NUTRIENT ECONOMY THROUGH SEED COATING WITH VERMICOMPOST IN COWPEA

[Vigna unguiculata (L. Walp)]

by

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Thesis
submitted in partial fulfilment of the requirement
for the Degree
Master of Science in Agriculture
Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE
VELLAYANI
THIRUVANANTHAPURAM

1998

DECLARATION

I hereby declare that this thesis entitled "**Nutrient economy through seed coating with vermicompost in 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 of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**Nutrient economy through seed coating with vermicompost in cowpea [*Vigna unguiculata* (L. Walp)]**" is a record of research work done independently by **Miss. MEERA. A.V.** (Admission No. 95-11-37) 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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ACKNOWLEDGEMENT

The author wishes to place on record her heartfelt gratitude and indebtedness to:

Dr. P. Prabhakumari, Associate Professor, Department of Soil Science and Agricultural Chemistry for her kind treatment, sustained and inspiring guidance, constructive criticisms and everwilling help throughout the period of investigation and preparation of thesis

Dr. Thomas Varghese, Professor and Head, Department of Soil Science and Agricultural Chemistry for the genuine interest, helpful suggestions and critical scrutiny of the manuscript

Dr. Alice Abraham, Professor, Department of Soil Science and Agricultural Chemistry for the valuable guidance, timely help and pertinent suggestions during the course of this study

Dr. R. Pushpakumari, Associate Professor, Department of Agronomy for the valuable guidance, timely assistance and critical scrutiny of the manuscript

Dr. P. Padmaja, former Professor and Head, Department of Soil Science and Agricultural Chemistry for the constant encouragement and goodwill

Smt. Brijit Joseph, Asssistant Professor and Mr. C.E. Ajith kumar, Junior Programmer of the Department of Agricultural Statistics for their generous help in the statistical analysis and interpretation of the experimental data

the teaching and non-teaching staff of the Department of Soil Science and Agricultural Chemistry for their whole hearted co-operation and timely assistance

Rani Jasmin, Jubina, P.A., Dovelyn Peters, Gayathri, K., Sindhu, J., Beena, V.I., Sailaja, Byju, G., Rajan, S., Santhosh, V.S., Moossa, P.P., Sreeraj, V. and all other friends who helped her at one stage or another during the course of this project work

Mr. K. Chandrakumar and ARDRA computers for the prompt and neat typing of the manuscript and preparing the graphs

Kerala Agricultural University for the award of Junior Research Fellowship

and her mother, sister, brother-in-law, Simi and Karthi for their enthusiastic encouragement and manifold assistance rendered to her.

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INTRODUCTION

INTRODUCTION

Soil is a dynamic body of mineral and organic constituents and the dynamic nature is solely due to the activity of micro and macroorganisms supported by the organic matter. Modern agriculture with its potential to free the country out of food trap and ways to reach self sufficiency in food grain production has resulted in many adverse effects on soil health. Soil organic matter plays a key role in the maintenance of soil fertility and productivity. Proper maintenance of soil organic matter is one of the major pre-requisites to attain sustainable crop production. Increased use of chemical fertilizers and pesticides without adequate organic recycling has not only deteriorated soil fertility but also poisoned the soil, water, microflora, atmosphere, human beings and other animals, causing several deformities, inabilities and serious diseases. Even with the most progressive hi-tech agriculture, the land has collapsed with intensive overcropping, sinking water tables and deteriorated soil leading to unsustainability of agriculture. This shows the clear cut need for a shift to ecological and sustainable hi-tech agriculture for long-run crop production.

Composting of the organic waste materials on farms, in households and in rural and urban habitats turns them into valuable agricultural inputs and minimize environmental problems.

The role of earthworms as biological agents in the degradation of organic wastes is already recognised. Vermicompost, an organic manure produced due to the activity of earthworms is a rich source of macro and micronutrients, vitamins, growth hormones like gibberellins and immobolized microflora. Earthworms eat soil, remains of decayed plants, animal dung and other organic matter which undergo complex biochemical changes in the earthworm's intestine and are excreted as granular castings. Hence these castings are rich in essential plant nutrients than the ordinary compost. Further, they reduce the composting period to 45 to 60 days from 6 to 7 months. Vermicompost influences the physico-chemical as well as the biological properties of soil which inturn improves the fertility status of soil and also the efficiency of chemical fertilizers in soil.

India has a vast variety of manurial resources and organic wastes for recycling which includes livestock and human wastes, crop residues, tree wastes and aquatic weeds, urban and rural wastes, agro-industries by-products, marine wastes, etc. The farmers and all those concerned with agriculture are conscious of the benefits of these wastes in crop production. But the availability of these wastes is restricted due to socio-economic constraints.

A number of beneficial micro-organisms like cellulolytic organisms, N fixers and P solubilizing bacteria are present in close association with earthworms and vermicompost. Vermicompost when applied along with half the recommended dose of chemical fertilizers in rice, selectively enhances the activities of N fixers, symbiotic association of mycorrhizae and other spore formers (Purakayastha and Bhatnagar, 1997). As the microbial activity is induced due to the addition of vermicompost, it indirectly enhances the activities of different endocellular enzymes. Hence coating seeds with vermicompost helps to introduce these beneficial micro-organisms into the rhizosphere of the plant, which helps to increase the N and P availability by making available the biologically fixed N and biologically solubilised P. So there is a possibility of decreasing N and P fertilizers by coating seeds with vermicompost. The method is cost effective, eco-friendly and easy to do.

The present study is proposed by taking cowpea [*Vigna unguiculata* (L. Walp)] as the test crop with the following objectives:

1. to investigate the effect of coating seeds with vermicompost on the growth, nodulation, yield and chemical composition of cowpea.

2. to study the effect of coating seeds with vermicompost on the P solubilisation and N fixing capacity of soil.

3. to find out the effect of coating seeds with vermicompost on the availability and uptake of major and micronutrients.

4. to observe the residual effects of these treatments in the soil as revealed by the yield of the subsequent crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The unilateral use of chemical fertilizer devoid of organic sources have made our soils sick and problematic. The effective utilization of available organic resources for enhancing crop productivity is very relevant. A number of beneficial microorganisms are closely associated with earthworms and vermicompost. Coating seeds with vermicompost helps to introduce these beneficial organisms into the rhizosphere of plant, which helps to increase N and P availability by making available the biologically fixed N and biologically solubilised P. So the present study is undertaken with a view to explore the possibility of reducing N and P fertilizers by coating seeds with vermicompost. The literature pertaining to vermicompost coating of seeds on plant productivity is scanty. The available literature pertaining to these aspects are reviewed hereunder.

2.1 Effect of organic manures and biofertilizers on growth and yield of crops

2.1.1 Germination and establishment

Muhammed and Naimat Ali (1987) reported that germination percentage in redgram was unaffected by *Rhizobium* inoculation or fertilizer application.

Kim and Min (1988) observed significant increase in seedling emergence and establishment on Rhizo-kote seed coating in alfalfa.

Highest seed germination of 98.4 per cent was obtained on pelleting greengram seeds with 50 per cent biodigested slurry (Kuppuswamy *et al.*, 1992).

Seed treatment with *Azotobacter* increased the germination percentage of both *Cassia* and *Prosopis juliflora*, while the best response in *Prosopis juliflora* was obtained with *Rhizobium* inoculation which improved seedling growth (Meshram *et al.*, 1994).

Sharma *et al.* (1994) found that there was no significant response to *Rhizobium* inoculation in seed germination in *Dalbergia*, *Acacia auriculiformis* and *Acacia catechu*.

2.1.2 Growth

Seed inoculation with *Rhizobium* increased CGR, unit leaf area, LAI and leaf weight ratio in blackgram (Sudhakar *et al.*, 1989).

Increase in dry matter production with *Rhizobium* inoculation was reported by Namdeo *et al.* (1991) in pigeonpea and Jadhav *et al.* (1993) in chickpea.

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

Racheward *et al*. (1991) obtained increased biomass production on inoculation of maize seeds with phosphate solubilising biofertilizer, *Bacillus polymyxa*.

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

Margaritha and Maria (1993) opined that soil inoculation of *Bradyrhizobium* in cowpea increases biomass production.

Seed treatment with Gibberellic acid along with *Azospirillum* inoculation enhanced total number of leaves and leaf length. The root characters were also positively influenced (Sundaravelu and Muthukrishna, 1993).

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

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

2.1.3 Root : Shoot ratio

Davidson and Robinson (1985) reported that the grass plants in the swords receiving low N had high root : shoot ratio.

In soybean, *Rhizobium japonicum* inoculation increased plant dry weight by 20-40 per cent and root dry weight by 20-80 per cent (Romero *et al*., 1988).

Negi *et al*. (1991) found enhanced root and shoot DM production of barley 80 DAS on inoculation with *Azospirillum brasilense* + P fertilization.

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 in P deficient, 6.9 in K deficient and 10.2 in Mg deficient plants.

Fulchieri and Frioni (1994) reported that inoculation of maize plants with *Azospirillum* strains increased shoot and root dry weight over the control.

2.1.4 Nodulation

Nadkernichnaya *et al*. (1989) observed significant increase in root nodules on inoculation of carrot roots with *Azospirillum*.

Adu and Nnadi (1990) reported that seed inoculation with *Rhizobium* had no significant effect on nodulation in cowpea.

According to Santos *et al*. (1990) inoculation with *Bradyrhizobium* showed greatest number of nodules per plant and nodule weight per plant in cowpea.

In an experiment with pigeonpea, Namdeo *et al*. (1991) reported that seed inoculation with *Rhizobium* significantly increased nodulation.

Patel and Patel (1991a)observed significant increase in number of nodules per plant with *Rhizobium* inoculation in greengram.

Rhizobium inoculation increased the number of nodules per plant by 38 per cent compared to that of control in cowpea (Mundra and Bhati, 1994).

Prabhakaran and Srinivasan (1993) reported that coir dust application increased nodule number and nodule biomass in pigeonpea.

2.1.5 Yield

Rhizobium inoculation in cowpea increased seed yield significantly (Iyer and Vats, 1985; Sunaryono and Prasodjo, 1988; Santos *et al*. 1990; Lindsay and Gumbs, 1993).

Mundra and Bhati (1991) reported that seed yield in cowpea was unaffected by *Rhizobium* inoculation.

Namdeo *et al*. (1991) observed significant increase in seed yield of pigeonpea on inoculation with *Rhizobium*.

In cowpea, Baldeo *et al*. (1992) obtained the highest seed yield with *Rhizobium* inoculation along with Mn and Mo fertilization.

Kuppuswamy *et al*. (1992) obtained highest seed yield on pelleting greengram seeds with 50 per cent biodigested slurry and 5 per cent DAP.

In hyacinth bean, highest seed yield was obtained with the incorporation of FYM alongwith chemical fertilizers (Noor *et al*., 1992).

Prasad and Ram (1992) found that seed inoculation of greengram with *Bradyrhizobium* strain + Zn and Cu application gave the highest seed yield.

Yadav *et al*. (1992) reported that inoculation with *Azospirillum lipoferum* increased the stalk and grain yield in maize.

According to Khurana *et al*. (1993) seed inoculation with *Bradyrhizobium* strains increased the seed yield of mungbean by 21.8 per cent to 35.1 per cent over uninoculated control.

Srinivasa and Khalak (1993) found that *Rhizobium* inoculation in *Vigna umbellata* gave seed yields of 1.41-1.45 t ha^{-1} compared to the control which yielded only 1.22 t ha^{-1}. Also seed inoculation gave the best cost : benefit ratio.

Tomar *et al*. (1993) reported that seed yield of blackgram was increased by seed inoculation with phosphate solubilising bacteria.

Arokiaraj and Kannappan (1994) studied the effect of organic wastes on yield and economics of rainfed sorghum and reported that higher straw yield and grain yield resulting in higher net returns and benefit cost ratio could be obtained by the application of 5 t ha^{-1} of FYM.

Inoculation either increase or decrease seed yield depending on variety, year, and season. In lentil, the greatest fall in yield relative to uninoculated control was 39.2 per cent and the greatest rise was 315.5 per cent (Dziambia and Miroslaw, 1994).

Gnanamani and Bai (1994) obtained highest grain yield for rice and seed yield for blackgram with 40t biodigested slurry + NPK fertilizer application.

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

Patel and Patel (1994) reported that *Rhizobium* inoculation had no beneficial effect on grain yield in pigeonpea.

In cowpea, seed inoculation with *Rhizobium* gave significantly higher seed and stover yields. (Rajput, 1994).

Mikanova *et al*. (1995) found that the yield of pea increased with the use of P solubilising inoculants in the absence of fertilizers.

Baboo and Kumar (1996) examined that seed inoculation with *Rhizobium* + 35 kg N ha^{-1} resulted in increased pod and shoot yield and net returns over their individual application.

2.1.6 Quality of produce

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

Addition of pressmud increased the juice quality of sugarcane (Mariappan *et al*., 1983).

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

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

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

Hoshiyar *et al.* (1994) found that inoculation of greengram seeds with *Rhizobium* increased the crude protein content of seeds.

According to Patel and Patel (1994), protein yield of pigeonpea remained unaffected by *Rhizobium* inoculation.

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

In broadbean, fibre protein and P content in pod were increased by seed inoculation with *Rhizobium* (Baboo and Kumar, 1996).

2.2. Effect of organic manures and biofertilizers on the availability of nutrients

2.2.1 Nitrogen

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

In cowpea plants inoculated with *Rhizobium*, N fixation was significantly reduced by N application (Fernandez and Miller, 1986).

Seed inoculation increased the nitrogenase activity and reduced the nitrate reductase activity in *Vigna radiata* and the maximum nitrogen fixation occured at the flowering stage (Kothari and Saraf, 1987).

Badanur *et al*. (1990) reported that incorporation of sorghum stubbles and safflower stalks increased the available N content in vertisol.

Rajeswari (1991) observed enhanced nitrogenase and nitrate reductase activity in groundnut inoculated with *Rhizobium* compared with no inoculation.

In cowpea, Baldeo *et al*. (1992) observed that rhizobial inoculation along with Mn and Mo application increased the N availability in soil.

Yadav *et al*. (1992) examined optimal nitrogenase activity in maize inoculated with *Azospirillum lipoferum* + N application (60 kg ha^{-1}).

Rhizobial inoculation in white clover increased N fixation by 46.3 to 65.6 per cent (Cao, 1993).

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

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

Bhalu *et al*. (1995) found that rhizobial inoculation in blackgram helped the plants in fixing atmospheric N.

Rhizobium inoculation accelerate the activity of N fixing bacteria and helps to fix abundant quantity of atmospheric N. Seed inoculation with *Rhizobium* culture helps in N economy of pulses (Baboo and Kumar, 1996).

2.2.2 Phosphorus

Fellaca *et al*. (1983) reported that humified organic matter can significantly reduce the amount of phosphates required to maintain a concentration necessary for plant growth.

Available P content in soil significantly increased with the incorporation of subabul, sunnhemp loppings and FYM (Badanur *et al*., 1990).

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

Gaind and Gaur (1991) reported that seed inoculation of mungbean with phosphate solubilising bacteria increased the available P content of the soil.

Bradyrhizobium solubilized phosphate from hydroxyapatite and tricalcium phosphate in ammonium yeast extract glucose broth (Halder *et al*., 1991).

Racheward *et al*. (1991) found that seed inoculation with phosphate solubilising bacteria, *Bacillus polymyxa* increased the P_2O_5 content in soil.

Humic substance by virtue of its chelating properties increase the available P content in soil by virtue of its high ion exchange capacity and ligand exchange sites (Gaur, 1994).

More (1994) noticed increased available P content in soil on the application of farm wastes and organic manures.

Mikanova *et al*. (1995) found that *Rhizobium leguminosarum* was able to solubilize P from TCP and the yield of pea increased with the use of P solubilizing inoculant.

2.2.3 Potassium

Sharma *et al* (1984) reported that available K increased significantly with the addition of FYM for a long time.

Increased use of nitrogenous fertilizer reduced the available potassium content of soil, but the incorporation of FYM inreased its availability (Srivastava, 1985).

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

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

Bharadwaj (1995) observed that among different nutrients, the most significant role of organic matter is in supplying K.

2.2.4 Exchangeable Ca and Mg

Kurumthottical (1982) revealed that exchangeable Ca and Mg were higher in the treatments which received organic manure either alone or in combination with phosphate fertilizers in the permanent manurial experiment on paddy at Pattambi and Kayamkulam.

Udayasooriyan *et al*. (1988) noticed that continuous use of compost improved the status of exchangeable Ca but lowered the exchangeable Mg content in the permanent manurial experiment conducted at Coimbatore.

Exchangeable Ca and Mg in soil decreased with applied K and increased with FYM application (Singh and Tomar, 1991).

Mather (1994) reported that addition of spent mushroom waste increased the Mg content of soil.

2.2.5 Micronutrients

Available Zn, Cu, Mn and Fe content increased considerably with the continuous use of FYM in a long term fertilizer experiment at Ranchi under wheat-maize rotation (Prasad and Singh, 1980).

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

2.3 Effect of organic manures and biofertilizers on the uptake of nutrients

2.3.1 Nitrogen

Patra *et al.* (1986) observed that *rhizobial* inoculation in cowpea increased N uptake by the crop.

In trials with pea/maize cropping sequence, seed inoculation of peas with *Rhizobium* or phosphobacteria increased its N uptake (Rai and Sinha, 1986).

Romero *et al.* (1988) found that N concentration in soybean increased by 1.5 to 3.5 fold on inoculation with *Rhizobium japonicum*.

Sharma and Mittra (1988) noticed higher uptake of N by rice with the application of organic manures along with increasing doses of inorganic nitrogen.

Santos *et al.* (1990) observed the highest content of N in cowpea cultivars inoculated with *Bradyrhizobium*.

Use of phosphate solubilising microorganisms increased the uptake of N in mungbean (Gaind and Gaur, 1991).

Mundra and Bhati (1991) reported that nutrient uptake in cowpea was unaffected by *Rhizobium* inoculation.

N uptake in barley was highest in *Azospirillum* inoculated plants. At harvest, nearly 36 per cent of the total N uptake was from N fixed by *Azospirillum brasilense* (Negi *et al.*, 1991).

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

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

Hoshiyar *et al.* (1994) reported that inoculation of greengram seeds with *Rhizobium* significantly enhanced the total uptake of N.

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

2.3.2 Phosphorus

Maurya and Dhar (1983) reported that chilli plants grown on compost prepared in sunlight from water hyacinth and basic slag resulted in the highest P uptake than in the composts from paddy straw or mango leaves with or without basic slag.

Rai and Sinha (1986) observed enhanced P uptake by peas on seed inoculation with *Rhizobium* or phosphobacteria.

Seed inoculation with phosphate solubilising biofertilizer, *Bacillus polymyxa* enhanced P content and P uptake in maize. Inoculation + P application was found to be more effective than inoculation alone (Racheward *et al.*, 1991).

Satpul Singh and Kapoor (1992) noticed that seed inoculation with phosphate solubilising bacteria increased the phosphate uptake by mungbean.

Cao (1993) reported that *Rhizobium* inoculation increased the absorption of P by white clover.

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

Baboo and Kumar (1996) observed the highest uptake of P by broad bean grown with seed inoculation + 35 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}.

2.3.3 Potassium

Rai and Sinha (1986) observed an increased uptake of K by pea on inoculation with either *Rhizobium* or phophobacteria.

Organic manures applied in conjunction with optimal dose of NPK fertilizers resulted in the highest K uptake by crops (Sarkar *et al*., 1989; Singh and Tomar, 1991).

Prasad and Ram (1991) found that *Rhizobium* inoculation in *Vigna radiata* reduced K content, but increased K uptake due to increased drymatter production.

FYM was more effective than seed inoculation in increasing K uptake by chickpea (Raju *et al*., 1991).

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

2.3.4 Minor nutrients

Lal and Mathur (1989) observed the highest removal of Ca by maize grain receiving the treatments NPK + lime than with FYM.

Application of FYM + K had a positive effect on the uptake of Ca and Mg by wheat crop (Singh and Tomar, 1991).

Rabie *et al*. (1995) found a significant increase in the uptake of Fe, Mn and Zn by barley, groundnut and maize on the application of waterhyacinth compost.

2.4 Effect of combined inoculation of organic manures and biofertilizers on growth and yield of crops

2.4.1 Germination

Stalin *et al*. (1993) observed the best germination and seedling growth in silver oak pre-treated with organic manure and various combinations of *Azospirillum brasilense* and phosphobacterin.

2.4.2 Growth

According to Brechelt (1991), *Azospirillum lipoferum* inoculation along with the application of grass mulch increased the shoot DW of sorghum.

In groundnut, nodule number and nodule weight were higher with the combined application of farmyard manure *Rhizobium*, *Azospirillum* and *Phosphabacterium* (Balasubramanian and Palaniappan, 1994).

Rhizobium inoculation in subterranean clover increased the total number of root nodules by 5 times and the number of nodules on the primary root by 4-6 times in the presence of earthworm. Also increased plant top weight by 125 per cent and root dry weight by 20-30 per cent (Doube *et al*., 1994).

2.4.3 Yield

Solanki *et al*. (1987) reported higher yield in barley on seed inoculation with *Azotobacter* in combination with 10t FYM ha^{-1}.

Combined application of *Azospirillum* and organic manure increased the grain yield of rice significantly, but showed no significant difference to straw yield (Subramanian and Rangarajan, 1990).

In groundnut, more number of mature pods per plant were produced owing to the application of FYM, *Rhizobium* and *Azotobacter* alone and in combinations. Pod yield and haulm yield were increased with the application of FYM as well as combined use of microbial inoculants with FYM. However, shelling per cent and 100 kernel weight were not affected by the treatments (Balasubramanian and Palaniappan, 1994).

2.4.4 Nutrient uptake

Brechelt (1991) reported that *Azosprillum lipoferum* inoculation in combination with organic manure application increased N and P concentration and uptake in sorghum.

Graveilla robusta pretreated with organic manure and various combinations of *Azospirillum brasilense*, VAM and phosphobacterin al. increased nutrient uptake (Stalin *et al*., 1993).

Doube *et al.* (1994) found that *Rhizobium trifolii* inoculation in combination with earthworms increased the foliar N concentration by 5-25 per cent in subterranean clover.

2.5 Effect of combined inoculation of biofertilizers on growth and yield of crops

Co-inoculation with *Rhizobium* and *Azotobacter chroococcum* was found to be better than *Rhizobium* alone in respect of leaf, stem, root and nodule DW and P uptake (Kothari and Saraf, 1987).

Kumar *et al.* (1988) obtained increased straw yield and seed yield with combined inoculation of *Rhizobium* and *Azotobacter* in lentil. This combined inoculation also resulted in highest seed protein content and N uptake.

Raverkar and Konde (1988) found that mixed inoculation of *Rhizobium* and *Azospirillum lipoferum* had an adverse effect on nodulation, N content and yield compared to single inoculation.

Andreeva *et al.* (1990) obtained enhanced growth and nitrogenase activity in *Phaseolus vulgaris* on mixed inoculation with *Rhizobium* and *Azospirillum brasilense*. This combined inoculation increased the number of infection sites on legume roots and thus increased nodule number and weight.

Seed inoculation with *Azospirillum* and phospho bacterin gave the highest grain yield (692 kg ha^{-1}) in sorghum (Kandiannan and Rangaswamy, 1994).

Positive effects of combined inoculation of *Rhizobium* and *Azospirillum* were reported for different legumes and were related to the favourable influence of *Azospirillum* on nodule number, plant development, dry weight and N fixation (Okon and Itzigsohn, 1995).

According to Gunawardena and Vlassak (1986) combined inoculation of *Rhizobium* and *Azospirillum* gave the highest values for acetylene reduction, shoot DW and symbiotic effectiveness.

Sundaram and Balasubramanian (1986) reported beneficial effects of combined inoculation of *Azospirillum* with other N fixing organisms such as *Azotobacter*, *Rhizobium* and BGA on yield of both leguminous and non-leguminous plants. The best combination was found to be with *Rhizobium* and *Azospirillum* strains in groundnut (Mascarenhas, 1990).

Seed inoculation with *Rhizobium* and *Azotobacter* showed no residual effect on sorghum growth (Kothari and Saraf, 1987).

Halsall and Gibson (1991) reported that there was no significant effect of co-inoculation of *Azospirillum brasilense* and *Cellulomonas* on Acetylene Reduction Activity.

Combined inoculation of potted common bean plants with *Rhizobium* and *Azospirillum* significantly increased both upper and total nodule number and N2 fixation as compared with *Rhizobium* inoculation alone (Saul Burdman *et al.*, 1997).

2.6 Effect of vermicompost/vermiculture

2.6.1 Growth and yield of crops

2.6.1.1 Germination and establishment

Vadiraj *et al.* (1993) reported that use of vermicompost as a component of potting mixture in cardamom nursery helped better seedling growth within a shorter period of time.

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.

Sagaya Alfred and Gunthilagaraj (1996) obtained a more germination percentage of Amaranthus seeds raised in beds incorporated with earthworms.

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

2.6.1.2 Growth

Atlavinyte and Zimkuviene (1985) obtained improved growth in barley crops by using worm activated soil.

Grappelli *et al.* (1985) reported the initiation of rooting of layers and shoots when grown in worm cast.

Lee (1985a) reported that in temperate climate earthworms are capable of stimulating plant 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 wormcast 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, number of branches per plant compared to FYM treated plants.

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

2.6.1.3 Root : shoot ratio

Earthworms stimulate root biomass and depth of rooting, height and biomass of aboveground 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.

Stephens *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, whereas maize had a much higher aboveground portion and reduced root production and rice produced more roots in the presence of earthworm (Lauret *et al.*, 1997).

2.6.1.4 Yield

Atlavinyte and Zimkuviene (1985) noticed improved yield in barley crops by using worm activated soil.

Application of worm 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 (Senapathi *et al.*, 1985).

Sacirage and Dzelilovic (1986) obtained higher dry matter yield for leek growing in vermicompost. They also found that by the application of 4, 6 and 8 kg m^{-2} of vermicompost, the cabbage dry matter yield increased from 1 to 66 per cent.

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 pots.

Organic compost and chemical control resulted in similar yields, but with vermicomposting an additional yield of 3.4 t/ha was obtained in lettuce (Santos *et al.*, 1993).

In wheat and maize, yield increased with the application of organic wastes. The effect of organic wastes was enhanced with the incorporation of earthworms (Sharma, 1994).

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

Sagaya Alfred and Gunthilagaraj (1996) obtained higher yield in Amaranthus with the incorporation of earthworms into the seed bed.

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

Introduction of *Aporrectodea trapezoides* into the soil increased the wheat grain yield by 35 per cent and plant biomass by 39 per cent (Baker *et al.*, 1997).

