EFFECT OF VERMI COMPOST ON THE ELECTRO-CHEMICAL PROPERTIES AND NUTRITIONAL CHARACTERISTICS OF VARIABLE CHARGE SOILS

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DECLARATION

I hereby declare that this thesis entitled "**Effect of vermicompost on the electro-chemical properties and nutritional characteristics of variable charge soils**" 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 "**Effect of vermicompost on the electro-chemical properties and nutritional characteristics of variable charge soils**" is a record of research work done independently by Mr. BIJULAL B. L., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

1. INTRODUCTION

World population, currently estimated at slightly more than six billion, has increased at a rate of two per cent per year during the last few decades. During the past 25 years many chemically food deficient countries of the Asian region have been able to raise food output above the rate of growth in population. This has been achieved primarily through increased productivity per unit of land and time. Dulal (1980) estimated that agricultural production in the tropics must increase by 60 per cent by 2000 A D in order to meet food requirements at the present rate of population growth.

Population of India is growing ..... . Besides population increase, increased purchasing power among the poor will enhance the demand for food since under nutrition and poverty go together. In contrast, per capita availability of arable land is shrinking, water use efficiency is still on the whole low and water disputes are growing. In addition, the gradual decline in per capita availability of land and water, various forms of biotic and abiotic stresses are spreading. A prediction of Lester Brown says that at the current rate of population growth and environmental degradation coupled with an improvement in consumption capacity of poor, India will have to import annually over 40 million tonnes of food grains by the year 2030 (Swaminathan, 1996). In order to combat this situation in future, increase in food production in the tropics must come from intensification of agriculture of the impoverished, highly weathered, low activity variable charge soils which accounts nearly 70 per cent of the total goegraphical area of the humid tropics(NAS 1982).

To meet the goal of increased food production in areas dominated by these variable charge soils through the development of efficient crop production systems, it is essential that appropriate soil management technology be practiced to alleviate specific physical and chemical soil related constraints. Introduction of high yielding varieties with increasing dose of fertilizers and improved irrigation techniques have resulted in spectacular increase in crop production. This replaced the use of organic manures which were the key sources of plant nutrients since ancient times. The recent energy crisis and consequent price hike of fertilizers coupled with the low purchasing capacity of the farming community have again revived the interest in organic recycling throughout the world.

This strategy of organic recycling and organic farming is a major component of the low input management technology suggested for sound soil management to alleviate problems of nutrient deficiency, toxic effects of heavy metals, fixation problems of specific nutrient ions and soil degradation through laterization. Besides the beneficial effects of soil improvement, use of organic amendments and biofertilizers incorporate into the soil appreciable amounts of costly plant nutrients also. A simple calculation reveals that total potential sources of nutrients from these sources in India is about seven million tonnes of N, P and K and is approximately the calculated deficit of the projected nutrient requirements (29 million tonnes) and consumer fertilizer supply (22 million tonnes).

As the ill-effects of modern intensive agriculture are slowly killing our soil and earth, an integrated use of mineral and organic nutrients is an integral part of the ecologically sound, viable and sustainable farming systems. The organic amendments available in our country are plenty covering mostly the degradable refuse of plant and animal origin at various stages of decomposition.

In recent years the role of earthworms in incorporating dung and vegetable organic wastes into soil and increasing the available major nutrients and other essential elements has been emphasised by several workers.

The passage of organic wastes through the gut of worms lead to the acceleration of humification process by the gut microflora. Though the nutrient contents in the vermicompost are much less compared to standard inorganic fertilizers, its influence on nutrient uptake, plant growth and yield are found to be substantial. However,not much attention is paid to study the effect of vermicompost on the electro-chemical properties and nutritional characteristics of the low activity variable charge soils of the state which represented nearly 60 per cent of the total geographic area. Thus with the above background in view, the following major objectives were set for the programme.

