EFFECT OF VERMICOMPOST ENRICHED WITH ROCK PHOSPHATE ON COWPEA (*Vigna unguiculata* L. Walp)

By

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DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
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VELLAYANI, THIRUVANANTHAPURAM

1999

DECLARATION

I hereby declare that this thesis entitled **" Effect of vermicompost enriched with rock phosphate on cowpea (*Vigna unguiculata* L. Walp)"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
-1999.

M. S. SAILAJAKUMARI

CERTIFICATE

Certified that this thesis entitled **"Effect of vermicompost enriched with rock phosphate on cowpea (*Vigna unguiculata* L. Walp)"** is a record of research work done independently by **Miss. M.S. Sailajakumari** 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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M. S. SAILAJAKUMARI

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LIST OF ABBREVIATIONS

FYM	-	Farmyard manure
KAU	-	Kerala Agricultural University
MRP	-	Mussoorie rockphosphate
PDB	-	Phosphorus dissolving bacteria
POP	-	Package of practices recommendation
PUE	-	Phosphors use efficiency
RP	-	Rockphosphate
SSP	-	Single super phosphate
TRP	-	Tunisia rockphosphate
VAM	-	Vesicular arbuscular mycorrhiza
VAMF	-	Vesicular arbuscular mycorrhizal fungi

INTRODUCTION

INTRODUCTION

World population is expected to increase from 5.2 billion to more than 8.4 billion by 2025 AD. To provide the increasing population with food and fibre the present agricultural production will have to be increased to two fold. Agricultural production can be increased by bringing more land under cultivation or by intensifying the agriculture in the land presently under cropping. For developing countries like India where availability of land is limited, the scope of bringing more land under cultivation is impossible. So an alternative is to intensify the agriculture in the land presently under cropping. For intensive agriculture efficient use of fertilizer is a must. Fertilizers are however expensive and for many of the resource poor farmers investment in fertilizer is luxury beyond their means. So one way to reduce dependence on expensive fertilizers is to use indigenous resources if available. The recent energy crisis and consequent price hike of fertilizers coupled with low purchasing capacity of farming community have again revived interest in organic recycling throughout the world.

The strategy of organic recycling and organic farming is a major component of low input management technique suggested for sound soil management to alleviate problems of nutrient deficiency, toxic effects of heavy metals, fixation problems of specific nutrient ions and soil degradation through laterisation. Besides the beneficial effects of soil improvement, use of organic manures and biofertilizers incorporate into soil appreciable amounts of plant nutrients also. Organic manure ensures the quality of the produce also. But most of the organic manures are low in nutrient content and is the main hindrance in their large scale use.

The success of sustainable agriculture is very much dependent upon the availability of cheap and good quality organic manures. Among the sources of available organic manures, vermicompost is a potential source due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms like N fixing, P solubilising and cellulose decomposing organisms. About 10^6 bacteria, 10^5 fungi and 10^5 actinomycetes were reported to be present in vermicompost. P solubilising bacteria, N fixing organisms and entomophagous fungi were observed in the range of 10^5 to 10^6 (Indira *et al.*, 1996). These organisms are known to induce many biochemical transformations like mineralisation of organically bound forms of materials, exchange reactions, fixation of atmospheric N and various other changes leading to better availability of nutrients already in soil.

Indigenous deposits of phosphate rocks occur in several parts of our country which are of poor quality with low reactivity and may not be suitable for direct application. The effectiveness of such rock phosphate (RP) can be increased by several means. One such means is enriching organic matter with RP. Addition of RP at the time of composting is reported to hasten the process of composting and improve the manurial value of compost. When vermicompost is enriched with RP it may enhance the multiplication of micro organisms of the compost which are expected to react with RP and convert insoluble RP to plant available forms.

With a view to explore the possibility of improving the quality of vermicompost by enriching with indigenous RP, the present study is proposed by taking cowpea [*Vigna unguiculata* (L.) Walp.] as the test crop with the following objectives

i) to investigate the effect of enriched vermicompost on the growth characters, yield and yield attributes and quality of cowpea.

ii) to investigate the effect of enriched vermicompost on the availability of macro nutrients especially phosphorus

iii) to investigate the effect of enriched vermicompost on the uptake of macro and micronutrients

iv) to assess the feasibility of reducing inorganic P.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The success of sustainable agriculture is very much dependent upon the availability of cheap and good quality organic manures. Among the organic manures available vermicompost is a potential source due to the presence of readily available plant nutrients, growth enhancing substances and number of beneficial organisms. When vermicompost is enriched with RP it may enhance the multiplication of microorganisms of the compost which are expected to react with RP and convert insoluble RP to plant available forms. So the present study is under taken with a view to explain the possibility of improving the quality of vermicompost by enriching with indigenous RP. The literature pertaining to enriched vermicompost is scanty. Hence the available literatures pertaining to these aspects are reviewed hereunder.

2.1.1. Effect of organic manures on the growth and yield of the crops

Dhillon and Dhillon (1991) obtained significant increase in wheat yield due to incorporation of groundnut residue.

In soybean FYM application along with NPK fertilizer increased plant height and number of branches per plant (Singh *et al.* 1993).

Prabhakaran and Srinivasan (1993) reported that coirdust application increased nodule number and nodule biomass in pigeon pea.

More (1994) found that application of farm waste and other organic manures significantly enhanced the grain yield and straw yield of rice and wheat.

2.1.2. Effect of organic manures on quality of crop produce

Lampkin (1990) reported better keeping quality for tomato due to application of FYM.

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

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

Sabrah *et al.* (1995) reported the beneficial effect of town refuse compost in enhancing protein content in maize.

Organic manures like FYM, compost, oil cakes, green leaf, poultry manure etc. improve the quality of vegetables in crops like tomato, onion, gourd, chillies etc. Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetable crops (Rani *et al.*, 1997).

2.1.3. Effect of organic manures on the availability of nutrients

Organic manures or composts contain a very large population of bacteria, actinomycetes and fungi and stimulate those already present in the soil. The application of organics helps microorganisms to produce polysaccharides which build up better soil structure. Nitrogen fixation and phosphorus solubilisation are also increased due to improved microbiological activity in organic amended soils. The beneficial effects of humus on soil characteristics ultimately result in increased crop yields (Balasubramaniam *et al.*, 1972 and Gaur, 1972).

2.1.3.1. Effect on phosphorus availability

The humic substances especially increase phosphorus availability as they have a very high cation exchange capacity (Eberhardt and Piper, 1974 and Gaur, 1994).

Fellaca *et al.* (1983) reported that humified organic matter can significantly reduce the amount of phosphates required to maintain a solution concentration necessary for crop growth. Srivastava (1985) reported that FYM application increased available P status of soil. Bajansingh *et al.* (1985) reported that FYM application increased available P content of soil, but it was decreased with the application of green manure.

Dhillon and Dhillon (1991) obtained significant increase in available phosphorus of soil due to incorporation of groundnut residue.

More (1994) reported that addition of farm water and organic manures increased the status of available phosphorus of the soil.

2.1.3.2. Effect on availability of other nutrients

Humus, by virtue of its chelating properties increase the availability of nitrogen, phosphorus, sulphur and other nutrients to plants growing in humus rich soil (Eberhardt and Piper, 1974 and Gaur, 1994).

Application of FYM increased the availability of both native and applied micro nutrient cations. These ions form stable complexes with organic ligands which decrease their susceptibility to adsorption and fixation (Swarup, 1984).

Srivastava (1985) observed that FYM addition increased total N and K status in the soil. More (1994) reported that addition of farm wastes and organic manures increased the status of organic carbon, available nitrogen, phosphorus and potassium of the soil. Among nutrients, the most significant role in organic matter is in supplying K (Bharadwaj, 1995).

2.1.4. Effect of organic manures on the uptake of nutrients

2.1.4.1. Effect on phosphorus uptake

Ahmed *et al.* (1984) reported that organic matter promoted grain P uptake. Dhillon and Dhillon (1991) obtained increased P uptake in wheat due to incorporation of groundnut residue. Minhas and Sood (1994) reported that FYM application enhanced P uptake in potato and maize.

2.1.4.2. Effect on the uptake of other nutrients

Absorption of N, P and K was found to be increased with increasing amounts of FYM alone. Increase in K was highest followed by N and P (Yamashita, 1964). Hartenstein and Rothwell (1973) observed an increase in uptake of all nutrients except Mn by sorghum on compost application. Khan *et al.* (1981) reported that city compost raised the zinc and iron contents of plants from deficiency to sufficiency level.

Ganguly (1988) reported the beneficial effect of FYM on the uptake of all nutrients in maize. Dhillon and Dhillon (1991) obtained increased N and K uptake in wheat due to incorporation of groundnut residue. Minhas and Sood (1994) opined that FYM application was beneficial in enhancing the uptake of all three major nutrients in potato and maize.

2.2.1. Effect of vermicompost on growth and yield of crops

2.2.1.1. Effect on germination and establishment

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

In coriander vermicompost application significantly increased the germination percentage and growth of seedlings (Vadiraj *et al.*, 1996).

2.2.1.2. Effect on growth

Curry and Boyle (1987) obtained enhanced plant growth in the presence of earthworms which was attributed to an increased supply of readily available plant nutrients.

Kale *et al.* (1987) found that worm cast when used as a manure in place of FYM, significantly influenced vegetative and flowering characters. In watermelon, vigorous growth and increased number of flowers and fruits were observed when treated with vermicompost (Ismail *et al.*, 1991).

Shuxin *et al.* (1991) obtained 30-50 per cent increase in plant growth and 10 per cent increase in height and effective tillering and diameter of sugarcane. They also reported 20-25 per cent increase in height and 50 per cent increase in weight of soyabean plants when vermicompost was applied.

Ismail *et al.* (1993a) studied the influence of vermicompost on the relative appearance, height of plants, number of flowers and branches of Zinnea and reported that vermicompost treated plants showed more number of brighter coloured flowers and number of branches per plant compared to FYM treated plants.

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

2.2.1.3. Effect on shoot root ratio

Earthworms stimulate root biomass and depth of rooting, height and biomass of above ground tissues (Rhee, 1977; Edwards and Lofty, 1980). Haimi and Einbork (1992) showed that root shoot ratio of birch seedlings was not affected by the application of NH_4^+ - N fertilizer or by mixing with earthworms. Stephen *et al.* (1994) reported that the presence of earthworms increased the root and shoot dry weight of wheat in sandy loam soil.

Short term effects of different earthworm species on the production of rice, maize and groundnut were studied. Groundnut did not respond to earthworm application, where as maize had a much higher above ground portion and reduced root production and rice produced more roots in the presentcof earthworm (Lauret *et al.*, 1997).

2.2.1.4. Effect on nodulation

In an experiment to study the relative efficiency of vermicompost, FYM and chemical fertilizers in influencing the physical, chemical and biological properties, it was found that microbial population was high in soil where vermicompost was applied. Application of vermicompost increased number as well as weight of functional nodules compared to farmyard manure and chemical fertilizers (Reddy and Mahesh, 1995).

2.2.1.5. Effect on yield

Application of worms worked compost resulted in higher yield of paddy crop to the tune of 95 per cent increase in grain and 128 per cent in straw and root production (Senepathi *et al.*, 1985). Gunjal and Nikam (1992) reported earthworm inoculation in combination with heavy mulching of agricultural wastes all the year round as a successful practice for grape production without the application of chemical fertilizers. Vermicompost application in grape resulted in higher yield (Barve, 1993). Phule (1993) obtained more sugarcane yield from vermiculture treated plots.

Dharmalingam *et al.* (1995) studied the effect of vermicompost pelleting in soybean and reported 16 per cent increase in yield over non pollected seeds.

Ushakumari *et al.* (1996) found that POP with cattle manure as the organic source, vermicompost as organic source along with half the recommended dose of inorganic fertilizers and vermicompost as the sole source of nutrients recorded almost the same yield in bhindi.

Reddy and Mahesh (1995) observed significant increase in dry matter and pod yield of greengram due to the application of vermicompost and farmyard manure over control. Between the organic manures vermicompost was found to be superior to FYM on equivalent basis.

2.2.2. Effect of vermicompost on quality of produce

Considerable scientific data were generated recently to show that produce obtained from organic farming is nutritionally superior with good taste, lusture and better keeping qualities. The better storage life of spinach grown with organic manure was found to be associated with lower free amino acid content, lower level of nitrate accumulation and higher protein N to nitrate N (Lampkin, 1990).

Barve (1993) reported that vermicompost application resulted in improvement in the quality of grapes both in taste and attractive lusture.

Application of vermicompost produced healthier coccinia plants and better keeping quality of vegetables (Khamkar, 1993).

Phule (1993) observed that insitu application of earthworms obtained sugarcane juice having 3-4 extra brix and lesser salts.

2.2.3. Effect of vermicompost on availability of nutrients

2.2.3.1. Effect on phosphorus availability

Higher concentration of available P in worm casts compared with surrounding soil had been reported by Mansell *et al.* (1981); Tiwari *et al.* (1989); Miura *et al.* (1993) and Rao *et al.* (1996).

The growth of *Mathiola incana* stocks in compost mixture indicated that vermicompost could supply the full requirement of P

(Handreck, 1996). According to Romero and Chamooro (1993) the activity of earthworm increase the available P status in soil. Available P_2O_5 of soil was increased by the application of vermicompost compared to FYM (Reddy and Mahesh, 1995).

2.2.3.2. Effect on the availability of other nutrients

2.2.3.2.1. Effect on nitrogen availability

Scheu (1987) found large amounts of mineralised N in the presence of large earthworm biomass. Increased availability of N in earthworm casts compared to non-ingested soil had been reported by several workers (Tomati *et al.*, 1988; Tiwari *et al.*, 1989; Romero and Chamooro, 1993; Parkin and Berry, 1994 and Rao *et al.*, 1996).

Haimi and Huhta (1990) reported that earthworms increase the proportion of mineral N available for plants at any given time, although N was clearly immobilised in the initial stage. Vermicompost analysed for N content showed that mineral N constituted 20.2 per cent of total N, easily hydrolysable 20 per cent, non easily hydrolysable 32.4 per cent and non hydrolysable 32.2 per cent (Kalembasa *et al.*, 1993).

Parkin and Berry (1994) found that earthworms are actively involved in the cycling of C and N in soil and earthworm casts are enriched in mineral N. Worm cast also have elevated denitrification rates. Bohlen and Edwards (1995) reported that earthworms had significant effects on amounts of extractable nitrate and they increased the amount of extractable nitrate at 0 to 5 cm soil depth by 1.88 fold in microcosm supplied with manure. According to Bano and Devi (1996), N level in vermicompost ranged from 1.4 to 2.17 per cent.

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

2.2.3.2.2. Effect on potassium availability

Increased concentration of available and exchangeable K content in casts were reported by Lal and Vleeschauwer (1982) and Tiwari *et al.* (1989). According to Handreck (1996), vermicompost could supply the initial improvement of K for the growth of *Mathiola incana* stocks.

Increased availability of K by earthworm activity was revealed by Miura *et al.* (1993); Romero and Chamooro (1993) and Rao *et al.* (1996). Das *et al.* (1996) found that the content of K_2O in vermicompost obtained from sericultural wastes was about one per cent. Compared to non ingested soil, different forms of K increased in value in earthworm casts. Selective feeding of earthworms on organically rich substances which break down during passage through the gut and biological grinding together with enzymatic influence on finer soil materials were like to be responsible in increasing different forms of K (Rao *et al.*, 1996).

Reddy and Mahesh (1995) reported an increase in the availability of K by the application of vermicompost compared to FYM.

2.2.3.2.3. Effect on calcium and magnesium availability

Kale and Krishnamoorthy (1980) reported that earthworm castings were richer in soluble forms of Ca. The concentration of soluble Ca was 11.8 times more than that in the surrounding soil. But in the case of total Ca, it was only 1.3 times more than the surrounding soil.

Shinde *et al.* (1992) examined an increased concentration of exchangeable Ca and Mg in the worm cast than in the surrounding soil. Similar results were reported by Miura *et al.* (1993) Romero and Chamooro (1993).

But Basker *et al.* (1994) reported that there exists no consistent trends for changes in exchangeable Ca and Mg as a result of soil digestion by earthworms. Stephens *et al.* (1994) studied the ability of earthworms to increase plant growth and foliar concentration of elements in wheat in sandy loam soil. They observed a significant increase in the plant yield, root and shoot weight and the foliar concentration of elements like Ca, Na, Mn, Cu, Fe and Al.

2.2.3.2.4. Effect on micronutrient availability

Handreck (1996) found that vermicompost as potting mixtures can fully supply the requirement of trace elements for the growth of *Mathiola incana* stocks.

In another experiment Das *et al.* (1996) found that vermicompost obtained from sericultural farm wastes was rich in micronutrients like Fe, Zn and Cu.

Stephans *et al.* (1994) observed a significant increase in the foliar concentration of elements like Mn, Cu and Fe on introduction of earthworm species. Vasanthi and Kumaraswamy (1996) reported highest concentration of micronutrients in the treatment that received vermicompost along with NPK fertilizer compared to NPK alone.

2.2.4. Effect of vermicompost on uptake of nutrients

2.2.4.1. Effect on phosphorus uptake

Kale *et al.* (1992) reported significant increase in uptake of P by rice plants treated with vermicompost. Introduction of earthworm species increased the foliar concentration of P in wheat crop (Stephens *et al.*, 1994). Sagaya and Gunthilagaraj (1996) obtained more P content in amaranthus plants grown with introduction of earthworms.

According to Vasanthi and Kumaraswamy (1996) P content of rice plants was higher in the treatment that received vermicompost + NPK. Application of vermicompost significantly increased the P uptake in greengram compared to FYM (Reddy and Mahesh, 1996).

2.2.4.2. Effect on uptake of other nutrients

2.2.4.2.1. Effect on nitrogen uptake

Bouche and Ferrieric (1986) reported that N^{15} labelled nitrogen from earthworm was rapidly and almost entirely taken up by plants in the spring in undisturbed soil. Introduction of earthworms greatly increased

N content of *Panicum maximum* (Lavelle *et al.*, 1991). Shuxin *et al.* (1991) observed 30-50 per cent increase in N uptake by soybean on vermicompost application.

Kale *et al.* (1992) found significantly higher levels of N uptake by rice plants treated with vermicompost. Application of earthworms increased foliar N concentration of clover by 5-20 per cent (Doube *et al.*, 1994). Stephens *et al.* (1994) found that presence of earthworms caused a significant increase in foliar concentration of N in wheat.