2.6.1.5 Quality of produce

Considerable scientific data were generated recently to show that produce obtained from organic farming is nutritionally superior with good taste, lustre and better keeping qualities. The better storage life of spinach grown with organic manure was found to be associated with lower free aminoacid 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 lustre.

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.

2.6.2 Availability of nutrients

2.6.2.1 Nitrogen

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; Srinivasa Rao *et al*., 1996).

Haimi and Huhta (1990) reported that earthworm 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. Wormcast 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 microcosms supplied with manure.

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

2.6.2.2 Phosphorus

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 Srinivasa Rao *et al*. (1996).

Mackey *et al* (1983) found that incorporation of earthworm to soil incubated with rock phosphate resulted in 32% increase in Bray-extractable soil P after 70 days.

The growth of *Mathiola incana* stocks in compost mixture indicated that vermicompost could supply the full requirement of P (Handreck, 1986).

According to Romero and Chamooro (1993) the activity of earthworm increases the available P status in the soil.

2.6.2.3 Potassium

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 (1986), vermicompost could supply the initial requirement 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 Srinivasa Rao *et al*. (1996).

Das *et al*. (1996) found that the content of K_2O in vermicompost obtained from sericultural wastes was about 1 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, biological grinding, together with enzymatic influence on finer soil materials were likely to be responsible in increasing the different forms of K (Srinivasa Rao *et al*., 1996).

2.6.2.4 Exchangeable Ca and Mg

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 wormcast than in the surrounding soil. Similar results were reported by Miura *et al*. (1993) and Romero and Chamooro (1993).

But Basker *et al*. (1994) opined that there exists no consistent trends for changes in exchangeable Ca and Mg as a result of soil digestion by earthworms.

2.6.2.5 Micronutrients

Handreck (1986) found that vermicompost as potting mixture 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.

2.6.3 Uptake of nutrients

2.6.3.1 Nitrogen

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

Introduction of earthworm greatly increased N content of *Panicum maxinum* (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 earthworm increased foliar N concentration of clover by 5-25 per cent (Doube *et al*., 1994).

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

Sagaya Alfred and Gunthilagaraj (1996) noticed more N content in *Amaranthus* plants grown with earthworm application.

Organic C content and N content were higher in rice in the treatment that received vermicompost plus NPK than in the treatment with NPK alone (Vasanthi and Kumaraswamy, 1996).

Baker *et al.* (1997) observed that introduction of different earthworm species increased grain N content (14 per cent) and straw N content (19 per cent) of wheat compared to control.

2.6.3.2 Phosphorus

Kale *et al.* (1992) reported significant increase in the uptake of P by rice plants treated with vermicompost.

Introduction of earthworm species increased the foliar concentration of P in wheat crop (Stephans *et al.*, 1994).

Sagaya and Gunthilagaraj (1996) obtained more P content in Amaranthus plants grown with the interoduction of earthworm.

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

2.6.3.3 Potassium

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.

2.6.3.4 Calcium and Magnesium

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).

2.6.3.5 Micronutrients

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

In French bean, uptake of S was more in soils which received vermicompost compared to ammonium sulphate and control at harvest. Residual availability 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 in rice.

2.6.4 Microbial Activity

Syers and Springett (1984) reported that the burrowing and feeding activities of earthworms would enhance the microbial activity in soil.

Krisstufeck *et al*. (1993) noticed that the total number of microbes in the gut content of *Lumbricus rubellus* was higher compared to that in the soil, especially, *Streptomyces* and *Micromonospora*.

Earthworms occurred in greater number in the outdoor experiment in Germany and showed a short-term increase in phosphatase, dehydrogenase, protease and nitrogenase activity (Weiss and Trespendorfer, 1993).

Mba (1994) found that the earthworm casts of *Pontoscolex correthrurus* were found to contain tolerant actinomycetes and efficient rock phosphate solubilisers.

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

Serra Wittling *et al*. (1995) opined that vermicompost had no marked effect on compost enzyme activity, either before or during the incubation.

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

Earthworm casts of *Eudrillus eugeniae* were rich in rock-phosphate solubilizing microbes and had high rock-phosphate solubilizing capacity (Mba, 1997).

MATERIALS AND METHODS

MATERIALS AND METHODS

The study entitled "Nutrient economy through seed coating with vermicompost in cowpea" has been carried out during the period from September 1996 to March 1997 in the College of Agriculture, Vellayani. The main objective was to study the effect of coating cowpea seeds with vermicompost on growth parameters and yield and to study the possibility of reducing inorganic fertilizer requirement through this method. The details of the study are given below.

3.1 Location

The experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani. The site is situated at 85°N latitude and 76.9°E longitude at an altitude of 29 m above MSL.

3.2 Season

The experiment was carried out during September 1996 to March 1997. Monthly average of rainfall and relative humidity collected from the the meterological observatory attached to the College of Agri culture, Vellayani are presented in Figure 1.

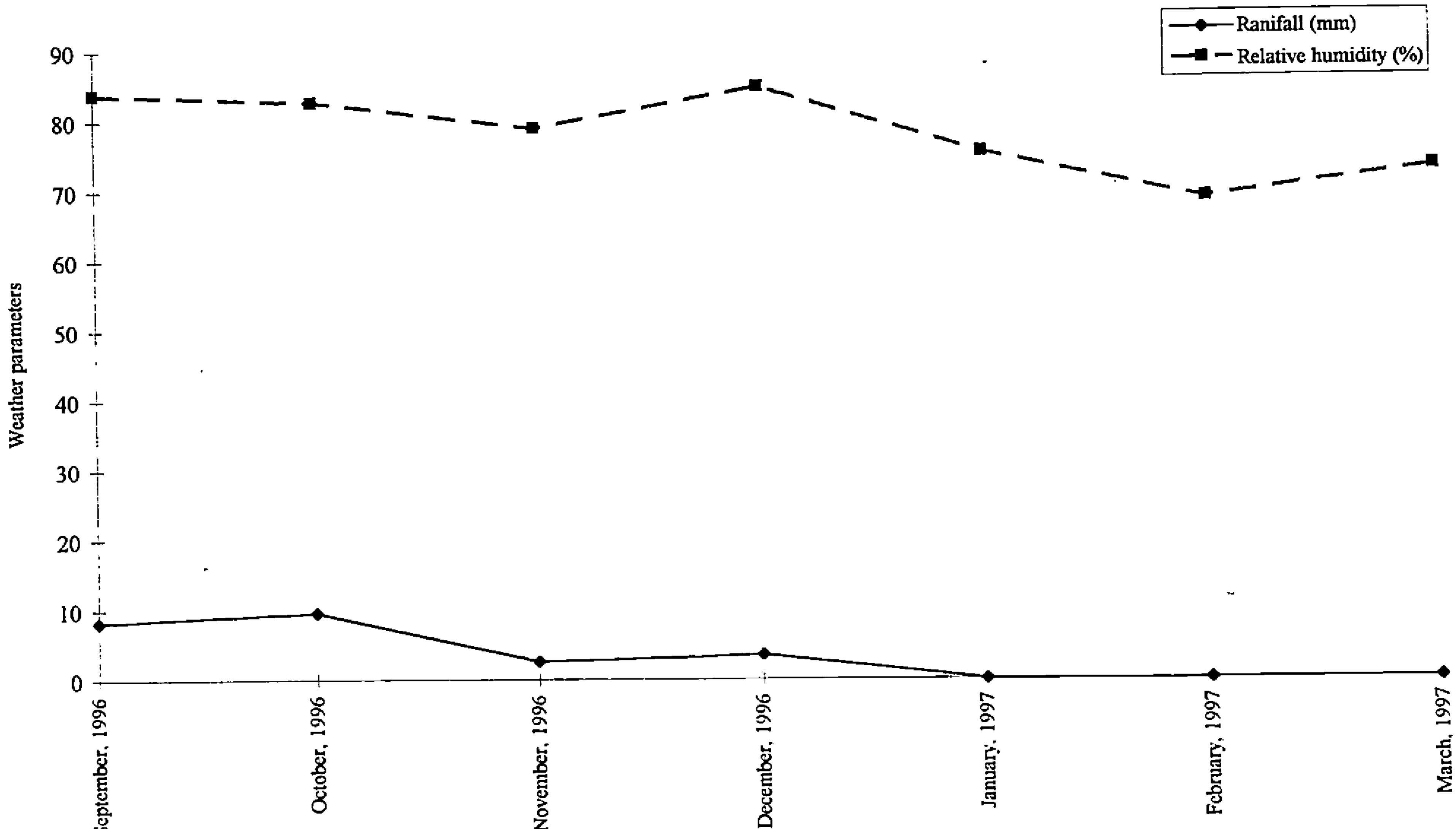


Fig. 1 Weather data during the cropping period

3.3 Soil

The experiment was conducted using the red loam soil of Vellayani as a pot culture study. The soil is taxonomically classified as Clayey Kaolinitic Isohyperthermic Rhodic Haplustox. The important physico-chemical properties of the soil used for the study are given in Table 1.

Table 1. Physico-chemical properties of the soil

Parameter	Content	Rating
pH	5.2	Acidic
Electrical conductivity	<0.05 dSm^{-1}	-
Organic carbon	0.18%	Low
CEC	4.1 c mol kg^{-1}	-
Available N	220.25 kg ha^{-1}	Low
Available P_2O_5	30.94 kg ha^{-1}	High
Available K_2O	123.20 kg ha^{-1}	Low
Exchangeable Ca	0.81 c mol kg^{-1}	
Exchangeable Mg	1.32 c mol kg^{-1}	
Coarse sand	14.2%	
Fine sand	32.8%	
Silt	27.3%	
Clay	25.7%	
Texture	Loam	

3.4 Variety and seeds

Cowpea variety Kanakamoni (Ptb-1) was used for the experiment. It is a medium duration, bushy, moderately high yielding and dual purpose variety. It is excellent both as a grain pulse and green vegetable. The seed materials were obtained from the Farm Office, College of Horticulture, Vellanikkara.

3.5 Biofertilizer

Rhizobium culture used for seed inoculation was obtained from National Biofertilisers, Sasthamangalam, Thiruvananthapuram.

3.6 Manures and fertilizers

The nutrient status of organic manures used in the study is as follows:

	%N	%P	%K
FYM	0.60	0.20	0.54
Vermicompost	1.62	0.75	1.84

The carrier fertilizers for NPK were Urea containing 46 per cent N, Mussooriephos containing 20 per cent P_2O_5 and Muriate of potash containing 60 per cent K_2O respectively.

3.7 Layout and Design of the experiment

The pot culture experiment was carried out in Completely Randomised Design with nine treatments and three replications. An additional set of three replications was kept apart for carrying out destructive sampling at maximum flowering stage. The layout of the experiment is given in Figure 2.

3.8 Details of treatments

T_1 : Uncoated seeds + fertilizers as per POP*

T_2 : Seeds treated with Bradyrhizobium + fertilizers as per POP

T_3 : Seeds treated with vermicompost + fertilizers as per POP

T_4 : Seeds treated with Bradyrhizobium and vermicompost + fertilizers as per POP

T_5 : Seeds treated with Bradyrhizobium+ 1/2 recommended N and P + full K as per POP

T_6 : Seeds treated with vermicompost + 1/2 recommended N and P + full K as per POP

T_7 : Seeds treated with Bradyrhizobium and vermicompost + 1/2 recommended N and P + full K as per POP

T_8 : Uncoated seeds + inorganic fertilizers as per POP + vermicompost @ 20 t ha^{-1}.

T_9 : Uncoated seeds + inorganic fertilizer as per POP + vermicompost @ 10 t ha^{-1}

The POP recommendation for cowpea is 20kg N ha^{-1}, 30 kg P_2O_5 ha^{-1} and 10 kg K_2O ha^{-1} and farmyard manure @ 20 t ha^{-1}.

*POP - Package of Practices Recommendation

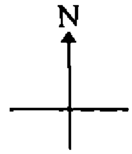
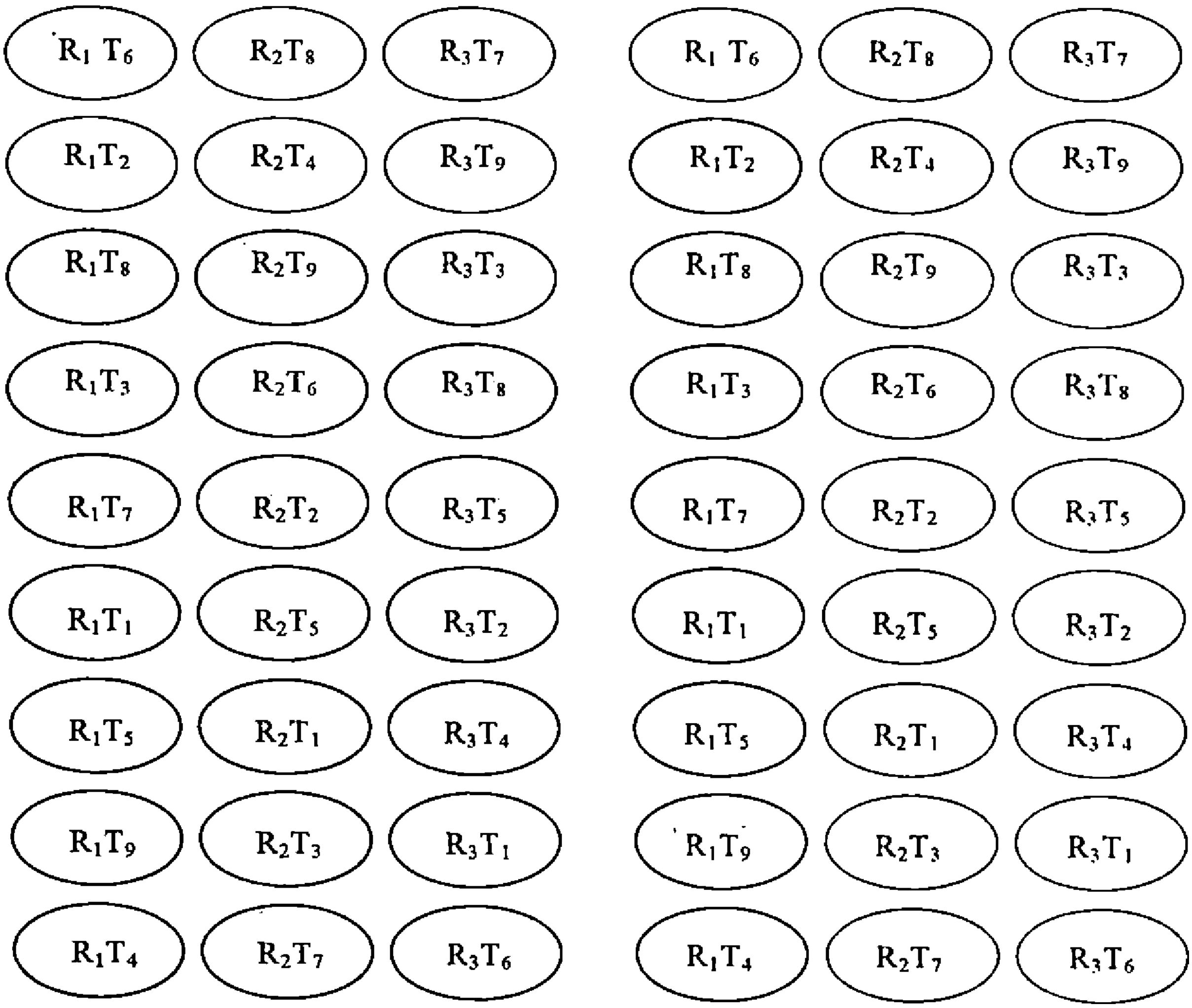


Fig: 2 **Layout (Pot culture study)**



Design : C.R.D.
Treatments : 9
Replications : 3

3.9 Preparation of pots

Earthern pots of 25 cm diameter and 30 cm height were used for raising the crop. The pots were filled with 8 kg of the sand - red loam soil mixture mixed in the proportion 1:1.

3.10 Seed treatment

Seeds were mixed uniformly with *Rhizobium* culture/vermicompost @ 375 g for 40 kg seeds using starch solution (Kanjivellam) for ensuring better stickiness. The coated seeds were dried under shade over a clean paper and sown immediately in the respective pots.

3.11 Sowing and application of manures and fertilizers

Organic manures were applied as per the treatments at the time of sowing of seeds. Lime was applied in all the pots as per POP recommendations. The soil, manure and lime were intimately mixed and four seeds per pot were sown. Half the quantity of N and whole of P and K were applied as basal dose and the remaining N was applied twenty days after sowing.

3.12 Plant protection

Three sprayings were given with Malathion to control pea aphid and stemfly attack. Two sprayings were given with Kelthane against red spider mite.

3.13 After cultivation

Resowing was done in those pots where seeds failed to germinate. Prior to top dressing, thinning was done so as to retain one healthy plant per pot. During the initial stages, daily irrigation was given. Later, irrigation was provided once in two days. Handweeding was done at biweekly intervals.

3.14 Harvesting

Harvesting was done by picking the mature green pods and the pod yield of individual pots was recorded.

3.15 Second crop

A second crop of cowpea was taken in the same pots without applying manures and fertilizers to study the residual effect of manures and fertilizers applied to the first crop.

3.16 Biometric observations

Biometric observations of the plants were taken two weeks after sowing, at flowering and at harvest.

3.16.1 Height of plant

The height of the plant was measured in cm. from the scar of the first cotyledonous leaves of the plant to the top of the growing point.

3.16.2 Number of leaves

The total number of leaves per plant was counted two weeks after sowing and at flowering.

3.16.3 Girth of plant

The girth of plant at 2 cm above ground level was measured two weeks after sowing and expressed in cm.

3.16.4 Number of fruiting branches

Fruiting branches per plant in each pot were counted separately at flowering and at harvest.

3.16.5 Number of pods per plant

During harvest, the number of pods present in each plant were counted.

3.16.6 Root characters

3.16.6.1 Root length

This observation was taken at maximum flowering stage. The sample plants were uprooted carefully and the length of tap root was measured in cm.

3.16.6.2 Root spread

This was measured at maximum flowering stage by placing the dried roots on a graph paper and measuring the width of the root at its broadest point. The root spread was expressed in cm.

3.16.6.3 Root : shoot ratio

Root : shoot ratio was studied at maximum flowering stage. From each sample plant, root and shoot portions were taken separately, sundried for two days and then ovendried at 65-70°C for 24 hours and the dry weights were recorded. The ratio of root dry weight to shoot dry weight was expressed as root : shoot ratio.

3.16.6.4 Number of nodules per plant

Plants from the additional replication were uprooted carefully at maximum flowering stage, root portion was washed and nodules were separated from the roots. The nodules were separated into effective and ineffective nodules and counted. Effective nodules were selected based on their size, shape and red colour.

3.17 Yield and yield attributes

3.17.1 Grain yield

Yield of grain obtained from each pot was recorded separately and expressed in g plant^{-1} adjusted to 12 per cent moisture.

3.17.2 Number of pods

Pods collected from each plant at each harvest were counted separately and the total number was worked out.

3.17.3 Weight of pods

Weight of pods at each harvest was measured and tabulated.

3.17.4 Number of seeds per pod

Number of seeds in the pods were counted and the average was worked out.

3.17.5 Hundred seed weight

Hundred seeds were selected at random from the bulk in each pot and weighed.

3.17.6 Bhusa yield

After the pods were picked from each plant, the plants were uprooted, washed free of adhering soil, air dried uniformly and then ovendried at 65-70°C for 24 hours and weighed.

3.17.7 Dry matter yield

The uprooted plants were airdried and then oven-dried at 65-70 °C for 24 hours and the whole weight was taken at flowering stage and at harvest.

3.18 Soil studies

Periodical estimation for P solubilisation capacity and N fixation capacity of the soil sample in the pots was made at fortnightly intervals upto flowering.

3.18.1 P solubilisation

Ten gram soil collected from the pots were mixed with 10 mg finely powdered rock phosphate and incubated for 21 days after adding sufficient water. The solubilised P was estimated after extraction with Bray I reagent.

3.18.2 N fixation

One gram soil from the pot was incubated with 50 ml N free Ashby's nutrient medium for a period of 21 days. After 21 days the volume was reduced to 5 to 10 ml by evaporation in a water bath and the total nitrogen fixed was estimated by microkjeldahl method and compared with uninoculated samples (Allen, 1953).

Composition of N-free Ashby's nutrient medium

Mannitol	:	15 g
$K_2 H PO_4$	:	0.2 g
$MgSO_4.7 H_2O$	:	0.2 g
$CaCl_2$	:	0.02 g
$FeCl_3.6H_2O$ (10 per cent solution)	:	0.05 ml
Molybdenum Trioxide (0.1 per cent aqueous solution)	:	1 drop
Distilled water	:	1000 ml

3.18.3 Soil chemical analysis

The soil samples collected from each pot at maximum flowering stage were analysed for available N, P_2O_5, K_2O, Ca, Mg, and micronutrients Mn, Zn, and Cu as given below.

Parameter	Method	Reference
Available N	Alkaline permanganate method	Subbiah and Asija (1956)
Available P_2O_5	Bray No.1 chlorostannous reduced molybdophosphoric blue colour method using Klett Summerson photoelectric colo.rimeter	Bray and Kurtz (1945)
Available K_2O	Neutral normal ammonium acetate extraction and flame photometry	Jackson (1973)
Exchangeable Ca and Mg	Neutral normal ammonium acetate extraction and atomic absorption spectro-photometry	Jackson (1973)
Available micronutrients Mn, Zn, Cu	DTPA extraction and atomic absorption spectrophotometry (Perkin-Elmer model)	Lindsay and Norvell (1969)

3.19 Plant analysis

Plant samples were collected at maximum flowering stage and after harvest. The samples were ovendried at 65-70°C for 24 hours and powdered in a Willeymill and used for chemical analysis. The contents of N, P, K, Ca, Mg, Mn, Zn and Cu were determined following the procedure given below.

Parameter	Method	Reference
N	Microkjeldahl digestion in sulfuric acid and distillation	Jackson (1973)
P	Nitric-Perchloric-Sulfuric acid (10:4:1) digestion and colorimetry making use of Vanado molybdate yellow colour method.	Jackson (1973)
K	Nitric-Perchloric-Sulfuric acid (10:4:1) digestion and flame photometry.	Jackson (1973)
Ca, Mg	Nitric-perchloric-sulfuric (10:4:1) acid digestion and atomic absorption spectro-photometry.	Piper (1967)
Mn, Zn, Cu	Nitric-Perchloric-Sulfuric acid (10:4:1) digestion and atomic absorption spectro-photometry	Piper (1967)

3.20 Seed analysis

Seed samples were prepared in the same way as that for plant analysis and analysed for protein content and minerals like P, K, Ca and Mg. Percentage of protein in the grain was calculated by the multiplying the percentage of N with the factor 6.25 (Simpson *et al.*, 1965).

3.21 Uptake studies

The total uptake of major and micro nutrients by the plants was calculated as the product of these nutrients in the plant samples and respective dry weights and expressed in g $plant^{-1}$ at maximum flowering stage and at harvest.

3.22 Microbial analysis

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

The composition of media for isolating different groups of microorganisms is given below:

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

Preparation of soil extract:

100 g of sieved garden soil is 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 is filtered through a double filter paper.

Dissolved the agar in 900 ml water by steaming it for an hour or more added 100 ml of the stock soil extract solution. Added glucose and K_2HPO_4 and pH adjusted to 6.8 using IN NaOH.

2. Media for isolation of fungi

Peptone dextrose agar with rose bengal and streptomycin

Dextrose	:	10 g
Peptone	:	5 g
K_2HPO_4	:	1 g
Mg SO_4	:	0.5 g
Agar	:	15 g
Rose bengal	:	to give colour
Streptomycin	:	30 mg
Distilled water	:	1000 ml

3. Media for isolation of actinomycetes

Kenknights medium

Glucose	: 1 g
K_2HPO_4	: 0.1 g
$MgSO_4$	: 0.1 g
KCl	: 0.5 g
$FeSO_4$ $7H_2O$	: 0.01 g
Distilled water	: 1000 ml

pH adjusted to 6.8 - 7 using IN NaOH

Serial dilutions of 10^4, 10^5 and 10^6 were prepared for taking counts of fungi, actinomycetes and bacteria, respectively. One ml each of the diluted solution was seperately plated in triplicate petridishes each containing the specific media for fungi, bacteria and actinomycetes. After incubation for seven days at room temperature the number of colonies formed in the plates for bacteria and fungi was counted. The number of colonies of actinomycetes was counted after 14 days incubation. The total number of each organism in one gram of the vermicompost was calculated from the average number obtained from three plates.

3.23 Statistical analysis

Data generated from the experiment were subjected to statistical analysis by applying analysis of variance technique and significance tested by F-test (Snedecor and Cochran, 1975).

Simple correlations were worked out between biometric characters, yield, nutrient availability and nutrient uptake to arrive at the relation between variables.

RESULTS

RESULTS

The present investigation was undertaken in the College of Agriculture, Vellayani during 1996-97 to study the effect of coating cowpea seeds with vermicompost on growth, nutrition, yield and quality. The data on various observations were statistically analysed and are presented in this chapter.

4.1 Biometric characters

4.1.1 Seedling vigour

The data on seedling vigour as measured by height of seedling, number of leaves and girth of seedling are given in Table 2.

There was no significant difference among the treatments for these characters. However, maximum height (11.50 cm) and number of leaves (3.33) were obtained for the treatment T_2 (coating seeds with Rhizobium and full NPK application). The highest value for seedling girth (1.03 cm) was recorded by the treatment T_3 (vermicompost coating and full NPK application). The treatment T_8 (uncoated seeds + full NPK + full vermicompost as organic source) recorded the lowest value for seedling height (9.00 cm) while T_9 (uncoated seeds + full NPK + half vermicompost as organic source) recorded the lowest value for number of leaves (2.00) and seedling girth (0.57 cm).

Table No.2 Seedling vigour at two weeks after sowing

Treat-ments	Height (cm)	Number of leaves	Girth (cm)
T_1	10.27	2.33	0.93
T_2	11.50	3.33	0.97
T_3	11.17	2.67	1.03
T_4	10.93	2.67	0.93
T_5	10.50	2.33	0.87
T_6	10.60	2.00	0.87
T_7	10.47	2.33	0.83
T_8	9.00	2.33	0.87
T_9	9.83	2.00	0.57
CD	NS	NS	NS
SE m±	0.795	0.294	0.098

4.1.2 Height of plant, number of leaves and fruiting branches at maximum flowering stage

The mean values on the height of plant, number of leaves and fruiting branches taken at maximum flowering stage are presented in Table 3.

