study are summarised below.

1. The height of the plant was significantly influenced only by organic manures, which also at 90 and 120 DAP only. At 90 DAP, FYM recorded maximum plant height but was on par with 1/2 FYM + 1/2 NC. At 120 DAP, 1/2 FYM + 1/2 NC recorded the highest value of plant height, but was on par with FYM and 1/2 CCP + 1/2 NC. Application of P and AMF inoculation did not have any significant influence on the height of the plant.

2. Organic manures had significant influence on number of branches per plant at 30 DAP only, the highest value being recorded by the treatment 1/2 FYM + 1/2 NC. Levels of P and AMF inoculation did not have any significant influence on number of branches per plant. Positive response to inoculation was obtained with 30 kg P_2O_5 ha^{-1} and negative response with 60 kg P_2O_5 ha^{-1} at all growth stages.

3. Application of different organic manures had influenced the plant spread in the later stage of plant growth. At 60 and 90 DAP, FYM recorded superior values. At 120 DAP and harvest, 1/2 FYM + 1/2 NC recorded the highest value of plant spread. P levels and AMF inoculation had no significant influence on plant spread.

4. Different organic manures influenced the number of leaves per plant during the later stages of plant growth. FYM recorded the highest number of leaves at 90 DAP whereas 1/2 CCP + 1/2 NC recorded the highest leaf number at harvest but was on par with FYM. Application of 60 kg P_2O_5 ha^{-1} recorded maximum leaf number at 90 DAP. AMF inoculation produced no significant influence on the leaf number.

5. LAI was maximum at 60 DAP for all the treatments and afterwards it showed a declining trend. The effect of organic manures alone was significant. FYM performed better at 60 and 90 DAP whereas 1/2 FYM + 1/2 NC or 1/2 CCP + 1/2 NC recorded higher LAI at harvest. LAI was not influenced by P application and AMF inoculation. M x B interaction significantly influenced LAI at 90 DAP and FYM along with AMF showed higher LAI.

6. FYM was found to be the best organic manure for the highest DMP irrespective of growth stages. No significant variation in DMP due to the effect of organic manures was observed during later stages. DMP was not influenced by P levels and AMF inoculation.

7. Significant influence of organic manures on CGR was observed at all growth stages and the treatments, FYM, 1/2 FYM + 1/2 NC and 1/2 CCP + 1/2 NC recorded superior values. Application of 60 kg P_2O_5 ha^{-1} and AMF inoculation produced significant effect on CGR at harvest. The interactions M x P and M x B influenced CGR from 120 DAP upto harvest. The treatments FYM and 1/2 CCP + 1/2 NC combined with 30 kg P_2O_5 ha^{-1} and CCP and 1/2 FYM + 1/2 NC combined with 60 kg P_2O_5 ha^{-1} produced higher rates of crop growth. Plants which were inoculated with AMF and treated with m_3 and m_4 showed higher CGR.

8. RGR was not appreciably influenced by organic manures, P levels and AMF inoculation at all stages except that organic manures had significant effect at 90-120 DAP. At 90-120 DAP, CCP was found inferior to other sources.

9. Organic manures had profound influence on NAR at all growth stages. CCP was found inferior to other sources. NAR increased with increase in P level at 60-90 DAP and 120 DAP to harvest. AMF inoculation significantly increased NAR from 90 DAP upto harvest. The interactions M x P and M x B also had significant effects.

10. Tuber bulking rate was influenced by different organic manures at all growth stages except at 90-120 DAP. At all stages, FYM recorded higher values except at 60-90 DAP. At 60-90 DAP, all treatments except FYM were on par. P levels had no significant effect on BR at all stages except at 60-90 DAP. At 60-90 DAP the effects of both levels of P, though significant, were on par. The interaction M x P was also significant at all stages except at harvest. BR was not influenced by AMF inoculation.

11. Full dose of organic manure as FYM or 1/2 FYM + 1/2 NC produced more number of tubers per plant. Neither P levels nor AMF inoculation produced significant influence on tuber number.