1. To evaluate different compost materials with respect to their relative efficiency of releasing nutrients from the soil with and without added mineral sources.
2. To study the major electro-chemical changes in soils due to application of various organic amendments.
3. To study the agronomic effectiveness of different compost materials and organic manures using cowpea as a test crop.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Bulky organic manures and soil fertility

Millions of farmers in developing countries need adequate resources for augmenting crop productivity. Proper soil management ensuring continued maintenance and building up of soil fertility is indispensable for achieving higher productivity from agricultural land. There is no need to emphasise that organic manures favourably influence plant growth and yield directly as well as indirectly.

The indirect effects include augmentation of beneficial microbial population and their activities such as organic matter decomposition (Gaur *et al.*, 1971, Gaur and Pareek, 1974), biological nitrogen fixation (Gaur and Mathur, 1966: Bhardwaj and Gaur, 1970), solubilisation of insoluble phosphates (Gaur, 1972) and availability of plant nutrients. In addition to nitrogen, phosphorus and potassium, a fair amount of micronutrients such as manganese, zinc, copper and iron are simultaneously added to soil. Organic manures thus improve soil structure (Gaur *et al.*, 1972), seed germination, water holding capacity, drainage, base exchange capacity and check soil erosion.

The direct effects relate to the uptake of humic substances or its decomposition products affecting favourably the growth and metabolism of plants (Gaur, 1972). Humic substances have been reported to increase the efficiency of bio and chemical fertilizers.

The crops remove annually large quantities of plant nutrients from soil. Much of the plant nutrients thus removed can be restored through application of organic manures. Moreover, Indian soils are poor in organic matter and in major plant nutrients. The research work carried out in All India Co-ordinated Project on "Decomposition of Organic Matter in Indian soils" during 1967-71 showed that farmyard manure or compost was the best source for maintenance of soil organic matter at higher level. Therefore, regular application of organic manure is a sound practice for maintaining the soil fertility in tropical soils. The preparation of organic manure from rural and urban wastes will not only provide the valuable manure so badly required for our soils, but will also result in hygienic disposal of solid and liquid wastes which otherwise would cause pollution problems.

Havanagi and Mann (1970) observed that continuous application of FYM and use of green manures decreased the bulk density of the soil and increased the water holding aggregates in a long term manurial experiment under dry farming conditions in Delhi. Farm yard manure has favourable effect on soil aggregation compared to chemical fertilizers (Rabindra *et al*,. 1985).

Addition of organic matter primarily provides nitrogen to the crop. The organically bound form of nitrogen becomes available to the crop after decomposition, followed by mineralisation into inorganic forms. (Tusneem and Patrick, 1971). Havanagi and Mann (1970) reported that FYM application increases the organic carbon and available P_2O_5 content of the soil.

Humus by virtue of its chelating properties increases the availability of nitrogen, phosphorus, sulphur and other nutrients to plants grown in humus rich soils. The humic substances especially increase phosphorus availability as they have a very high ion exchange capacity and ligand exchange sites (Eberhardt and Pipes, 1974).

Gattani *et al.* (1976) reported that the continuous use of FYM had increased the organic carbon level of the soil to a greater extent. The manifold importance of organic matter in soil formation and soil fertility has been demonstrated by the experience of agriculture over many countries and by numerous investigations. The role of organic matter in soil processes as well as in supplying plant available nutrients and biologically active substances has been elucidated (Kononova, 1966).

Fellaca *et al.* (1983) reported that humified organic matter can significantly reduce the amount of phosphates required to maintain a solution concentration necessary for crop growth. 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). Swarup (1984) reported that application of FYM increased the availability of both native and applied micro nutrient cations. These ions form stable complexes with organic ligands which decrease their susceptibility to adsorption and fixation.

Organic residue incorporation to the soil improves the overall physical, chemical and biological properties of the soil and regular return of crop residues to the soil contributes to the soil nutrient pool in a gradual manner, besides offering other indirect benefits (Srivastava, 1988, Sindhu and Beri, 1989 and Bhat *et al*., 1991).

Similar results were also reported by Palaniappan and Natarajan (1993). They further stressed the role of organic matter in the maintenance of fertility and productivity.