4.1.2.1 Height of plant

The different treatments did not have any significant variation on the height of plant at flowering stage. Treatments T_2 (Rhizobium coating + full NPK application) and T_3 (Vermicompost coating + full NPK application) recorded the highest value for plant height (40.00 cm) which is closely followed by T_4 (combined coating of *Rhizobium* and vermicompost + full NPK application) with the mean value 39.33 cm. Treatment T_9 (uncoated seeds + half vermicompost as organic source) showed the lowest value (29.67 cm).

4.1.2.2 Number of leaves

Scanning through the results, it can be inferred that the different treatments had no significant influence on the number of leaves per plant at flowering stage. However, the maximum value (19.33 cm) was obtained for the treatment T_3 (vermicompost coating + full NPK application). Treatment T_7 (combined coating of *Rhizobium* and vermicompost + half N and P and full K application) registered the minimum value (11.67 cm).

Table No. 3 Height of plant, number of leaves and fruiting branches per plant at flowering stage

Treatments	Height (cm)	Number of leaves	Fruiting branches
T_1	32.17	13.33	3.33
T_2	40.00	15.67	4.33
T_3	40.00	19.33	3.67
T_4	39.33	15.33	3.67
T_5	35.43	13.00	3.67
T_6	34.33	14.00	3.33
T_7	34.33	11.67	4.33
T_8	34.67	14.67	4.31
T_9	29.67	12.00	2.33
CD	NS	NS	NS
SE m±	2.903	2.625	0.816

4.1.2.3 Fruiting branches

There was no significant difference among the treatments for this character. The highest mean value (4.33) was recorded by the treatments T_2 (Rhizobium coating + full NPK) and T_8 (uncoated seeds + full NPK + vermicompost as organic source). The treatment T_9 (uncoated seeds + half vermicompost as organic source) recorded the lowest mean value (2.33).

4.1.3 Height of plant, number of fruiting branches, and number of pods per plant at harvest

The data on height of plant, number of fruiting branches and the number of pods per plant were recorded and the results are entered in Table 4.

4.1.3.1 Height of plant

From the Table, it can be inferred that the different treatments had no significant influence on the height of plant at harvest. The treatment T_4 (combined coating of vermicompost and *Rhizobium* + full NPK application) obtained the highest value of 53.00 cm. This was closely followed by the treatments T_2 (*Rhizobium* coating + full NPK) and T_3 (vermicompost coating + full NPK) with a mean value of 51.17 cm. The lowest value (42.00 cm) was obtained for the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

Table No.4 Height of plant, number of fruiting branches and pods per plant at harvest

Treat-ments	Height (cm)	Fruiting branches	Pods per plant
T_1	44.83	1.67	2.67
T_2	51.17	4.33	6.67
T_3	51.17	5.33	7.33
T_4	53.00	4.67	4.33
T_5	48.17	4.67	5.67
T_6	48.17	4.67	6.67
T_7	48.83	4.67	5.67
T_8	47.50	4.00	5.67
T_9	42.00	3.33	4.67
CD	NS	NS	NS
SE m±	3.005	1.257	1.764

4.1.3.2 Fruiting branches

The different treatments did not produce any significant variation on the number of fruiting branches per plant at harvest. However the treatment T_3 (vermicompost coating + full NPK application) obtained the maximum value (5.33) and T_1 (uncoated seeds + full NPK application) recorded the minimum value (1.67).

4.1.3.3 Number of pods per plant

This character at harvest was not significantly influenced by the different treatments. However, the highest value of 7.33 was obtained for the treatment T_3 where seeds were coated with vermicompost and supplied with full NPK fertilizers. The treatment T_1 (uncoated seeds supplied with full NPK fertilizers) recorded the lowest value.

4.1.4 Rooting pattern at flowering

Data pertaining to root length, root spread and number of effective and ineffective nodules are furnished in Table 5. All the characters except the number of ineffective nodules were significantly influenced by the different treatments.

4.1.4.1 Root length

The different treatments had produced significant variation on the length of roots at maximum flowering stage.

Table No.5 Rooting pattern and root : shoot ratio at maximum flowering stage

Treatments	Root length (cm)	Root spread (cm)	Effective nodules (no.)	Ineffective nodules (no.)	Root : shoot ratio
T_1	13.17	9.70	13.67	16.00	0.08
T_2	21.90	14.80	37.00	25.33	0.13
T_3	20.00	12.93	31.33	20.00	0.11
T_4	17.17	12.50	28.67	18.33	0.09
T_5	21.33	12.03	29.00	20.33	0.09
T_6	22.27	9.83	28.00	23.67	0.09
T_7	20.83	11.17	26.33	21.00	0.08
T_8	22.72	13.60	30.67	20.00	0.11
T_9	16.17	10.00	17.00	13.00	0.07
CD	3.248	2.876	7.937	NS	0.016
SE m±	1.093	0.968	2.671	2.459	0.005

The highest mean value for root length (22.77 cm) was recorded by the treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source) which was found to be on par with the treatments T_2 (*Rhizobium* coating + full NPK), T_3 (vermicompost coating + full NPK), T_5 (*Rhizobium* coating + half N and P and full K), T_6 (vermicompost coating + half N and P and full K) and T_7 (combined coating of *Rhizobium* and vermicompost + half N and P + full K). The lowest value (13.17 cm) was recorded by the treatment T_1 (uncoated seeds + full NPK).

4.1.4.2 Root spread

Root spread at maximum flowering stage was significantly influenced by the different treatments. The treatment T_2 (*Rhizobium* coating + full NPK application) registered the highest mean value of 14.80 cm and T_1 (uncoated seeds + full NPK application) yielded the lowest value of 9.70 cm. The treatment T_2 was found to be on par with T_3 (vermicompost coating + full NPK), T_4 (combined coating of *Rhizobium* and vermicompost + full NPK), T_5 (*Rhizobium* coating + half N and P and full K) and T_8 (uncoated seeds + full NPK + full vermicompost as organic source).

4.1.4.3 Effective nodules

Scanning through the results, it can be inferred that the number of effective nodules per plant was significantly influenced by the different treatments. The treatment T_2 (*Rhizobium* coating + full NPK application) registered the maximum value of 37.00. This treatment was found to be on par with the treatments T_3 (vermicompost coating + full NPK) and T_8 (uncoated seeds + full NPK + vermicompost as organic source). The lowest value (13.67) was registered by the treatment T_1 (uncoated seeds + full NPK application).

4.1.4.4 Ineffective nodules

This character was not significantly influenced by the different treatments. However, the maximum value (25.33) was obtained for the treatment T_2 (*Rhizobium* coating + full NPK) and the minimum value (13.00) for the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.1.5 Root : shoot ratio

The results of the study are presented in Table 5.

Root : shoot ratio at maximum flowering stage was significantly influenced by the different treatments. The treatment T_2 (*Rhizobium* coating + full NPK application) registered the highest mean value (0.13) and was found to be significantly superior to all the other treatments. The lowest value of 0.07 was recorded by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.2 Yield and yield attributes

The important yield attributes studied were number of pods, weight of pods, number of seeds per pod, hundred seed weight and total grain yield. The mean values are presented in Table 6.

4.2.1 Number of pods per plant at harvest

From the data, it is observed that the number of pods per plant at harvest was significantly influenced by the different treatments. The highest mean value (33.33 $plant^{-1}$) was obtained for the treatment T_3 (vermicompost coating + full NPK) and was found to be on par with all the treatments except T_1 and T_9. The lowest value of 21.33 $plant^{-1}$ was recorded by the treatment T_1 (uncoated seeds + full NPK application).

4.2.2 Weight of pods

This character was not significantly influenced by the different treatments. The treatment T_3 (vermicompost coating + full NPK application) recorded the highest mean value (210.32 g $plant^{-1}$) while T_1 (uncoated seeds + full NPK application) recorded the lowest mean value (126.60 g $plant^{-1}$).

4.2.3 Number of seeds per pod

There was no significant variation among the treatments for the number of seeds per pod. T_6 (vermicompost

Table No.6 Total grain yield and yield attributes

Treat-ments	Number of pods	Weight of pods (g plant^{-1})	Number of seeds pod^{-1}	Hundred seed weight (g)	Grain yield (g plant^{-1})	Bhusa yield (g)
T_1	21.33	126.60	16.33	11.00	38.19	28.05
T_2	32.33	203.21	18.00	11.35	65.31	36.27
T_3	33.33	210.32	17.33	11.48	66.20	39.25
T_4	31.67	194.48	17.33	11.71	64.26	37.29
T_5	26.33	165.24	17.67	11.03	51.25	31.57
T_6	27.00	165.08	18.33	11.07	54.73	32.48
T_7	25.67	163.85	18.33	11.04	51.86	31.41
T_8	28.33	198.35	17.33	11.33	55.16	36.83
T_9	23.33	147.64	17.33	10.71	43.19	30.63
CD	7.990	NS	NS	NS	14.518	5.809
SE m±	2.733	22.579	0.497	2.063	4,886	1.955

coating + half N and P + full K) and T_7 (combined coating of vermicompost and *Rhizobium* + half N and P + full K) registered the highest value of 18.33. The lowest value (16.33) was recorded by the treatment T_1 (uncoated seeds + full NPK application).

4.2.4 Hundred seed weight

This character was also not significantly influenced by the different treatments. However, the maximum value (11.71 g) was obtained for the treatment T_4 (combined coating of *Rhizobium* and vermicompost + full NPK) and minimum value (10.71 g) for the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.2.5 Total grain yield

Total grain yield of cowpea was found to be significantly influenced by the different treatments. The highest mean value (66.20 g plant^{-1}) was obtained for the treatment T_3 (vermicompost coating + full NPK application) and was found to be on par with all the other treatments except T_1, T_5 and T_9. The treatment T_1 (uncoated seeds + full NPK application) recorded the lowest mean value for grain yield (38.19 g plant^{-1}).

Table No.7 Dry matter yield at maximum flowering stage and at harvest

Treatments	Maximum flowering stage (g)	Harvest (g)
T_1	19.35	36.50
T_2	22.82	45.00
T_3	24.31	47.90
T_4	21.19	41.83
T_5	20.78	40.72
T_6	21.34	43.04
T_7	20.29	42.52
T_8	23.59	45.24
T_9	19.25	39.83
CD	2.419	2.570
SE m±	0.812	0.868

4.2.6 Bhusa yield

Bhusa yield was significantly influenced by the different treatments. The treatment T_3 (vermicompost coating + full NPK) produced the maximum bhusa yield (39.25 g) which was found to be on par with the treatments T_2, T_4 and T_8. The lowest bhusa yield of 28.05 g was obtained for the treatment T_1 (uncoated seeds + full NPK application).

4.3 Total dry matter yield

The data on total dry matter yield calculated at maximum flowering stage and harvest are presented in Table 7.

4.3.1 At maximum flowering stage

Total dry matter yield at maximum flowering stage was significantly influenced by the different treatments. The highest dry matter yield (24.31 g) was obtained for the treatment T_3 (vermicompost coating + full NPK application). This was found to be on par with the treatments T_2 (*Rhizobium* coating + full NPK application) and T_8 (uncoated seeds + full NPK + full vermicompost as organic source). The lowest mean value (19.25 g) was obtained for the treatment T_9 where the seeds were uncoated and supplied with full NPK fertilizers.

4.3.2 At harvest

There was significant difference among the treatments for total dry matter yield at harvest stage also. T_3

Table No.8 Total grain yield and yield attributes of the residual crop

Treat-ments	Number of pods	Weight of pods (g $plant^{-1}$)	Grain yield (g $plant^{-1}$)
T_1	11.33	52.11	13.40
T_2	20.67	107.01	31.61
T_3	22.67	123.06	39.33
T_4	17.00	95.75	27.76
T_5	14.00	81.02	18.86
T_6	15.67	90.58	23.49
T_7	15.33	81.89	24.89
T_8	18.00	92.68	31.05
T_9	13.67	69.48	18.00
CD	5.831	29.876	11.284
SE m±	1.962	10.056	3.797

(vermicompost coating + full NPK application) produced the highest dry matter yield of 47.90 g.The lowest dry matter yield (36.50 g) was obtained for the treatment T_1 (uncoated seeds + full NPK application).

4.4 Yield of Residual crop

Data pertaining to the yield of second crop of cowpea grown as residual crop are presented in Table 8.

4.4.1 Number of pods

The different treatments showed a significant influence upon the number of pods obtained for the residual crop of cowpea. Maximum yield (22.67 plant^{-1}) was obtained for the treatment T_3 (vermicompost coating + full NPK application) and it was found to be on par with the treatments T_2 (*Rhizobium* coating + full NPK), T_4 (combined coating of *Rhizobium* and vermicompost + full NPK) and T_8 (uncoated seeds + full NPK + vermicompost as the organic source). The treatment T_1 (uncoated seeds + full NPK) registered the lowest value (11.33 plant^{-1}) for the number of pods of the residual crop.

Table No.9 Phosphorus solubilisation capacity of soil at periodical intervals upto flowering stage (μg 10 g^{-1} soil)

Treatments	15 DAS	30 DAS	45 DAS
T_1	6.77	9.57	9.50
T_2	8.77	11.17	11.20
T_3	9.40	12.83	12.33
T_4	9.20	11.83	11.73
T_5	7.17	10.43	10.07
T_6	8.17	10.93	10.87
T_7	8.07	10.60	10.33
T_8	8.97	12.07	12.10
T_9	7.53	10.27	10.17
CD	NS	NS	NS
SE m±	0.779	0.886	0.882

DAS - Days after sowing

4.4.2 Weight of pods

This character was also significantly influenced by the different treatments and the highest yield (123.06 g $plant^{-1}$) was recorded by the treatment T_3 (vermicompost coating + full NPK application). T_2 (*Rhizobium* coating + full NPK application) and T_4 (combined coating of *Rhizobium* and vermicompost + full NPK) were found to be on par with the treatment T_3. The lowest pod weight of 52.11 g $plant^{-1}$ was recorded by the treatment T_1 (uncoated seeds + full NPK).

4.4.3 Total grain yield

From the table, it can be inferred that the different treatments had a significant influence on the grain yield of the residual crop of cowpea. The treatment T_3 (vermicompost coating + full NPK application) recorded the maximum mean value of 39.33 g $plant^{-1}$ and was found to be on par with the treatments T_2 and T_8. The lowest yield of 13.40 g $plant^{-1}$ was obtained for the treatment T_1 (uncoated seeds + full NPK application).

4.5 Soil studies

4.5.1 Phosphorus solubilisation capacity

Data on P solubilisation capacity of soil as influenced by the different treatments at periodical intervals upto flowering viz., 15 DAS, 30 DAS and 45 DAS are given in Table 9.

Table No.10 Nitrogen fixation capacity of soil at periodical intervals upto flowering stage (µg g^{-1} soil)

Treatments	15 DAS	30 DAS	45 DAS
T_1	7.13	12.03	12.12
T_2	9.07	17.22	17.25
T_3	8.03	14.98	15.00
T_4	8.74	15.15	15.17
T_5	8.69	15.03	15.04
T_6	8.64	14.76	14.74
T_7	8.47	14.88	14.90
T_8	8.71	16.02	16.00
T_9	7.70	13.06	13.13
CD	NS	2.242	2.043
SE m±	0.720	0.755	0.687

It can be inferred from the results that the different treatments had no significant influence on the P solubilisation capacity of soil at any of the three growth stages. But, there was a greater increase in the P solubilisation capacity at 30 DAS compared to that at 15 DAS, while the amount of P solubilised at 30 DAS and 45 DAS was almost the same. During all the three growth stages, the treatment T_3 (vermicompost coating + full NPK) recorded the maximum mean value for the amount of P solubilised (9.40, 12.83 and 12.33 µg 10 g^{-1} soil respectively).

4.5.2 Nitrogen fixation capacity

Periodical estimation of soil samples for N fixation capacity at fortnightly intervals upto flowering was done and the results are presented in Table 10.

The different treatments significantly influenced the N fixation capacity of soil at 30 DAS and 45 DAS. There was a noticeable increase in the amount of N fixed by soil from 15 DAS to 30 DAS. During all the three growth stages, the treatment T_2 (*Rhizobium* coating + full NPK) showed the highest mean value for the amount of N fixed (9.07, 17.22, 17.25 µg g^{-1} soil) T_1 registered the lowest mean value (7.13, 12.03 and 12.12 µg g^{-1} soil). At 30 DAS, the treatment T_2 was found to on par with the treatments T_3, T_4, T_5 and T_8 and at 45 DAS, T_2 was found to be on par with T_8.

4.5.3 Soil analysis at maximum flowering stage for major and micro nutrients

Table 11 shows the status of available major and micro nutrients in the soil at maximum flowering stage. Data relating to available N, P, K, exchangeable Ca and Mg, Cu, Mn and Zn are tabulated. It may be seen that the content of all the nutrients except N, P and K were significantly influenced by the different treatments.

4.5.3.1 Nitrogen

Eventhough there was a significant increase in the N fixation capacity of soil upto flowering stage, available N at maximum flowering stage was not significantly influenced by the different treatments. However, the treatment T_2 (*Rhizobium* coating + full NPK) recorded the maximum value of 301.05 kg ha^{-1} for available N content of soil. The lowest value was recorded by the treatment T_9 (236.25 kg ha^{-1}).

4.5.3.2 Phosphorus

This character was also not significantly influenced by the different treatments. The maximum (61.81 kg ha^{-1}) and minimum (46.68 kg ha^{-1}) values were recorded by the treatments T_3 (vermicompost coating + full NPK) and T_9 (uncoated seeds + full NPK + half vermicompost as organic source) respectively.

Table No.11 Analysis of soil at maximum flowering stage for major and minor nutrients

Treatments	N	P_2O_5	K_2O	Ca	Mg	Cu	Mn	Zn
	(kg ha^{-1})			(c mol(+) kg^{-1})		(ppm)		
T_1	261.33	50.38	171.73	0.87	1.43	1.20	13.47	1.83
T_2	301.05	61.49	224.00	1.33	2.90	2.57	24.77	2.33
T_3	292.69	61.81	231.47	1.37	2.90	3.23	27.67	2.50
T_4	284.33	59.92	201.60	1.20	2.60	2.80	21.27	2.27
T_5	250.88	56.60	194.13	1.07	1.97	2.20	16.50	2.03
T_6	242.52	56.30	201.60	1.03	2.00	2.33	17.50	1.90
T_7	278.06	53.63	194.13	1.00	2.17	2.13	15.97	1.90
T_8	271.79	54.32	182.99	1.50	3.17	3.63	24.60	2.57
T_9	236.25	46.68	153.81	0.83	1.60	2.23	14.63	1.73
CD	NS	NS	NS	0.362	0.645	1.177	3.941	0.388
SE m±	21.162	5.243	27.864	0.121	0.217	0.396	1.326	0.131

4.5.3.3 Potassium

The amount of available K content of soil at maximum flowering stage was not significantly influenced by the different treatments. The treatments T_3 (vermicompost coating + full NPK) and T_9 (uncoated seeds + NPK + half vermicompost as organic source) recorded the maximum and minimum values (231.47 and 153.81 kg ha^{-1} respectively).

4.5.3.4 Exchangeable calcium and magnesium

Both the characters were significantly influenced by the different treatments. The treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source) recorded the highest mean value (1.50 and 3.17 c $mol^{(+)} kg^{-1}$, respectively) for both exchangeable Ca and Mg and it was found to be on par with the treatments T_2 (*Rhizobium* coating + full NPK), T_3 (vermicompost coating + full NPK) and T_4 (combined coating of *Rhizobium* and vermicompost + full NPK). The lowest value for exchangeable Ca and Mg was obtained for the treatments T_9 (0.83 c $mol^{(+)} kg^{-1}$) and T_1 (1.43 c $mol^{(+)} kg^{-1}$) respectively.

4.5.3.5 Copper

There was a significant influence of different treatments on the available Cu status of the soil at maximum flowering stage. Maximum value of 3.63 ppm was obtained for the treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source). It was found to be on par with the treatments T_2, T_3 and T_4.

4.5.3.6 Manganese

From the table, it is evident that there was a significant variation in the available Mn content of the soil as influenced by the various treatments. T_3 (*Rhizobium* coating + full NPK application) recorded the maximum mean value for available Mn content (27.67 ppm) which was found to be on par with the treatments T_2 and T_8. The lowest value (13.47 ppm) was registered by the treatment T_1 (uncoated seeds + full NPK application).

4.5.3.7 Zinc

The different treatments had a significant influence on the availability of Zn in soil at maximum flowering stage. The treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source) which recorded the highest mean value (2.57 ppm) was found to be on par with the treatments T_2, T_3 and T_4. The lowest value of 1.73 ppm was recorded by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.6 Plant analysis for major and micronutrients

4.6.1 At maximum flowering stage

Table 12 presents the mean data on the content of N, P, K, Ca, Mg, Cu, Mn and Zn in cowpea at maximum flowering stage. All the nutrients except P and Zn were significantly influenced by the different treatments.

4.6.1.1 Nitrogen

Nitrogen content of plant parts at maximum flowering stage was significantly influenced by the different treatments. The treatment T_3 (vermicompost coating + full NPK) was significantly superior to all the other treatments (3.97 per cent) while the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source) was significantly inferior to all the other treatments with a mean value of 2.78 per cent.

4.6.1.2 Phosphorus

Phosphorus content at maximum flowering stage was not significantly influenced by the different treatments. However, the treatments T_3 (vermicompost coating + full NPK application) and T_2 (*Rhizobium* coating + full NPK) recorded the maximum value (0.29 per cent). The lowest value of 0.23 per cent was recorded by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

Table No.12 Plant analysis at maximum flowering stage for major and micro nutrients

Treat-ments	N	P	K	Ca	Mg	Cu	Mn	Zn
	(%)					(ppm)		
T_1	3.02	0.24	0.66	1.25	0.29	14.87	16.37	20.60
T_2	3.55	0.29	0.84	1.32	0.34	20.20	22.07	26.71
T_3	3.97	0.29	0.80	1.40	0.33	19.00	22.20	25.85
T_4	3.65	0.28	0.81	1.31	0.35	15.87	19.97	25.09
T_5	3.17	0.26	0.82	1.31	0.30	16.20	19.20	23.67
T_6	3.19	0.26	0.72	1.26	0.30	15.20	18.07	21.12
T_7	2.98	0.25	0.80	1.21	0.29	17.20	17.63	21.20
T_8	3.10	0.28	0.82	1.37	0.34	20.57	22.70	24.73
T_9	2.78	0.23	0.70	1.24	0.29	17.50	19.30	24.06
CD	0.176	NS	0.106	0.109	0.035	3.788	2.436	NS
SE m±	0.059	0.015	0.035	0.036	0.012	1.275	0.820	1.605

4.6.1.3 Potassium

Potassium content of plant parts was significantly influenced by the different treatments. T_2 (*Rhizobium* coating + full NPK application) which recorded the highest mean value (0.84 per cent) was found to be on par with all the other treatments except T_1, T_6 and T_9. The lowest value of 0.66 per cent was obtained for the treatment T_1 (uncoated seeds + full NPK application).

4.6.1.4 Calcium

This character was also significantly influenced by the different treatments T_3 (vermicompost coating + full NPK) recorded the highest mean value of 1.40 per cent. T_3 was found to be on par with the treatments T_2, T_4, T_5 and T_8. T_7 (combined coating of *Rhizobium* and vermicompost + 1/2 N and P + full K) recorded the lowest value (1.21 per cent).

4.6.1.5 Magnesium

Magnesium content in plant parts was significantly influenced by the different treatments and the highest value (0.35 per cent) was recorded by the treatment T_4 (combined coating of *Rhizobium* and vermicompost + full NPK) and was found to be on par with T_2, T_3 and T_8.

4.6.1.6 Copper

A significantly higher content of Cu was recorded by the treatment T_8 (20.57 ppm) and was found to be on par with the treatments T_2 (20.20 ppm), T_3 (19.00 ppm), T_7 (17.20 ppm) and T_9 (17.50 ppm). T_1 (uncoated seeds + full NPK) recorded the lowest mean value (14.87 ppm) for Cu content of plant parts.

4.6.1.7 Manganese

This character was also significantly influenced by the different treatments. The treatment T_8 (22.70 ppm) registered the maximum value and was found to be on par with the treatments T_2 and T_3.

4.6.1.8 Zinc

Zinc content of plant parts was not significantly influenced by the different treatments. The highest value was recorded by the treatment T_2 (26.71 ppm) and the lowest value was recorded by the treatment T_1 (20.60 ppm).

4.6.2 At harvest

The mean data on the concentration of N, P, K, Ca, Mg and micronutrients viz., Cu, Mn and Zn of cowpea plants under different treatments of vermicompost are presented in Table 13.

Table No.13 Plant analysis at harvest for major and minor nutrients

Treat-ments	N	P	K (%)	Ca	Mg	Cu	Mn (ppm)	Zn
T_1	2.14	0.21	0.54	0.84	0.27	10.37	16.37	16.72
T_2	2.40	0.22	0.71	0.96	0.31	15.13	22.07	20.42
T_3	2.39	0.23	0.68	0.92	0.30	13.30	22.20	18.47
T_4	2.11	0.21	0.69	0.97	0.30	10.07	19.97	19.49
T_5	2.17	0.21	0.69	0.86	0.28	12.90	19.20	16.94
T_6	2.21	0.22	0.59	0.92	0.27	12.43	18.07	15.33
T_7	2.07	0.22	0.65	0.83	0.27	11.03	17.63	17.20
T_8	2.27	0.21	0.71	0.97	0.31	13.13	22.70	20.55
T_9	1.83	0.20	0.57	0.84	0.26	10.90	19.30	19.29
CD	NS	NS	0.109	NS	0.027	NS	2.435	3.253
SE m±	0.189	0.018	0.036	0.058	0.009	1.286	0.819	1.095

The different treatments had significant influence only towards K, Mg, Mn and Zn content of plant parts at harvest.

4.6.2.1 Nitrogen

A higher value for N content at harvest was observed for the treatment T_2 (2.40 per cent) closely followed by the treatment T_3 (2.39 per cent) and the lowest value of 1.83 per cent was recorded by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.6.2.2 Phosphorus

The treatment T_3 (vermicompost coating of seeds + full NPK) registered the highest P content of cowpea plant at harvest (0.23 per cent), closely followed by T_2, T_6 and T_7 having a mean value (0.22 per cent) and T_9 recorded the lowest value of 0.20 per cent.

4.6.2.3 Potassium

A significantly higher content of 0.71 per cent K was registered by the treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source) and T_2 (*Rhizobium* coating + full NPK) which was on par with all the other treatments except T_1, T_6 and T_9, while T_1 recorded the lowest mean value for K content (0.54 per cent).