Sagaya and Gunthilagaraj (1996) noticed more N content in amaranthus plants grown with earthworm application. Reddy and Mahesh (1995) reported that vermicompost application increased organic carbon and nitrogen uptake in greengram compared to FYM.

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

2.2.4.2.2. Effect on potassium uptake

Stephens *et al.* (1994) found that the presence of earthworms caused a significant increase in the foliar concentration of K.

Vasanthi and Kumaraswamy (1996) obtained highest content of K in the treatment that received combined application of vermicompost and NPK fertilizers.

2.2.4.2.3. Effect on calcium and magnesium uptake

Stephens *et al.* (1994) found that the presence of earthworms caused a significant increase in the foliar concentration of Ca and Mg in wheat.

Ca and Mg content in rice plants were higher with the combined application of vermicompost and NPK fertilizers (Vasanthi and Kumaraswamy, 1996).

2.2.4.2.4. Effect on micronutrient uptake

Stephens *et al.* (1994) observed a significant increase in foliar concentration of elements like Mn, Cu and Fe on introduction of earthworm species.

In french bean, uptake of S was more in soils which received vermicompost compared to ammonium sulphate and control at harvest. Residual activity of S was highest in vermicompost treated soil at flowering and at harvest (Shivananda *et al.*, 1996).

Vasanthi and Kumaraswamy (1996) observed highest content of micronutrients in the treatment that received vermicompost along with NPK fertilizers compared to NPK alone.

2.3. Rock phosphate solubilisation by phosphorus solubilising organisms

From studies on the solubility of RP in liquid medium with various mixed inoculants, Bromfield (1959) has shown that phosphorus solubility was closely related to the magnitude of acidity produced in the medium.

Mayer and Kong (1960) studied the effect of 24 strains of fungi and three strains of streptomyces on the solubilisation of RP and repeated that solubilisation of RP proceeds through the utilization of small amounts of initial P available in the medium followed by the use of soluble phosphorus dissolved by organic acids and secreted by the growing mycelia.

Ahmed and Jha (1968) published results regarding the solublization of hydroxy apatite and RP by gram positive and gram negative rods, cocci shape bacteria, fungi (*Aspergillus, Penicillium, Rhizopus* and species of *Nocardia* and *Micromonospora*).

Gaur *et al.* (1973) tested the bacterial and fungal isolates obtained from rock phosphate mines and found *Aspergillus carbonum* as the best culture since it solubilised the three types of RP tested.

Bardiya and Gaur (1974) isolated yeasts, fungi and bacteria from rhizosphere of leguminous crops and soils of RP deposit area which were capable of solublising MRP and reported that *Schwanniomyces occidentalis, Aspergillus awamori* and *Penicillium digitatum* were better than other in RP solubilisation. Most efficient bacteria were identified as strains of *Pseudomonas striata.*

Khan and Bhatnagar (1977) identified *Aspergillus niger* and *Penicillium* sp. as better solubilisers of RP. The solubilisation of 32^P tagged hydroxy apatite by *Pseudomonas striata, Bacillus polymixa* and *Aspergillus awamori* was studied in liquid medium (Arara and Gaur, 1978). They have found that extent of P solublisation increased progressively and reached a maximum in the sixth week of incubation.

The microbial solublisation of RP of varying origin was investigated in liquid medium by Singh *et al.* (1984) and the results showed that *Pseudomonas strita* solublized Jordan RP to a maximum extent followed by the RP of Jhabua, Mussoorie and Udaipur.

Gupta *et al.* (1993) suggested the ability of *Bacillus licheniformis* to solubilise inorganic phosphates and low grade Indian RP in broth culture in a sandy loam soil. The results indicated that *Bacillus licheniformis* was able to solubilise RP in soil and thus had potential for improving soil phosphorus level.

Dilution plate technique followed to enumerate the microbial count in vermicompost revealed that the compost contain phosphorus solublising bacteria, N fixing organisms and entomophagous fungi in the order of 10^5 and 10^6 (Indira *et al.*, 1996).

Mba (1997) isolated rock phosphate solublising and cellulolytic actinomycetes from earthworm casts. Earthworm casts of *Eudrillus eugeniae* were much rich in rock phosphate solubilising microbes and had high rock phosphate solublising capacity.

Nine Streptosporangium isolates of *Eudrillus eugeniae* were found to be acidogenic and acid tolerant, RP solubilizers which could grow on synthetic glucose or carboxy methyl cellulose (CMC) N free or NH_4Cl enriched media as sole carbon source. CMC induced production of extracellular cellulase enzyme and release of reducing sugar in all isolates. Both CMC media were acidified by all isolates. The ability to solubilise RP varied among isolates and ranged from 800 mg P g^{-1} RP 7 d^{-1} to 9500 mg P g^{-1} RP 7 d^{-1}. Caroline (1997) reported that these isolates could therefore be exploited in the industrial production of cellulolytic enzyme and microbial phosphate fertilizers which would enhance organic residues and plant nutrient recycling in acid soils of Nigeria.

2.4.1. Effect of organic manure enrichment on yield of crops

Kavimandan and Gaur (1971) reported that the inoculation of phosphorus dissolving bacteria (PDB) increased the yield of maize. Nair and Padmaja (1982) reported that efficiency of MRP applied to moist aerobic soil 1-2 weeks before flooding was similar to or higher than that of SP in increasing paddy yields. Deshpande *et al.* (1983) reported that when RP incorporated FYM was applied there was an increase in the yield of low land rice.

Tomar *et al.* (1983) observed an increase in yield of wheat when MRP inocubated with FYM for 15 weeks was applied. Incubation with FYM reduced the difference in effectiveness of MRP and SSP than MRP in combination with FYM previously decomposed for 15 weeks. Singh (1985) found that phospho compost prepared by enrichment with RP was as good as that of single super phosphate in micro plot field experiment taking mungbean and wheat as test crop. Mishra and Banagar (1986) also emphasized that the P enriched compost was comparable to SSP in crop yield and P uptake.

Basak and Debnath (1987) reported that composted RP significantly increased the grain yield in rice. Banerjee and Das (1988) reported that application of phospho compost produced more tuber yield in potato as compared to uninoculated control.

Dhinakaran and Santhi (1995) reported that effect of Vesicular Arbuscular Mycorhizal Fungi (VAMF) in increasing dry matter production was positive and it was more pronounced at higher levels of P application in onion.

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

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

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

Performance of MRP and SSP with bio-organic material was found superior to its single application.

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

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

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

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

2.4.2. Effect of organic manure enrichment on quality

Gowda (1995) reported that sugarcane yield was highest with MRP + SSP (1:1) along with green manure with no adverse effect on the quality parameters tested.

Krishnababa *et al.* (1995) reported that a combination of super phosphate and MRP with P solubilising fungi in mulberry resulted in better leaf quality through enhanced micro nutrient status in the leaf. It produced significant increase in secondary nutrient content of leaf especially Ca.

Kathiresan *et al.* (1995) reported that soil inoculation with phosphobacteria increased yield and quality of sugar cane.

2.4.3. Effect of organic manure enrichment on availability of nutrients

Bajpai and Rao (1971) conducted soil incubation studies in the lab with super phosphate and apatite with and without FYM using *Bacillus megatherium* var. *Phosphaticum* and *Bacillus circulans.* They found that in sterilized soils introduction of organisms increased available P_2O_5.

Rangaswamy and Morachan (1974) reported that application of phosphobacterin increased available P content in soil.

Banik and Dey (1981) obtained higher levels of available P in soil to which FYM, RP and phosphorus solubilising isolates like *Bacillus, Streptomyces, Penicillium* and *Aspergillus* sp. were added.

Ahamed *et al.*, 1987 reported that the release of available P was greater on the bacterial inoculation with organic matter and or P than with inoculation alone.

The level of $NaHCO_3$ extractable P in soil was found to increase after the addition of *Penicillium bilaji* both with and without RP.

Asea *et al.* (1988) observed that *Penicillium bilaji* was able to solubilize added RP.

In pot culture experiment with Jute, Banik *et al.* (1989) tested the effect of inoculation of two strains of P solubilising bacteria and observed that available P from RP increased to a maximum after thirty days of crop growth and declined after 120 days.

Mohod *et al.*, 1989 reported that the use of P solubilising culture alone or in combination with phosphate fertilizers in rice increased the available P in soil. The culture increased the P release efficiency of RP and made it equivalent to SSP with respect to available P status in soils.

Patgiri and Bezhauruah (1990) have reported that out of 46 strains of ascorbic heterotrophic bacteria isolated from tea soils of Assam, *Bacillus* sp. and *Pseudomonas* sp. processed significant P solubilising activity. Inoculation increased available P content of soil during a 22 day period in the presence or absence of leaf litter or SSP.

A very high level of available P was reported in the rhizosphere soil (Datta and Banik, 1994) when *Bacillus firmus* was applied along with poultry manure and MRP in an acid sandy clay loam soil of Tripura.

Singal *et al.* (1994) have reported that *Aspergillus japonicus* and *Aspergillus foetida* were able to solubilise fine types of RP at pH eight and nine.

Mahimairaja *et al.* (1994-95) examined the distribution of phosphate rock during composting with poultry manure. The dissolution during incubation with poultry manure was enhanced by the addition of sulphur to the compost.

Dhinakaran and Savithri (1995) evaluated different levels of P and VAMF in influencing P availability. The effect of VAMF in increasing olsen P status was positive and more pronounced at higher levels of P application.

Sudhir *et al.*, 1995 reported that combined application of green manure and MRP enhanced the P content of red and laterite soil. Beneficial effect of green manure in enhancing P content of soil was almost equal to that of 10 ppm P supplied in the form of SSP.

Ravikumar *et al.* (1995) reported that among the various sources tried the P use efficiency (kg pod / kg P_2O_5) and build up of P in soil at harvest were highest in MRP with FYM or biogas spent slurry mixture inoculated with P solubilising fungi than MRP alone.

Mahimairaja and Raniperumal (1995) revealed that combined with organic or biofertilizers MRP could safely be substituted for inorganic

P fertilizers like diammonium phosphate in rice pulse cropping systems and available P content of soil was significantly increased when organics or biofertilizers were added.

There is a significant and progressive increase in total and citrate soluble P in enriched compost over control. Among the enrichment treatment RP + P solubilising culture was found to be highest in total and citrate soluble P followed by SSP and RP enriched compost (Dhawan *et al.*, 1995).

Sunilkumar *et al.* (1995) reported that the application of 1:1 mixture of MRP and SSP with green leaf manure in rice resulted in increased available P_2O_5 of soil.

Srinivasamurthy *et al.* (1995) conducted an incubating study under submerged conditions for 90 days with different phosphatic fertilizers with or without green leaf manure and *Aspergillus awamori*. The results revealed that the efficiency of water insoluble P sources could be increased through the application of adjuncts which not only help in the dissolution of water insoluble sources, but also help in maintaining the released P in solution by reducing fixation, which is the major problem in acid soils.

Prakash *et al.*, 1995 reported that in a rice-cowpea cropping system there is higher phosphates activity and higher available P_2O_5 contents in the soil when the soil was treated with green leaf manure and phosphorus solubilising fungi along with MRP. He suggested that addition of green leaf manure along with P solublising fungi will help in maintaining higher enzyme activity and available P levels in soil for sustainable crop production.

Savithri *et al.*, 1995 reported that incubating RP with coir pith will increase water soluble P content.

Viswambaran (1995) has reported that the use of 100 per cent P as RP along with VAM and P bacteria (PB) resulted in the highest available P content in cowpea (C-152) in a red loam soil and the combined application of VAM and P bacteria was found to be better than individual application of either VAM or PB.

Shehana (1997) reported that for increasing the efficiency of utilization of applied P to banana in the acidic laterite soils a combined application of MRP and P solubilising bacteria along with FYM and mulch is essential. This package was reported to be very effective in increasing the available P status of the soil. Combined application of poultry manure and phosphate fertilizers increased the P availability in soils (Toor and Bahl, 1997).

Thakur and Sharma (1998) studied the effect of inoculation with *Azotobacter* and addition of varying levels of RP on N and P transformation during composting. RP enrichment accelerated decomposition and P from RP was solubilized during composting and transformed into available forms.

2.4.4. Effect of organic manure enrichment on uptake of nutrients

2.4.4.1. Effect on P uptake

Kavimandan and Gaur (1971) reported that inoculation of P solubilising bacteria increased P uptake and yield of maize.

Rangaswamy and Morachan (1974) reported that application of phosphobacterin increased the P content in the crop.

From a study conducted to evaluate the effect of seed treatment of bengalgram with *Bacillus circulans* on P uptake, Subramanian and Purushothaman (1974) reported that crop absorbed more P after inoculation with *Bacillus circulans*.

The results of a pot experiment conducted by Osman (1975) indicated that P uptake in Sudan grass was increased due to inoculation with P solubilising bacteria. They have also reported that combined inoculation and fertilization had the greatest effect.

Similarly Gaur *et al.* (1980) reported an increase in growth and P uptake by wheat in response to addition of RP and P solubilising micro organism cultures of *Pseudomonas striata* and *Aspergillus awamori*.

Basak and Debanath (1987) reported that composted MRP significantly increased the total P uptake by the crop.

Aseo *et al.* (1988) using 32^P isotope dilution method found that wheat when inoculated with *Penicillium bilaji* was able to obtain 18 per cent of its P from sources unavailable to the inoculated plants and was also able to solubilise added RP.

Dry matter production and P uptake in wheat has been reported (Kucey, 1988) to increase under field and green house condition in response to *Penicillium bilaji* inoculation in the absence of added RP and addition of RP resulted in a further increase in dry matter production and P uptake.

Salih *et al.* (1989) reported that dry matter content and P uptake were better in soil treated with RP and inoculated with fungi *Pencillium* sp. and *Aspergillus* sp. Positive and signficant correlation between available P, P uptake and dry matter content at different periods of growing seasons were observed following inoculation.

Zachariah (1995) reported that the enrichment of compost with nitrogen fixing *Aspergillus* and P solubilising micro organisms along with one per cent RP had a significant effect on nutrient content.

The effect of VAMF in increasing P uptake was positive and it was more pronounced at higher levels of P application in onion (Dhinakaran and Savithri, 1995).

Sudhir *et al.* (1995) reported that the uptake of P by the rice crop from MRP was distinctly higher in the case of laterite and red soil as compared to the black clacareous and alluvial soils when green manure was not applied while it was comparable in all the four soils when green manure was added.

The plant uptake of P was highest in MRP with FYM or biogas spent slurry with P solubilising fungi (Ravikumar *et al.*, 1995). The beneficial effect of green leaf manure and a phosphobacterin was clearly seen on the P uptake at lower levels of P_2O_5 in a rice pulse cropping system (Mahimairaja and Raniperumal, 1995).

Sunil Kumar *et al.* (1995) reported that in rice higher P uptake by grain by the application of 1:1 mixture of MRP and SSP with green leaf manure. Highest P uptake was recorded when neem leaves plus FYM incubated with MRP applied in rice (Savithri *et al.*, 1995).

2.4.4.2. Effect on uptake of other nutrients

Kundu and Gaur (1980) found positive response of wheat to single and combined inoculation with phosphobacterin and Azotobacter on N uptake by wheat crop.

Cohen *et al.* (1980) reported increased N uptake for a wide range of tropical and temperate crops under a wide range of controlled condition in green house and the laboratory by *Azospirillum* inoculation.

Uptake of P from RP and nitrogen by ferrum significantly increased due to inoculation of phosphate biofertilizer in presence of FYM (Sundara Rao, 1981).

Azospirillum inoculation enhanced uptake of nitrate and K and P by roots of maize, wheat and sorghum (Okon, 1982; Lin *et al.*, 1983; and Kapulni *et al.*, 1985).

Abdel and Abdel (1983) investigated the effects of super phosphate or RP and residues of sugarcane, clover and oranges on dry matter yields and contents of N, P, K, Ca, Mg, Fe and Zn of barley. N content increased in orange residue and RP than orange residue alone. There wa no significant effects on P, Ca, Mg or Fe while effects on K and Zn contents were variable.

Datta and Gupta (1983) found that RP along with bone meal increased the uptake of P, K and Ca in paddy and wheat than their single application. Solubility of Cu, Zn and Fe in soils and their concentration in paddy grain decreased.

Subba Rao (1984) reported that beneficial response of crop plants to inoculation with *Azotobacter* can be attributed to growth substances produced by the organisms in addition to nitrogen fixation.

In lime seedlings Mn and Zn contents when P was applied as RP B and Cu contents slightly decreased (Nicoli and Souza, 1985).

Shinde *et al.* (1985) reported that the enriched mechanical composts increased nutrient uptake in wheat plants than the treated with unamended compost.

In a green house trial, cocoa grown in a lattosol with added RP of low solubility was inoculated or not with mycorrhizae. It was found that uptake of macro and micro nutrients was better in mycorrhizal plants (Baon, 1986).

The protein, P and Ca contents of grain were higher when aerobically composted organic matter and RP in the ratio 20:1 was applied to wheat, greengram and rice (Singh and Yadav, 1986).

With the use of N and P enriched products of garbage compost it would be possible to substitute 25 per cent nitrogen and 50 per cent P doses recommended for rice, when applied on N and P basis (Talashilkar and Vimal, 1986).

A pot culture experiment conducted by Hussain and Ibrahim (1987) revealed that N uptake by plants significantly increased by the addition of dried and ground leaves of sesbania to soil supplemented with N as Urea ammonium sulphate.

Mohod *et al.* (1989) revealed that the use of P solublising culture significantly increased the N uptake in rice and the beneficial effects were greater with RP than SSP.

Krishnababa *et al.* (1995) reported that a combination of super phosphate and MRP along with P solublising fungi in mulberry produced significant increase in secondary nutrient content except Mg content of leaf. Further combination of SSP and MRP along with P solubilising fungi recorded significantly higher Ca content of leaf and better leaf quality through enhanced micro nutrient status in the leaf.

Ghandour *et al.* (1996) studied the effect of *Rhizobium* inoculation, VAM fungi on growth, P, N and Fe uptake by faba bean plants grown in virgin sandy soils treated with SP or RP and found that P, N and Fe uptake increased due to inoculation and dual inoculation resulted in the highest effect.