Gupta *et al.* (1988) reported that irrespective of the levels of FYM used, carbon content was increased upto 52 days after application and thereafter it decreased. Carbon content of soil increased from 0.91 to 1.58 per cent by the continuous application of organic manures, and among the organic manures, FYM had a significant influence (Udayasoorian *et al.*, 1988).

Srivastava (1985) observed that increased use of nitrogenous fertilizer decreased organic C content and total N, while FYM increased the above parameters. More (1994) reported that addition of farm wastes and organic manures increased the available N status of the soil.

An increase in available N content of soil upto 20 days after FYM application and a decrease thereafter was noticed in a long term field experiment with wheat (Gupta *et al.*, 1988). Humic substances by virtue of its chelating properties increase the available P content in soil by virute of its high ion exchange capacity and ligand exchange sites (Gaur, 1994). Debnath and Hajra (1972) observed from their incubation studies that available K_2O content increased upto 16^{th} day, a decrease on 30^{th} day followed by an increase and then stabilised when FYM and daincha were added. Dhanokar *et al.* (1994) reported that continuous use of FYM raised available K_2O by 1.3 to 5.4 folds over control. Olsen *et al.* (1970) inferred that the application of manures increased the exchangeable Ca and Mg particularly at higher rates of their application. Singh and Tomar (1991) reported that the contents of exchangeable Ca and Mg in soil decreased with applied K and increased with FYM application.

2.2 Sources of bulky organic manures

Organic materials are valuable by-products of farming and allied industries derived from plant and animal sources. Organic manures which are bulky in nature, but supply the plant nutrients in small quantities are termed bulky organic manures. These include farm yard manures, rural and town compost, night soil etc.

2.2.1 Farm yard manure

This is the traditional organic manure and is most readily available to the farmers. In Western countries, it is the product of decomposition of the liquid and solid excreta of the live stock, stored in the farm along with varying amounts of straws or other litter used as bedding. Indian litter is rarely used as bedding owing to the values of straw as a good fodder. On an average well-rotten farm yard manure contains 0.5 per cent N, 0.2 per cent P_2O_5 and 0.5 per cent K_2O (Gaur *et al.*, 1971). The characteristics of live stock wastes are functions of the digestibility, composition of the feed ration, the species of animals, age and their physiology.

2.2.2 Compost

Compost manures are the decayed refuse like leaves, twigs, roots, stubble, crop residue and hedge clippings, street refuse collected in towns and villages, water hyacinth, saw dust and bagasse. The process of decomposition is hastened by adding nitrogenous material like cow dung, night soil, urine or fertilizers. A large number of soil micro organisms feed on these wastes and convert them into well rotten manure. The final product is the compost. The chemical composition of compost varies depending on the sources from which it is prepared. On an average, the rural compost contains 0.5, 0.2, 0.5 per cent N, P_2O_5, K_2O, respectively whereas the corresponding values for urban compost is 1.5, 1.0 and 1.5 (Gaur *et al.*, 1971).

2.3 Role of vermicompost as an organic source

Since the days of Darwin (1881) study on earth worms associated with decomposition of organic matter and increased soil fertility had been initiated. Of late earth worms have gained importance because of their detritivorous habit and are being exploited commercially in waste management and biodegradation technology (Hartenstein and Rothwell, 1973).

In recent years, the role of earth worms in incorporating dung and vegetable organic matter into soil and increasing available N and essential minerals has been emphasised by several research workers (Nijhawan and Kanwar, 1952 ; Lunt and Jacobson, 1944). The passage of organic wastes through the gut of worms enhanced humification process by the gut microflora. The wormcast is proved to be an excellent organic manure, not only to increase soil productivity but also to improve soil physical and microbiological conditions (Edwards and Lofty, 1980).

2.3.1 Effect of vermicompost on nutritional characters

Earth worms feed on any organic waste, consume two to five times their body weight and after using 5-10 % of the feed stock for their growth, excrete the mucus coated undigested matter as wormcasts. Worm casts consist of organic matter that has undergone physical and chemical breakdown through the activity of the muscular gizzard which grinds the material to a particle size of 1-2 micron. The nutrients present in the worm cast are readily soluble in water for the uptake of plants (Bhawalkar and Bhawalkar, 1993).