4.6.2.4 Calcium

The highest value for Ca content (0.97 per cent) was recorded by the treatments T_4 (combined coating of *Rhizobium* and vermicompost and full NPK) and T_8 (uncoated seeds + full NPK + vermicompost as organic source). T_7 (combined coating of *Rhizobium* and vermicompost + half N and P + full K) recorded the lowest value of 0.83 per cent.

4.6.2.5 Magnesium

Magnesium content in cowpea plants at harvest was significantly influenced by the different treatments. The highest mean value recorded by T_2 and T_8 (0.31 per cent) was found to be on par with T_3 and T_4 (0.30 per cent).

4.6.2.6 Copper

Copper content of cowpea plants at harvest was not significantly influenced by the different treatments. However, the highest value (15.13 ppm) was recorded by the treatment T_2 (*Rhizobium* coating of seeds + full NPK) while the lowest value (10.07 ppm) was recorded by the treatment T_4 (combined coating of *Rhizobium* and vermicompost and full NPK).

4.6.2.7 Manganese

The treatment T_8 (uncoated seeds + full NPK + full vermicompost as organic source) recorded a significantly higher

Mn content of 22.70 ppm which was on par with the treatments T_2 and T_3. The lowest value (16.37 ppm) was recorded by plants receiving the treatment T_1 (uncoated seeds + full NPK).

4.6.2.8 Zinc

A significantly higher Zn content (20.55 ppm) was obtained for the treatment T_8 closely followed by the treatment T_2 (20.42 ppm). The lowest mean value was recorded for plants receiving the treatment T_6 (combined coating of *Rhizobium* and vermicompost + half N and P and full K).

4.7 Grain analysis

Grain samples were analysed for protein and minerals like P, K, Ca and Mg and the data are presented in Table 14. Results revealed that the different treatments significantly influenced only the K and Ca content of grain.

4.7.1 Protein

The different treatments did not show any significant influence on the protein content of cowpea grains. However, the highest mean value (25.43 per cent) for protein content was obtained for the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source). This was closely followed by the treatments T_3 (uncoated seeds + full NPK) and T_8 (uncoated seeds + full NPK + vermicompost as organic source) with mean

Table No.14 Analysis of grain for protein content and minerals

Treat-ments	Protein	Phosphorus	Potassium	Calcium	Magnesium
			(%)		
T_1	23.31	0.48	1.43	0.08	0.19
T_2	24.13	0.51	1.78	0.14	0.22
T_3	24.97	0.50	1.68	0.16	0.22
T_4	23.94	0.48	1.67	0.11	0.21
T_5	23.97	0.48	1.59	0.10	0.17
T_6	24.07	0.48	1.59	0.10	0.20
T_7	23.83	0.45	1.48	0.09	0.18
T_8	24.85	0.48	1.55	0.16	0.23
T_9	25.43	0.47	1.65	0.12	0.18
CD	NS	NS	0.091	0.028	NS
SE m±	0.426	0.024	0.030	0.009	0.014

values of 24.97 and 24.85 per cent respectively. The lowest mean value (23.31 per cent) was obtained for the treatment T_1 (uncoated seeds + full NPK).

4.7.2 Phosphorus

There was not much variation among the treatments for P content of seeds. The value ranged from 0.51 per cent for the treatment T_2 (Rhizobium coating + full NPK) to 0.45 per cent for the treatment T_7 (combined coating of *Rhizobium* and vermicompost + half N and P + full K).

4.7.3 Potassium

The different treatments showed significant influence on the K content of cowpea seeds. The maximum mean walue of 1.78 per cent was obtained for the treatment T_2 (*Rhizobium* coating + full NPK). This was found to be significantly superior to all the other treatments. The treatment T_1 (uncoated seeds + full NPK) recorded the lowest mean value for K content of cowpea seeds.

4.7.4 Calcium

The treatments T_8 (uncoated seeds + full NPK + vermicompost as organic source) and T_3 (vermicompost coating + full NPK) recorded a significantly higher value of 0.16 per cent for Ca content of seeds. This treatment was on par with

T_2 (0.14 per cent), T_1 (uncoated seeds + full NPK) recorded the lowest value of 0.08 per cent for Ca content.

4.7.5 Magnesium

This character was not significantly influenced by the different treatments. However, the treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source) obtained the highest mean value of 0.23 per cent. The treatment T_5 (*Rhizobium* coating + half N and P + full K) recorded the lowest mean value of 0.17 per cent.

4.8 Uptake of nutrients

4.8.1 At maximum flowering stage

From the data presented in Table 15, it may be seen that the different treatments had a significant influence only on the uptake of Mn at maximum flowering stage.

4.8.1.1 Nitrogen

Nitrogen uptake by plants was not significantly increased when vermicompost was used for coating of seeds. The highest value of 0.76 g $plant^{-1}$ recorded by T_3 was closely followed by T_2 (0.75 g $plant^{-1}$) and T_4 (0.71 g $plant^{-1}$). The lowest value (0.51 g $plant^{-1}$) was recorded by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

Table No.15 Uptake of major and micronutrients at maximum flowering stage

Treatments	N	P	K	Ca	Mg	Cu	Mn	Zn
	(g $plant^{-1}$)					(mg $plant^{-1}$)		
T_1	0.60	0.05	0.13	0.25	0.06	0.21	0.32	0.41
T_2	0.75	0.06	0.18	0.29	0.07	0.30	0.48	0.58
T_3	0.76	0.06	0.15	0.27	0.06	0.30	0.43	0.50
T_4	0.71	0.05	0.15	0.25	0.07	0.31	0.38	0.47
T_5	0.69	0.06	0.19	0.30	0.07	0.28	0.44	0.54
T_6	0.66	0.05	0.14	0.28	0.06	0.26	0.35	0.41
T_7	0.55	0.04	0.15	0.22	0.06	0.23	0.33	0.39
T_8	0.69	0.06	0.18	0.30	0.08	0.31	0.49	0.53
T_9	0.51	0.04	0.13	0.23	0.05	0.22	0.36	0.45
CD	NS	NS	NS	NS	NS	NS	0.092	NS
SE m±	6.225	7.128	1.709	0.025	0.006	0.041	0.031	0.045

4.8.1.2 Phosphorus

Phosphorus uptake was highest in plants which received the treatments T_2, T_3, T_5 and T_8 (0.06 g plant^{-1}). The lowest value was recorded by the treatments T_9 and T_7 (0.04 g plant^{-1}).

4.8.1.3 Potassium

On scrutinizing the results, it may be noted that the treatment T_5 (*Rhizobium* coating + half N and P + full K) recorded the highest K uptake by plants (0.19 g plant^{-1}). The treatments T_9 (uncoated seeds + half vermicompost as organic source + full NPK) and T_1 (uncoated seeds + full NPK) obtained the lowest mean value for K uptake (0.13 g plant^{-1}).

4.8.1.4 Calcium

The treatments T_8 (uncoated seeds + full vermicompost as organic source) and T_5 (*Rhizobium* coating of seeds + half N and P + full K) registered the highest value 0.30 g plant^{-1}) for Ca uptake by plants at maximum flowering stage. The lowest value was recorded by the treatment T_7 (0.22 g plant^{-1}).

4.8.1.5 Magnesium

Here again, the highest value (0.08 g plant^{-1}) for Magnesium uptake was recorded by the treatment T_8 (uncoated seeds + full NPK + vermicompost as organic source). The treatments T_9 (uncoated seeds + full NPK + half vermicompost as organic source) recorded the lowest value (0.05 g plant^{-1}).

4.8.1.6 Copper

The different treatments had no significant influence on the copper uptake of plants at flowering stage. However, highest mean value (0.31 mg plant^{-1}) for copper uptake was obtained for the treatments T_8 and T_4. The lowest value was obtained for the treatment T_1 (0.21 mg plant^{-1}.

4.8.1.7 Manganese

Manganese uptake by plants at maximum flowering stage was significantly influenced by the different treatments. The highest value for manganese uptake was obtained for the treatment T_8 (0.49 mg plant^{-1}) and was found to be on par with the treatments T_2, T_3 and T_5. The lowest value was obtained for the treatment T_1 (0.32 mg plant^{-1}).

4.8.1.8 Zinc

This character was not significantly influenced by the different treatments. The maximum mean value was obtained for the treatment T_2 (0.58 mg plant^{-1}), while the minimum value was recorded by the treatment T_7 (0.39 mg plant^{-1}).

4.8.2 At harvest

Data pertaining to the uptake of nutrients such as N, P, K, Ca, Mg, Cu, Mn, and Zn are presented in Table 16. Scanning through the data, it can be revealed that the different treatments had got significant influence only in the uptake of N, K and Mn.

4.8.2.1 Nitrogen

Nitrogen uptake by plants was significantly influenced by the different treatments. The highest mean value (1.35 g plant^{-1}) was recorded by the treatment T_3 (vermicompost coating + full NPK) and the lowest value of 0.89 g plant^{-1} by the treatment T_9 (uncoated seeds + full NPK + half vermicompost as organic source).

4.8.2.2 Phosphorus

This character was not significantly influenced by the different treatments. The treatment T_3 (vermicompost coating + full NPK) recorded the maximum value (0.20 g plant^{-1}) for P uptake at harvest stage, while the treatment T_1 (uncoated seeds + full NPK) recorded the lowest mean value of 0.13 mg plant^{-1}.

4.8.2.3 Potassium

The different treatments showed significant influence on K uptake by plants at harvest stage and the highest mean

Table No.16 Uptake of major and micronutrients at harvest

Treatments	N	P	K	Ca	Mg	Cu	Mn	Zn
	(g plant^{-1})					(mg plant^{-1})		
T_1	0.90	0.13	0.21	0.21	0.09	0.52	0.68	0.69
T_2	1.32	0.19	0.34	0.30	0.13	0.86	1.08	1.02
T_3	1.35	0.20	0.33	0.30	0.14	0.85	1.13	1.03
T_4	1.21	0.18	0.32	0.31	0.13	0.69	1.01	0.99
T_5	1.11	0.16	0.29	0.28	0.11	0.69	0.86	0.82
T_6	1.12	0.16	0.23	0.26	0.11	0.69	0.84	0.77
T_7	1.04	0.15	0.27	0.23	0.10	0.62	0.88	0.80
T_8	1.23	0.17	0.33	0.31	0.13	0.76	1.06	1.00
T_9	0.89	0.14	0.23	0.22	0.09	0.56	0.78	0.78
CD	0.334	NS	0.078	NS	NS	NS	0.271	NS
SE m±	0.113	0.015	0.026	0.041	0.012	0.080	0.091	0.086

value was obtained for the treatment T_2 (0.34 g plant^{-1}). This treatment was found to be on par with all the treatments except T_1, T_6 and T_9. The lowest mean value was recorded by the treatment T_1 (0.21 g plant^{-1}).

4.8.2.4 Calcium

There was no significant influence on the uptake of Ca by plants by the different treatments. However, the highest value was obtained for the treatments T_4 and T_8 (0.31 g plant^{-1}). This was closely followed by the treatments T_2 and T_3 (0.30 g plant^{-1}). The lowest value was obtained for the treatment T_1 (0.21 g plant^{-1}).

4.8.2.5 Magnesium

The different treatments had no significant influence on the Mg uptake by plants. The highest mean value (0.14 g plant^{-1}) was registered by the treatment T_3 (vermicompost coating + full NPK). It was closely followed by the treatments T_2, T_4 and T_8 with mean value 0.13 mg plant^{-1}. The lowest value was recorded by the treatments T_1 and T_9 (0.09 g plant^{-1}).

4.8.2.6 Copper

It was noticed that there exists no significant difference among the treatments in the uptake of copper by plants at harvest stage. Yet, the maximum mean value (0.86 mg $plant^{-1}$) was obtained for the treatment T_2 (*Rhizobium* coating + full NPK) and the minimum value (0.52 mg $plant^{-1}$) for the treatment T_1 (uncoated seeds + full NPK).

4.8.2.7 Manganese

The different treatments had significant influence on the uptake of Mn by plants at harvest stage. The treatment T_3 (vermicompost coating + full NPK) obtained the highest value (1.13 mg $plant^{-1}$) for Mn uptake at harvest stage. This treatment was found to be on par with the treatments T_2, T_4, T_5, T_7 and T_8. The lowest value (0.68 mg $plant^{-1}$) was recorded by the treatment T_1 (uncoated seeds + full NPK).

4.8.2.8 Zinc

This character was not significantly influenced by the different treatments. The mean values for Zn uptake during harvest stage varied from 0.69 mg $plant^{-1}$ for treatment T_1 (uncoated seeds + full NPK) to 1.03 mg $plant^{-1}$ for treatment T_3 (vermicompost coating + full NPK).

4.9 Microbial analysis of vermicompost

Dilution plate method followed to enumerate the micro organisms present in vermicompost revealed the following results:

Table No.17 Correlation between yield and biometric characters

Characters	Grain yield	Number of pods	Weight of pods
1. Seedling vigour			
1.1 Height of plant	0.235	0.140	0.009
1.2 Number of leaves	0.294	0.229	0.169
1.3 Girth of seedling	0.348	0.304	0.221
2. At flowering			
2.1 Height of plant	0.530**	0.460*	0.348
2.2 Number of leaves	0.314	0.268	0.187
2.3 Fruiting branches	0.419*	0.400*	0.393*
3. At harvest			
3.1 Height of plant	0.489**	0.363	0.275
3.2 Fruiting branches	0.345	0.331	0.305
3.3 Number of pods per plant	0.192	0.171	0.110
4. Root : Shoot ratio	0.552**	0.954*	0.892*
5. Root characters			
5.1 Root length	0.463*	0.394*	0.443*
5.2 Root spread	0.550**	0.490**	0.475*
5.3 Effective nodules	0.554**	0.464*	0.407*
5.4 Ineffective nodules	0.414*	0.280	0.221
6. Bhusa yield	0.389*	0.310	0.282

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

Bacteria	:	67×10^6
Actinomycetes	:	8.3×10^5
Fungi	:	1.3×10^5

4.10 Correlation studies

4.10.1 Correlation between yield and biometric characters

Grain yield was significantly and positively correlated with height of plant at flowering and at harvest and number of fruiting branches at flowering. Similarly root : shoot ratio and root characters like root length, root spread and effective nodules also significantly influenced the grain yield. Effective nodules at flowering stage showed the highest degree of correlation with grain yield (r = 0.554).

Number of pods per plant was significantly and positively correlated with height of plant and number of fruiting branches at flowering stage. Root shoot ratio showed the highest degree of correlation with number of pods (r = 0.954). It was also significantly and positively correlated with root length, root spread and number of effective nodules.

Weight of pods plant^{-1} was significantly and positively correlated with fruiting branches at flowering stage. Root : shoot ratio, root length, root spread and effective nodules also positively influenced weight of pods. Root ; shoot ratio showed the highest degree of correlation with weight of pods (r = 0.892).

Table No.18 Correlation between yield and soil available nutrients

Nutrients	Grain yield	Number of pods	Weight of pods
Nitrogen	0.387*	0.346	0.296
Phosphorus	0.597**	0.271	0.193
Potassium	0.644**	0.586**	0.476*
Calcium	0.370	0.353	0.428*
Magnesium	0.550**	0.454*	0.441*
Copper	0.319	0.292	0.343
Manganese	0.705**	0.695**	0.660**
Zinc	0.595**	0.548**	0.592**

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

Table No.19 Correlation between uptake of nutrients and yield

(a) maximum flowering stage

Nutrients	Grain yield	Number of pods	Weight of pods
N	0.446*	0.475*	0.506**
P	0.294	0.317	0.467*
K	0.177	0.203	0.334
Ca	0.098	0.133	0.253
Mg	0.245	0.274	0.416*
Cu	0.120	0.124	0.297
Mn	0.304	0.350	0.460*
Zn	0.209	0.236	0.280

(b) harvest

Nutrients	Grain yield	Number of pods	Weight of pods
N	0.837**	0.818**	0.786**
P	0.876**	0.893**	0.858*
K	0.646**	0.600**	0.586**
Ca	0.496**	0.420*	0.422*
Mg	0.704**	0.645**	0.602**
Cu	0.816**	0.778**	0.744**
Mn	0.742**	0.689**	0.646**
Zn	0.785**	0.759**	0.739**

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

4.10.2 Correlation between nutrient uptake by plants and yield

Nutrient uptake by plants was positively correlated with grain yield, number of pods and weight of pods. Among the uptake of nutrients at flowering stage, N uptake was significantly correlated with grain yield, number of pods and weight of pods (r = 0.446, 0.475 and 0.506 respectively). P, Mg and Mn uptake at flowering stage were positively and significantly correlated with weight of pods per plant.

At harvest, uptake of all the nutrients showed positive and significant correlation with grain yield, number of pods and weight of pods. Among them, P uptake gave the highest correlation with all the above three parameters with r values being 0.876, 0.893 and 0.858, respectively.

4.10.3 Correlation between yield and soil available nutrients

Grain yield, number of pods and weight of pods were positively correlated with soil available nutrients. Available P, Mg, Mn and Zn showed significant positive correlation with all the three yield attributing characters. Grain yield was positively and significantly correlated with available P, K, Mg, Mn and Zn. Available Mn status of soil showed the highest degree of correlation with grain yield (r = 0.708). Number of pods $plant^{-1}$ was positively and significantly correlated with available K, Mg, Mn and Zn content of soil. Similarly,

Table No.20 Co-efficient of correlation between nutrient uptake and soil available nutrients

Uptake	Soil available nutrients							
	N	P	K	Ca	Mg	Cu	Mn	Zn
N	0.338	0.519**	0.143	0.642**	0.377	0.262	0.558**	0.443*
P	0.074	0.280	0.018	0.620**	0.285	0.268	0.390*	0.391*
K	0.139	0.309	0.069	0.624**	0.300	0.308	0.300	0.345
Ca	0.047	0.256	-0.142	0.516**	0.172	0.105	0.265	0.322
Mg	0.036	0.294	-0.022	0.662**	0.269	0.290	0.364	0.432*
Cu	0.183	0.204	0.074	0.669**	0.422*	0.410*	0.395*	0.427*
Mn	0.217	0.382*	-0.007	0.720**	0.523**	0.472*	0.623*	0.598**
Zn	0.265	0.245	0.148	0.521**	0.439*	0.238	0.460*	0.394*

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

available K, Ca, Mg, Mn and Zn showed significant positive correlation with weight of pods $plant^{-1}$.

4.10.4 Correlation between soil available nutrients and nutrient uptake

The available P content of soil is significantly and positively correlated with the uptake of N by plants. Available Ca content of soil is also significantly and positively correlated with the uptake of N, P, K, Ca, Mg, Mn, Zn and Cu by plants with r values being 0.642, 0.620, 0.624, 0.516, 0.622, 0.669, 0.720 and 0.521 respectively. Mg content of soil enhances the uptake of Cu, Mn and Zn as evident from the r values (0.422, 0.523 and 0.439). N, P, Cu and Zn uptake by plants is significantly influenced by the Mn content of soil while Zn content of soil shows a significant positive correlation with N, P, Mg, Cu and Mn uptake by plants. A negative correlation is observed between the K content of soil and the uptake of Ca, Mg and Mn.

DISCUSSION

DISCUSSION

Several scientists have studied the feasibility of economically utilizing vermicompost and a few of the botanicals like leaf dust, saw dust,etc. by coating them on seeds prior to sowing. Such organic pelleting of seeds, besides improving germination and seedling growth has resulted in higher yield. It has been observed that a number of beneficial microorganisms are present in close association with vermicompost. 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 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 in the soil. The group of microorganisms responsible for nitrogen fixation, P solubilisation and organic matter decomposition are put to beneficial use in the form of biofertilizer. Preliminary studies conducted at the College of Agriculture, Vellayani have shown the effectiveness of vermicompost coating of seeds on germination, seedling vigour and nodulation. Coating seeds with vermicompost will help to introduce these beneficial micro-organisms into the rhizosphere of the plant resulting in an increase in the availability of N and P due to biological fixation of N and biological solubilisation of P. The present study is taken up to find out the feasibility of using vermicompost as an inoculum of these beneficial microbes through seed coating. Hence studies are conducted to compare the effect of coating seeds with vermicompost as well as rhizobium and their direct application in soil by using cowpea as the test crop. Seed pelleting is an innovative approach for successful agriculture for precision sowing and maintenance of desired population of vigorous plants.

The results generated from present study are discussed in the light of published information and fundamental theoretical knowledge.

5.1 Biometric characters

From the results, it is inferred that the seedling vigour as measured by height, number of leaves and seedling girth was not significantly influenced by the different treatments. The maximum value for seedling girth was obtained for treatment where seeds were coated with vermicompost (Fig. 3)

At maximum flowering stage, coating seeds with vermicompost produced the maximum value for plant height and number of leaves, while uncoated seeds supplied with

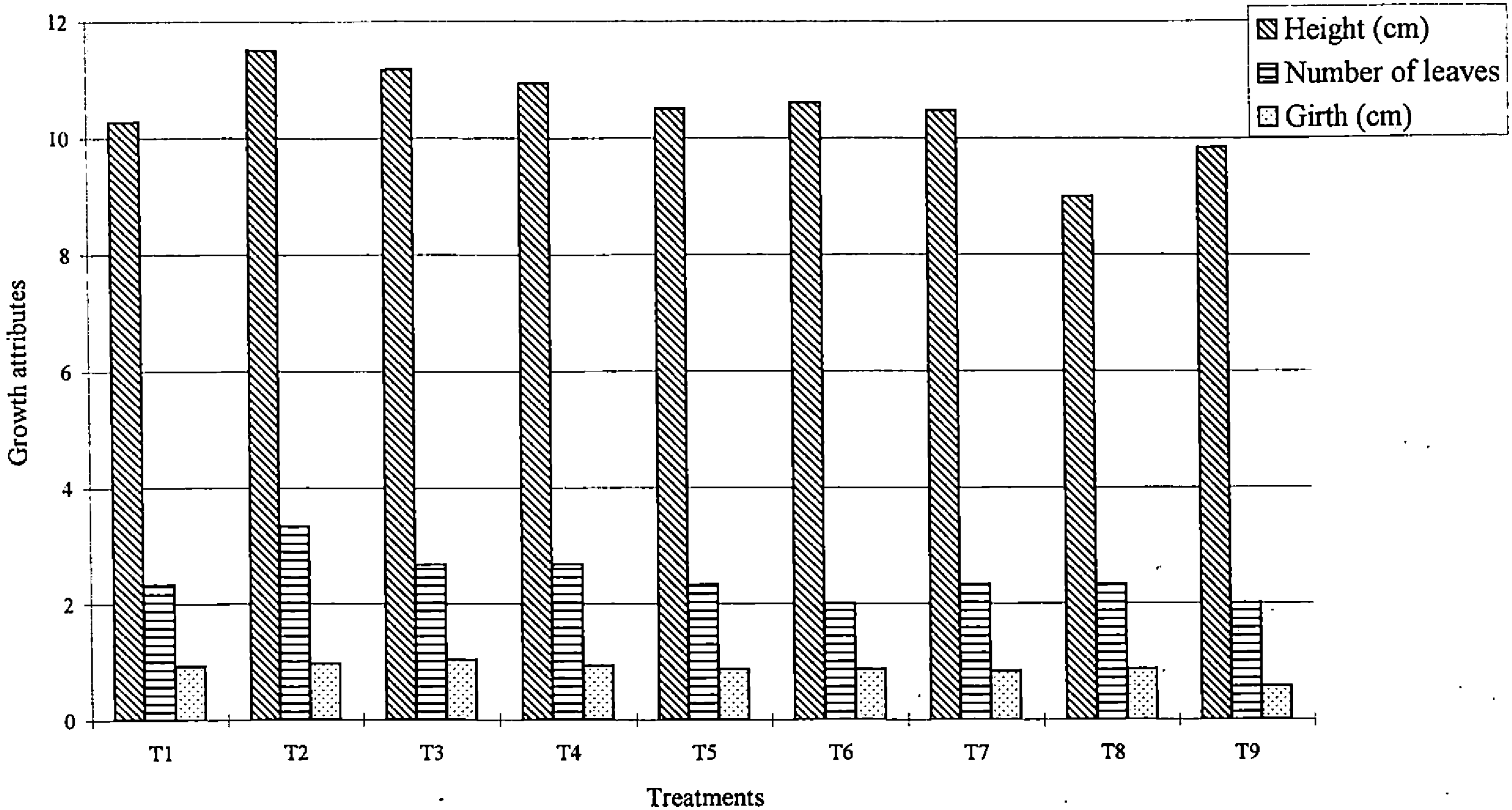


Fig. 3 Seedling vigour at two weeks after sowing

vermicompost as organic source recorded the maximum value for number of fruiting branches per plant (Fig. 4). Similar observations were made by scientists on the influence of vermicompost in enhancing the flowering characters of rice. The presence of phytohormones, enzymes, antibiotics, vitamins etc. in vermicompost may be positively influencing the early flowering in plants as well as the number of fruiting branches per plant. Enhanced plant height on vermicompost application was in confirmity with the findings of Ismail *et al*. (1991, 1993a), Shuxin *et al*. (1991), Stephens *et al*. (1994) and Vadiraj *et al*. (1996). The increase in plant height is attributed to the rapid meristmatic activity due to the positive influence of vermicompost leading to an increase in the vegetative growth.