2.5.1. Effect of organic manure enrichment on growth and yield of pulses

2.5.1.1. Effect on growth

Patel and Patel (1991) found that FYM had no effect on any growth parameters in red gram.

In legume forages Cao (1993) obtained significant increase in plant height, tiller number and plant dry matter when inoculated with *Rhizobium*.

Wang *et al.* (1994) reported that inoculation with *Rhizobium leguminosarum* increased plant height in *Vicia villosa*.

In soybean FYM along with NPK fertilizer increased plant height and number of branches per plant (Singh *et al.*, 1994).

In an experiment with bean plants Catmak *et al.* (1994) found that shoot : root dry weight ratios were 4.9 in the control, 1.8 m P different, 6.9 in K deficient and 10.2 in Mg deficient plants.

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

Podile (1995) reported the effect of seed bacterisation of pigeon pea with *Bacillus subtilis* in enhancing the percentage emergence of seedlings.

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

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

2.5.1.2. Effect on yield

Bajpai and Sundara Rao (1971) conducted pot culture experiments in cowpea using SSP and apatite with and without FYM using *Bacillus* sp. It was seen that under specific conditions these organisms increased crop yield. This finding was further supported from the data in a field trial on a soil with low available P status. Yousry (1978) has obtained significantly higher dry matter and yield of cowpea when inoculated with phosphobacterin compared with uninoculated control.

Tiwari *et al.* (1988) reported that three months old enriched compost with *Azotobacter* P solubilising organisms and MRP increased the nodulation and yield of greengram. Bidanchandra (1992) found that the enrichment of compost with *Azotobacter chroococcum*, RP, N, pyrite and P solublising cultures of *Bacillus* and *Pencillium* significantly increased the dry matter yield of rice and green gram. Dubey and Billore (1992) reported that microbial inoculation and fertilization of P and their interaction significantly influenced the grain and straw yield of chickpea. Favourable effect of *Pseudomonas striata* on chickpea has been reported by Prabhakar and Saraf (1990) and Kumar *et al.* (1993).

Mussoriephos treated with FYM and P solubilising fungi recorded maximum pod yield in chickpea over the control (Ravikumar *et al.*, 1995).

Manjaiah *et al.* (1995) reported a significant increase in dry matter accumulation and weight per plant in groundnut when treated with a combination of organic amendments and P solubilisers plus MRP. The pod yield was also superior in these treatments.

Srivastava and Ahlawat (1995) reported that seed inoculation with Rhizobium or P bacteria alone or in combination resulted in a conspicous increase in the yield of cowpea over uninoculated control.

From field experiments with soybean in a vertisol, Dubey (1996) has reported that yield increased with the use of *Pseudomonas striata* either alone or in conjunction with SSP and MRP.

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

2.5.3. Effect of organic manure enrichment on the availability of nutrients in pulses

In a pot experiment to study the effect of P solubilising fungi on the availability of P from RP on the growth of chickpea, Rasal *et al.* (1988) noticed that inoculation with *Aspergillus awamori* increased the availability of P in soil.

Manjaiah *et al.* (1995) studied the influence of added organic amendments and or P solubilisers with MRP on the availability of nutrients in acidic sandy loam soil at different growth stages of groundnut. It was found that combination of organic amendments and P solubilisers with MRP were effective in making P more available.

2.5.4. Effect of organic manure enrichment on P uptake in pulses

Kabesh (1957) reported that P uptake was significantly increased by inoculation with P dissolving bacteria (PDB) and P fertilization either singly or in combination. Application of PDB, SSP or basic slag alone increased P uptake by 14.3, 19.1 and 6.7 over the control treatment while the combined application of PDB and P fertilizers raised P uptake by 44 per cent.

Bajpai and Sundara Rao (1971) conducted pot cultured experiment in cowpea using SSP and apatite with and without FYM using *Bacillus* sp. It was seen that under specific conditions, these organisms increased P uptake by the crop. This finding was further supported from the data in a field trial on a soil with low available status.

Khalafalkeh *et al.* (1982) reported an increased P uptake by inoculation of fava bean with *Bacillus megatherium* var. *Phosphaticum*. The P concentration in the plant tissue was also high.

Bidanchandra (1992) reported that the enrichment of compost with microbial culture, RP, N and pyrite increased the N and P uptake in greengram.

Viswambaran (1995) has reported that the use of 100 per cent P as RP along with VAM and P bacteria resulted in the highest available P content in cowpea (C-152) in a red loam soil and the combined application of VAM and P bacteria was found to be better than the individual application of either VAM or P bacteria.

Srivastava and Ahlawat (1995) have also confirmed that seed inoculation with rhizobium or P bacteria alone or in combination resulted in an increased P uptake by cowpea over uninoculated control.

In soybean with the use of *Pseudomonas striata* either alone or in conjunction with SSP and MRP resulted in an increased P content in different plant parts at various stages (Dubey, 1996).

Sudhirkumar *et al.* (1997) observed an increase in the uptake of P by chickpea in grain and straw by the combined application of RP and organic ammendments (FYM and Biogas slurry) along with P bacteria over sole application of MRP.

Application of 100 per cent recommended dose of inorganic P_2O_5 as enriched FYM along with seed and soil inoculation of phosphobacterin significantly influenced the nutrient uptake in soybean (Marimuthu and Wahab, 1998).

Effect of organic manure enrichment on uptake of other nutrients in pulses

An experiment was conducted in cowpea using SSP and apatite with and without FYM using *Bacillus* sp. and it was found that these micro organisms increased the nitrogen uptake in cowpea (Bajpai and Sundara Rao, 1971). Alagawadi and Gaur (1980) observed that inoculation of P solubilisers in chickpea increased the N uptake in seed over uninoculated control.

Biju (1994) reported higher N uptake in soybean by the application of P solubilisers and organic amendments with MRP.

Manjaiah *et al.* (1995) observed a significant increase in nitrogen accumulation in groundnut plant when treated with combination of organic amendments and P solublizers plus MRP.

Vashiya *et al.* (1996) have reported that use of P solubilizing micro organisms along with RP for bengal gram in a vertisol resulted in a significantly higher P uptake.

Sudhirkumar *et al.* (1997) revealed that combined application of RP and organic amendments (FYM and Biogas slurry) along with P solubilising bacteria significantly increased N uptake in grain, P uptake in grain and straw and K uptake in straw over sole application of MRP. Combined application of RP and organic ammendments (FYM and Biogas slurry) along with P bacteria significantly enhanced the K uptake in chickpea over sole application of MRP (Sudhirkumar *et al.*, 1997).

2.6.1. Effect of vermicompost enrichment on yield of crops

Mackay *et al.* (1982) studied the effect of mixed population of *Lumricus rubellus* and *Allolobophora caliginosa* on the availability to perennial rhye grass of P in super phosphate and RP. Performance of pelletized RP increased in the presence of earthworms. There was increase in yield of rhyegrass.

Vermicompost and phosphobacteria in combination with two inorganic P sources namely SSP and Tumis RP (TRP) were verified in a calcareous black soil for their effect on yield parameters of black gram (Co5) and cotton (LRA 5166) mix. SSP and TRP were soil applied at 100 per cent with and without vermicompost and phosphobacteria. The application of TRP (100 per cent) with vermicompost and phosphobacteria in blackgram recorded the highest grain and haulm yield. In cotton the effect of SSP and TRP on the kapas yield and stover yield were on par (Thiyageshwari and Raniperumal, 1998).

2.6.2. Effect of vermicompost enrichment on P availability

Earthworm population can increase the availability of P in SSP and RP. Mackay *et al.* (1982) reported that performance of pelletized

RP increased in the presence of earthworms by 15-30 per cent. There was an increase in plant available N also. Increased performance result from the incorporation and intimate mixing of RP by earthworms.

Mackay *et al.* (1983) found that incorporation of earthworms to soil incubated with RP resulted in 32 per cent increase in Bray extractable soil P after 70 days.

Integrated nutrient supply of TRP with vermicompost and phosphobacterin increased P use efficiency (PUE). The soil available Olsen's P was increased in blackgram cotton mix due to this integrated supply. The PUE with SSP and vermicompost was higher than SSP with vermicompost and phosphobacteria. The PUE was greater when Phosphobacterin was applied with TRP and vermicompost than with TRP and vermicompost (Thiyageswari and Raniperumal, 1998).

2.6.3. Effect of vermicompost enrichment on P uptake

Mackay *et al.* (1982) reported that the uptake of P by rhye grass increased when SP and RP was applied along with a mixed a population of *Lumbricus rubellus* and *Allolobophora caliginosa*.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study entitled "Effect of vermicompost enriched with rockphosphate on cowpea [*Vigna unguiculata* L. Walp.] has been carried out at the Instructional Farm attached to the College of Agriculture, Vellayani during 1997-98. The main objective of the study was to assess the effect of vermicompost enriched with rockphosphate on P availability yield and quality of cowpea and the feasibility of reducing inorganic P. The details of the experimental site, season, weather condition, materials used and method adopted are presented in this chapter.

3.1. Experimental site

The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani.

3.1.1. Location

The Instructional Farm, Vellayani is located at 8° 30' N latitude and 76° 54' E longitude and at 29 M above MSL.

3.1.2 Soil

The soil of the experimental site comes under the order Oxisol and belongs to the family loamy, skeletal, Kaolinitic, isohyperthermic

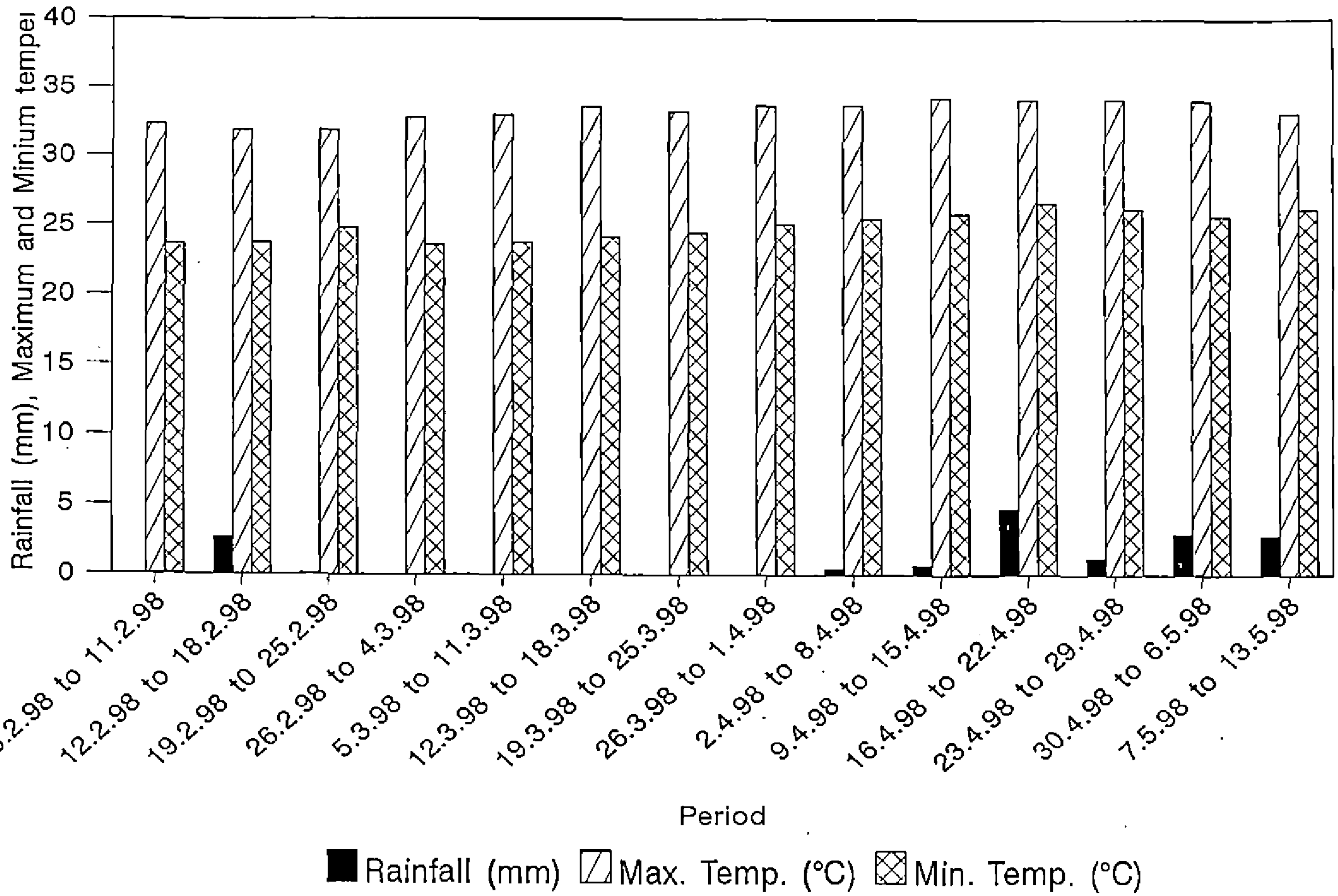

Fig. I. Weather data during the cropping period

rhodic haplustox. The physical and chemical properties of soil where the experiment was conducted are given in Table I.

3.1.3. Season

The experiment was carried out during the period from February to May in the year 1998 which received a rainfall of 1293 mm. The maximum and minimum temperature during the cropping period were 32.26°C and 24.46°C. respectively. The weekly distribution of rainfall and temperature prevailed during the cropping period was collected from the agrometeorological observatory attached to the Department of Agronomy, College of Agriculture, Vellayani and is presented in the Fig. I.

3.2. Preparation of Vermicompost

Vermicomposting was carried out in pits of size 2x1x0.5 m. Raw materials used were dried banana leaves and pseudostem. Banana leaves and pseudostem were chopped and mixed with cowdung in the ratio 8:1 on volume basis and vermicompost was prepared according to Package of Practices recommendation (POP) of Kerala Agricultural University (KAU) using earthworm sp. *Eudrillus eugeniae* (KAU, 1996).

3.3. Preparation of enriched vermicompost

For the preparation of enriched vermicompost RP was added to the biowastes (pseudostem and dried banana leaves in the ratio 8:1 on

Table I. Physical and chemical properties of the experimental site

	Parameter	Content	Method	Reference
1.	Mechanical composition			
	Coarse sand	14.2 %	International pipette method	Piper (1966)
	Fine sand	31.1 %		
	Silt	27.5 %		
	Clay	24.6 %		
2.	Texture	Sandyloam		
3.	Bulk density	1.3 mg m^{-3}	Core method	Gupta and Dakshinamoorthy (1980)
4.	pH (soil : water - 1 : 2.5)	5.0	pH meter with glass electrode	Jackson (1973)
5.	EC (soil : water - 1 : 2.5)	< 0.05 dSm^{-1} bridge	Conductivity	- do -
6.	CEC	5 cmol kg^{-1}	Neutral Normal Ammonium acetate method	Scholenberger and Drei belbis (1930)
7.	Organic carbon	0.6 %	Walkley and Black's rapid titration method	Jackson (1973)
8.	Sesquioxides	13.2 %		
9.	Available N ($KMnO_4$-N)	219.28 kg ha^{-1}	Alkaline permanganate method	Subbiah and Asija (1956)
10.	Available P_2O_5 (Bray-IP)	30.58 kg ha^{-1}	Bray colorimetry method	Jackson (1973)
11.	Available K_2O (Ammonium acetate K)	167.33 kg ha^{-1}	Flame photometer method	Jackson (1973)
12.	Exchangeable Ca	0.78 Cmol kg^{-1}	Flame photometer method	Jackson (1973)
13.	Exchangeable Mg	1.12 Cmol kg^{-1}	Atomic absorption spectrometer model PE 3030 using ammonium acetate extract	Jackson (1973)

volume basis) and cowdung mixture on dry weight basis during vermicomposting. Quantity of RP (24% P_5O_5) added to the biowaste was fixed as per POP of KAU for cowpea.

3.4. Priming of organic manures

Priming of vermicompost and FYM was done separately. For priming, RP (24% P_2O_5) was added to the organic manures and incubated at 60 per cent moisture for fifteen days. Quantity of RP used for priming was fixed as per POP of KAU for cowpea.

Nutrient status of the organic manures used in the experiment were determined using standard analytical procedures given for plant analysis (Table II) and data are presented in the Table III.

3.5. Fertilizers

The carrier fertilizers for NPK were urea containing 46 per cent N, Rajphos containing 24 per cent. P_2O_5 and muriate of potash containing 60 per cent K_2O.

3.6. Crop and Variety

Cowpea variety Kanakamoni (Ptb-1) was used for the experiment. The seed materials were obtained from RARS, Kayamkulam.

Table II. Standard procedures for plant analysis

Parameter	Method	Reference
N	Micro-kjeldahl digestion in sulphuric acid and distillation	Jackson (1973)
P	Nitric perchloric digestion and estimation by calorimetry making use of vanadomolybdate yellow colour method	Jackson (1973)
K	Nitric perchloric digestion and estimation by flame photometry	Jackson (1973)
Ca and Mg	Nitric perchloric digestion and estimation atomic absorption spectrophotometry	Piper (1966)
Mn, Zn, Cu, Fe	Nitric perchloric digestion and determination by atomic absorption spectrophotometry	Piper (1966)

Table III. Analysis of manures used in the experiment

Manures	Nutrient content (%) N	P_2O_5	K_2O	Ca	Mg
Cowdung	0.5	0.32	0.50		
Vermicompost	1.83	1.37	2.42	0.22	1.2
Enriched vermicompost	1.95	2.15	2.66	0.46	1.3

Type of compsot	Microbial count / 100g Bacteria	Actinomycetes	Fungi
Ordinary vermicompost	52×10^5	8×10^4	2×10^5
Enriched vermicompost	64×10^6	23×10^4	1.8×10^5

N ↑

R$_1$

T_8	T_4
T_3	T_{12}
T_5	T_9
T_{11}	T_7
T_6	T_1
T_{13}	T_{10}
T_2	

R$_2$

T_7	T_{12}
T_5	T_2
T_{11}	T_6
T_8	T_{13}
T_{10}	T_1
T_9	T_3
	T_4

R$_3$

T_3	T_{12}
T_{11}	T_7
T_{13}	T_{10}
T_2	T_8
T_4	T_5
T_9	T_6
T_1	

Fig. II. Layout plan of the experiment

3.7. Design and Lay out of the experiment

Design	-	Randomised Block Design
Treatments	-	13
Replication	-	3
Plot size	-	5 m x 4 m
Spacing	-	25 cm x 15 cm
Variety	-	Kanakamoni

Lay out plan of the experiment is given in Fig II.