12. Number of marketable tubers per plant was influenced only by AMF inoculation which produced a negative response. Inoculation was found effective at lower P level (p_1) than at higher P level (p_2).

13. FYM as the source of organic manure recorded the highest value of tuber weight per plant and CCP the lowest value. No change in tuber weight was observed with increase in applied P or with AMF inoculation. The same trend was observed in the case of weight of marketable tubers per plant.

14. Different organic manures exerted noticeable difference in tuber yield. The highest tuber yield was produced by FYM and the lowest by CCP. The effects of the treatments, 1/2 FYM + 1/2 NC and 1/2 CCP + 1/2 NC were on par and in between FYM and CCP. Enhancement of

applied P or inoculation with AMF did not help in increasing tuber yield.

15. UI was not influenced by any of the treatments.

16. Neither the starch content nor the protein content of tuber was affected by the treatments.

17. Regarding shelf life of tubers, sprouting of 50 % of samples was observed in all the treatments within 30-40 days after storage but no loss in weight or decay of tubers was observed till the day on which sprouting of 50 % tubers was observed.

18. Higher uptake of N, P and K was recorded by the treatments, FYM and 1/2 FYM + 1/2 NC compared to others. Uptake of P increased significantly with increase in the level of P but the uptake of N and K were not influenced by P levels. AMF inoculation did not produce any significant effect on nutrient uptake.

19. Available N, P and K contents of soil after the experiment were not influenced by the treatments.

20. The incidence of nematode attack was not observed in the crop. The nematode population was less than the infective level in the soil samples collected before and after the experiment.

21. Net income and BCR were maximum when FYM was used as the organic manure. CCP recorded the lowest net income. Application of FYM along with 60 kg P_2O_5 ha^{-1} or with 30 kg P_2O_5 ha^{-1} + AMF inoculation produced higher net income and BCR. Lower values were

recorded by CCP or 1/2 CCP + 1/2 NC along with 60 kg P_2O_5 ha^{-1} with or without inoculation.

The study clearly revealed that the present recommended dose of 60 kg P_2O_5 ha^{-1} can be reduced to 30 kg P_2O_5 ha^{-1} along with 60 kg N and 100 kg K_2O ha^{-1} combined with 10 t ha^{-1} of FYM. The above recommendation is economically superior also. FYM was found to be the best source of organic manure. If there is scarcity of FYM, 5 t of FYM + 1.78 t ha^{-1} NC can be substituted for 10 t ha^{-1} of FYM. Wherever CCP is easily available, 1.78 t ha^{-1} of CCP + 1.78 t ha^{-1} of NC can also be used to substitute 10 t ha^{-1} of FYM.

Future line of work

Studies may be conducted with other sources of organic manure like enriched compost and vermicompost. The effect of application of different proportions of FYM and CCP or CCP and vermicompost on coleus may be studied. The method of application of AMF under field condition needs further investigation especially for vegetatively propagated crops like coleus. Also co-inoculation of phosphorus solubilising organisms and AMF in coleus may be studied under field condition.

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*Original not seen

Appendix

APPENDIX – I

Weather data for the cropping period
(October 2000-March 2001) – weekly averages

Standard week	Temperature (^0C)		Relative humidity (%)	Evaporation (mm/day)	Total rainfall (mm)
	Maximum	Minimum			
42	29.90	22.00	91.00	3.26	76.6
43	30.80	21.57	79.93	4.00	0.6
44	31.49	22.41	77.93	3.96	0.0
45	30.93	22.24	81.21	2.97	73.1
46	30.14	21.98	79.79	2.61	6.6
47	28.74	21.14	86.21	2.10	50.0
48	30.40	18.34	78.29	2.75	-
49	30.86	20.27	76.07	3.24	2.2
50	30.30	19.38	79.07	3.44	-
51	30.90	19.68	73.14	2.91	-
52	28.86	20.54	82.07	1.81	45.6
1	30.56	20.63	76.93	2.94	2.4
2	30.49	20.46	77.93	2.84	-
3	30.24	19.70	76.29	3.28	-
4	30.46	21.01	77.79	2.97	0.8
5	29.10	21.04	78.14	2.63	16.2
6	30.83	20.19	77.21	3.74	-
7	31.44	20.29	75.03	3.71	-
8	31.96	21.27	79.07	4.07	-
9	32.20	20.77	76.57	4.46	-
10	32.44	21.54	73.93	4.51	-
11	32.37	21.76	71.36	4.89	-
12	32.88	22.40	73.50	5.04	-