Introducing *Rhizobium* through seed inoculation and use of vermicompost is known to improve the physico-chemical properties of soil. They improve the biometric characters by way of increased biological N fixation, increased availability and uptake of nutrients through solubilisation or increased absorption, stimulation of plant growth through hormonal action or by decomposition of organic residues. This results in a better establishment of plants with a higher number of leaves and photosynthetic area. This is in confirmity with the findings of Sudhakar *et al*. (1989), Cao (1993), Margaritha and

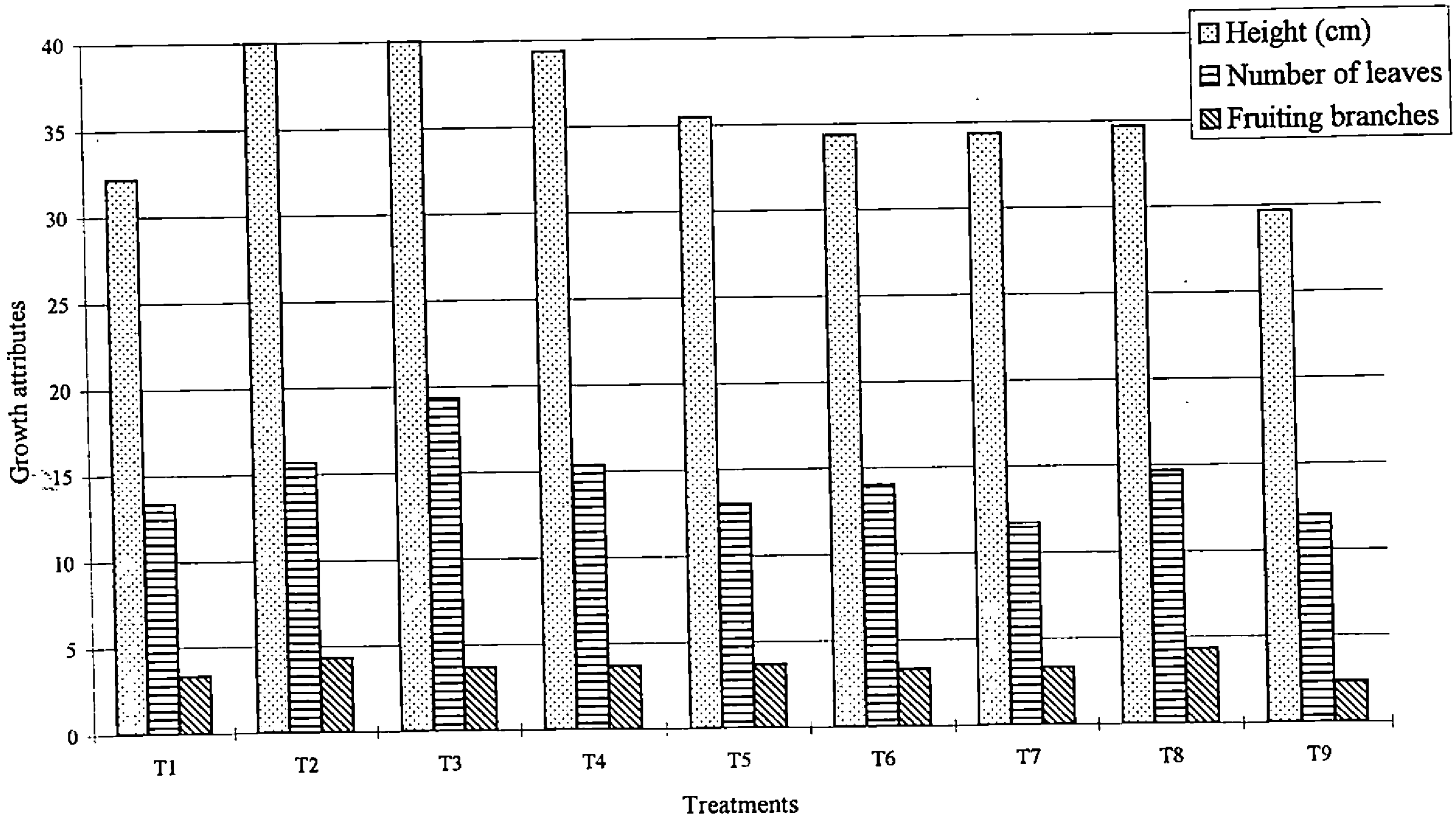


Fig. 4 Height of plant, number of leaves and fruiting branches per plant at flowering stage

Maria (1993), Sundaravelu and Muthukrishna (1993) and Doube *et al*. (1994).

At harvest stage, as indicated in Fig. 5, the maximum value for number of fruiting branches and pods per plant was recorded by the treatment in which seeds were coated with vermicompost. Combined coating of seeds with *Rhizobium* and vermicompost produced the highest plant height. Since vermicompost is reported (Indira *et al*, 1996) to contain nitrogen fixing bacteria, inoculation of seeds with vermicompost can lead to an increase in the N content of soil through biological N fixation thereby promoting the vegetative growth of plants. Similar observations of increasing plant growth by the application of vermicompost have been reported by Edwards and Lofty (1980), Grappelli *et al*. (1985), Tomati *et al*. (1987, 1988) and Sharma and Maden (1988).

The vegetative growth in vermicompost treated plants is enhanced by the release of plant growth promoting compounds by earthworms into their casts (Nielson, 1965). This can increase the polymerisation of aromatic compounds thereby accelerating the humification and growth characteristics (Neuhauser and Hartenstein, 1978 and Neuhauser *et al*., 1978). The significant influence of vermicompost in enhancing the biometric characters may be due to the improved plant metabolism resulting in a higher utilization of plant nutrients leading to an increased vegetative growth.

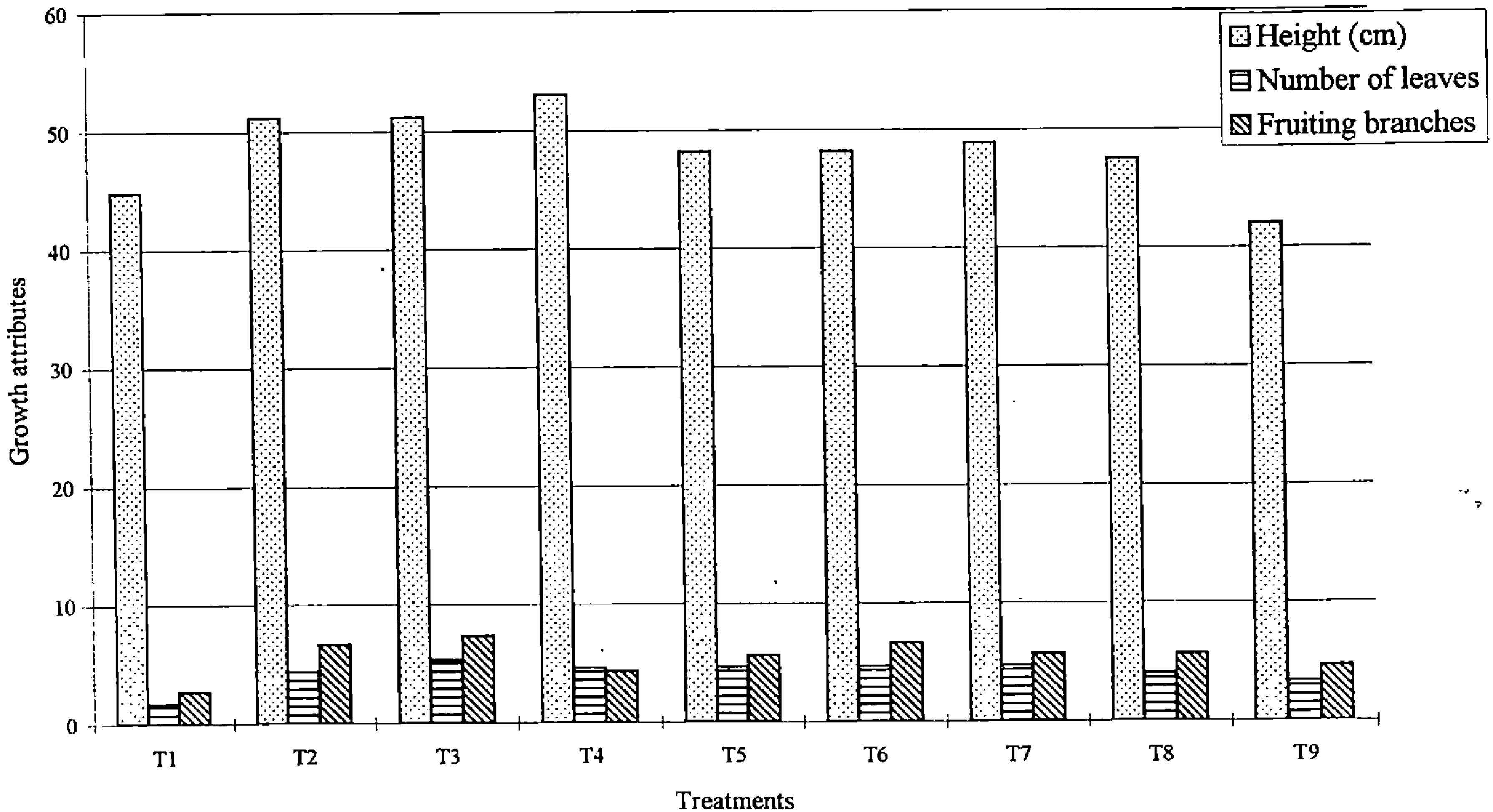


Fig. 5 Height of plant, number of fruiting branches and pods per plant at harvest

5.2 Rooting pattern, Nodulation and Root : Shoot ratio

The results revealed that the root length, root spread and number of effective nodules were significantly influenced by the different treatments (Fig. 6 and 7). Application of vermicompost as an organic source (T_8) produced the maximum root length while coating of seeds with *Rhizobium* (T_2) resulted in maximum root spread and effective and ineffective nodules. Application of vermicompost as an organic source as well as a seed inoculant has influenced positively the root : shoot ratio in cowpea. The results obtained from the present study are in confirmity with the findings of Sairam *et al.* (1989) that inoculation with *Rhizobium* improved the rooting pattern, nodulation and nodule leghaemoglobin content of cowpea. Inoculation with vermicompost might have increased the bacterial number in the rhizosphere which in turn might have produced more plant growth promoting substances resulting in better root growth. The rooting pattern plays an important role since the exudation sites are constantly displaced depending on the pattern of its root system.

The root exudates help in the build up of microbial population introduced by vermicompost into the rhizosphere of the plant. Thus the microenvironment created by the interaction between chemicals secreted by living roots and micro-organisms in the rhizosphere positively influences the

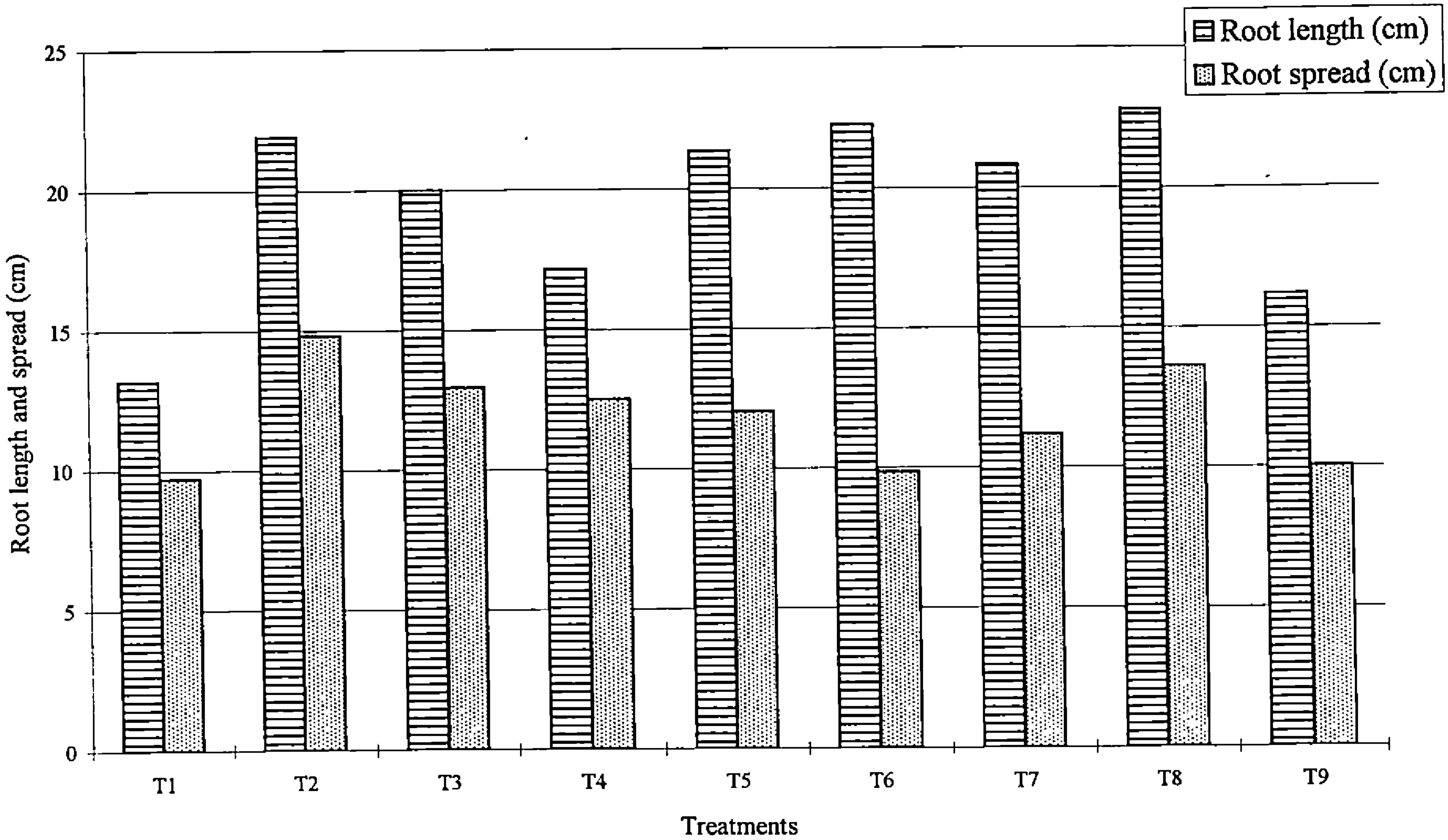


Fig. 6 Rooting pattern at maximum flowering stage

root growth and root ramifications, thereby the nodulation. Vermicompost application enhances root growth and root spread and also the production of root exudates. The flavonoids in root exudates also induces the transporation of an important set of nodulation genes (Peters *et al*., 1986 and Kosslak *et al*., 1987). The mechanism by which the plants inoculated with vermicompost and *Rhizobium* derive positive benefits in terms of plant biomass and nodulation can be attributed to the development and branching of roots, production of plant growth hormones, increased nitrate reductase activity and production of antifungal and antibacterial compounds (Okon, 1985; Pandey and Kumar, 1989 and Wani, 1990). Increased nodulation in vermicompost treated plants is not only due to the increased supply of nutrients to plants but also due to the direct effect on nodule bacteria. It stimulates the multiplication of nodule forming bacteria and was found conducive to the development of motile forms which are essentially required to migrate through the soil towards the root system (Madhok, 1961).

Several workers have reported significant increase in nodulation of legumes on inoculation with biofertilizers like *Rhizobium* (Santos *et al*., 1990; Namdeo *et al*., 1991, Patel and Patel, 1991a; Mundra and Bhati, 1994; Rajput, 1994; Bhalu *et al*., 1995 and Purushottam Kumar *et al*., 1995).

Application of farmyard manure as an organic source along with vermicompost as a seed inoculant has produced almost

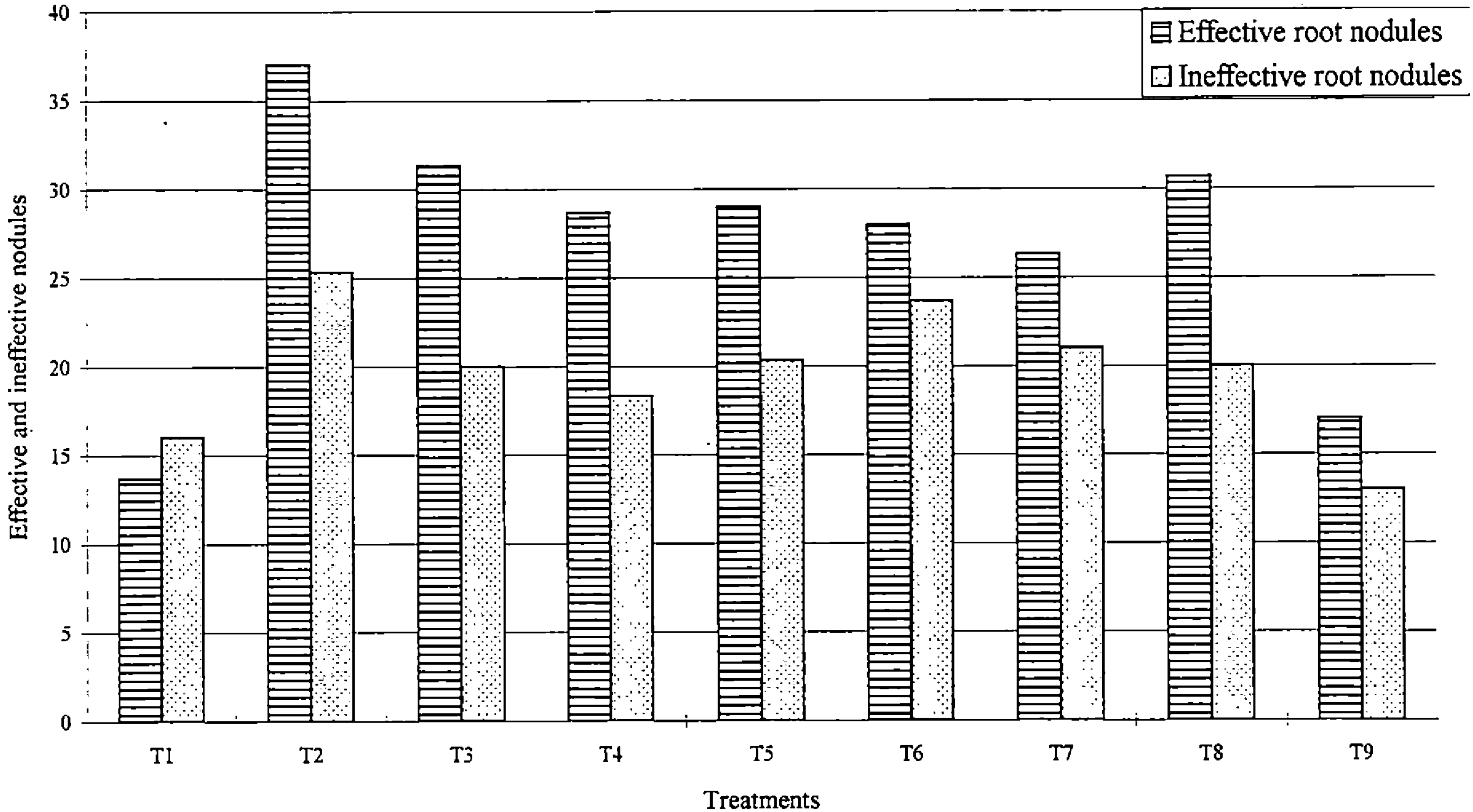


Fig. 7 Effective and ineffective nodules at maximum flowering stage

the same effect as that of the application of vermicompost as an organic source on biometric and root characters.

5.3 Yield and yield attributes

The total grain yield of cowpea was significantly influenced by the different treatments. Seeds coated with vermicompost along with FYM as organic source yielded the maximum value for total grain yield, number of pods, weight of pods and number of seeds per pod. However, among the different yield attributes studied, a significant effect was shown only by the number of pods per plant (Fig. 8 and 9).

Application of vermicompost as an organic source or as a seed inoculant stimulates microbial activity and enhances nitrogen fixation (Parkin and Berry, 1994 and Bohlen and Edwards, 1995). This enrichment of soil nitrogen due to N fixation increased N uptake and result in increased yield. The increased yield cannot be explained by N effect alone, but it may be due to several factors like improved soil physical, chemical and biological properties (Bezdicek and Granatstein, 1989).

Increase in grain yield owing to the seed treatment with vermicompost (T_3) may be attributed in part to the production of humic substances which improves the physical and chemical properties of soil as well as the release of nutrients and

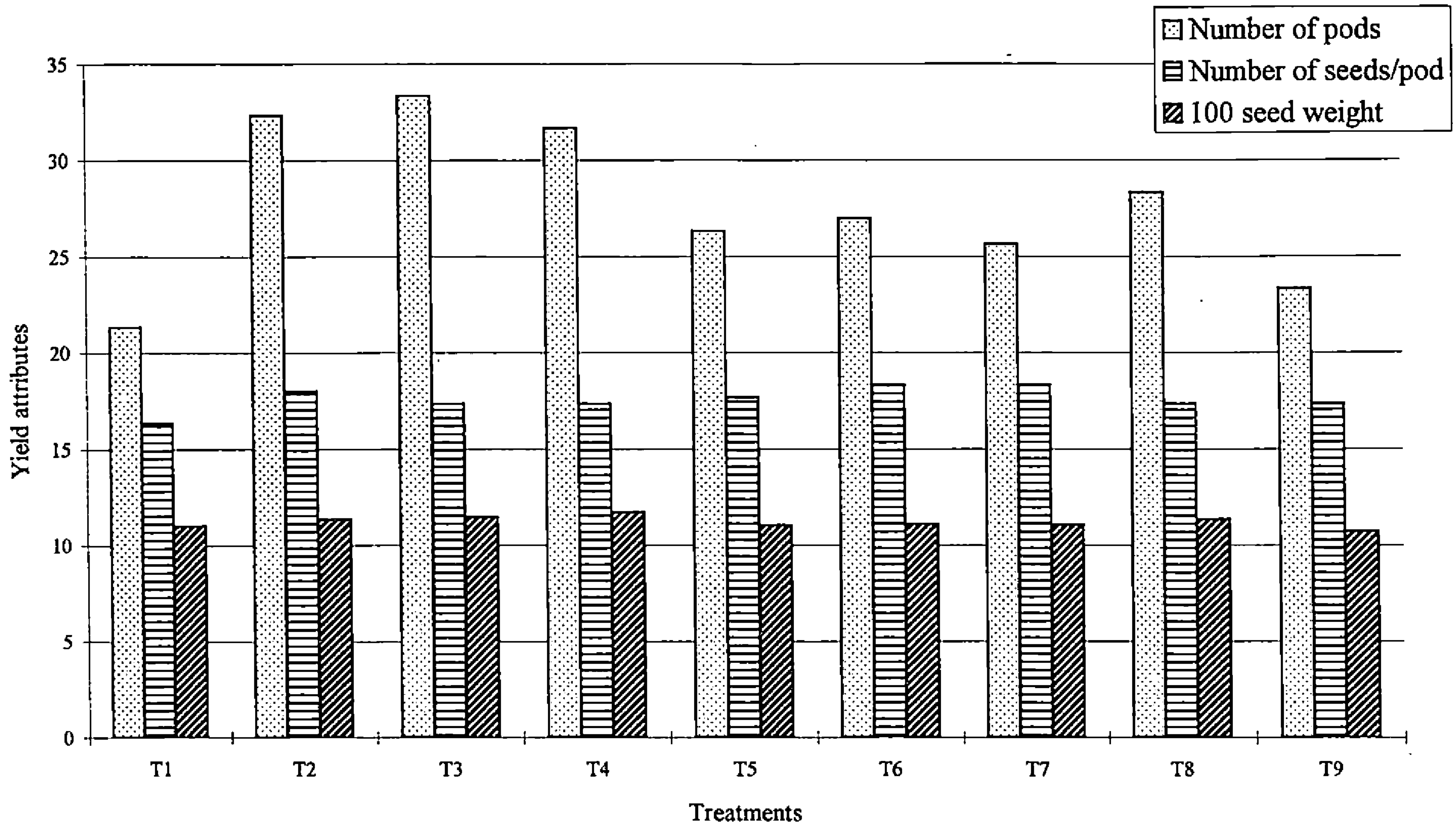


Fig. 8 Effect of treatments on yield attributes

hence their availability to plants (Nafadi and Gohar, 1975 and Sakr, 1985). Effect of worm activated soil or worm worked compost in enhanching the yield of crops was reported by Atlavinyte and Zimkuviene (1985) in barley, Senapathi *et al.* (1985) in paddy, Sacirage and Dzelilovic (1986) in cabbage, Ismail *et al.* (1991) in watermelon, Shuxin *et al.* (1991) and Phule (1993) in sugarcane, Barve (1993) in grapes, Desai (1993) and Ismail *et al.* (1993b) in chilli, Sharma (1994) in wheat and maize, Zacharia and Prabhakumari (1996) in chilli and Baker *et al.* (1997) in wheat. Dharmalingam *et al.* (1995) observed 16 per cent increase in grain yield when soybean seeds were coated with vermicompost. The grain yield of second crop of cowpea which was grown to study the residual effect of inputs supplied to the first crop was also significantly influenced by the different treatments. Seeds coated with vermicompost and supplied with NPK fertilizers recorded the highest grain yield of the residual crop. This reveals the residual effect of vermicompost in enhancing the growth and yield of plants. The higher availability of N and P due to improved physical environment created by worms, N fixing and P solubilising organisms might have contributed to highest yield (More, 1994).