Treatment Details

T1 - Absolute control

T2 - RP alone

T3 - FYM alone

T4 - Vermicompost alone

T5 - Enriched vermicompost alone

T6 - FYM + full RP (POP of KAU)

T7 - FYM + half RP (½ POP of KAU)

T8 - Vermicompost + full RP (POP of KAU)

T9 - Vermicompost + half RP (½ POP of KAU)

T10 - Vermicompost + full RP (primed for 15 days at 60% moisture)

T11 - Vermicompost + half RP (primed for 15 days at 60% moisture)

T12 - FYM + full RP (primed for 15 days at 60% moisture)

T13 - FYM + half RP (primed for 15 days at 60% moisture)

Experimental site

The POP for cowpea is 250 kg ha^{-1} lime, 20 kg N ha^{-1}, 30 kg P_2O_5 ha^{-1}, 10 kg K_2O ha^{-1} and 20 t FYM ha^{-1}.

Nitrogen, potash and lime were applied in all the plots except T1 and all the cultural operations were done as per POP of KAU (KAU 1996).

3.8. Details of cultivation

3.8.1. Sowing

Cowpea seeds of Kanakamoni variety were sown in the field in furrows. All cultivation practices as per POP of KAU were followed.

3.8.2. Application of manures and fertilizers

Lime was applied at the time of first digging. Entire quantity of potash and the half the quantity of nitrogen were given as basal dose before sowing. Remaining half dose of nitrogen was applied 20 days after sowing.

Phosphorus was applied as RP as a basal dose through primed FYM or primed vermicompost or through enriched vermicompost or RP with FYM or vermicompost as per treatments.

FYM, vermicompost, enriched vermicompost and primed manures were applied to different plots as basal dose according to the POP of KAU for cowpea.

3.9. Biometric observations

Five plants from each plot were selected randomly for recording biometric observations and average values were recorded.

3.9.1 Height of the plant (cm)

The height of the plant was measured from the scar of the first cotyledenous leaves of the plant to the tip of the growing point and expressed in cm.

3.9.2. Number of branches per plant

Number of branches per plant at harvest was recorded.

3.9.3. Date of first flowering

Date of first flowering in each plot was noted.

3.9.4. Root shoot ratio

Root shoot ratio of the observation plants from each plot was recorded at harvest stage using root dry weight and shoot dry weight.

3.9.5. Nodule number per plant

Nodules were separated from the roots at maximum flowering stage. The separated nodules were carefully washed, counted and average worked out.

3.9.6. Weight of nodulesper plant

The nodules used for taking count were oven dried, weighed and the average value was recorded.

3.9.7. Reaction to pest and diseases

Incidence of pest and diseases was noted.

3.9.8. Yield and yield attributes

3.9.8.1. Number of pods per plant

Pods collected from observation plants were counted separately and average value were recorded.

3.9.8.2. Number of seeds per pod

Number of seeds in each pod of the observational plant was counted and the average value was recorded.

3.9.8.3. Hundred seed weight

Hundred seeds were randomly selected from the bulk in each plot, weighed and weight recorded in gram.

3.9.8.4. Grain yield

Yield of grain obtained from each net plot was recorded separately and expressed in kg ha^{-1} adjusted to 12 per cent moisture.

3.9.8.5. Bhusa yield

After the pods were picked from each net plot, the plants were uprooted, sun-dried uniformly and weighed and weight was expressed in kg ha^{-1}.

3.10. Chemical analysis

3.10.1. Soil analysis

The soil sample collected from each plot after harvest of the crop was processed and analysed for available N, P_2O_5 and K_2O using standard procedures as given in Table I.

3.10.2. Microbial analysis of vermicompost

The total number of bacteria, actinomycetes and fungi in vermicompost and enriched vermicompost used in the experiment was determined by serial dilution plate method (Timonin, 1940).

The composition of media for isolating different groups of micro organisms is given below.

3.10.2.1. Media for isolation of bacteria

Soil extract agar

Soil extract stock - 100 ml

Tap water	-	900 ml
Glucose	-	1 g
K_2HPO_4	-	0.5 g

3.10.2.2. Preparation of soil extract

100 g of sieved garden soil was mixed with 1000 ml of tap water and steamed in the autoclave for 30 minutes. A small amount of $CaCO_3$ was added and the whole was filtered through a double filter paper.

The agar was dissolved in 900 ml water by steaming it for an hour and added 100 ml of the stock soil extract solution. Glucose and KH_2PO_4 were added and pH was adjusted to 6.8 using 1N NaOH.

3.10.2.3. Media for isolation of fungi

Peptone dextrose agar with rose bengal and streptomycin

Dextrose	-	10 g
Peptone	-	5 g
K_2HPO_4	-	1 g
$MgSO_4$	-	0.5g
Agar	-	1 g
Rose bengal	-	to give colour
Streptomycin	-	30 mg
Distilled water	-	100 ml

3.10.3. Plant analysis

Plant samples were collected from each plot after harvest. The samples were ovendried at 65°C for 24 hours and powdered in a Willey mill and used for chemical analysis. The content of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu were determined using the standard procedures given in Table II.

3.10.4. Seed analysis

Seed samples were prepared in the same way as that of plant analysis and analysed using the same procedures given for plant analysis. Seed samples were analysed for protein content, P, K, Ca and Mg. Percentage of protein in the grain was computed from the nitrogen content.

3.11. Uptake of nutrients

The total uptake of macro and micronutrients by the plants was calculated from their contents in the plant multiplied by the dry matter yield and expressed in kg ha^{-1}.

3.1.. Statistical analysis

Statistical methods of analysis such as analysis of variance and correlations were carried out to find out the relationship between variables and to draw definite conclusions.

RESULTS

RESULTS

The present investigation was carried out at the College of Agriculture, Vellayani to study the effect of vermicompost enriched with RP on P availability, yield and quality of cowpea and the feasibility of reducing the inorganic P.

4.1. Chemical and biological analysis of organic manures

The analysis of organic manures were done following the standard analytical procedures. A perusal of data in Table III reveals the superiority of enriched vermicompost over other organic manures. The enriched vermicompost used for the study showed a nutrient composition of 1.95 per cent N, 2.15 per cent P_2O_5 and 2.66 per cent K_2O. FYM showed a lesser value compared to vermicompost and enriched vermicompost. With regard to the microbial count of various organic manures enriched vermicompost is found to be superior over others. Enriched vermicompost contained about 64 x 10^6 bacteria, 23 x 10^4 actinomycetes and 1.8 x 10^5 fungi.

4.2. Growth characters

The important growth characters studied were height of the plant, number of branches per plant, days to flower, root shoot ratio, nodule number per plant and weight of nodule per plant. The results are presented in Tables IV and V and the values in the tables are mean values of two replications.

4.2.1. Height of the plant (cm)

The different treatments had produced significant variation on the height of the plant at harvest stage (Table IV). The highest mean value for height of the plant (60 cm) was recorded by treatment T_{11} [vermicompost + half RP (primed for 15 days at 60 per cent moisture)] which was found to be on par with the treatments T_5 (enriched vermicompost alone), T_{10} vermicompost + full RP (primed for 15 days at 60 per cent moisture), T_4 (vermicompost alone), T_8 (vermicompost + full RP) and T_9 (vermicompost + half RP). The lowest mean value (49.2 cm) was recorded by treatment T_1 (absolute control). The treatment T_5 (enriched vermicompost alone) was significantly superior to treatment T_6 (FYM + full RP (POP of KAU) which registered a mean value of 55.5 cm for height of the plant. The treatment T_{10} was on par with T_{11} and T_{12} was on par with T_{13}.

4.2.2. Number of branches per plant

Number of branches per plant at harvest was significantly influenced by different treatments. (Table IV). The treatment T_5 (enriched vermicompost alone) registered the highest mean value of 13 and T_1

Table IV. Height of the plant and number of branches per plant at harvest

Treatments	Plant height (cm)	Number of branches $plant^{-1}$
T_1	49.25	10.70
T_2	52.50	11.20
T_3	56.25	11.80
T_4	58.23	12.70
T_5	59.55	13.00
T_6	55.50	11.50
T_7	56.00	11.30
T_8	58.00	12.20
T_9	57.25	12.70
T_{10}	59.00	12.70
T_{11}	60.10	12.40
T_{12}	55.40	12.60
T_{13}	56.25	12.45
CD	2.896	1.136
SEM±	0.9399	0.3688

(absolute control) yielded the lowest value of 10.7. The treatments T_4, T_5, T_9 and T_{10} were significantly superior to the treatment T_6 (FYM + full RP (POP of KAU) which registered a mean value of 11.5. The treatment T_6 was on par with the treatment T_7. The treatment T_5 was found to be on par with treatments T_4, T_8, T_9, T_{10}, T_{11}, T_{12} and T_{13}.

4.2.3. Date of first flowering

There was no significant difference between treatments in respect of date of first flowering. Eventhough there was no significant difference between treatments, delayed flowering was noted in Treatment T_1 (absolute control) and T_2 (RP alone).

4.2.4. Nodule number per plant

There was significant difference among treatments for nodule number (Table V). The highest nodule number was recorded by the treatment T_5 (enriched vermicompost alone) which registered a mean value of 12.25. The treatment T_5 was significantly superior to all other treatments. The lowest mean value was recorded by treatments T_1 followed by T_2. Treatments T_8, T_9, T_{10} and T_{11} were found to be on par.

4.2.5. Weight of nodule per plant

The table V reveals that weight of nodule per plant was significantly influenced by different treatments. The highest mean value

Table V. Root shoot ratio, nodule number and weight of nodules per plant at harvest

Treatment	Root shoot ratio	Nodule number $plant^{-1}$	Dry weight of nodules $plant^{-1}$ (g)
T_1	0.183	5.10	0.010
T_2	0.200	7.50	0.015
T_3	0.233	9.64	0.019
T_4	0.244	10.65	0.0205
T_5	0.294	12.25	0.0235
T_6	0.239	10.00	0.0195
T_7	0.232	9.84	0.019
T_8	0.273	11.00	0.022
T_9	0.262	11.50	0.022
T_{10}	0.283	11.25	0.023
T_{11}	0.274	11.05	0.023
T_{12}	0.253	10.05	0.020
T_{13}	0.230	9.79	0.0190
CD	0.022	0.6966	0.0014
SEM±	0.007	0.226	0.0004

of 0.0235 g was recorded by the treatments T_5 (enriched vermicompost alone) and the lowest mean value of 0.01 g was recorded by treatment T_1 (absolute control). The treatment T_5 significantly differed from treatments T_6 (FYM + full RP (POP of KAU)) and T_8 (vermicompost + full RP (POP of KAU)). The treatments T_8, T_9, T_{10} and T_{11} were found to be on par.

4.2.6. Root shoot ratio

Table V presents the root shoot ratio obtained from different treatments. There was significant difference among treatments for root shoot ratio. The treatment T_5 (enriched vermicompost alone) registered the highest mean value (0.294) for root shoot ratio. The lowest values (0.183) recorded by the treatment T_1 (absolute control). The treatment T_5 significantly differed from treatment T_6 and was on par with treatment T_8. The treatment T_{10} was on par with T_{11}.

4.3. Yield and yield attributes

The important yield attributes studied were number of pods per plant, number of seeds per pod and hundred seed weight.

4.3.1. Number of pods per plant

From the results (Table VI) it can be inferred that number of pods per plant was significantly influenced by different treatments. The treatments T_5 (enriched vermicompost alone) registered the maximum

Table VI. Yield attributes

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Hundred seed weight
T_1	7.5	6.9	10.66
T_2	8.0	7.1	11.53
T_3	8.6	8.3	11.91
T_4	9.5	9.8	12.03
T_5	12.4	12.1	12.56
T_6	9.0	8.5	12.06
T_7	9.2	8.8	12.00
T_8	9.5	10.2	12.13
T_9	9.1	9.89	12.10
T_{10}	9.6	11.1	12.24
T_{11}	9.7	11.1	12.16
T_{12}	8.7	9.2	11.44
T_{13}	8.6	9.2	11.41
CD	0.744	0.438	0.2511
SEM±	0.241	0.1423	0.0815

value of 12.4 and was found to be significantly superior to all other treatments. The lowest value (7.5) for number of pods per plant was recorded by treatment T_1. The treatments T_4, T_6, T_7, T_8, T_9, T_{10} and T_{11} were found to be on par.

4.3.2. Number of seeds per pod

The results revealed that the number of seeds per pod was significantly influenced by different treatments (Table VI). The highest mean value of 12.1 was recorded by treatment T_5 (enriched vermicompost alone) and it was significantly superior to all other treatments. The lowest mean value for number of seeds per pod was registered by treatment T_1 (absolute control) (6.9). The treatments T_{10} and T_{11} were found to be on par, but these treatments were significantly superior to treatments T_8 and T_9.

4.3.3. Hundred seed weight

There was significant variation among the treatments for hundred seed weight (Table VI). The highest mean value of 12.56 g was recorded by treatments T_5 (enriched vermicompost alone) and was significantly superior to all other treatments. The lowest value of 10.66 g was registered by treatments T_1 (absolute control). The treatments T_8, T_9, T_{10} and T_{11} were found to be on par.

4.3.4. Grain yield

Grain yield of cowpea was significantly influenced by different treatments (Table VII).

Table VII. Yield at harvest

Treatments	Grain yield kg ha^{-1}	Bhusa yield (kg ha^{-1})
T_1	585.0	1145.0
T_2	690.0	1324.5
T_3	817.5	1619.5
T_4	877.5	1823.0
T_5	1072.5	2093.5
T_6	837.5	1650.0
T_7	831.5	1575.5
T_8	882.5	1839.5
T_9	879.0	1830.0
T_{10}	909.0	1850.0
T_{11}	898.5	1810.5
T_{12}	859.0	1678.0
T_{13}	833.5	1623.5
CD	54.05	137.05
SEM±	17.54	44.55

Maximum value of 1072.5 kg ha^{-1} for grain yield was recorded by treatment T_5 (enriched vermicompost alone). This treatment was significantly superior to all other treatments. It differed significantly from treatments T_6 and T_8. The lowest mean value of 585 kg ha^{-1} was recorded by treatments T_1 (absolute control). The treatment T_{10} was on par with T_{11} and T_{12} was on par with T_{13}.

4.3.5. Bhusa yield

There was significant difference among treatments for bhusa yield (Table VII). The treatments T_5 (enriched vermicompost alone) recorded the highest bhusa yield (2093.5 kg ha^{-1}). This was significantly superior to all other treatments. The treatments T_6 and T_8 registered a mean value of 1650 kg ha^{-1} and 1839.5 kg ha^{-1} respectively and were significantly inferior to treatment T_5. As expected treatment T_1 (absolute control) recorded the lowest mean value of 1145 kg ha^{-1}. The treatment T_{10} was on par with T_{11}.

4.4. Reaction to pest and diseases

No major pest and disease was noticed

4.5. Soil analysis at harvest for major nutrients

Table VIII shows the status of available N, P and K in the soil after harvest of the crop. It may be seen that contents of all the nutrients were significantly influenced by different treatments.

Table VIII. Analysis of soil after harvest for major nutrients (kg ha^{-1})

Treatments	N	P_2O_5	K_2O
T_1	210.05	30.60	168.55
T_2	215.50	33.00	149.20
T_3	230.40	34.55	187.15
T_4	243.00	45.45	200.05
T_5	249.30	53.85	209.15
T_6	225.70	35.30	187.10
T_7	225.70	35.95	186.20
T_8	243.00	46.30	198.35
T_9	238.30	44.75	197.00
T_{10}	246.10	45.05	199.70
T_{11}	243.70	46.50	199.70
T_{12}	230.40	37.40	190.25
T_{13}	228.10	37.30	192.95
CD	6.00	2.733	8.789
SEM±	1.949	0.887	2.85

4.5.1. Nitrogen

Available N of soil was significantly influenced by different treatments. Maximum value for available N registered by treatments T_5 (enriched vermicompost alone) (249.3 kg ha^{-1}) followed by treatment T_{10} (vermicompost + full RP (primed for 15 days at 60 per cent moisture)). The treatment T_5 significantly differed from treatments T_6 and T_8. The lowest mean value for available N was recorded by treatment T_1 (absolute control) (210.5 kg ha^{-1}). The treatments T_1 and T_2 were significantly inferior to all other treatments. The treatment T_{10} was on par with T_{11} and T_{12} was also on par with T_{13}.

4.5.2. Phosphorus

Available P_2o_5 content of soil was significantly influenced by different treatments (Table VIII). The highest mean value wa recorded by treatment T_5 (enriched vermicompost alone) (53.85 kg ha^{-1}). This was significantly superior to all other treatments. The treatments T_6 and T_8 were significantly inferior to treatment T_5. The treatment T_{10} was on par with T_{11}. The lowest mean value for available phosphorus was recorded by treatment T_1 absolute control (30.6 kg ha^{-1}).

4.5.3. Potassium

There was significant difference among treatments for available K_2O of soil after harvest of the crop (Table VIII). Maximum mean value of available K_2O of soil after harvest of the crop was recorded by treatment T_5 (enriched vermicompost alone). This was significantly superior to all other treatments. The treatments T_6 and T_8 were significantly inferior to treatments T_5. The minimum mean value was registered by treatment T_2 (RP alone). Maximum and minimum value registered were 209.15 kg ha^{-1} and 149.2 kg ha^{-1} respectively. The treatment T_{10} was on par with T_{11} and T_{12} with T_{13}.

4.6. Plant analysis for macro and micro nutrients

4.6.1. Major nutrients

Table IX presents the data on the content of N, P, K, Ca and Mg in cowpea at harvest stage. All the macronutrients were significantly influenced by different treatments.

4.6.1.1. Nitrogen

N content of plants at harvest stage was significantly influenced by different treatments (Table IX). The treatment T_5 (enriched vermicompost alone) registered the highest value (1.684 %) for N content. The treatment T_5 was on par with treatment T_4, T_8, T_{10} and T_{11}. It was significantly superior to treatment T_6 (FYM + full RP (POP of KAU)).