Bano *et al.* (1987) reported that wormcast was found to be rich in all the mineral nutrients especially of iron and calcium suggesting the acceleration of mineralisation during the passage of food through the gut of earth worms. Thus this wormcast has all the qualities of a fertilizer and can replace organic manures and also to some extent chemical fertilizers. Comparing the nutrient status of vermicompost with other commonly used organic manures. Bano *et al.* (1987) found the percentage of nitrogen to be same as that of the organic manures compared. But the high P_2O_5 content in earth wormcast supports the phosphate availability which is essential for root growth and microbial enhancement. Thus vermicompost is superior to other organic manures.

Tomati *et al* (1988) also reported that wormcasts were rich in available nutrient for plant growth. Sharpley and Syres (1977) found increased P availability to plants when vermicasts were used. Bouche and Ferriere (1986) reported that ^{15}N labelled nitrogen from wormcasts was rapidly and almost entirely taken up by the plants. Kale *et al* (1992) found significantly higher levels of uptake of N and P in rice treated with vermicompost.

The application of worm worked compost resulted in higher yields of paddy crop ranging from 95 per cent increase in grain and 128 per cent increase in straw and root production and 38 per cent decrease in weed growth (Senapathi *et al.*, 1985).

2.3.2 Effect of vermicompost on organic matter fractions

The organic matter of most mineral soils accounts for about 30-65 per cent of the total CEC. The organic matter of different soils vary greatly in their CEC; the more humified the organic matter, the higher is its CEC (Allison, 1973).

Humic colloids are believed to play an important role in controlling the availability of the metal ions through chelation. The organic matter can hold metallic ions both by cation exchange and by chelation (Allison, 1973). Wright and Schnitzer (1963) suggested that under natural conditions, fulvic acid is the chief ligand causing the movement of iron and aluminium in podzol development. Thus there is a strong possibility that soil organic matter is involved in chelation reactions with metals and that they play a very important role in making metal ions available to plants.

Kononova (1966) reported that small concentration (upto 60 ppm) of humic acids (HA) enhance root development and plant growth.

Schnitzer and Poapst (1967) examined the effect of fulvic acid (FA) in root formation in Beans. They noted that root formation was increased by over 300 per cent when between 3000 to 6000 ppm. of FA was administered. They believe that the stimulating effect of FA is due to its ability to form stable complexes with metal ions, such as Fe^{3+} which in the absence of FA are transported within the plant with difficulty only. It is also possible that stable free radicals in FA are active in stimulating root formation.

Senesi *et al.* (1992) had isolated humic acid -like components (HAL) by conventional procedures from various organic wastes, including animal manures, a municipal solid refuse and a sewage sludge, that were composted for 2-3 months with earthworms. Vermicompost HAL contained appreciable amounts of Fe and Cu similar to those found in humic acids from soil and other sources. Similar to soil HA and irrespective of the nature of the parent material, vermicompost HAL are able to bind large amounts of Fe and Cu ions. Vermicompost HAL can be considered as adequate analogues of soil HA with respect to their metal complexation properties and behaviour.

2.3.3 Effect of vermicompost on microbiological properties

The possibility of reducing the use of chemical fertilizer by using vermicompost as organic fertilizer was tested by Kale *et al.* (1992) on the summer crop of paddy variety HAMSA in Bangalore, India. The control plot received the recommended dosage of FYM and chemical fertilizers. The experimental plot received half the recommended dosage of chemical fertilizers and the vermicompost. At the time of seed setting and two months after harvest of the crop, the soil samples were analysed for total microbes, N-fixers, actinomycetes and spore formers. The per cent mycorrhizal colonisation in the plant system was also assessed. Significant increase in the colonisation of these microbes in the experimental plot over the control plot was observed. The symbiotic association of mycorrhiza in the roots showed a marked difference in infection which was 2.85 per cent in control plots compared to 10 per cent in the experimental plot. Except for actinomycetes, the colonies of the other microbes assessed two months after the harvest of the crop in the drained plots showed significantly higher counts in the experimental plot. The stubbles in the experimental plots retained higher counts of mycorrhizae than those in the control plots. It was concluded that the vermicompost application enhanced the activity of selected microbes in the soil system. There was high level of total N in the experimental plot which comparatively received less fertilizers. This may be due to the higher count of N-fixers observed in the experimental plot than that of control plot.