Similar observations were made by Rewari (1984, 1985) and Verma and Bhattacharya (1990). Hence the response of cowpea plants to inoculation with vermicompost and *Rhizobium* are manifested in increased grain yield and plant biomass

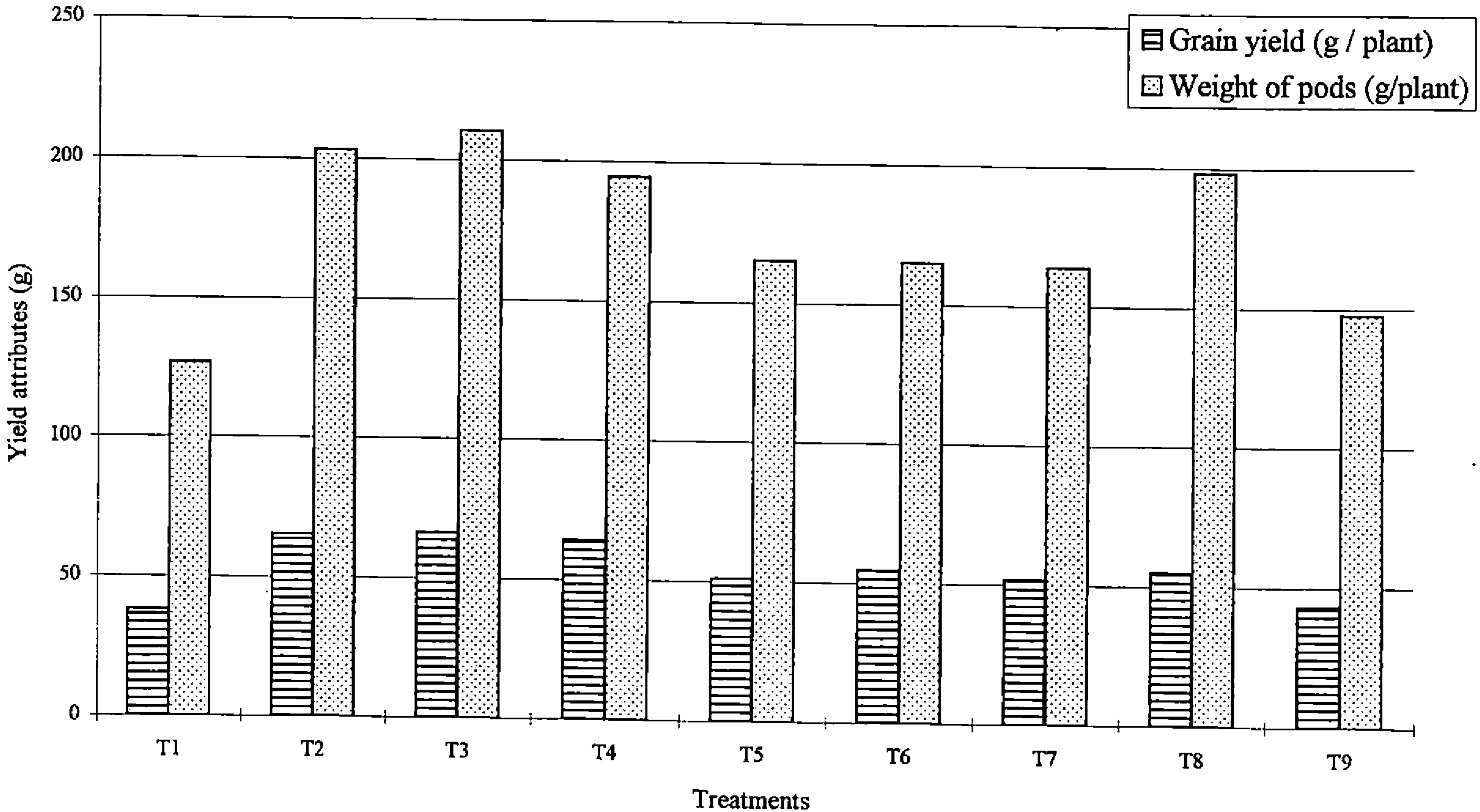


Fig. 9 Total grain yield and weight of pods

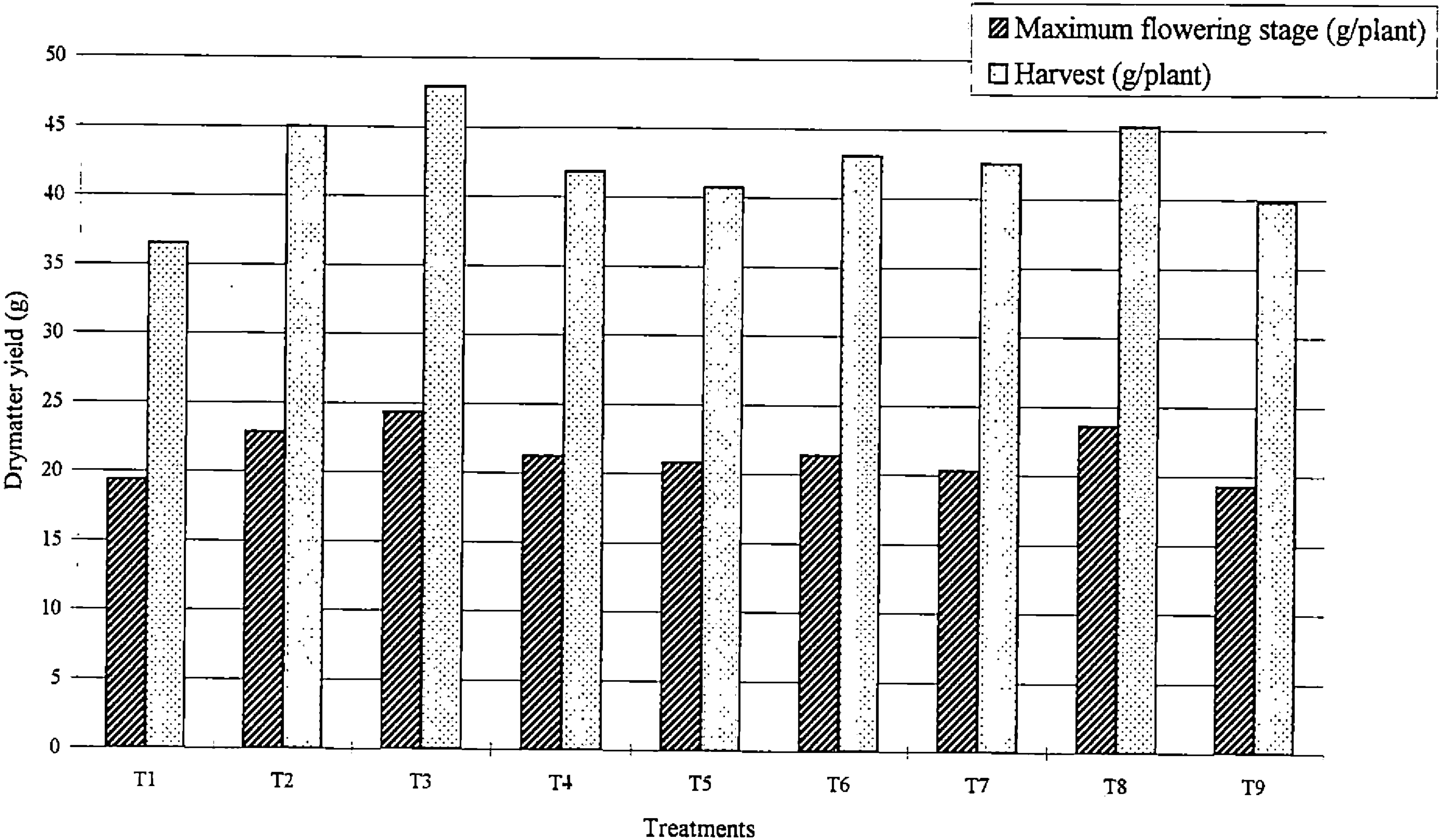


Fig. 10 Drymatter yield at maximum flowering stage and at harvest

yield, which may be due to increased nutrient uptake, grain and tissue N content, nitrogenase actvity, early flowering, increased enzyme level in plants and reduced insect and disease infestation.

The total grain yield obtained in the present study was significantly higher in treatments where vermicompost was applied either as an organic source or as a seed inoculant. However, highest yield was reported by plants where seeds were coated with vermicompost. The plants from vermicompost pelleted seeds supplemented with NPK fertilizers gave higher yield of 66.20 g plant^{-1} as against 38 g plant^{-1} for nonpelleted control striking an increase of 42 per cent. Since the method of coating seeds with vermicompost along with application of 20 t of FYM ha^{-1} as an organic source gave better results in terms of yield when compared to soil application, it is very cost effective. Also the method is eco-friendly and easy to do. Similar observations of increased yield in pearlmillet by inoculation with biofertilizer has been reported by Tien *et al*. (1979). They have attributed the yield increase to indole acetic acid, gibberellins and cytokinin like substances produced by the microbes.

5.4 Phosphorus solubilisation capacity

Eventhough P solubilisation capacity of soil was not significantly influenced by the different treatments at any of

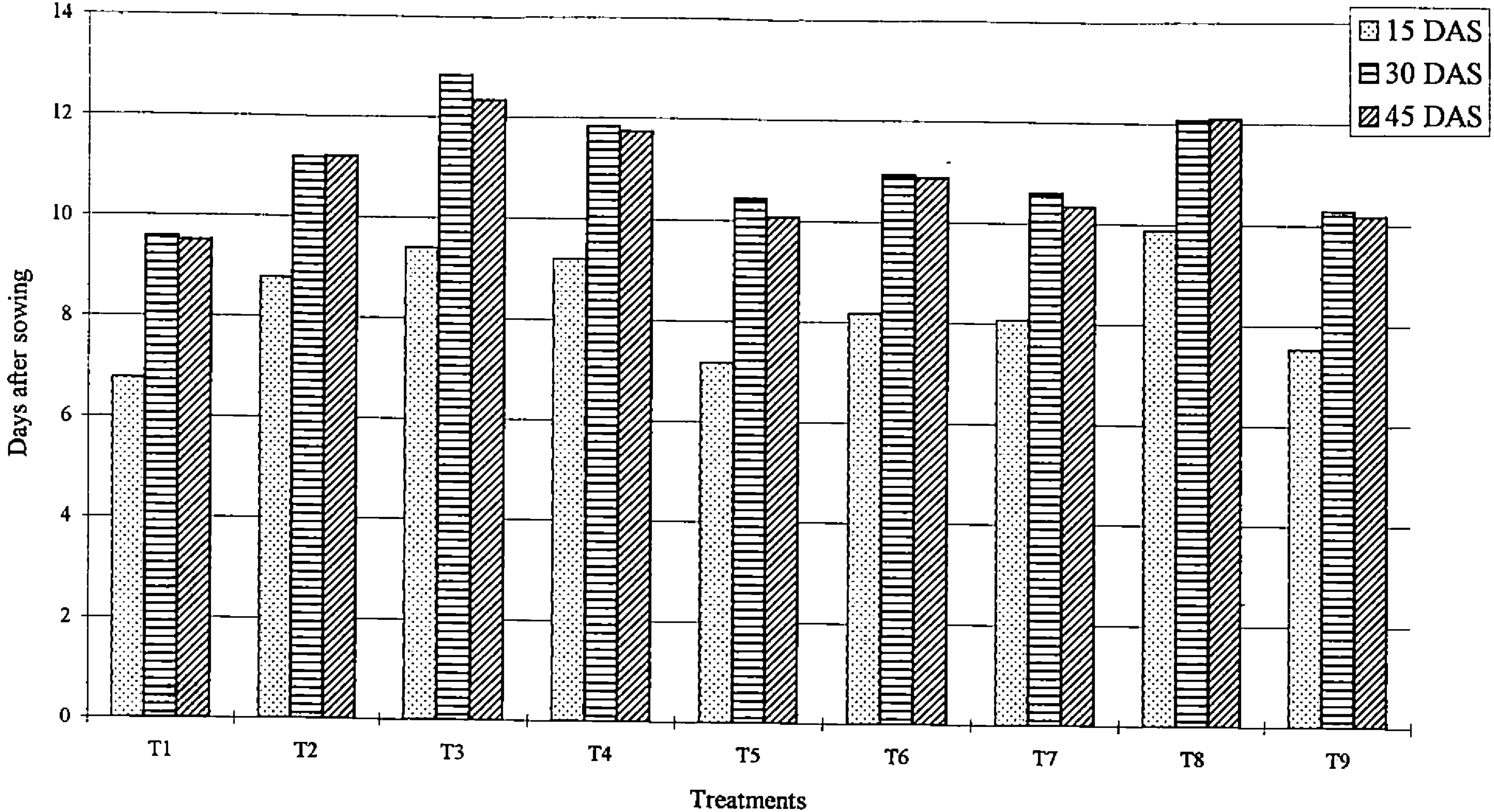


Fig. 11 Phosphorus solubilisation capacity of soil at periodical intervals upto flowering stage (μ g 10 g^{-1} soil)

the stages, the maximum value was obtained for the treatment (T_3) where seeds were coated with vermicompost and supplied with farmyard manure as the organic source and full NPK fertilizers (Fig. 11). P solubilisation capacity was studied at periodical intervals upto flowering viz., 15 DAS, 30 DAS and 45 DAS. This study was undertaken to assess the potential of using P solubilising bacteria in vermicompost with a view to utilise them as biofertilizer source to boost the fertility of acid soils of Kerala.

5.5 Nitrogen fixing capacity

Nitrogen fixing capacity of soil was studied at fortnightly intervals upto flowering and it was noticed that maximum amount of N fixation occurs at flowering stage. The different treatments had significant influence on the N fixing capacity of soil during the later stages of crop growth viz, 30 DAS and 45 DAS. During all the three crop growth stages, coating of seeds with *Rhizobium* combined with full NPK fertilizers yielded the highest value for N fixation. However, it was on par with T_8 where vermicompost as organic source along with inorganic fertilizers was supplied. Vermicompost is reported to contain about 10^6 N fixers per g of soil (Indira *et al.*, 1996). N fixing micro-organisms together with other microbes are common in the gut content of earthworms (Edwards, 1974). They synthesize nitrogenase enzyme responsible for converting inert nitrogen to plant usuable ammonia. The presence of N fixers in the gut of earthworms could indicate that there is a true symbiotic relationship that promotes N fixation.

Inoculation with biofertilizers enhances nitrogenase activity, the enzyme responsible for the fixation of atmospheric nitrogen (Sekhon *et al.*, 1986; Kothari and Saraf, 1987; Patyka *et al.*, 1987; Maiti *et al.*, 1988; Nadkernichnaya *et al.* 1989; Rajeswari, 1991; Yadav *et al.*, 1992 and Baboo and Kumar, 1996). This resulted in increased N fixation by plants and helps in N economy of pulses. The effect of bio-inoculants in increasing N fixation in crops has been reported by Fernandez and Miller (1986) in cowpea, Rai and Sinha (1986) in peas, Cao (1993) in clover, Sundaravelu and Muthukrishna (1993) in radish and Bhalu *et al.* (1995) in blackgram. Considerable amount of N was fixed by plants where seeds were coated with vermicompost (T_3). Seed inoculation with organic materials aid in the survival of N fixing organisms on the seed or at close proximity of roots in the rhizosphere. The presence of growth hormones such as cytokinins, IAA, gibberellins etc. in vermicompost have accelerated the nitrogen fixation since the growth hormones alleviate some of the inhibitory effects of nitrate on the curling of root hairs, development of infection thread and formation of nodules.

The mechanism by which plants inoculated with vermicompost derive positive benefits in terms of plant biomass

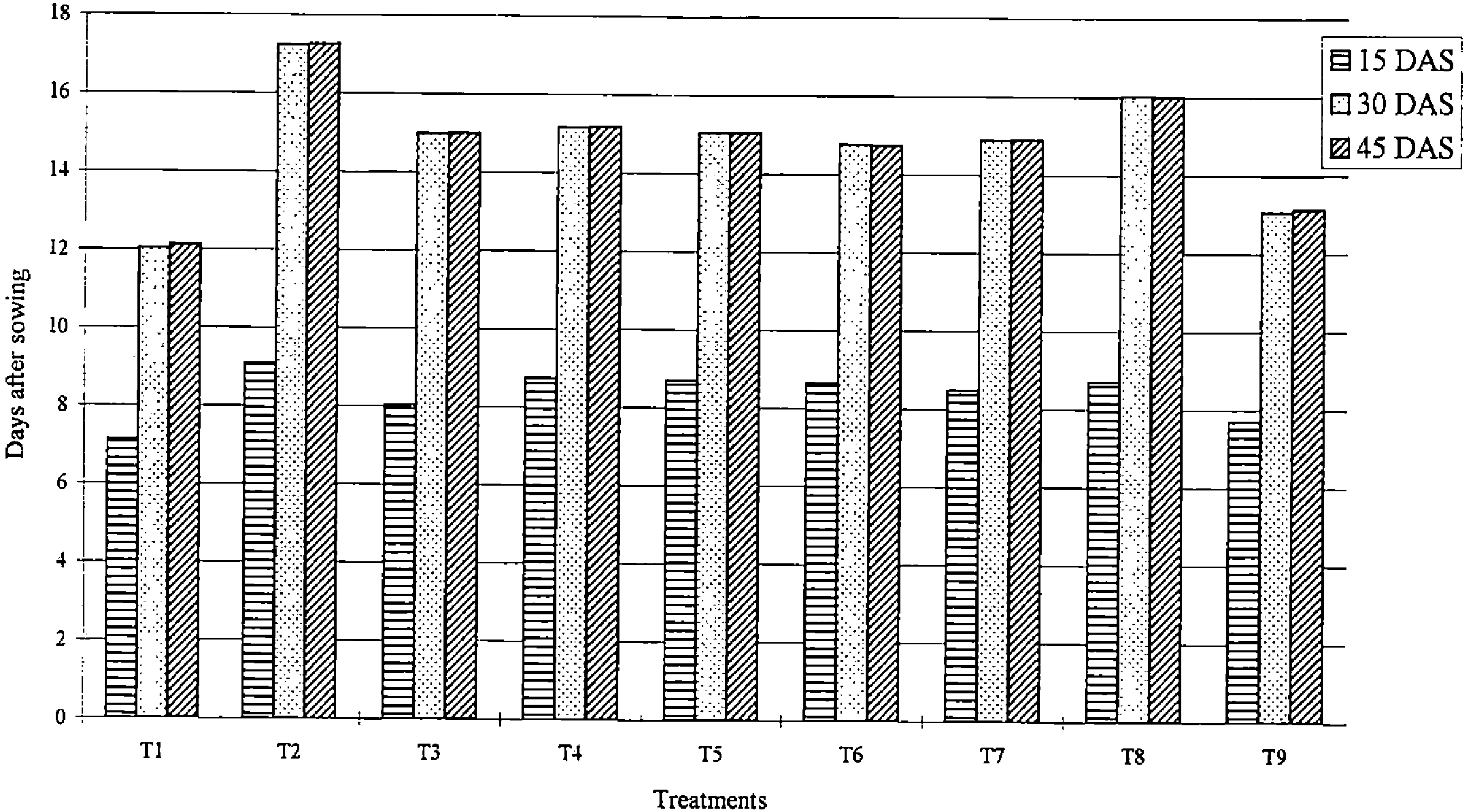


Fig. 12 Nitrogen fixation capacity of soil at periodical intervals upto flowering stage ($\mu g\ g^{-1}$ soil)

and N uptake are attributed to small increase in N input, enhancement in uptake of NO^-_3, NH^+_4, $H_2PO^-_4$, K^+, Rb^+ and Fe^{2+}, increase in nitrate reductase activity in plants etc. The extent of establishment of inoculated bacteria in soil through biofertilizer' is dependent on the type of legumes, effectiveness of strain, inorganic mineralisable N content of the soil, level of soil available P and K, pH and presence of usuable forms of secondary nutrients.

The available plant nutrients in vermicompost might have influenced the nodulation and N fixation which were reflected in the seedling vigour and growth of the host plant. Also, the application of vermicompost enhances the soil pH, which is again favourable for N fixation since at low pH N fixation will be inhibited by the high H^+ ion^- concentration as well as the presence of high Fe or Al and low Mo ions. Nodulation and N fixation are dependent on the carbohydrate : N ratio within the plant, which is favourably maintained by the application of vermicompost as an organic source. The N fixing bacteria introduced into the rhizosphere of the plant by coating seeds with vermicompost, fix N by using varied carbon sources (Mohan *et al*., 1987). Symbiotic N fixing bacteria in the bioinoculant infect the host plant with the subsequent formation of nodules (Triplett, 1990).

5.6 Soil available nutrients

The available nutrient status of soil is greatly enhanced by the application of vermicompost as an organic source or as a seed inoculant to the soil. Earthworm casts are enriched with nutrients essential for the growth of plants (Edwards and Lofty, 1977 and Lee, 1985a). The enrichment may be due to preferential feeding of earthworms in horizons of higher nutrient status and/or clay content and/or organic matter and higher microbial activity in the cast compared to soil (Gorberko *et al*., 1986 and Tiwari *et al*.,1989). The worm casts have been reported to contain more exchangeable cations and organic carbon (Cook *et al*., 1980; Tiwari *et al*., 1989 and Hullugale and Ezumath, 1991). The effect of earthworms or worm cast activity on plant nutrient availability may be due to trituration and comminution of organic matter in the earthworm gut. The process increases microbial activity and generally accelerates organic matter decomposition with the subsequent release of plant nutrients in the earthworm casts (Lavelle *et al*., 1989). Earthworms increased the amount of extractable N by feeding on microbial biomass and increasing the turnover and mineralization of microbial tissues (Bohlen and Edwards, 1995).

The treatments had no significant influence on the availability of N, P and K in soil at flowering stage (Fig. 13). However, the treatment (T_2) where seeds were coated with *Rhizobium* and supplied with full NPK fertilizers and farmyard manure as organic source recorded the highest availability of N in the soil. The maximum availability of P and K was obtained for vermicompost coating of seeds (T_3) combined with full NPK fertilizer and farmyard manure as organic source. Ca and Mg status of soil and also the availability of micronutrients was significantly influenced by the different treatments. Soil application of vermicompost @ 20 t ha^{-1} recorded the highest value for available Ca, Mg, Zn and Cu in the soil. Mn availability was highest for vermicompost coating of seeds (T_3) and supplied with inorganic fertilizers.

Inoculating seeds with vermicompost and *Brady rhizobium* stimulates nitrogenase enzyme responsible for the fixation of atmospheric N in legumes. This inturn enriches the N status of soil and thereby increases the availability of N in soil. This is in confirmity with the findings of Baldeo *et al*. (1992) in cowpea and Yadav *et al*. (1992) in maize. Srivastava (1985) opined that increased use of nitrogenous fertilizer decreased the organic carbon content and total N, which retards the N fixing capacity. Increased availability of N in vermicompost treated plots may be due to increased content of N in vermicompost which may be due to the presence of relatively higher percentage of N in wormcasts when compared to farmyard manure. Earthworms have been associated with increased cast levels of available N (Tomati *et al*., 1983). Earthworm casts have been found to contain elevated amounts of NH^{+}_{4}, NO^{-}_{3}, Mg,

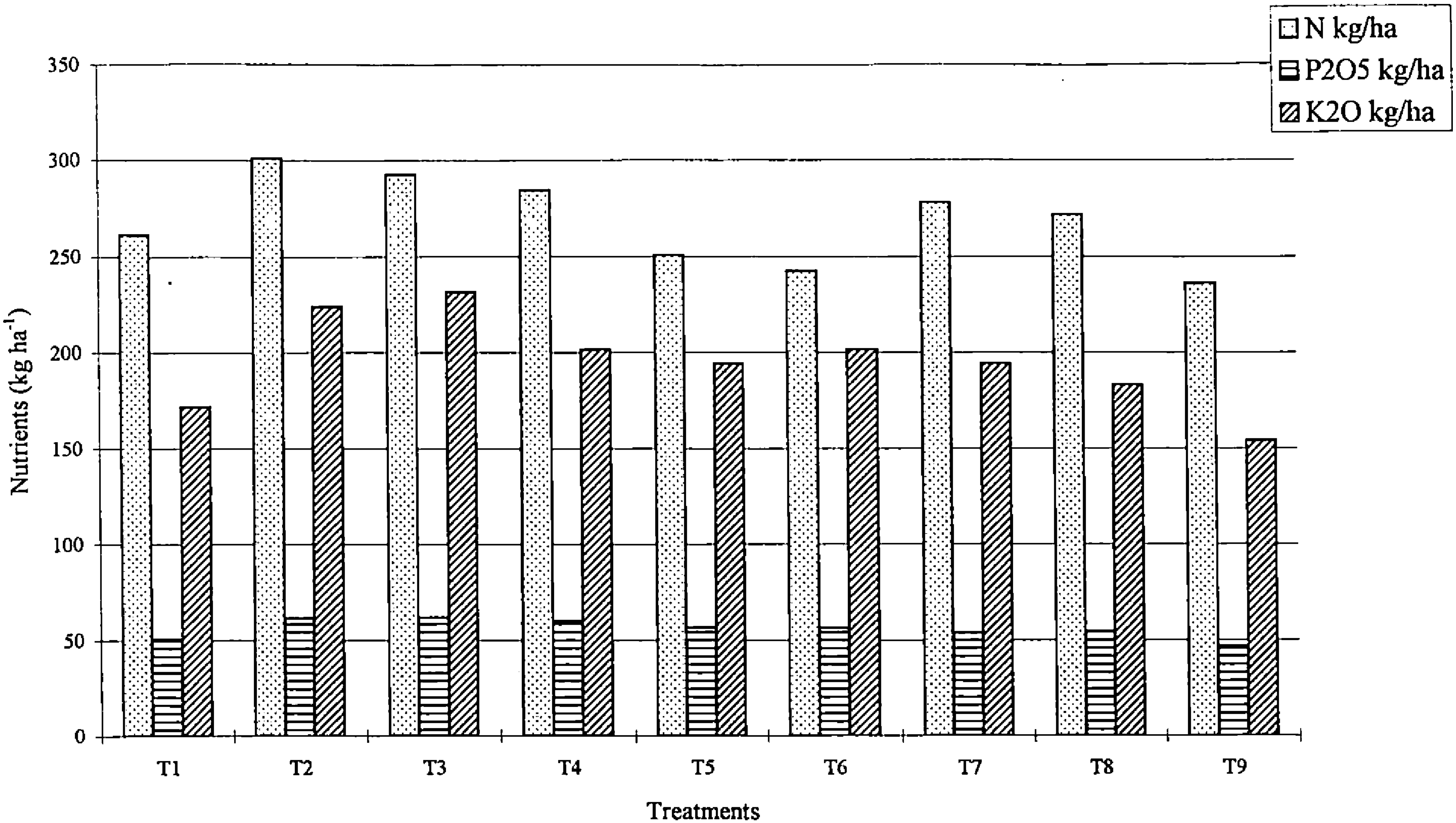


Fig. 13 Analysis of soil at maximum flowering stage for nitrogen, phosphorus and potassium

K and P relative to surrounding soil (Gupta and Sakal, 1967; Tiwari *et al*., 1989 and Parkin and Berry, 1994). Increased availability of N in soil and increased N recovery due to the application of vermicompost as an organic source has been reported by several workers (Srivastava, 1985; Bouche and Ferrierie, 1986; Azam, 1990; Lavelle *et al*., 1991; Kale *et al*., 1992; Kalembasa *et al*., 1993; Miura *et al*., 1993; Romero and Chamooro, 1993; Hameed *et al*., 1994; Parkin and Berry, 1994; Srinivasa Rao *et al*., 1996 and Vasanthi and Kumaraswamy, 1996). Increased availability of N in wormcast treated plots may be due to the release of nitrogenous products of earthworm metabolism to the soil through the cast, urine as well as the mucoproteins.

The vermicompost used in the present study is prepared by using the epigeic earthworm sp. *Eudrillus eugineae*. Since this worm belongs to the merenephridial species, the casts would be more enriched with N, since the urine produced by septal nephridia is discharged into the gut and voided along with casts. So the addition of these wormcasts either as a seed coat or as an organic source has significantly improved the N status of soil.

Phosphorus availability in soil was not significantly influenced by the different treatments. However, the treatment where seeds were coated with vermicompost (T_3) recorded the highest avaialbility of P in soil. Increased P_2O_5 availability in soil during crop growth by phosphorus fertilization and farmyard manure addition was reported by Muthuvel *et al*. (1987) and Shanmugham (1989). Increase in total and available P_2O_5 content due to vermicompost application was reported by Gaur (1990). The higher P content of vermicompost might have reflected in higher P status of soil. This may be due to greater mineralisation of organic matter with the aid of microflora associated with earthworms. As discussed earlier, the presence of P solubilising organisms in vermicompost may be enhancing the biological solubilisation of P thereby increasing the available P_2O_5 status of the soil.

The increased availability of P in wormcasts is not entirely due to enhanced microbial and phosphatase activity. The increased availability was attributed to the intimate mixing of ingested phosphate particles with soil in earthworm casts and to the movement of particles from the surface down into earthworms burrows with infiltrating rain water (Mackay *et al*., 1982). Sharpley and Syers (1977) concluded that most of the additional P present in casts must be held in physically sorbed rather than chemically stabilized forms and would consequently be readily available to plants. The increase in pH of wormcast might have resulted in higher solubility of P in casts. Also the greater release of P from casts was due to a shift in the P sorption isotherm relative to that in the undistrubed soil.