4.6.1.2. Phosphorus

P content of plant parts at harvest was significantly influenced by different treatments (Table IX). The treatment T_5 (enriched vermicompost

Table IX. Macro and secondary nutrients in cowpea at harvest stage (%)

Treatments	N	P	K	Ca	Mg
T_1	1.148	0.183	0.565	0.715	0.2545
T_2	1.176	0.185	0.480	0.720	0.2605
T_3	1.372	0.235	0.595	0.775	0.2775
T_4	1.667	0.240	0.760	0.805	0.285
T_5	1.684	0.320	0.765	0.820	0.285
T_6	1.484	0.220	0.615	0.785	0.277
T_7	1.512	0.222	0.615	0.760	0.276
T_8	1.596	0.245	0.755	0.800	0.287
T_9	1.568	0.245	0.750	0.800	0.284
T_{10}	1.602	0.270	0.730	0.805	0.288
T_{11}	1.604	0.265	0.760	0.790	0.2875
T_{12}	1.512	0.270	0.615	0.775	0.273
T_{13}	1.568	0.240	0.600	0.775	0.275
CD	0.099	0.022	0.038	0.027	0.004
SEM$\pm$	0.032	0.073	0.012	0.008	0.0013

alone) was significantly superior to all other treatments. The lowest value of 0.1838 per cent was recorded by treatment T_1 (absolute control). The treatment T_5 was significantly superior to treatments T_6 and T_8. The treatment T_{10} was on par with T_{11}.

4.6.1.3. Potassium

There was significant difference among treatments for plant K content. Table IX shows that the highest mean value for K content was registered by treatments T_5 (enriched vermicompost alone) closely followed by treatment T_{11}. The lowest mean value was recorded by treatment T_2 (RP alone). The treatments T_5 and T_8 was on par and was significantly superior to treatment T_6. K content of these treatments T_5, T_6 and T_8 were 0.765 per cent, 0.615 per cent and 0.755 per cent respectively.

4.6.1.4. Calcium

Ca content in cowpea plant at harvest was significantly influenced by different treatments (Table IX). Maximum mean value recorded by treatment T_5 (enriched vermicompost alone) (0.82 per cent). This was on par with treatments T_4, T_8, T_9 and T_{10} and significantly differed from T_6. Minimum mean value recorded by treatment T_1 (absolute control) (0.715 per cent).

4.6.1.5. Magnesium

The treatment T_{10} (vermicompost + full RP (primed for 15 days at 60 per cent moisture) recorded the maximum value (0.288 per cent) for Mg content of plant parts at harvest stage (Table IX). This treatment was on par with T_4, T_5, T_8, T_9 and T_{11}. The treatment T_5 was on par with treatment T_4 (vermicompost alone) and T_8 (vermicompost + full RP (POP of KAU)). The lowest mean value 0.254 per cent was registered by treatment T_1 (absolute control).

4.6.2. Micro nutrients

Table X presents the data on the content of micro nutrients in cowpea at harvest stage. None of the micro nutrient was significantly influenced by different treatments.

4.6.2.1. Iron

Fe content in cowpea plants at harvest was not significantly influenced by different treatments. The highest mean value (118 ppm) was recorded by treatments T_5 (enriched vermicompost alone) and T_{11} (vermicompost + half RP (primed for 15 days at 60 per cent moisture). The lowest mean value 114.5 ppm recorded by treatments T_2 and T_{13}.

4.6.2.2. Manganese

The treatment T_9 (vermicompost + half RP (POP of KAU)) recorded the highest mean value (25 ppm) for Mn content of cowpea

Table X. Micronutrient concentration in cowpea at harvest stage (ppm)

Treatments	Fe	Mn	Zn	Cu
T_1	117.00	16.25	25.00	17.00
T_2	114.50	22.50	28.00	18.00
T_3	116.50	22.13	27.00	17.50
T_4	116.00	22.00	30.00	18.00
T_5	118.00	22.18	34.00	21.50
T_6	115.50	21.00	20.50	19.00
T_7	116.50	20.00	21.00	18.00
T_8	116.50	19.00	23.50	19.50
T_9	117.00	25.00	34.00	18.00
T_{10}	117.40	21.00	33.50	18.00
T_{11}	118.00	24.00	32.00	21.50
T_{12}	115.00	19.00	28.00	19.00
T_{13}	114.50	17.50	29.00	18.50

plants and the lowest mean value (16.25 ppm) recorded by treatment T_1 (absolute control). The treatment T_5 recorded a mean value of 22.18 ppm. However there was no significant difference between the treatments for this character.

4.6.2.3. Zinc

Zn content of cowpea plants at harvest was not significantly influenced by different treatments. From the table it is evident that the highest mean value (34 ppm) recorded by treatment T_5 (enriched vermicompost alone) and T_9 (vermicompost + half RP). The lowest value recorded by treatment T_6 (FYM + full RP (POP of KAU)) (20.5 ppm).

4.6.2.4. Copper

There was no significant difference between treatments for Cu content of cowpea plants (Table X). However the maximum mean value for Cu content was recorded by treatments T_5 (enriched vermicompost alone) and T_{11} (vermicompost + half RP (primed for 15 days at 60 per cent moisture)). Lowest value registered by treatment T_1 (absolute control). Maximum and minimum value recorded were 21.5 ppm and 17 ppm respectively.

4.7. Grain analysis

Grain samples were analysed for protein and minerals like P, K, Ca and Mg. The data are presented in Table XI.

Table XI. Analysis of grain for protein content and minerals (%)

Treatments	Protein	Phosphorus	Potassium	Calcium	Magnesium
T_1	19.875	0.420	1.450	0.615	0.250
T_2	20.125	0.425	1.470	0.620	0.223
T_3	21.560	0.44	1.635	0.625	0.253
T_4	23.810	0.475	1.660	0.638	0.254
T_5	24.935	0.515	1.710	0.643	0.254
T_6	21.620	0.435	1.630	0.630	0.253
T_7	21.620	0.445	1.590	0.620	0.253
T_8	23.870	0.485	1.680	0.639	0.254
T_9	23.810	0.485	1.680	0.638	0.254
T_{10}	24.375	0.485	1.710	0.640	0.265
T_{11}	24.185	0.475	1.700	0.640	0.253
T_{12}	22.185	0.445	1.610	0.630	0.253
T_{13}	22.060	0.435	1.610	0.630	0.252
CD	0.4215	0.026	0.068	0.014	0.013
SEM±	0.1368	0.008	0.022	0.003	0.004

Results revealed that the different treatments significantly influenced the protein and mineral content of grain.

4.7.1. Protein

The different treatments showed significant influence on the protein content of cowpea grain. The highest mean value (24.94 per cent) for protein content was obtained for treatment T_5 (enriched vermicompost alone) closely followed by treatment T_{10} and T_{11}. The lowest value (19.88 per cent) was registered by treatment T_1 (absolute control) and this was on par with treatment T_2. The treatment T_5 was significantly superior to treatments T_6 and T_8. The treatment T_{10} was found to be on par with T_{11} and T_{12} was found to be on par with T_{13}.

4.7.2. Phosphorus

There was significant variation among the treatments for P content of seeds (Table XI). The highest mean value was recorded by treatments T_5 followed by T_8, T_9 and T_{10}. The treatment T_5 was significantly superior to treatment T_6. The lowest value recorded by treatment T_1 (absolute control). Maximum and minimum value recorded were 0.515 per cent and 0.42 respectively. There was no significant difference between T_{10} and T_{11} and also between T_{12} and T_{13}.

4.7.3. Potassium

The different treatments showed significant influence on the K content of cowpea seeds. The maximum mean value (1.71 per cent) was recorded by treatment T_5 and T_{10}. The treatment T_5 was significantly superior to treatment T_6 and was on par with treatment T_8. The lowest value of 1.45 per cent for K content was registered by treatment T_1 (absolute control). There was no significant difference between T_{10} and T_{11} and also between T_{12} and T_{13}.

4.7.4. Calcium

The treatment T_5 (enriched vermicompost alone recorded the highest value (0.64 per cent) for Ca content of cowpea seeds. But this was on par with treatments T_4, T_9, T_{10}, T_{11}, T_{12} and T_{13}. The treatment was significantly superior to treatment T_6. The lowest value for Ca content of cowpea seeds were recorded by treatment T_1 (absolute control) the value being (0.615 per cent).

4.7.5. Magnesium

This character was significantly influenced by different treatments. The highest mean value for Mg content was registered by treatment T_{10} (0.265 per cent). The treatment T_5 was not significantly different from T_6. The lowest value for Mg content was recorded by treatment T_2 (RP alone) (0.223 per cent).

4.8. Uptake of nutrients

4.8.1. Major nutrients

From the data presented in the Table XII it may be seen that different treatments had a significant influence on the uptake of major nutrients.

Table XII. Uptake of major and secondary nutrients at harvest stage (kg ha^{-1})

Treatments	N	P	K	Ca	Mg
T_1	40.00	4.53	18.42	11.07	4.34
T_2	42.50	5.42	18.61	13.83	5.25
T_3	50.42	7.39	22.99	17.61	6.55
T_4	63.33	8.57	28.41	21.81	7.41
T_5	77.88	11.94	33.72	26.31	8.68
T_6	53.42	7.26	23.78	18.15	6.67
T_7	52.45	7.37	22.91	16.68	6.45
T_8	63.13	8.78	28.71	22.14	7.47
T_9	62.62	8.78	28.51	22.06	7.44
T_{10}	65.08	9.39	29.46	22.27	7.62
T_{11}	63.58	8.95	29.03	21.83	7.47
T_{12}	55.86	8.35	24.14	18.55	6.50
T_{13}	54.85	7.64	24.30	17.90	6.56
CD	6.208	0.723	2.229	1.387	0.4094
SEM±	2.012	0.2347	0.7461	0.4501	0.1328

4.8.1.1. Nitrogen

N uptake was significantly influenced by different treatments (Table XII). The highest mean value (77.88 kg ha^{-1}) for N uptake was recorded by treatments T_5 (enriched vermicompost alone). This was found to be significantly superior to all other treatments. The lowest mean value (40 kg ha^{-1}) was recorded by treatment T_1 (absolute control). The treatment T_5 was significantly superior to treatments T_6 and T_8. There was no significant difference between treatments T_{10} and T_{11} and between treatments T_{12} and T_{13}.

4.8.1.2. Phosphorus

There was significant variation among treatments for P uptake. The maximum value (11.94 kg ha^{-1}) was recorded by treatment T_5 (enriched vermicompost alone). This treatment was significantly superior to all other treatments. The minimum value for P uptake was registered by treatment T_1 (absolute control) (4.53 kg ha^{-1}). The treatment T_{10} was on par with T_{11}.

4.8.1.3. Potassium

K uptake was significantly influenced by different treatments. Highest mean value for K uptake was registered by treatment T_5 (33.72 kg ha^{-1}). The lowest value for K uptake was 18.42 kg ha^{-1} recorded by treatment T_1 (absolute control). The treatment T_5 was significantly superior to all other treatments. The treatment T_{10} was on par with T_{11}.

4.8.1.4. Calcium

On scrutinizing the results it may be noted that highest mean value (26.3 kg ha^{-1}) for Ca uptake was recorded by treatment T_5 (enriched vermicompost alone). This was significantly superior to all other treatments. The next highest for Ca uptake was registered by treatment T_{10}. The minimum mean value for Ca uptake was registered by treatment T_1 (absolute control) (11.07 kg ha^{-1}). There was no significant difference between treatments T_{10} and T_{11} and also between T_{12} and T_{13}.

4.8.1.5. Magnesium

There was significant variation among treatments for Mg uptake by cowpea plants. The treatment T_5 (enriched vermicompost alone) was significantly superior to all other treatments. It recorded the maximum mean value of 8.68 kg ha^{-1} for Mg uptake. The lowest value 4.34 kg ha^{-1} was registered by treatment T_1 (absolute control). The treatment T_5 was significantly superior to treatments T_6 and T_8. The treatment T_{10} was on par with T_{11} and T_{12} was on par with T_{13}.

4.8.2. Micronutrients

From the data presented in the Table XIII it may be seen that different treatments had no significant influence on the uptake of micro nutrients at harvest stage of the crop.

Table XIII. Uptake of micro nutrients at harvest stage (g ha^{-1})

Treatments	Fe	Mn	Zn	Cu
T_1	201.5	33.6	48.1	29.00
T_2	223.5	33.3	59.5	32.00
T_3	287.0	52.7	74.7	43.75
T_4	312.5	59.5	82.5	46.00
T_5	381.5	66.5	93.2	56.00
T_6	287.00	55.5	74.0	44.10
T_7	280.0	49.5	71.5	40.85
T_8	316.5	60.5	81.3	48.10
T_9	316.5	61.5	81.1	47.85
T_{10}	323.5	61.5	85.3	49.85
T_{11}	319.0	60.5	83.5	47.00
T_{12}	291.5	55.8	76.0	45.90
T_{13}	281.00	53.50	73.5	44.10

4.8.2.1. Iron

The different treatment had no significant influence on the uptake of Fe by cowpea plants. However the highest value 381.5 g ha^{-1} was recorded by treatment T_5 (enriched vermicompost alone) and lowest value 201.5 g ha^{-1} was recorded by treatment T_1 (absolute control).

4.8.2.2. Manganese

There was no significant difference between treatments for Mn uptake. The highest mean value recorded by treatment T_5 (enriched vermicompost alone) followed by treatments T_9 and T_{10}. The lowest value recorded by treatment T_2 (RP alone). The highest and the lowest value recorded were 66.5 g ha^{-1} and 33.3 g ha^{-1} respectively.

4.8.2.3. Zinc

The maximum value for Zn uptake was registered by treatment T_5 and the minimum value registered by treatment T_1. But there was no significant difference between treatments for Zn uptake by cowpea plants.

4.8.2.4. Copper

The different treatments had no significant influence on the uptake of Cu by cowpea plants, maximum value recorded by treatments T_5 (enriched vermicompost alone) and the minimum value recorded by treatment T_1 (absolute control).

4.9. Correlation studies

4.9.1. Correlation between yield and growth characters

From the data presented in the Table XIV it is evident that grain yield was significantly and positively correlated with height of the plant at harvest. Number of branches per plant at harvest also significantly influenced the grain yield. Other growth characters like nodule number, nodule weight and root shoot ratio also significantly influenced the grain yield. Nodule number showed the highest degree of correlation with grain yield (r = 0.9281).

Number of pods per plant was significantly and positively correlated with height of the plant and number of branches per plant at harvest (Table XIV). Nodule number showed the highest degree of correlation followed by nodule weight and root shoot ratio, the r values being 0.7458, 0.737 and 0.716 respectively.

Number of seeds per pod was significantly and positively correlated with height of the plant and number of branches per plant at harvest. Nodule number, nodule weight and root shoot ratio also positively influenced the number of seeds per pod. Root shoot ratio showed the highest correlation with number of seeds per pod (0.8988).

Table XIV. Correlation between yield and growth characters

Growth characters	Grain yield	Number of pods $plant^{-1}$	Number of seeds pod^{-1}
Height of the plant	0.787**	0.663**	0.777**
Number of branches $plant^{-1}$	0.577**	0.403**	0.593**
Nodule number $plant^{-1}$	-0.9281**	0.745**	0.875**
Nodule weight $plant^{-1}$	0.910**	0.737**	0.891**
Root shoot ratio	0.856**	0.716**	0.8988**
Bhusa yield	0.956**	0.801**	0.908**

** Significant at 1 per cent level

4.9.2. Correlation between nutrient uptake by plants and yield

Nutrient uptake by plants at harvest was positively and significantly correlated with grain yield, number of pods per plant and number of seeds per pod. N, P and K uptake was significantly and positively correlated with grain yield (Table XV). The highest correlation was shown with P uptake and the lowest correlation with K uptake, the r values being 0.974 and 0.8712 respectively.

4.9.3. Correlation between yield and soil available nutrients

Grain yield, number of pods $plant^{-1}$ and number of seeds pod^{-1} were significantly and positively correlated with soil available nutrients N, P and K (Table XVI).

Soil available N showed the highest correlation with grain yield and soil available K showed the lowest correlation, the r values being 0.8815 and 0.8120 respectively.

With number of pods per plant the highest correlation was shown by soil available P (r = 0.8243). But with number of seeds per pod the highest correlation was shown by soil available N (r = 0.9417).

4.9.4. Correlation between soil available N, P and K and nutrient uptake

From the Table XVII it is evident that the soil available N, P and K showed significant and positive correlation with the uptake of all the

Table XV. Correlation between uptake of nutrients and yield

Nutrient uptake	Grain yield	Number of pods $plant^{-1}$	Number of seeds pod^{-1}
N	0.894**	0.876**	0.937**
P	0.974**	0.883**	0.946**
K	0.871**	0.828**	0.942**
Ca	0.936**	0.829**	0.936**
Mg	0.965**	0.826**	0.962**
Fe	0.970**	0.841**	0.920**
Mn	0.929**	0.770**	0.916**
Zn	0.975**	0.826**	0.920**
Cu	0.966**	0.793**	0.899**

** Significant at 1 per cent level

Table XVI. Correlation between yield and soil available N, P and K

Soil available nutrients	Grain yield	Number of pods plant^{-1}	Number of seeds pod^{-1}
Nitrogen	0.881**	0.767**	0.941**
Phosphorus	0.852**	0.824**	0.926**
Potassium	0.812**	0.696**	0.843**

** Significant at 1 per cent level

Table XVII. Coefficient of correlation between soil available N, P and K and nutrient uptake

Soil available nutrients	Uptake								
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu
N	0.9117**	0.968**	0.943**	0.941	0.942**	0.925**	0.924**	0.927**	0.895**
P	0.940**	0.914**	0.928**	0.948**	0.909	0.903**	0.858**	0.903	0.852**
K	0.876**	0.895**	0.921**	0.861**	0.858	0.852**	0.929**	0.850	0.860**

** Significant at 1 per cent level

macro and micro nutrients. The available P content of soil was significantly and positively correlated with the uptake of N, P, K and micro nutrients. N, P and Ca uptake was highly correlated with soil available P the r values being 0.940, 0.914 and 0.94 respectively. But K and Mg uptake was highly correlated with soil available N the r values being 0.943 and 0.942 respectively. Micro nutrient uptake was also highly correlated with available N. Soil available K showed the lowest correlation with uptake of major and macro nutrients.