Satchell *et al.* (1984) reported that earthworm activity stimulate the microbial phosphatase production. Indira *et al.* (1986) reported that an examination of vermicompost revealed the presence of a population of 10^6 of bacteria, 10^5 of fungi and 10^5 of actinomycetes, by dilution plate method. Population of beneficial organisms like phosphorus solubilising bacteria, nitrogen fixing organisms and entomophagous fungi were in the range of 10^5 to 10^6. Amongst the phosphorus solubilising organisms species belonging to Bacillus and Aspergillus genus were prominent, while species belonging to Azotobacter, Azospirillum and Rhizobium were prominent in the nitrogen fixing organism group.

Kale *et al.* (1987) studied the influence of wormcast on the growth and mycorrhizal colonisation of two ornamental plants (Salvia and Aster) and reported that the wormcast when used as a manure in place of FYM significantly influenced both their vegetative and flowering characters and increased mycorrhizal root colonisation.

Mba (1994) found that the earthworm casts of *Pontoscolex correthrurus* were found to contain tolerant actinomycetes and efficient rock phosphate solubilisers. Earthworm casts of *Eudrillus euginiae* were rich in rock phosphate solubilising microbes and had high rock phosphate solubilising capacity (Mba, 1997). However, Serra Wittling *et al.* (1995) opined that vermicompost had no marked effect on compost enzyme activity, either before or during the incubation.

2.3.4 **Effect of vermicompost on soil properties**

Kale and Krishnamoorthy (1981) reported the role of earthworms in the degradation of organic wastes and improving the physico-chemical properties of soil.

Bhawalkar and Bhawalkar (1993) opined that earthworms participate in soil forming process by influencing soil pH, by acting as agents of physical decomposition, promoting humus formation, improving soil structures and by enriching the soil.

Basker *et al.* (1994) reported that the pH of the earthworm casts was higher than that for non ingested soil. Similar results were also reported by Mulongoy and Bedoret (1989).

A field experiment with sorghum conducted from 1993 to 95 by Sarawad *et al.* indicated that physical properties of vertisol improved with vermicompost as compared to fertilizer application. The content of organic carbon and available P in soil increased with vermicompost application.

Shuxin *et al.* (1991) reported that by introducing earthworm and applying organic manure in the red arid soil, the organic carbon in the soil increased from 0.5 to 0.6 per cent.

Barley and Kleinig (1964) successfully introduced earthworms into newly sown irrigated pastures, on sandy loam soil in New South Wales with corresponding significant improvement in soil structure, loss of organic matter and increased productivity. Syres and Springett (1984) observed that earthworms redistribute organic material within the soil, increase the soil penetrability and under certain conditions influence ion transport in soils.

Vijayalekshmi (1993) reported that soil properties such as porosity, soil aggregation, soil transmission, conductivity and dispersive power of wormcast treated soil were improved when compared with no wormcast amended soil as reflected in the pot experiment on paddy growth. Rajalekshmi (1996) has also reported favourable effect of vermicompost / vermiculture on most of the soil physical properties.

2.3.5 **Effect of vermicompost on availability of nutrients**

Increased availability of nitrogen in earthworm casts compared to the non ingested soil has been reported by several workers (Tomati *et al.*, 1988; Tiwari *et al.*, 1989 ; Srinivasa Rao *et al.*, 1996). Scheu (1987) found large amounts of mineralised N in the presence of large earthworm biomass. Haimi and Huhta (1990) reported that earthworm increase either directly or indirectly the proportion of mineral N available for plants at any given time, although N was clearly immobilised in the initial stage.

Scheu (1994) reported that microbial biomass was not affected by earthworm ingestion in soil and N losses from earthworm tissue didnot contribute to earthworm N mobilisation, indicating the existence of earthworm mobilisable soil N pool linked to earthworm mobilisable carbon resources.