INTEGRATED NUTRIENT MANAGEMENT FOR COLEUS (*Solenostemon rotundifolius* (Poir) Morton)

BY

ARCHANA. B.

ABSTRACT OF THE THESIS
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ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani during October 2000 to March 2001 to study the combined effect of organic manures, fertilizers and biofertilizer on the productivity and quality of coleus, to find out the feasibility of reducing the present recommended dose (RD) of fertilizer P and to workout the economics of cultivation. The treatments included different organic manures (RD as FYM, RD as composted coir pith (CCP), 1/2 RD as FYM + 1/2 RD as neem cake (NC) and 1/2 RD as CCP + 1/2 RD as NC on N equivalent basis), levels of P (30 and 60 kg P_2O_5 ha^{-1}) and biofertilizer (with and without AMF inoculation). The experiment was laid out as a 4 x 2 x 2 asymmetrical confounded factorial RBD confounding ABC in all replications. A uniform dose of 60 kg N and 100 kg K_2O ha^{-1} was applied to all the plots.

Different organic manures had significant influence on plant height, plant spread and leaf number during later stages of growth. Significant influence of organic manures was observed on leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR) at all growth stages. The treatments, FYM and 1/2 FYM + 1/2 NC recorded superior values of growth characters. FYM was found to be the best source of organic manure for higher dry matter production irrespective of growth stages. In general, CCP was found inferior to other sources in its effects on growth characters. An increase in applied P from 30 to 60 kg P_2O_5 ha^{-1} did not produce any significant influence on growth characters except CGR, NAR and tuber

bulking rate (BR). Application of 60 kg P_2O_5 ha^{-1} registered higher values of CGR, NAR and BR during peak vegetative stage of the crop. Inoculation with AMF failed to produce any significant response in terms of growth characters except CGR and NAR.

FYM as the source of organic manure had positive influence on yield components like number and weight of tubers and weight of marketable tubers per plant. But CCP as the organic manure recorded lower values of the yield components. The yield components were not influenced by increased rate of P application. Inoculation with AMF was also not beneficial with respect to its effect on yield components.

Different organic manures exerted noticeable difference in tuber yield. The highest tuber yield was produced by FYM and the lowest by CCP. The effects of the treatments, 1/2 FYM + 1/2 NC and 1/2 CCP + 1/2 NC were on par and in between FYM and CCP. Enhancement of applied P or inoculation with AMF did not help in increasing tuber yield.

The quality parameters of the tuber such as starch content, protein content and keeping quality were not affected by the treatments.

The treatments, FYM and 1/2 FYM + 1/2 NC registered higher nutrient uptake. Uptake of P increased with increase in applied P but the uptake of N and K were not influenced by P levels. AMF inoculation did not produce any significant effect on nutrient uptake.

Available N, P and K contents of the soil after the experiment were not influenced by the treatments.

Net income and BCR were maximum when FYM was used as the organic manure. CCP recorded the lowest net income.

The study clearly revealed that the present recommended dose of 60 kg P_2O_5 ha^{-1} can be reduced to 30 kg P_2O_5 ha^{-1} along with 60 kg N and 100 kg K_2O ha^{-1} combined with 10 t ha^{-1} of FYM. FYM was found to be the best source of organic manure. If there is scarcity of FYM, half the dose of FYM can be substituted with NC on N equivalent basis. Wherever CCP is easily available, FYM can be substituted with CCP and NC in equal proportion.