DISCUSSION

DISCUSSION

Among the sources of available organic manures vermicompost is a potential source due to the presence of readily available plant nutrients, growth enhancing substances, a number of beneficial micro organisms like N fixing, P solubilising and cellulose decomposing organisms. P solubilising bacteria, N fixing organisms and entomophagous fungi were observed in the range of 10^5 to 10^6 (Indira *et al.*, 1996). These microorganisms are known to induce many biochemical transformations like mineralisation of organically bound forms of nutrients, exchange reactions, fixation of atmospheric N and various other changes leading to better availability of nutrients already present in soil. The group of microorganisms responsible for N fixation, P solubilisation and organic matter decomposition are put to beneficial use in the form of biofertilizer. Thus when vermicompost is enriched with RP, it is expected to enhance the availability of nutrients especially P due to biological solubilisation of P by the action of P solublising micro organisms present in vermicompost. The present study is taken to find out the feasibility of using vermicompost as an inoculum of the beneficial microorganisms for enhancing the solubility and availability of P from RP. The results generated from the present study are discussed in the light of published information and fundamental theoretical knowledge.

5.1. Growth characters

The main growth characters studied were height of the plant, number of branches per plant, date of first flowering, root shoot ratio, number of nodules per plant and weight of nodule per plant.

All the biometric characters showed significant difference between the treatments except the date of first flowering. Vermicompost treated plots came to flowering earlier compared to other treatments. Earlier flowering in vermicompost treated plots may be due to the growth promoting substances present in vermicompost. Pest and disease incidence was nil. All the treatments except two included organic manures either FYM or vermicompost. Thus organic manures might have enhanced the pest and disease resistance in plants. During decomposition organic manure produce various organic compounds, antibiotic substances etc. which might have improved pest and disease resistance in plants. Thamburaj (1994) has also reported that application of oil cakes reduce the intensity of root gall development in tomato.

From the results it is inferred that height of the plant was significantly influenced by different treatments. Vermicompost primed with half RP produced the maximum value for plant height closely followed by vermicompost primed with full RP (T_{10}) and enriched vermicompost (T_5). Increased plant height by the addition of vermicompost was reported by Shuxin *et al.* (1991), Ismail *et al.* (1993),

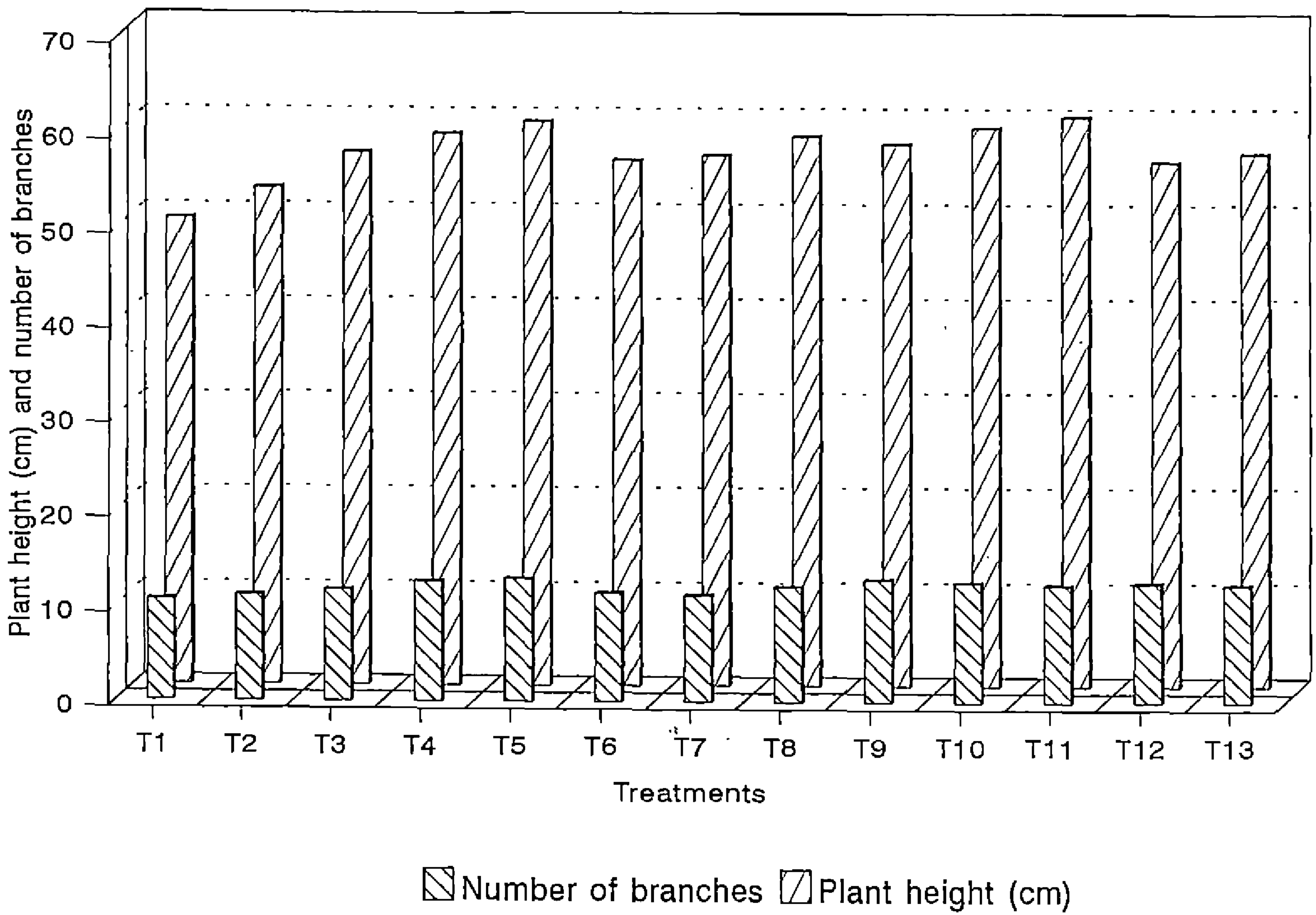

Fig. III. Plant height and number of branches per plant at harvest

Stephens *et al.* (1994), Vadiraj *et al.* (1996) and Bijulal (1997). P solubilising micro organisms in the vermicompost increased the available P content of vermicompost which resulted in a increased uptake of P and this might have resulted in increased utilization of N leading to increased vegetative growth. Worm casts when used as manure in place of FYM, significantly influenced vegetative characters·Kale *et al.* (1991). The vegetative growth in vermicompost treated plants is enhanced by the release of plant growth promoting compounds by earthworms into the casts (Nielson, 1965).

Dubey (1996) observed an improvement in growth and uptake of nutrients in soybean by the use of *Pseudomonas striata* in conjunction with SSP and MRP.

Maximum number of branches per plant was produced by the treatment T_5 (enriched vermicompost alone) closely followed by vermicompost primed with full RP (T_{10}) and half RP (T_{11}).

Joseph (1982) obtained increased plant height and number of branches due to higher levels of P application. Seed inoculation with *Rhizobium* or phosphobacteria and phosphatic fertilizers in cowpea caused an overall improvement in growth of the crop.

A significant variation in root shoot ratio was observed in plants that received different treatments. The maximum mean value for root shoot ratio was observed in plants treated with enriched vermicompost. Vermicompost treated plots registered higher values for root shoot ratio compared to FYM treated plots. Performance of enriched vermicompost was significantly superior to all other treatments. Vermicompost primed with full RP and vermicompost primed with half RP had similar effects on root characters.

The mechanisms by which plants inoculated with beneficial mircobes derived positive benefits in terms of plant biomass is attributed to small increase in N input from biological N fixation, development and branching of roots, production of plant growth hormones, enhancement in the uptake of NO^-_3, NH^+_4, $H_2PO^-_4$, K^+, RB^+, Fe^+, improved water status of the plants and production of antibacterial and antifungal compounds (Okon, 1985; Pandye and Kumar, 1989 and Wani, 1990). Higher levels of N increased shoot weight compared to root weight. But when P was applied, development of roots were better (Buckman and Brady, 1960) resulting in increased root shoot ratio. Meera (1998) reported that application of vermicompost as an organic source as well as the seed inoculant has influenced the root shoot ratio in cowpea (Mohammedkunju, 1968 and John, 1969). In an experiment with bean plants Catmark *et al.* (1994) found that shoot root dry weight ratios were 4.9 in the control, 1.8 in P deficient, 6.9 in K deficient and 10.2 in Mg deficient plants. This increased P availability in enriched vermicompost compared to other treatments promoted root growth and raised the root shoot ratio.

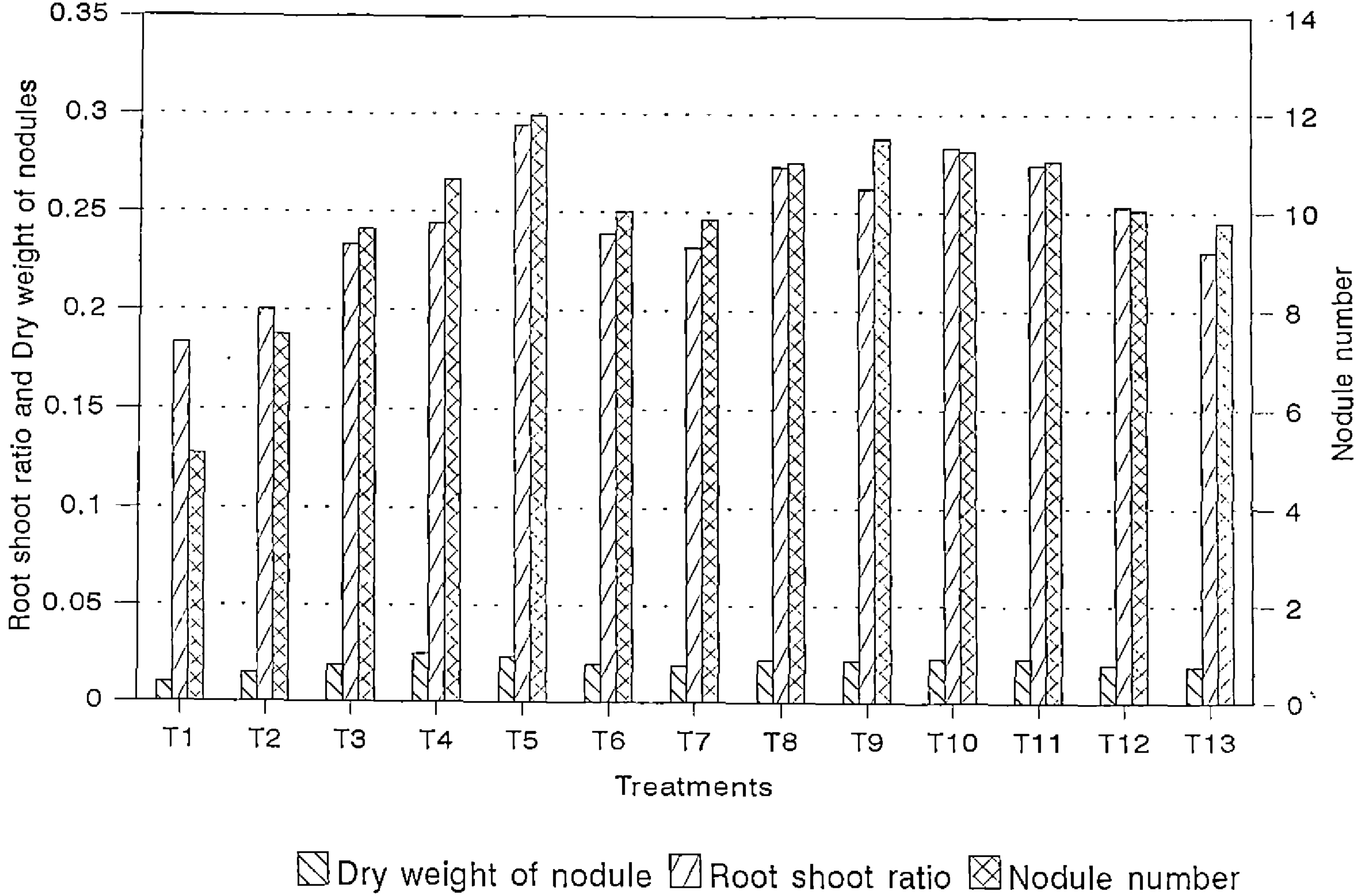

Fig. IV. Root shoot ratio, nodule number and weight of nodules per plant at harvest

Maximum number of nodules per plant was observed in plots treated with enriched vermicompost. Number of nodules per plant was in FYM treated plots was less compared to vermicompost treated plots. Performance of enriched vermicompost treated plots was significantly different from the rest of the treatments.

Vermicompost contain large number of N fixing and P solubilising micro organisms which increased the availability of nutrients in vermicompost compared to FYM. This increased nutrient concentration especially P content promoted multiplication of *Rhizobia* which resulted in better nodulation in vermicompost treated plots.

Prasad and Singhamia (1989) reported that manures enriched with N or P maintained higher levels of available N and P in the soil for longer periods than fertilizer alone. Increased availability of P in enriched vermicompost promotes nodulation. P application increased the number of nodules per groudnut plant (Muralidharan and George, 1971).

Weight of nodules per plant was also maximum in the treatment T_5 (enriched vermicompost alone). The treatment receiving enriched vermicompost was observed to be superior with respect to nodule count and nodule weight over treatment T_6 (FYM + full RP (POP of KAU)) and treatment T_8 (vermicompost + full RP (POP of KAU)). The effect might be attributed to the release of P from RP by the action of organic acids and chelates produced by the micro organisms and improved soil conditions (Tomer *et al.*, 1984). As the P makes the rhizobia active, their growth and multiplication which in turn increased the nodule number and weight per plant (Muralidharan and George, 1971).

Tiwari *et al.* (1988) reported increased nodulation of greengram in plots treated with 3 months old enriched compost with Azotobacter, P solubilising micro organisms and MRP. Srivastava and Ahlawat (1995) observed significant increase in nodulation in cowpea by seed inoculation with *Rhizobium* or P bacteria and phosphate fertilizer.

Rasal *et al.* (1988) found that P solubilising fungi increased the availability of P from RP and noticed that inoculation with *Aspergillus awamori* increased nodulation in chickpea.

From the observations it is evident that vermicompost enriched with RP and vermicompost primed with half RP had similar effects as far as the vegetative growth of plant was concerned.

5.2. Yield and yield attributes

Maximum grain yield was obtained from treatment T_5 (enriched vermicompost alone). It produced significant difference in yield from treatment T_8 (vermicompost + full RP (POP of KAU)). The treatment T_5 produced 28 per cent yield increase over treatment T_6 and 21 per cent yield increment over treatment T_8. There was no significant difference in yield in treatments receiving vermicompost primed with full RP and

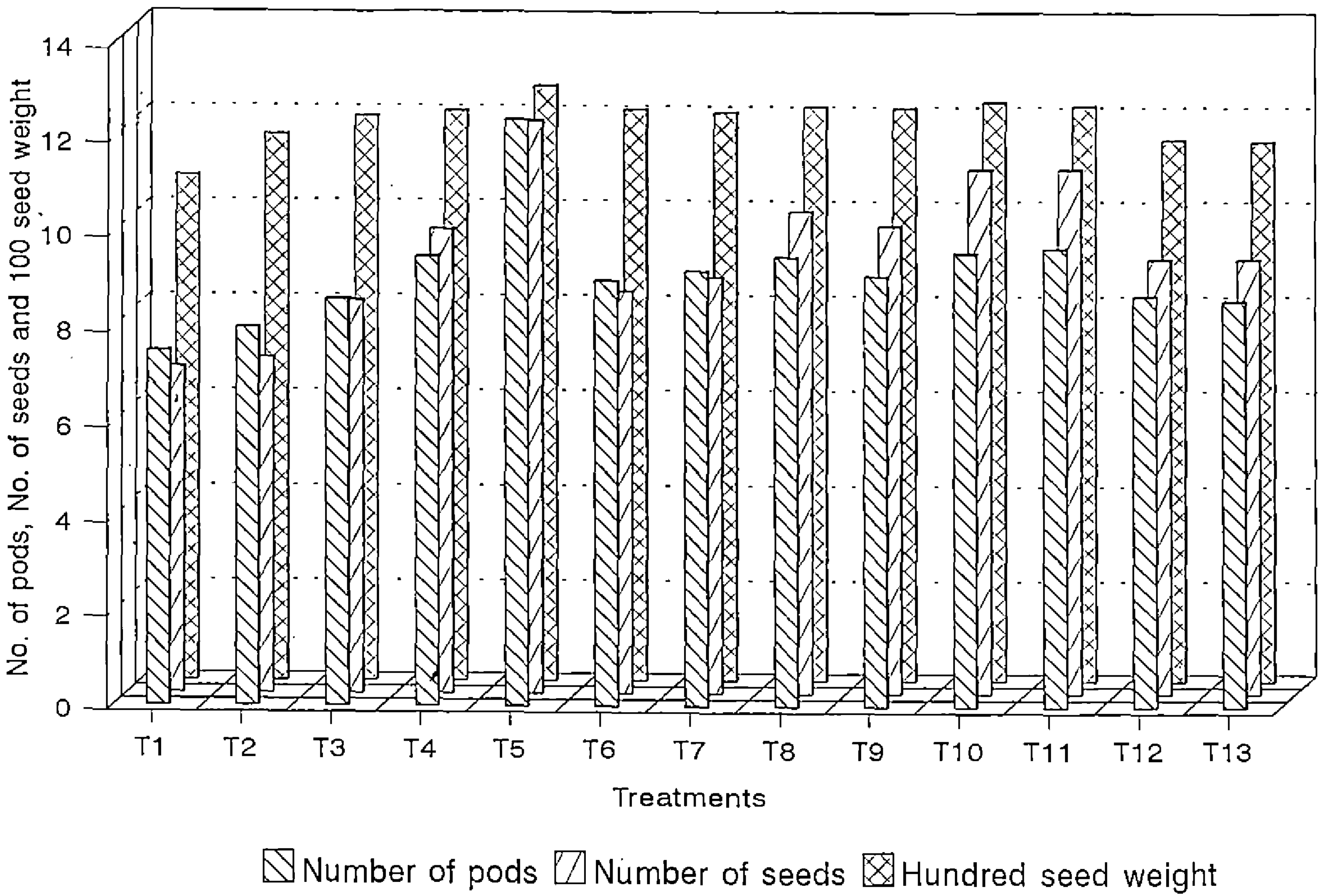

Fig. V. Yield attributes

vermicompost primed with half RP. From the results it is evident that there is no significant reduction in grain yield when the inorganic phosphate was reduced to half from full dose.