Higher concentrations of available P in earthworm casts compared with the surrounding soil or litter have been observed by Sharpley and Syres (1977), Mansell *et al.* (1981) and Tiwari *et al.* (1989). Mackey *et al.* (1983) found that incorporation of earthworm to soil incubated with phosphate rock resulted in a 32 % increase in Bray- extractable soil phosphorus after 70 days.

Basker *et al.* (1994) inferred from the incubation experiment that the exchangeable K content increased significantly due to earthworm activity. The higher concentration of exchangeable K of the soil with worms compared with that of the soil without worms at the same moisture level confirms the positive role of earthworms in influencing this fraction of K. Increased concentrations of available and exchangeable K content in casts compared to surrounding soil was reported by Lal and Vleeschauwer, 1982; and Tiwari *et al.*, 1989.

Compared to non-ingested soil, different forms of K increased in value in erathworm casts. Selective feeding of earthworms on organically rich substances which breakdown 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).

Kale and Krishnamoorthy (1980) reported that castings of earthworms were rich in soluble forms of Ca. The concentration of soluble Ca of castings was 11.8 times more than 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) reported that the concentration of exchangeable Ca and Mg was higher in the wormcast than in the surrounding soil. But Basker *et al.* (1994) suggested that no consistent trends emerged for changes in exchangeable Ca and Mg as a result of soil ingestion by earthworms.

2.3.6 **Effect of vermicompost on the uptake of nutrients and yield of crops**

Reddell and Spain (1991) suggested that part of growth stimulation credited to earthworms may be due to more rapid and intensive infection by mycorrhizal propagules which almost is ubiquitous in earthworm casts in field situations. 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.* (1992) found significantly higher levels of uptake of N and P in rice treated with vermicompost.

Mansell *et al.* (1981) observed in a glass house experiment, rye grass recovered more ^{32}P from labelled earthworm cast material than from labelled dead herbage suggesting that earthworm increases short term plant availability of P derived from plant litter by 2-3 fold.

Bouche and Ferriere (1986) reported that ^{15}N labelled nitrogen from earthworm was rapidly and almost entirely taken up by plants in the spring in undistrurbed soils. Sagaya Alfred and Gunthilagaraj (1996) noticed more N content in Amaranthus plant grown with earthworm application.

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

Kale *et al.* (1987) found that wormcast when used as a manure in place of FYM, significantly influenced vegetative and flowering characters of two ornamental plants.

Stephens *et al.* (1994) studied the ability of earthworms to increase plant growth and foliar concentration of elements in wheat in sandy loam soil. They observed a significant increase in the plant yield, root and shoot weight and the foliar concentration of elements like Ca, Na, Mn, Cu, Fe and Al.

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

Atlavinyte and Zimkuviene (1985) observed improved growth and yield on barley crops by using worm activated soils.

Phule (1993) obtained more sugarcane yield from vermicompost treated plots than the chemical fertilizer applied plots.

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

The application of worm worked compost resulted in higher yields of paddy crop ranging from 95 per cent increase in grain and 128 per cent increase in straw and root production and 38 per cent decrease in weed growth (Senapathi *et al.*, 1985).

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.

Ushakumari *et al.* (1996) found that Package of Practice Recommendation with cattle manure as 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.

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

2.4 Availability of added mineral sources of 'P'

Reactions of soluble phosphatic fertilizers in soils are widely studied and documented (Sample *et al.*, 1980).

Mono calcium phosphate (MCP) is the essential phosphate component in super phosphates. In soil, MCP of super phosphate undergoes hydrolysis to form an acid (pH 1.48) metastable triple point solution (MTPS) of MCP, dicalcium phosphate dihydrate (DCPD) and phosphoric acid. Over a period of seven days DCPD dissolves and less soluble DCP precipitates out (Stephen and Condron, 1986). The solution leaving the site of fertilizer granule by diffusion down the gradient of chemical potential becomes highly acidic and enriched in P. The DCP that remains in the fertilizer granule dissolves incongruently, and the highly insoluble hydroxyapatite precipitates out to form phosphoric acid in solution.