Increased availability of P_2O_5 in wormcasts compared to surrounding soil was reported by Lal (1974). Petal *et al*. (1977), Mansell *et al*. (1981), Tiwari *et al*. (1989), Miura *et al*. (1993), Romero and Chamooro (1993) and Srinivsa Rao *et al*. (1996).

The different treatments significantly influenced the status of available K_2O in the soil. Coating of seeds with vermicompost (T_3) combined with full inorganic fertilizer application resulted in the highest availability of potassium in soil. The soil organic matter because of its high adsorptive capacity usually carries substantial amount of exchangeable potassium. The increase in available K content of soil where vermicompost is applied either as an organic source or as a seed coat, is due to the increased concentration of available and exchangeable K contents in casts compared to the surrounding soil. The increase in available K status of soil, especially in vermicompost treated plots can be attributed to the ability of earthworms to increase K availability by shifting the equilibrium from relatively unavailable forms to

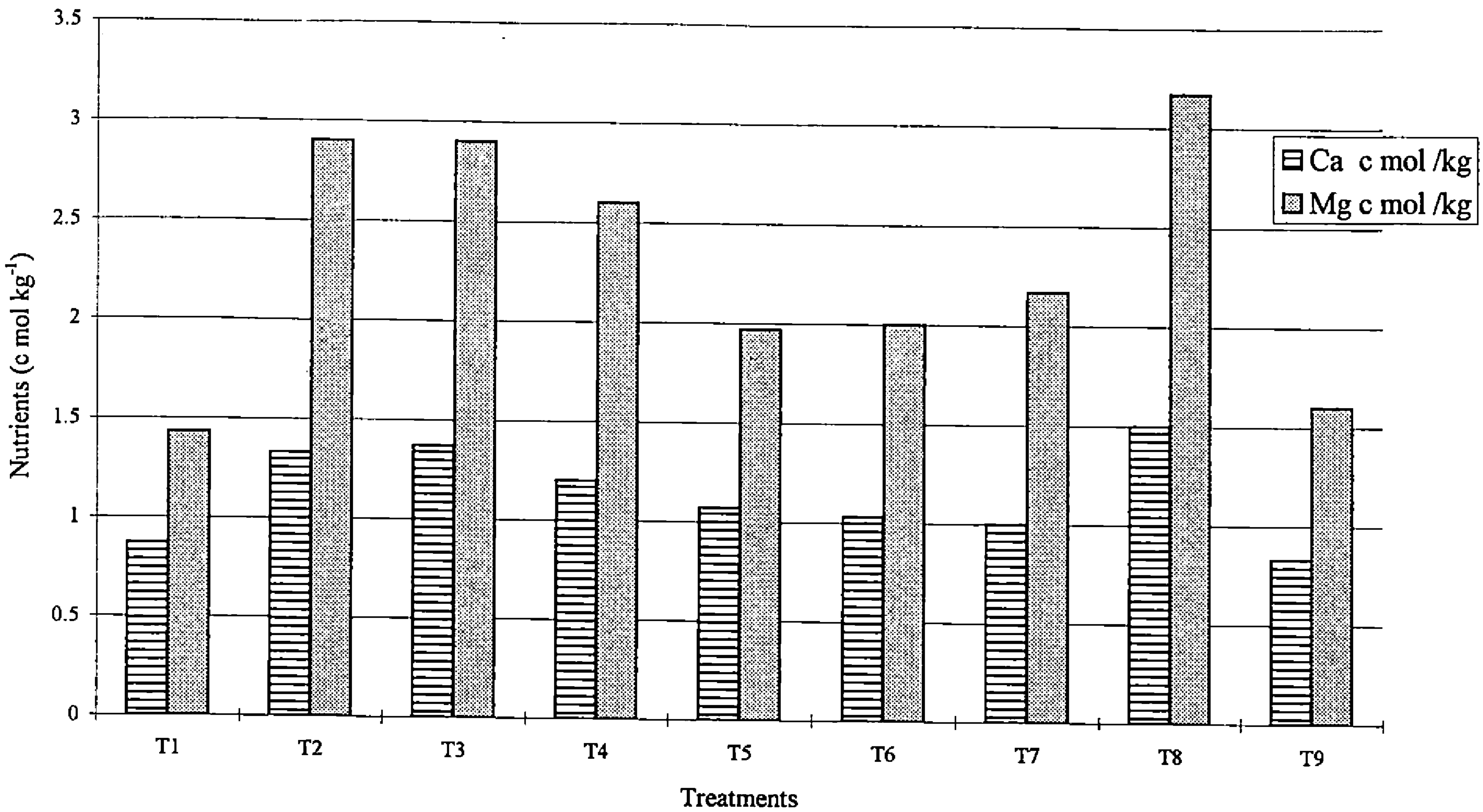


Fig. 14 Analysis of soil at maximum flowering stage for calcium and magnesium

more available form (Basker *et al.*, 1992). Selective feeding of earthworms on organically rich substances which break down during passage through the gut, biological grinding, together with enzymatic influence on finer soil particles were likely to be responsible in increasing the different forms of K (Srinivasa Rao *et al.*, 1996).

Increased availability of K by earthworm activity was revealed by Basker *et al.* (1992), Miura *et al.* (1993), Phule (1993), Romero *et al.* (1993), Ravignanam and Gunthilagaraj (1996) and Vasanthi and Kumaraswamy (1996).

Calcium and Magnesium availability in soil was significantly influenced by the different treatments (Fig. 14). Application of vermicompost @ 20 t ha^{-1} as an organic source resulted in the highest availability of Ca and Mg in the soil. The increase in available cations in wormcasts is related to the higher content of plant tissue in casts than in the soil. Considerable amount of total Ca in castings was due to the active feeding of Ca rich materials by earthworms (Kale and Krishnamoorthy, 1980). They also found that the concentration of soluble Ca in wormcast was 11.8 times more than that in the surrounding soil. According to Pierce (1972) species with active calciferous glands absorb excess Ca from their diet and transfer it to calciferous glands from which it is excreted via the digestive tracts. This excretion of $CaCO_3$ changes the soil

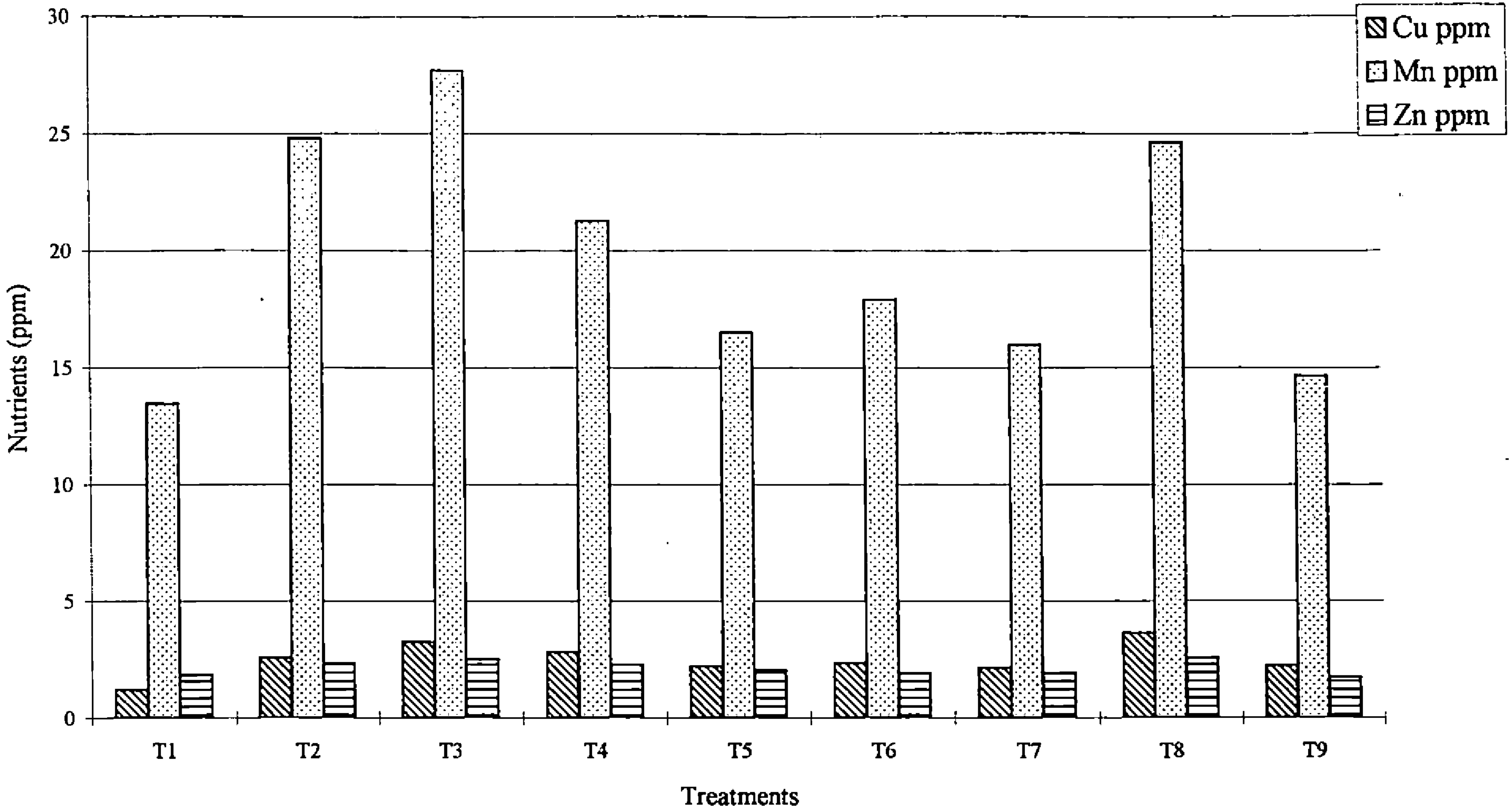


Fig. 15 Analysis of soil at maximum flowering stage for copper, manganese and zinc

pH and thus influences the solubility and availability of plant nutrients. Concentration of readily available nutrients in casts where surface casting species are numerous provide a favourable environment for seed germination and plant growth (Lee, 1985b). Increased concentration of exchangeable Ca and Mg in the wormcast compared to the surrounding soil was reported by several workers (Shuxin *et al*, 1991; Shinde *et al*., 1992; Miura *et al*., 1993 and Vasanthi and Kumaraswamy, 1996).

The different treatments significantly influenced the availability of micronutrients such as Mn, Zn and Cu content of soil. Application of vermicompost as an organic source @ 20 t ha^{-1} combined with inorganic fertilizer recorded the highest availability of Zn and Cu status in soil (Fig. 15). The treatment where seeds were coated with vermicompost and supplied with inorganic fertilizers recorded the maximum value for Mn availability in soil.

The initial available Mn, Zn and Cu content in the soil was 9.85, 1.27 and 0.89 ppm, respectively. Increased content of micronutrients in treatments receiving vermicompost either as an organic source or as a seed inoculant may be due to the enhanced availability of micronutrients in vermicompost as reported by Das *et al*. (1996).

Even if earthworms do not absorb all the micronutrients from their feed materials, those that are

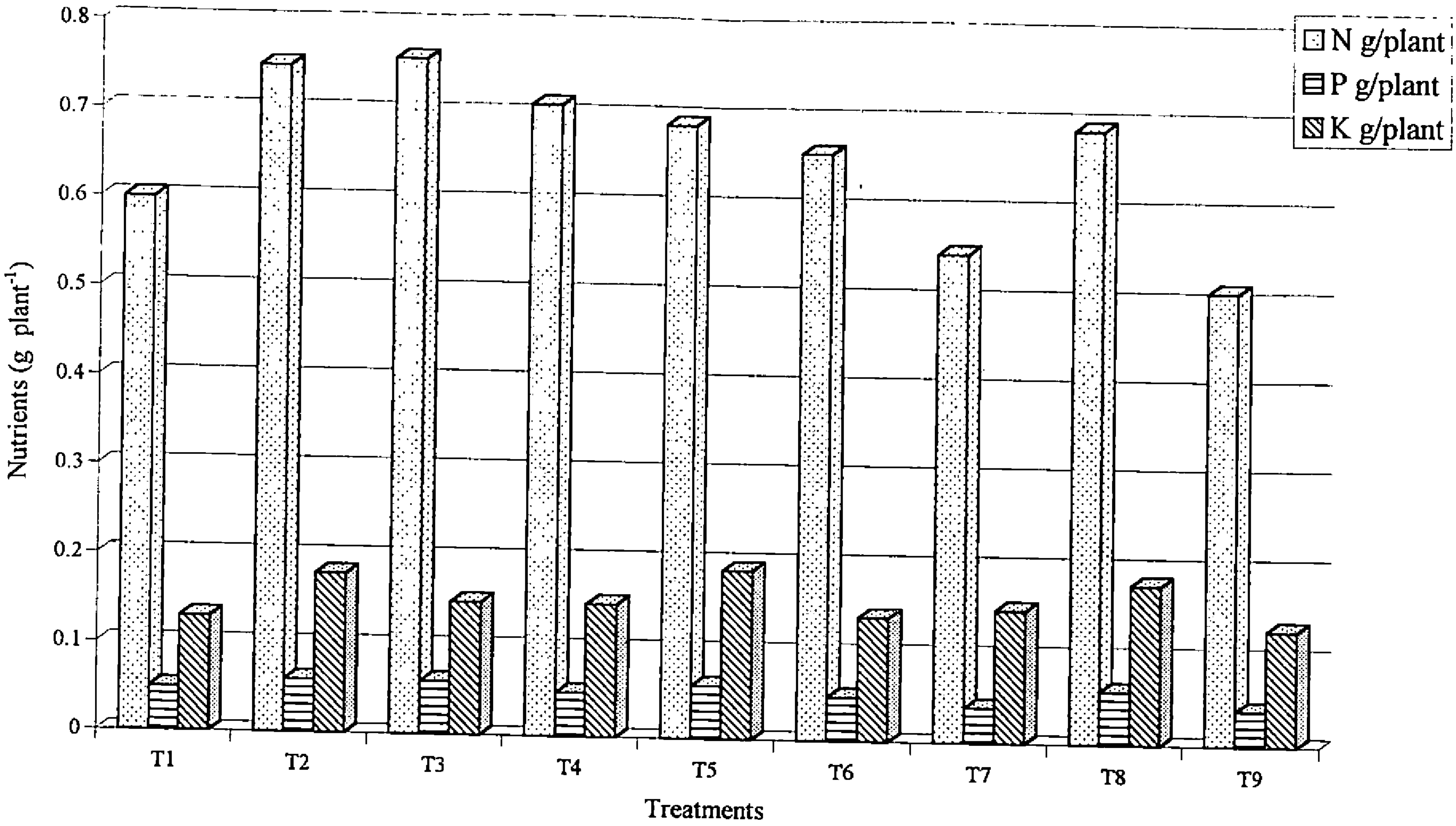


Fig. 16 Uptake of major nutrients at maximum flowering stage

absorbed show a tendency to accumulate in the body may be because of lack of adequate biochemical or physiological mechanisms to eliminate from their bodies. Zn was found to accumulate in the peritonial epithelium in nerve cells of the ventral nerve chord and in the chlorogogen cells that formed the outer layer of the intestine. However, these nutrients get incorporated into the compost upon the death of the worms. Lee (1985b) has reported that the micronutrients like Zn, Mn and Fe were excreted through the calciferous glands. These may be the reasons for the enhancement of micronutrient status of the soil. Increased copper availability in vermicompost treated plots may be due to the humic acid like components in vermicomposts which contain appreciable amount of Fe and Cu in inner sphere complex (Senesi *et al*., 1992). Handreck (1986) also reported increased availability of micronutrients in vermicompost.

5.7 Uptake studies

Uptake of nutrients showed an increasing trend from flowering stage upto harvest. Uptake of N was on par in vermicompost and *Rhizobium* coated treatments. For P uptake the maximum value was obtained for vermicompost coated treatments. Application of vermicompost as an organic source @ 20 t ha^{-1} recorded the maximum value for Ca, Mg, Cu and Mn uptake at flowering stage. At harvest, vermicompost coating of seeds

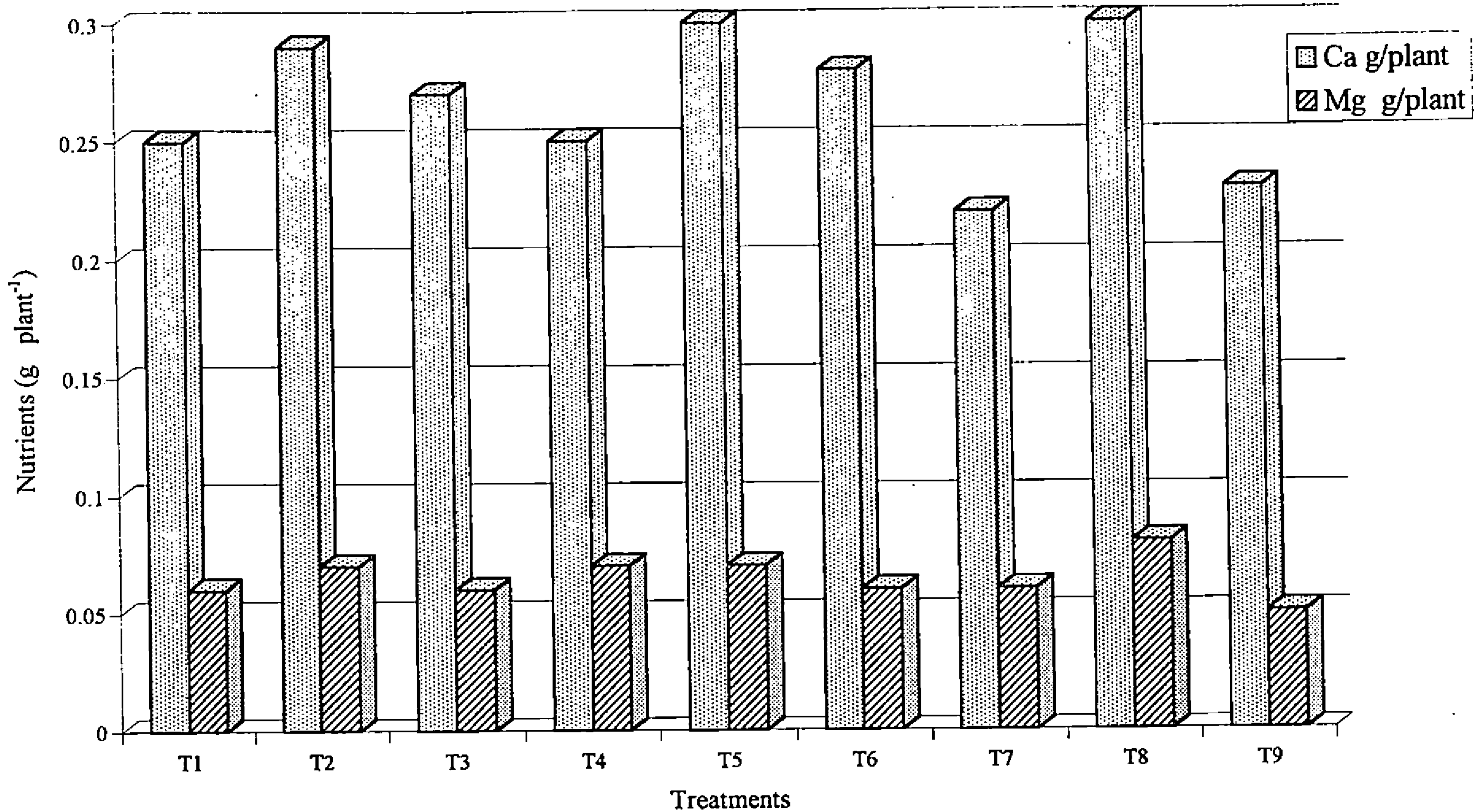


Fig. 17 Uptake of calcium and magnesium at maximum flowering stage

combined with inorganic fertilizer application recorded the maximum value for P, Mg, Mn and Zn uptake by plants. The different treatments had a significant effect on the dry matter content of plants. (Table 7). This may be one of the reasons for increased uptake of nutrients in vermicompost treated plants.

Uptake of N at harvest was significantly influenced by the different treatments. Seeds coated with vermicompost and supplied with full inorganic fertilizers along with farmyard manure as an organic manure recorded the maximum value during both the growth stages. The increase in N uptake may be due to the fact that vast portion of non-oxidisable N present in organic matter could be made available to plants through vermicomposting and microbial activity. Also it can be attributed to the increase in N input from biological N fixation, increased nitrate reductase activity with the enhancement in uptake of NO^{-}_{3} and NH^{+}_{4}. The increase in N use efficiency due to residue incorporation was reported by John *et al.* (1989). The higher rate of metabolic activity with rapid cell division brought about by vermicompost application resulted in high uptake of nutrients and this might have resulted in increased utilization of nitrogen (James *et al.*, 1967). Increased concentration of N in plant parts due to the application of vermicompost either as a seed inoculant or as an organic source was in confirmity with the findings of

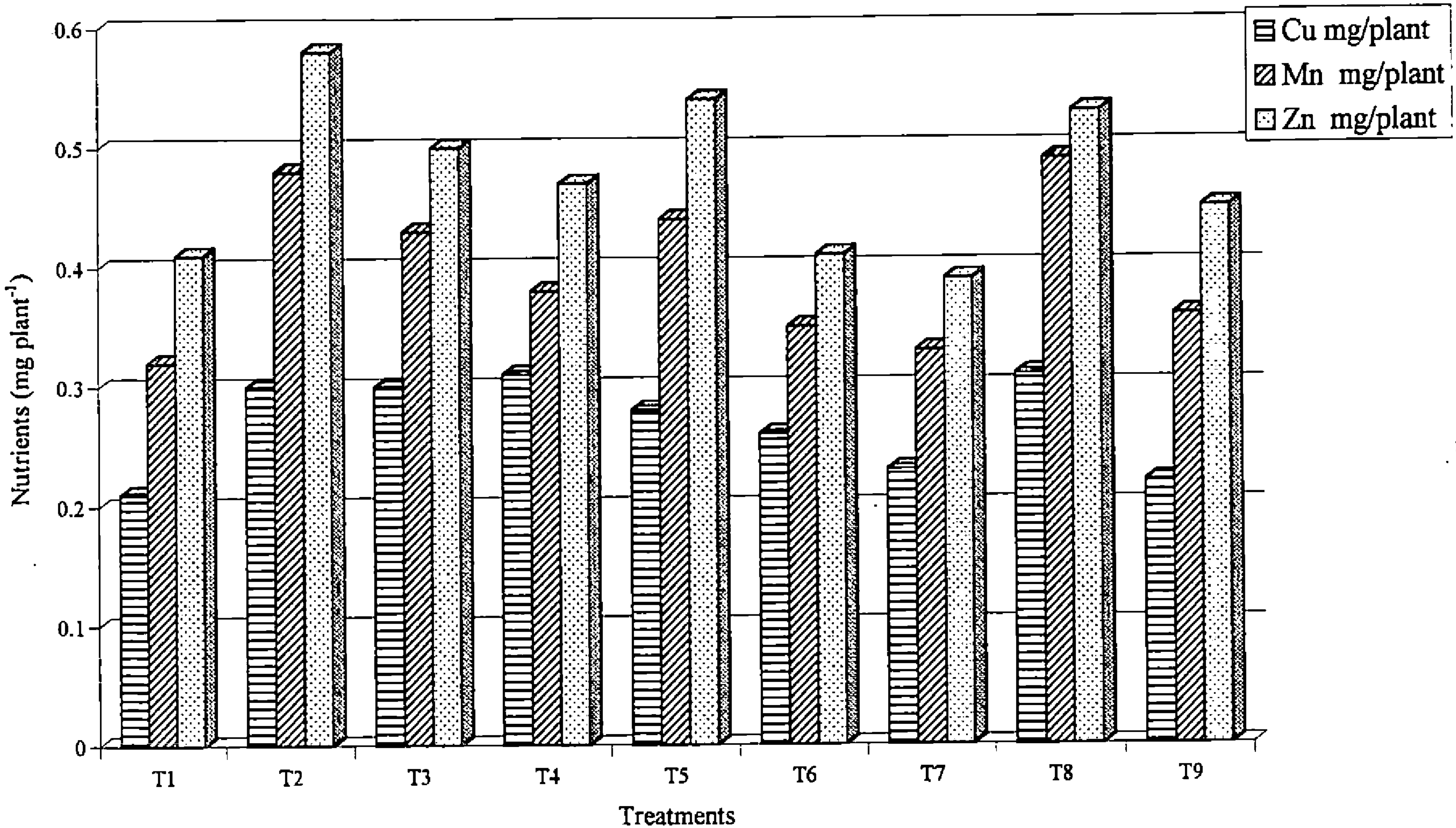


Fig. 18 Uptake of micronutrients at maximum flowering stage

Lavelle *et al.* (1991), Shuxin *et al.* (1991), Kale *et al.* (1992), Doube *et al.* (1994), Stephens *et al.* (1994), Zacharia (1995), Pushpa (1996), Rajalekshmi (1996) and Sagaya Alfred and Gunathilagaraj (1996) and Baker *et al.* (1997).