The enhanced microbial activity in the enriched vermicompost resulted in an increase in the concentration of nutrients in enriched vermicompost. Beneficial mircobes like P solublizers and N fixers in the vermicompost induced the solubilisation of RP in enriched vermicompost and helped in N fixation. The higher availability of nutrients especially N and P and improved soil physical, chemical and biological properties might have contributed to higher yields (More, 1994).

Significant increase in soybean yield was obtained due to inoculation with P solubilising bacteria along with RP application (Sundara Rao, 1968). Tiwari *et al.* (1988) reported increased yield in greengram by adding three months old enriched compost with *Azotobacter*, P solubilising organisms and MRP. Similar observations of increased yield by the application of enriched organic manures have been reported by Bidanchandra (1992) in greengram and rice, Zachariah (1995) in chilli and Sudhirkumar *et al.* (1997) in chickpea.

Large number of microorganisms are in close association with earthworms and vermicompost. These organisms slowly release the P from RP contributing to better PUE and enhanced availability, uptake and efficient utilization of all nutrients including P.

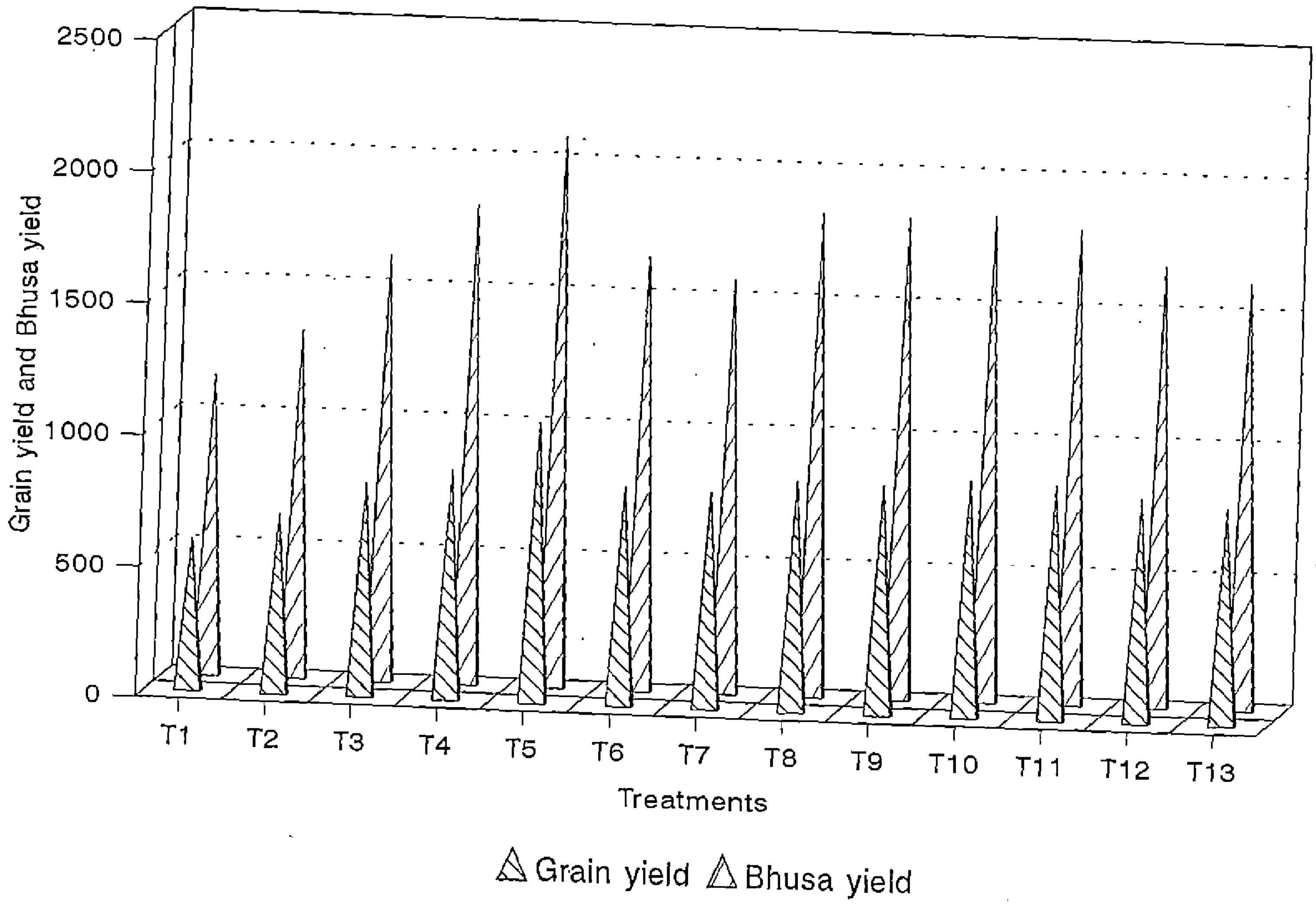

Fig. VI. Yield at harvest

Manjaiah *et al.* (1995) reported a significant increase in pod yield when MRP incubated with organic amendments and P solubilisers was added to groundnut. Tomar *et al.* (1993) observed an increase in yield when MRP incubated with FYM for 15 weeks was applied. Maximum number of pods per plant and seeds per pod was produced by the enriched vermicompost. It produced a significant difference in pod yield from treatments T_6 and T_8.

Data on hundred seed weight and bhusa yield revealed that enriched compost was significantly superior to other treatments. Maximum value for bhusa yield was registered by enriched vermicompost alone. Higher availability of plant nutrients brought about by enriched vermicompost can be cited as the major reason for above desirable effects.

Sunilkumar *et al.* (1995) observed that 1:1 mixture of MRP and SSP with green leaf manure resulted in highest straw yield. BasaK and Debnath (1987) reported that composted RP significantly increased the straw yield in rice.

SudhirKumar *et al.* (1997) reported that application of RP with organic amendments significantly increased the straw yield in chickpea. Manjaiah *et al.* (1995) reported a significant increase in dry matter accumulation and weight per plant in groundnut when treated with organic amendments and P solubilisers plus MRP.

5.3. Soil analysis

5.3.1. Available N

Maximum value for available N in the soil after harvest of the crop was recorded by treatments T_5 (enriched vermicompost alone). This treatment was significantly superior to all other treatments. Vermicompost treated plots yielded more available N than FYM treated plots.

Increased availability of N in vermicompost treated plots may be due to the presence of relatively high percentage of N in worm casts. The higher degree of decomposition and mineralisation in vermicompost may be one of the reason for high N content in worm casts and this might have finally contributed to available N status of the soil. N fixing organisms present in vermicompost may fix atmospheric N in significant quantities which also increase available N in the soil (Lee, 1992).

Manjaiah *et al.* (1995) reported an increase in available N content of acidic soil by the application of organic amendments and P solubilisers with MRP. Mackay *et al.* (1982) reported that performance of pelletized RP increased in the presence of earthworms by 15-30 per cent. There was an increase in plant available N also. Better performance result from incorporation and intimate mixing of RP by earthworms.

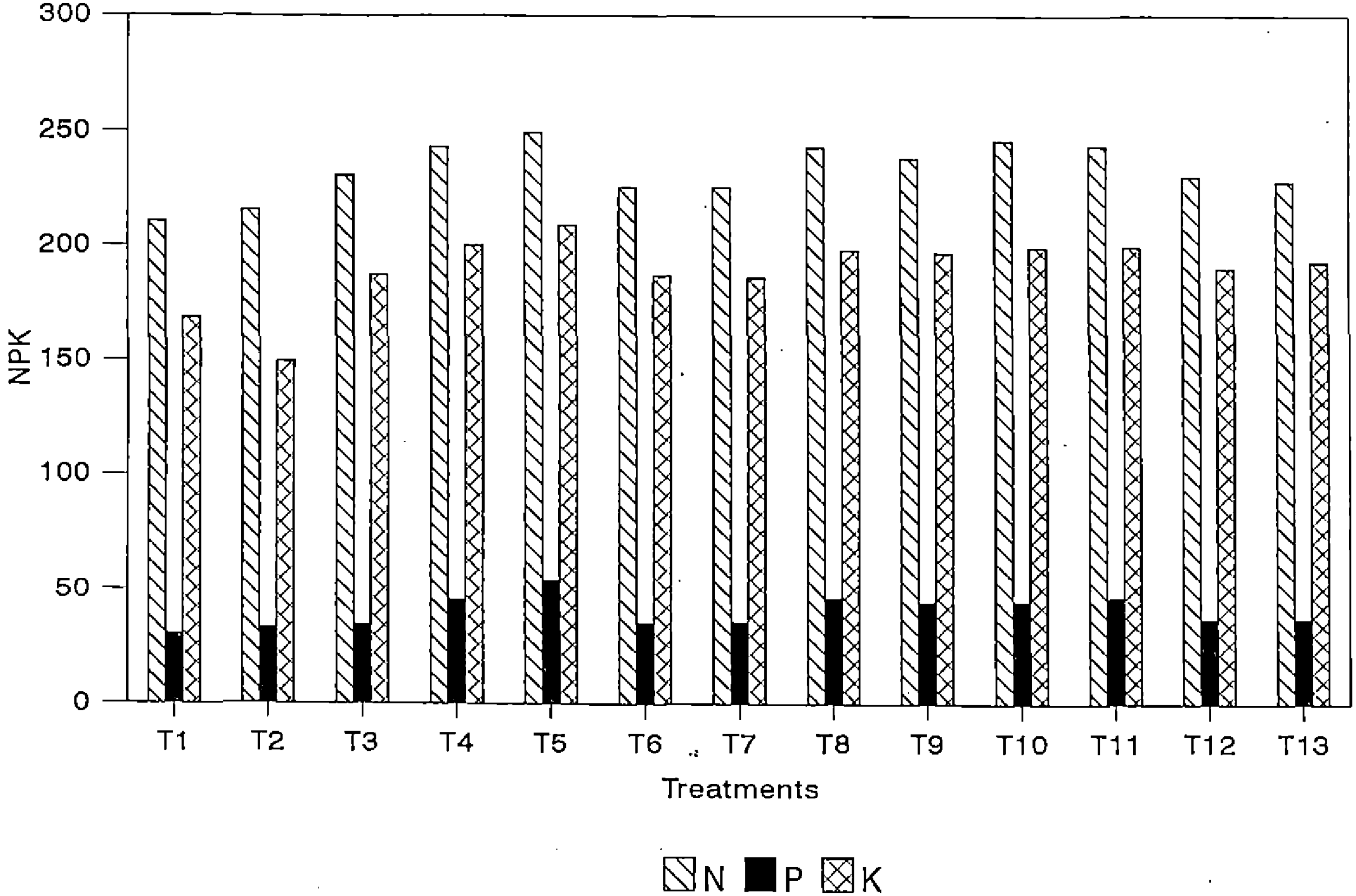

Fig. VII. Nutrient availability in post-harvest soil as influenced by treatments

5.3.2. Available P

Highest mean value for available P was registered by enriched vermicompost alone. This was significantly superior to all other treatments. The available P content in vermicompost treated plots was significantly higher than FYM treated plots. Mahesh (1996) reported that available P_2O_5 content of soil was increased by the application of vermicompost compared to FYM.

Increase in available P_2O_5 content due to vermicompost application was reported by Gaur (1990). The higher P content of vermicompost might have reflected in the higher P status of the soil. This may be because of the greater mineralisation of organic matter with the aid of micro flora associated with earthworms and increased phosphatase activity.

Indira *et al.* (1996) revealed the presence of beneficial microbes like P solubilising bacteria and N fixing organisms in vermicompost. The insoluble RP in the enriched vermicompost converted to soluble forms by the activity of micro organisms in the vermicompost. This may be the reason for increased availability of P in plots treated with enriched vermicompost.

Mackay *et al.* (1982) reported that performance of pelletized RP increased in the presence of earthworms by 15-30 per cent. Bray *et al.* (1983) found that incorporation of earthworms to soil incubated with RP resulted in 30 per cent increase in Bray extractable soil P after 70 days. Higher levels of available P was observed in the soil to which FYM, RP and P solubilising isolates like *Bacillus, streptomyces, penicillium* and *Aspergillus* sp. were added. Similar results were reported by Ahmed *et al.* (1987). A very high level of available P in the rhizosphere of soil was registered when *Bacillus firmus* was applied along with poultry manure and MRP in acidic sandy loam soil of Tripura (Dutta and Banik, 1994).

Indira *et al.* (1996) reported that in vermicompost among P solubilising organisms belonging to *Bacillus* and *Aspergillus* genus were prominent. Singh *et al.* (1994) reported that *Aspergillus japonicus* and *Aspergillus foetida* were able to solubilise fine types of RP at pH 8 and 9. The above literatures supports the increased availability of P in plots treated with vermicompost enriched with RP.

MRP when applied with lime produce maximum increase in available P (Haynes, 1994). Mba (1994) isolated RP solubilising and cellolytic actinomycetes from earthworms casts. Caroline (1997) identified nine *Streptosporangium* isolates of *Eudrillus eugeniae* and were found to be acidogenic, acid tolerant and RP solubilisers. This again support the finding of increased P availability in an acid soil treated with enriched vermicompost.

Reddy (1995) reported that P availability was increased by incubating the P fertilizers with green leaf manure and P solubilising fungi

Aspergillus awamori. Savithri *et al.* (1995) reported an increased water soluble P content by incubating RP with coir pith. Integrated nutrient supply of Tumis RP with vermicompost and P bacteria increased PUE. The soil available Olesen's P was increased in black gram cotton mix due to this integrated supply (Thiyageswari and Raniperumal, 1998). Application of adjuncts not only help in dissolution of insoluble sources but also help in maintaining the release of P in solution by reducing fixation which is a major problem in acid soils.

Thakur and Sharma (1998) reported that RP enrichment accelerated decomposition and P from RP was solubilised during composting and transformed into available forms. This is in confirmity with the present finding.

5.3.3 Available K

Different treatments significantly influenced the available K of the soil after the crop.

Maximum K availability was observed in plots treated with enriched vermicompost. There was significant increase in the available K in plots receiving treatment T_5 (enriched vermicompost alone) compared to treatments T_6 and T_8. Vermicompost treated plots registered high availability of K compared to FYM treated plots.

Increased availability of K is due to the increased concentration of available and exchangeable K contents in casts compared to surrounding soil. Baskar *et al.* (1992) inferred that earthworms increase the availability of K by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms. Increased availability of K by earthworm activity was also revealed by Miura *et al.* (1993); Romero and Chamooro (1993) and Rao *et al.* (1996).

Increased K availability in enriched vermicompost treated plots may be due to the increased K in enriched vermicompost. Increased microbial activity in enriched vermicompost accelerated mineralisation of organic wastes, when the degree of degradation increases, the nutrients get concentrated in the final product obtained. Reddy and Mahesh (1995) reported an increase in the availability of K by the application of vermicompost compared to FYM. Manjaiah *et al.* (1995) reported that RP with organic amendments and P solubilisers were effective in making N, P, K and S nutrients more available.

5.4. Seed analysis

5.4.1. Protein

Maximum protein content in seed was registered by enriched vermicompost. This treatment was significantly different from all other treatments. There was significant difference in seed protein contents of FYM treated and vermicompost treated plots.

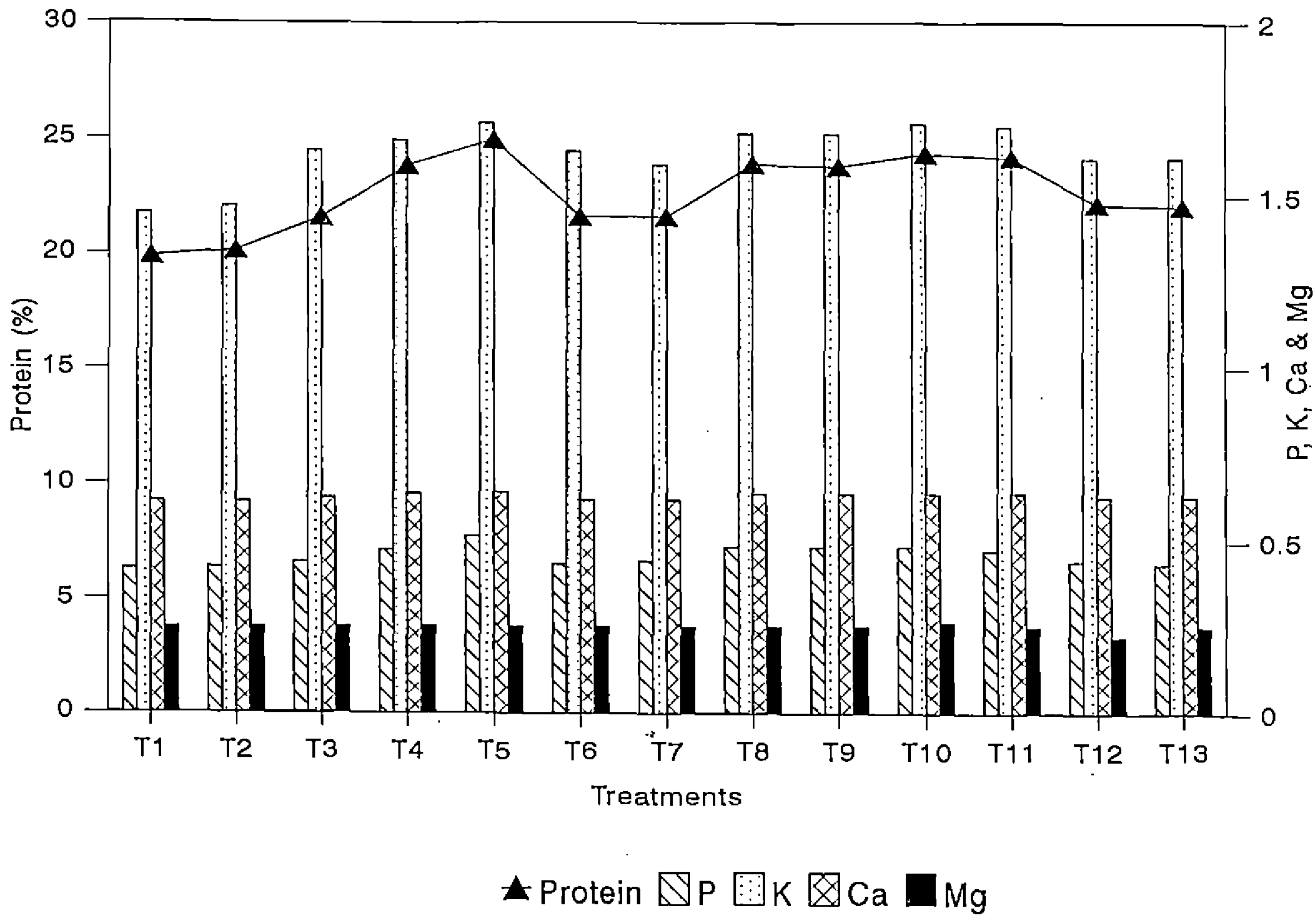

Fig. VIII. Content of protein and minerals (%) in cowpea grain

The increased nutrient uptake in vermicompost treated plots might have resulted in an increased protein content in these plots compared to FYM treated plots. Similar results of increased N uptake by the application of vermicompost compared to FYM were reported by Shuxin *et al.* (1991), Kale *et al.* (1992) and Reddy and Mahesh (1995).