The different treatments did not show any significant influence on the uptake of P, both at flowering stage and harvest. However, the highest P uptake was recorded for seeds coated with vermicompost and supplied with full inorganic fertilizers and farmyard manure as the organic source. The earthworms stimulate the uptake of P by the redistribution of organic matter and by increasing the enzymatic activation of phosphatase (Mackay *et al.*, 1982). P solubilising micro organisms present in vermicompost enhances phosphatase activity and increases the availability of soluble P. The solubilisation of P by these micro-organisms is attributed to the release of organic acids like citric acid, glutamic acid, succinic acid, lactic acid, oxalic acid, glyoxalic acid, maleic acid, fumaric acid and tartaric acid (Gaur, 1988, 1990 and Subba Rao, 1988). 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 whereby metal ion availability gets increased (Subbiah *et al.*, 1983). Application of vermicompost enhances P availability due to increased P solubility which inturn results from higher phosphatase

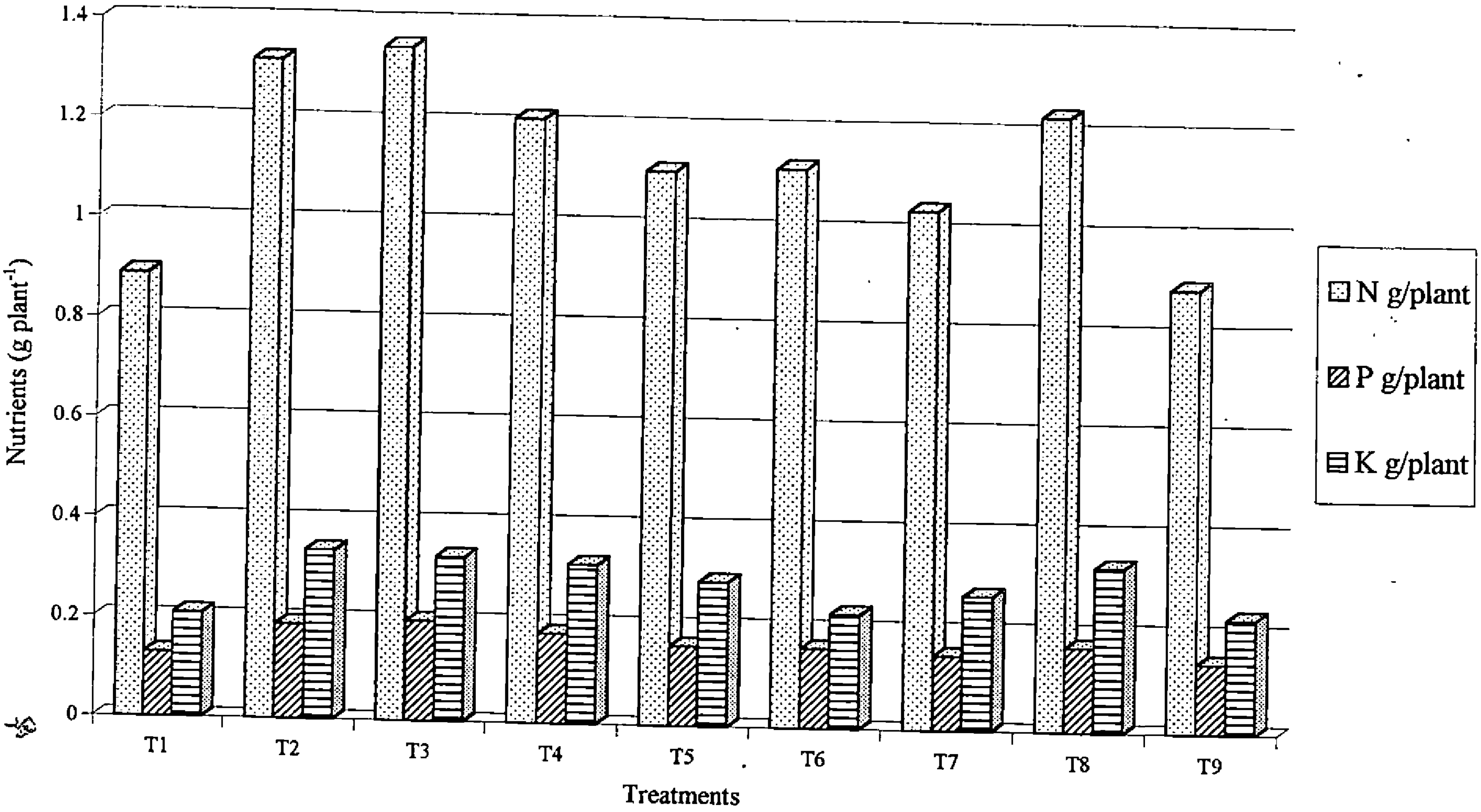


Fig. 19 Uptake of major nutrients at harvest

activity (Syers and Springett, 1984). Vermicompost application or introduction of earthworm species into the crop field enhances the P content of plant parts (Stephens *et al.*, 1994; Pushpa, 1996; Sagaya and Gunthilagaraj, 1996 and Vasanthi and Kumaraswamy, 1996).

Uptake of K by plants at harvest stage was significantly influenced by the different treatments. At flowering stage, *Rhizobium* coated seeds supplied with half the recommended dose of nitrogenous fertilizer and full P and K resulted in the highest uptake of K. This was found to be on par with the use of vermicompost as an organic source. While at harvest stage, *Rhizobium* coating of seeds produced the maximum value which was found to be on par with the vermicompost coating of seeds and also the soil application of vermicompost as the organic source. The increase in K uptake due to increased K availability consequent to shifting of the equilibrium among the forms of K from relatively unavailable forms to more available forms in the soil (Basker *et al.*, 1992). Several workers have reported the effect of organic manures in enhancing the K content of plant parts (Sharma *et al.*, 1984; Dhanokar *et al.*, 1994; Mather, 1994 and Bharadwaj, 1995). Increased use of nitrogenous fertilizer reduced the available K content of soil, but the incorporation of FYM increased its availability (Srivastava, 1985).

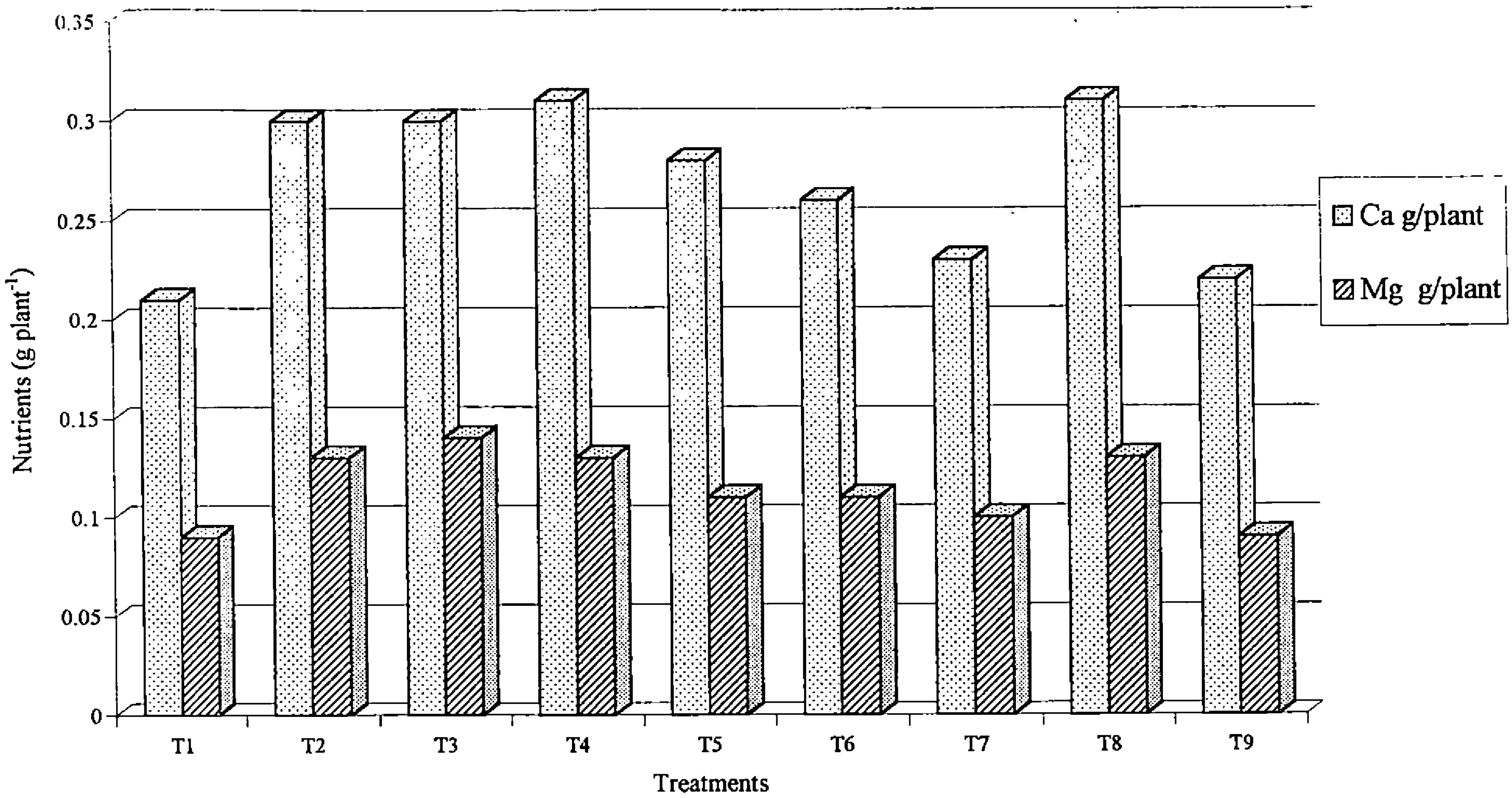


Fig. 20 Uptake of calcium and magnesium at harvest

Calcium and Magnesium uptake, both at flowering stage and harvest were not significantly influenced by the different treatments. Soil application of vermicompost as an organic source resulted in the highest uptake of Ca, both at flowering stage and at harvest. Use of vermicompost as an organic source @ 20t ha^{-1} obtained the highest value for Mg uptake at flowering stage, while at harvest, vermicompost coating of seeds produced the highest value for Mg uptake.

The increased Ca and Mg in vermicompost may be the reason for the increased uptake by plants (Shuxin *et al.*, 1991). The calciferous glands in earthworms contain carbonic anhydrase which catalyse the fixation of CO_2 as $CaCO_3$, thereby increasing the Ca availability, Zacharia (1995) also found increased Ca and Mg uptake in vermicompost treated chilli plants. Increased concentration of Ca and Mg in the presence of vermicompost was reported by Stephens *et al.*, (1994), Pushpa (1996) and Vasanthi and Kumaraswamy (1996).

Among the micronutrients, only Mn uptake was significantly influenced by the different treatments, both at flowering and harvest. Use of vermicompost as an organic source @ 20 t ha^{-1} (T_8) resulted in the highest uptake of Cu at flowering stage followed by the treatment where seeds were coated with vermicompost (T_3). For Mn uptake, application of vermicompost as an organic source recorded the highest value at

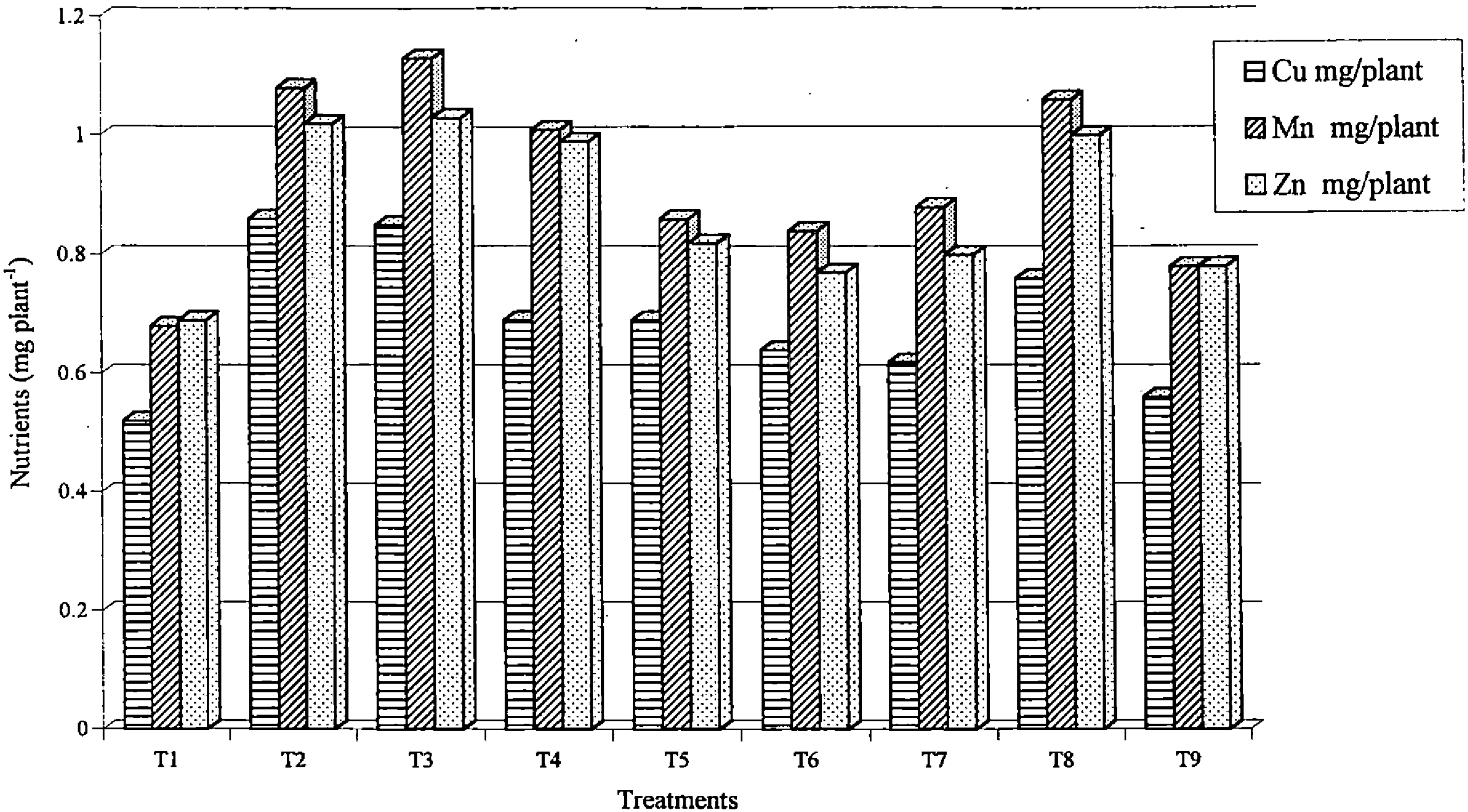


Fig. 21 Uptake of micronutrients at harvest

flowering stage. While at harvest stage, the highest value was recorded for coating seeds with vermicompost and supplied with full inorganic fertilizer. Coating seeds with *Rhizobium* recorded the highest uptake of Zn at flowering stage, while vermicompost coating of seeds recorded the highest value at harvest stage. Hartenstein and Rothwell (1973) when tried pelletised garbage composts as a source of nutrients observed an increase in the uptake of all the nutrients except that of Mn. But Zacharia (1995) found an increase in the uptake of Mn in plants treated with vermicompost enriched with *Azospirillum* and P solubilising organisms. Earthworms are reported to have the ability to accumulate trace elements in some parts of their bodies thereby decreasing final concentration in the compost. Only if the earthworms die and decay, these nutrients get fully incorporated into the compost.

Increased uptake of micronutrients in vermicompost treated plants was also reported by Stephens *et al*. (1994), Zacharia (1995), Shivananda *et al*. (1996) and Vasanthi and Kumaraswamy (1996).

Humic substances in vermicompost form stable complexes with micronutrients which are readily absorbed by plants. The chelating action of humic acid and fulvic acid has been attributed to the high amount of functional groups. A study for utilizing copper tailings in agriculture through vermicomposting using *Eudrillus eugeniae* showed the role of earthworm as a bioindicator for copper toxicity in the medium (Gangadhar and Kale, 1993).

5.8 Grain Analysis

Grain samples were analysed for protein content and minerals like P, K, Ca and Mg. Of these, only K and Ca content were significantly influenced by the different treatments (Fig.22).

Protein content of seeds were not significantly influenced by the different treatments. Application of vermicompost @ 10 t ha^{-1} combined with full inorganic fertilizers produced the highest value for protein content of seeds. Considerable scientific data were generated recently to show that produce obtained from organic farming is nutritionally superior with good taste, lustre, and keeping qualities. Aldag and Graff (1975) examined the effect of earthworms on crop quality. In the presence of *Eisenia foetida*, they found marked increase in drymatter production and total protein and protein N in plant tissues. Vermicompost application resulted in higher protein N to nitrate N accumulation in spinach resulting in better keeping quality (Lampkin, 1990), improvement in taste and lustre of grapes (Barve, 1993), healthier coccinia plants and better keeping quality of vegetables (Khamkar, 1993)

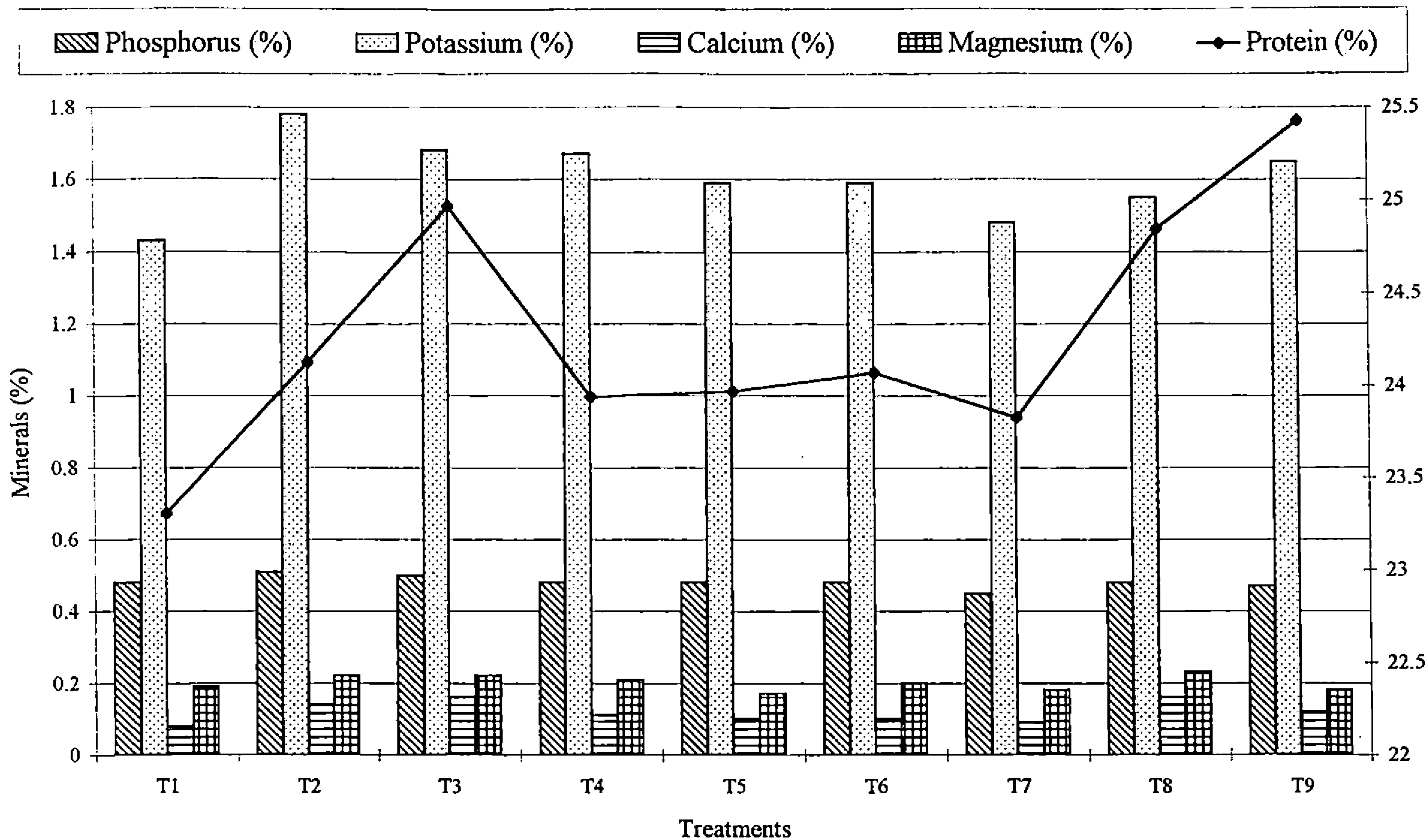


Fig. 22 Analysis of grain for protein content and minerals

and sugarcane juice having lesser salt concentration (Phule, 1993). According to Lampkin (1990), the better storage life of fruits is due to the lower content of free aminoacids. In the presence of earthworms, the proportion of acidic and neutral aminoacids in the protein was increased, while earthworm and cattle manure together resulted in a marked increase in basic aminoacids.

Potassium content of seeds was significantly influenced by the different treatments and the highest value was recorded for the treatment where seeds were coated with *Rhizobium* and supplied with full inorganic fertilizers. Ca content of seeds was also significantly influenced by the different treatments, while the different treatments had no significant influence on the Mg content of seeds. Soil application of vermicompost @ 20 t ha^{-1} recorded the highest content of Ca and Mg in seeds.

In the present study, use of vermicompost as a seed inoculant or as an organic source has given good results in terms of biometric characters, grain yield as well as the quality parameters. However, a superiority is shown by vermicompost inoculated plants where farmyard manure was given as the organic source indicating that at times of scarcity of vermicompost, seed treatment could serve the purpose. Also, this method is eco-friendly and easy to do. Vermicompost which has a neutral to alkaline pH greatly encourages the multiplication of beneficial microbes, especially under the acid conditions of Kerala. Thus using vermicompost as a bio-inoculant in the acid soils of Kerala deserves great importance.

SUMMARY

SUMMARY

An investigation was carried out at the Instructional Farm, College of Agriculture, Vellayani during the period September 1996 to February 1997 to assess the performance of vermicompost as a seed inoculum on the growth and yield of cowpea and also the possibility of reducing inorganic fertilizer requirement through this method. The variety used was Kanakamoni.

The experiment was laid out in Completely Randomised Design with nine treatments and three replications. The treatment consists of (T_1) - uncoated seeds supplied with full NPK fertilizers, (T_2) - seeds coated with *Rhizobium* and supplied with full NPK fertilizers, (T_3) - seeds coated with vermicompost and supplied with full NPK fertilizers, (T_4)- seeds coated with *Rhizobium* and vermicompost and supplied with NPK fertilizers, (T_5) - seeds coated with *Rhizobium* and supplied with half N and P and full K fertilizers, T_6 - seeds coated with vermicompost and supplied with half N and P and full K fertilizers, T_7 - seeds coated with *Rhizobium* and vermicompost and supplied with half N and P and full K. (T_8) uncoated seeds + full NPK + vermicompost as prgamoc spirce and (T_9) uncoated seeds supplied with full NPK and half vermicompost as organic source. In all the above treatments,

except T_8 and T_9, FYM was used as organic source. The results of the investigation are summarised below:

1. Biometric characters like seedling girth, height of plant, number of leaves and fruiting branches were not significantly influenced by any of the treatments.

2. Root characters like root spread, root length and number of effective nodules were significantly influenced by the different treatments. For all the above parameters, the results obtained for vermicompost coating of seeds and *Rhizobium* coating of seeds were found to be on par.

3. Total grain yield and number of pods per plant were significantly influenced by the different treatments. Other yield attributing characters like weight of pods, hundred seed weight and number of seeds per pod did not show any significant response to the different treatments. Vermicompost coating of seeds recorded the highest grain yield of 66.20 g $plant^{-1}$.

4. Dry matter production, both at flowering stage and harvest showed significant response to the use of vermicompost coating of seeds. Use of vermicompost as a seed inoculum and organic source produced almost the same results (24.31 and 23.59 g, respectively).

5. Phosphorus solubilising capacity of soil studied at periodical intervals viz., 15 DAS, 30 DAS and 45 DAS was not significantly influenced by any of the treatments.

6. Nitrogen fixing capacity of soil was significantly influenced by the different treatments at 30 DAS and 45 DAS. From the results, it is revealed that vermicompost coating of seeds and *Rhizobium* coating of seeds produced on par values.

7. Soil analysis at maximum flowering stage indicated that the availability of only Ca, Mg, Zn, Mn and Cu was significantly influenced by the treatments.

8. Plant analysis at maximum flowering stage indicated significant response to the N, K, Ca, Mg, Mn and Cu content of plant parts. At harvest, K, Mg, Mn and Zn content was significantly influenced by the different treatments.

9. Analysis of grain for protein content and minerals like P, K, Ca and Mg revealed that the different treatments had significant influence only on the K and Ca content of grains.

10. Uptake of nutrients was studied at maximum flowering stage and harvest. Results showed that the different treatments significantly influenced the uptake of N, K and Mn only.

11. Dilution plate method followed to calculate the amount of microorganisms present in vermicompost revealed that it contains $67x10^6$ bacteria, $8.3x10^5$ actinomycetes and 1.3×10^5 fungi g^{-1} of vermicompost.

12. Correlation studies showed that yield was significantly and positively correlated with height of plant, number of fruiting branches, rooting pattern, nodulation, nutrient uptake and available nutrients.

From the results, it could be concluded that the use of vermicompost either as a seed inoculant or as an organic source gives better results in terms of yield as well as biometric characters. The use of vermicompost as a bioinoculant resulted in increased availability of N and P due to biological fixation of N and biological solubilisation of P. Since T_6 (vermicompost coating with half N) produced 30 per cent increase in yield over T_1 (package of practice recommendation), it is quite evident that the quantity of fertilizer can be reduced to half when vermicompost was used as a seed inoculant.

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ABSTRACT

NUTRIENT ECONOMY THROUGH SEED COATING WITH VERMICOMPOST IN COWPEA *Vigna unguiculata* (L. Walp)

By

MEERA. A.V.

ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

COLLEGE OF AGRICULTURE

VELLAYANI

THIRUVANANTHAPURAM

1998

ABSTRACT

An investigation was carried out at the Instructional Farm, attached to the College of Agriculture, Vellayani to evaluate "Nutrient economy through seed coating with vermicompost in cowpea". The experiment was laid out in Completely Randomised Design with nine treatments and three replications. The variety used was Kanakamoni. The treatments include coating of seeds with *Rhizobium*, vermicompost and a combination of both and also uncoated seeds supplied with either farmyard manure or vermicompost as organic source.

Biometric observations like height of plant, number of leaves, seedling girth and number of fruiting branches were not significantly influenced by any of the treatments. However, root characters like root length, root spread and number of effective nodules were found to be significantly influenced by the different treatments. Coating of seeds with vermicompost significantly influenced the grain yield of cowpea and also the number of pods plant^{-1}. Coating seeds with vermicompost combined with the application of full inorganic fertilizers and farmyard manure as organic source recorded the highest grain yield. From the analysis of grain samples, it is inferred that only K and Ca content of grain was significantly influenced by the different treatments.

Phosphorus solubilisation capacity of soil was not significantly influenced by any of the treatments. N fixing capacity of soil was significantly influenced by the vermicompost coating of seeds during 30 DAS and 45 DAS. Soil analysis for available nutrients revealed that the different treatments had significant influence on the Ca, Mg, Zn, Cu and Mn content in soil.

Use of vermicompost coated seeds produced the maximum uptake of N, P and K at maximum flowering stage and at harvest. Soil application of vermicompost recorded the highest uptake of Ca, Mg, Cu and Mn during maximum flowering stage. Plant analysis for nutrient content indicated that the content of all the nutrients except P was significantly influenced by the different treatments during maximum flowering stage. Yield was positively and significantly correlated with the height of plant, root characters and availability and uptake of nutrients.

In the present study, a superiority is shown by vermicompost inoculated plants where farmyard manure was given as the organic source indicating that at times of scarcity of vermicompost, seed treatment could serve the purpose.