The nutrient status of enriched vermicompost is superior to ordinary vermicompost (Table III). This resulted in an increased availability of nutrients in enriched vermicompost which might have resulted in enhanced uptake of these nutrients by plants, finally contributing to more seed protein content.

Sudhirkumar *et al.* (1997) reported an improvement in the uptake of nutrients by chickpea when RP with organic amendments were applied along with P solubilisers. Bidanchandra (1992) reported that N and P uptake increased in greengram by the application of enriched compost. The protein, P and Ca content of grain were higher when aerobically composted organic matter and RP was applied to wheat, greengram and rice (Singh and Yadav, 1986).

From the results obtained it was found that maximum seed content if P, K and Ca was registered by enriched vermicompost alone. The increased nutrient availability in enriched vermicompost finally contributed to enhanced uptake of nutrients. Marimuthu and Waheb (1998) reported that inorganic P_2O_5 as enriched FYM along with seed and soil incubation of P bacteria significantly influenced the nutrient uptake in soybean. Ca content of grain were higher when aerobically composted organic matter and RP was applied to wheat, greengram and rice (Singh and Yadav, 1986).

5.5. Uptake of nutrients

5.5.1. Major nutrients

The data on the uptake of N by plants under different treatments have shown that N uptake by plants was considerably increased when enriched vermicompost was applied. Plots treated with enriched vermicompost recorded maximum N uptake which was significantly higher than other treatments. N uptake was less in FYM treated plots compared to vermicompost treated plots.

The increased in N uptake may be due to the fact that a vast portion of non available N present in organic matter could be made available to plants through vermicomposting and microbial activity. The increase in N uptake may be attributed to small increase in N input from biological N fixation and increased nitrate reductase activity with the enhancement in the uptake of NO^{-}_{3} and NH^{+}_{4}.

There are reports of about 30 to 50 per cent increase in plant absorbance of N by inoculation with N fixing organisms (Shuxin *et al.*, 1991). Bajpai and Rao (1971) reported that apatite with FYM using *Bacillus* sp. increased the N uptake in cowpea.

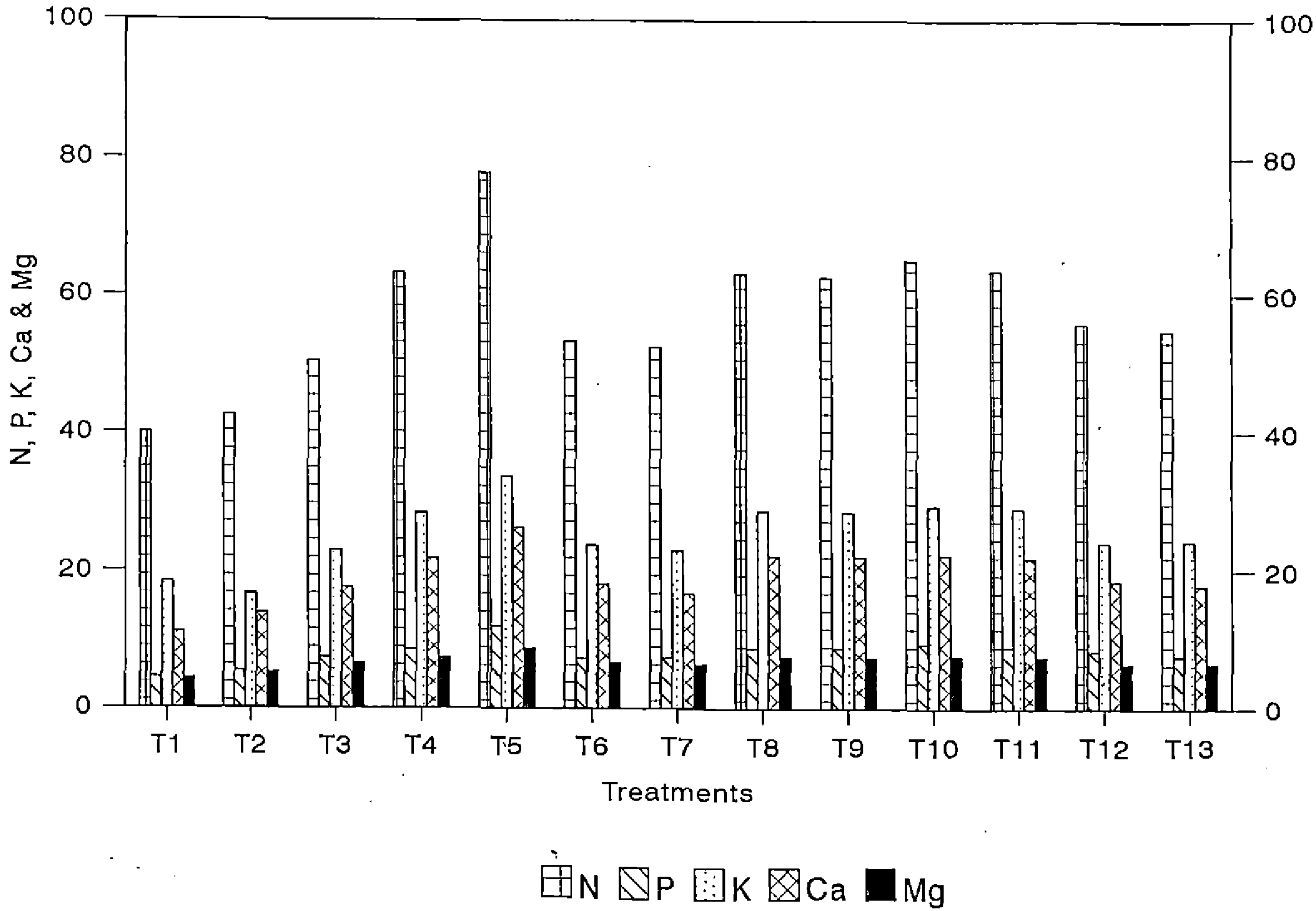

Fig. IX. Uptake of major and secondary nutrients in cowpea

Alagawadi and Gaur (1988) observed that inoculation of P solubilisers in chickpea increased the N uptake in seed over uninoculated control. Biju (1994) reported higher N uptake in soybean by application of P solubilisers and organic amendments with MRP. Manjaiah *et al.* (1995) reported similar results in groundnut.

Shinde *et al.* (1985) reported that enriched compost increased N uptake in wheat plants than unamended compost. This is in confirmity with the present finding. Similar results reported by Thalashilkar and Vimal (1986).

Maximum value for P uptake was recorded by treatment T_5 (enriched vermicompost alone). This treatment was significantly superior to treatments T_6 and T_8. P uptake was more in vermicompost treated plots than FYM treated plots.

The increased P availability as a result of increase in solubility of P by higher phosphatase activity by vermicompost application was noticed by Syres and Springett (1984). The increased mineralisation of native soil P as a result of production of organic acids during decomposition of organic matter may increase the P uptake by plants.

The solubilisation of RP in enriched vermicompost by P solubilising organisms is attributed to the excretion of organic acids. In addition to P solubilisation these micro organisms can mineralise organic

P into a soluble form. These reactions take place in the rhizosphere and because the organisms render more P into solution than that required for their growth and metabolism, the surplus is available for plants thereby increasing the P uptake. This explains the enhanced P uptake in plots treated with enriched vermicompost.

According to Mackay *et al.* (1982) performance of pelletized RP increased in the presence of earthworms. Bidanchandra (1992) reported that enriched compost increased N and P uptake in greengram. Zacharia (1995) observed that enriched compost enhanced the nutrient uptake in chilli.

Viswambaran (1995) has reported that use of 100 per cent P as RP along with VAM and P bacteria resulted in the highest available P content in cowpea. Enhanced uptake of P in grain and straw of chickpea was observed when RP was added with bio organic amendments (Sudhirkumar *et al.*, 1997).

The data on the uptake of K by plants under different treatments have shown that K uptake by plants was considerably increased when enriched vermicompost was applied. The treatment T_5 (enriched vermicompost alone) was significantly superior to all other treatments. The superiority of enriched vermicompost over other organic manures used for the study is evident from the analytical data presented in Table III.

The increased K uptake in vermicompost treated plots was observed and this may be due to increase in K availability by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms in the soil (Bhasker *et al.*, 1992).

Increased availability of P in enriched compost would have enhanced root proliferation which helped in more uptake of K in plots treated with enriched vermicompost. Also K uptake linearly increases with N uptake (Biswas, 1987., Salam, 1988). Similar results of increased K uptake in chickpea observed by Sudhirkumar *et al.* (1997).

The Ca and Mg uptake of plants under different treatments revealed that maximum Ca and Mg uptake was recorded by plants treated with enriched vermicompost. Uptake of Ca and Mg was more in vermicompost treated plots than FYM treated plots. Higher amount of Ca and other bases present in worm casts has been reported by Stephens *et al.* (1994) and Vasanthi and Kumaraswamy (1996). Thus the higher content of these cations present in plants treated with vermicompost may be due to increased uptake through enhanced availability from the soil.

5.5.2. Micronutrients

It was found that there was no significant variation in the micro nutrient uptake under different treatments.

The uptake of Fe by plants under different treatments ranged from 201.5 g ha^{-1} (absolute control) to 381.5 g ha^{-1} (enriched vermicompost alone). But there was no significant difference in the uptake of Fe under different treatments. In the case of Mn also the same trend was seen. Highest Mn uptake was in plots treated with enriched vermicompost alone. Earthworms have the capacity to accumulate trace elements in their bodies. Only if the earthworms die and decay these nutrients get full incorporated into the compost.

Increased uptake of micronutrients in vermicompost treated plants was reported by Stephens *et al.* (1994), Zachariah (1995), Shivande *et al.* (1996) and Vasanthi and Kumaraswamy (1996). Abdel and Abdel (1983) observed that RP with plant residues had no significant effects on P, Ca, Mg and Fe content of barley while effects on K and Zn contents were variable. Datta and Gupta (1983) found that bonemeal with RP decreased the concentration of Cu, Zn and Fe in paddy grain.

Zn uptake was also maximum in enriched vermicompost treated plots, but there was no significant difference between treatments. The increased Ca and Mg availability in vermicompost may be the reason for the increased uptake of Ca and Mg (Shuxin *et al.*, 1991). The calciferous glands in the earthworms contain carbonic anhydrase which catalyse the fixation of CO_2 as $CaCO_3$.

In plots treated with enriched vermicompost there is increased nutrients availability. In addition the microbial activity of beneficial mircobes improved the soil environment helping in better root proliferation thereby increasing the availability and uptake of native Ca and Mg.

RP with bone meal increased the uptake of Ca in paddy and wheat (Gupta and Dutta, 1983). Shinde *et al.* (1985) reported that enriched mechanical composts increased the uptake of all nutrients in wheat plants than that treated with unamended compost. The Ca content of grain were higher when aerobically composted organic matter and RP was applied to wheat, green gram and rice (Singh and Yadav, 1986).

Shinde *et al.* (1985) reported an enhanced nutrient uptake with enriched compost. Baon (1986) observed that micro nutrient uptake was better in mycorrhizal plants than non mycorrhizal plants with added RP of low solubility. Zachariah (1995) found an increase in Mn uptake in plants treated with enriched compost with P solubilising organisms and *Azospirillum.*

Cu uptake was as highest in plots treated with enriched vermicompost but there was no significant difference between treatments. Increased Cu uptake in vermicompost treated plants was observed by Stephen *et al.* (1994). The increase in uptake of nutrients can be attributed to the solubilising effect of minerals by decomposing organic matter as well as the chelating effect of this agent on metals.

5.6. Correlation studies

Correlation between growth and yield characters (Table XIV) show that the growth characters were positively correlated with yield. A significant positive correlation with uptake of all the nutrients and yield was also observed. A significant positive correlation between yield and uptake stresses the importance of a proper balance of nutrients.

SUMMARY

SUMMARY

An investigation entitled "Effect of vermicompost enriched with RP on cowpea (*Vigna unguiculata* L. Walp)" was carried out in the Instructional Farm of the College of Agriculture, Vellayani to study the effect of vermicompost enriched with RP on P availability, yield and quality of cowpea and the feasibility of reducing the inorganic P.

The experiment was laid out in RBD with 13 treatments and three replications. The treatments consisted of T_1 (absolute control), T_2 (RP alone), T_3 (FYM alone), T_4 (vermicompost alone), T_5 (enriched vermicompost alone), T_6 (FYM + full RP (full POP of KAU)), T_7 (FYM + half RP (half POP of KAU)), T_8 (Vermicompost + full RP (full POP of KAU)), T_9 (vermicompost + half RP (half POP of KAU)), T_{10} (vermicompost + full RP (primed for 15 days at 60 per cent moisture)), T_{11} (vermicompost + half RP (primed for 15 days at 60 per cent moisture)), T_{12} (FYM + full RP (primed for 15 days at 60 per cent moisture)) and T_{13} (FYM + half RP (primed for 15 days at 60 per cent moisture)).

The result of the investigation are summarised below.

1) Microbial count was taken using dilution plate method. It revealed that enriched vermicompost contained 64 x 10^4 bacteria, 25 x 10^4 actinomycetes and 1.8 x 10^5 fungi

2) Enriched vermicompost used for the study showed a nutrient composition of 1.95 per cent N, 2.15 per cent P_2O_5 and 2.66 per cent K_2O.

3) Biometric characters like height of the plant and number of branches per plant were significantly increased by enriched vermicompost and vermicompost primed with full RP or with half RP.

4) The highest values of nodule number per plant, weight of nodules per plant and root shoot ratio were recorded by treatment T_5 (enriched vermicompost alone). Yield attributes like number of pods per plant, number of seeds per pod and hundred seed weight and total grain yield were significantly influenced by different treatments. The treatment T_5 (enriched vermicompost alone) was significantly superior to all other treatments for the yield and all the yield attributes studied. The treatment T_5 produced 28 per cent yield increase over T_6 and 21 per cent yield increase over T_8. There was no significant difference in yield between treatments T_{10} and T_{11} (vermicompost primed with full RP or half RP)

5) Bhusa yield was also significantly influenced by different treatments. Highest value for bhusa yield was recorded by T_5 and lowest value recorded by T_1. No significant difference was observed for bhusa yield between T_{10} and T_{11}.

6) Soil analysis at harvest stage for major nutrients revealed that available N, available P_2O_5 and available K_2O in the soil after the experiment were significantly increased by the treatment T_5. There was no significant difference in available nutrients for treatments receiving vermicompost primed with full RP or with half RP.

7) Plant analysis at harvest indicated significant response to macro nutrients while none of the micro nutrients showed significant response. Maximum mean values for all macro nutrients except Mg were registered by treatment T_5. There was no significant difference between T_{10} and T_{11} for plant nutrient content.

8) Different treatments significantly influenced the protein and mineral content of grain. The highest mean value for protein content was recorded by the treatment T_5 while the maximum content of K recorded by both treatments T_5 and T_{10}.

9) Uptake of nutrients at harvest was studied. Significant increase in the uptake of nutrients like N, P, K, Ca and Mg was registered by the treatment T_5 (enriched vermicompost alone). Different

treatments had no significant influence on the uptake of micronutrients at harvest.

10) Correlation studies showed that grain yield was significantly and positively correlated with growth characters like number of branches per plant, nodule number, nodule weight and root shoot ratio. Nutrient uptake by plants at harvest was positively and significantly correlated with grain yield, number of pods per plant and number of seeds per pod. Among the macro nutrients highest correlation was shown with P uptake.

The study indicated the superiority of vermicompost enriched with RP on yield and quality of cowpea. P recommendation for cowpea can be reduced to half by priming vermicompost with RP.

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* Originals not seen

EFFECT OF VERMICOMPOST ENRICHED WITH ROCK PHOSPHATE ON COWPEA (*Vigna unguiculata* L. Walp)

By

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ABSTRACT OF THE THESIS
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ABSTRACT

An investigation was carried out at the College of Agriculture, Vellayani during 1998 to evaluate the effect of vermicompost enriched with RP on P availability yield and quality of cowpea and the feasibility of reducing the inorganic P. The variety used was Kanakamoni.

All the growth characters, yield and yield attributes studied were significantly influenced by different treatments. Nodule number per plant, weight of nodules per plant and root shoot ratio were maximum by the application of enriched vermicompost. Yield attributes like number of pods per plant, number of seeds per pod and hundred seed weight and total grain yield were significantly increased by the application of enriched vermicompost. Vermicompost primed with full RP or with half RP produced no significant difference in grain yield. Thus the results revealed that inorganic phosphoate for cowpea could be reduced to half of its recommended dose by priming vermicompost with RP.

Analysis of plant samples at harvest showed that maximum content of macronutrients except Mg was recorded by enriched vermicompost. It showed its superiority over other treatments for protein and P content of grain. Enriched vermicompost also registered significant increase in soil available N, P and K after the experiment.

Uptake of macronutrients was significantly influenced by different treatments. Enriched vermicompost registered maximum mean value for the uptake of all the macro nutrients. Priming of vermicompost with full RP or with half RP produced no significant difference in uptake of any macro or micronutrients.

Grain yield was positively and significantly correlated with the growth characters. Yield and yield attributes showed positive and significant correlation with nutrient uptake.

The study indicated the superiority of vermicompost enriched with RP on yield and quality of cowpea. P recommendation for cowpea can be reduced to half by priming vermicompost with RP.