The concentrated phosphoric acid solution moving out of the fertilizer granule enters into several reactions with soil minerals. Thereafter it induces the dissolution and/or exchange of appreciable quantities of cations such as Fe, Al, Mn, Ca and Mg (Sample *et al.*, 1980). After several reactions which take place, the soil solution gets saturated with one or more of the reaction products of widely varying solubilities, thus causing their precipitation. The nature of the compound precipitating and, hence, the plant availability of the concentrated P solution diffusing out of the application site would thus depend on the nature of the soil environment surrounding the fertilizer application site. In acid soils where Fe and Al concentrations are high, Fe and Al phosphates are the primary reaction products.

Mackey *et al.* (1982) reported the effect of a mixed population of earthworm on the availability to perennial rye grass of phosphorus in super phosphate and Chatham Rock Phosphate (CRP) which was evaluated in a glass house experiment. Increase in the yield of rye grass in the presence of earthworms varied from 2 to 32 per cent, whereas increase in P uptake by rye grass ranged from 0 to 40 per cent, over seven harvests. With super phosphate, the initial increase in rye grass yield and P uptake in the presence of earthworms ranged from 20-40 per cent at the first harvest to less than 10 per cent by the seventh. In marked contrast, earthworms increased the agronomic performance of pelletised CRP by 15-30 per cent, throughout the trial period. An increase in plant available soil nitrogen concentrations due to earthworm activity probably explains the initial difference in the performance of super phosphate.

2.5 Phosphorus dynamics in relation to soil properties

Many soil properties influence P adsorption by soils, soil minerals and sediments. These include the nature and amount of soil components (eg. clay, organic matter and hydrous oxides of iron and aluminium); back ground electrolytes, its concentration and valency of the constituent cations, and pH of the adsorption system. Of the soil properties tested, acid ammonium oxalate extractable (amorphous) iron and aluminium proved to be an important criterion for P adsorption in several soils (Araki *et al.*, 1986).

A significant correlation of P sorption parameters with clay content has been reported by several workers. In acid soils, P adsorption is generally attributed to hydrous oxides of iron and aluminium and to (1:1) layer lattice clays, particularly in tropical soils with low pH (Dolui and Gangopadhyay, 1984).

The pH influence both the P ionic species that is adsorbed and the charge and electrostatic potential of the variable charge surfaces that retain P in soil. With an increase in pH, the charge and electrostatic potential of positive sites on variable-charge materials in soil decrease causing a fall in P retention (Barrow, 1984).

Several authors have reported significant positive correlation between soil organic matter content and P sorption (Sanyal *et al.*, 1990). The role of organic matter in augmenting P sorption in soils has often been attributed to the association with the possible stabilisation of the soil organic matter by the "free" sequioxides (Wada and Gunjigake, 1979). Bennoah and Acquaye (1989) reported that iron and aluminium intimately associated with organic matter can sorb much more P than can the same amount of free Fe_2O_3 and Al_2O_3.

Harter (1969) however disagreed with the idea that organic matter and P were adsorbed in soil by the same mechanism. He suggested that P may even be directly bonded to organic matter by replacing the organic hydroxyl groups.

Reduction of P sorption by organic matter in soils has also been observed (Sibanda and Young, 1986). This can be explained by a possible competitive action between P and organic matter for sorption sites on, for instance, hydrous oxides of iron and aluminium. Yuan (1980) also supported the idea that some of the adsorption sites for P and organic matter in soils are common. This leads to a competitive effect. In agreement with this Sibanda and Young (1986) demonstrated that humic acid and fulvic acid competed strongly with P for adsorption sites on geothite and gibbsite at low pH values. Further, soils of their study also showed a similar effect with a reduction in P adsorption resulting from the adsorption of humic acid at the pH of soils. The effect was attributed to the strong reaction between humic or fulvic acid and hydrous oxides of iron and aluminium.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was undertaken to investigate the effect of vermicompost, in comparison with other organic manures, viz., FYM and ordinary compost, on the electro-chemical properties and nutritional characteristics of a low activity clay soil taken from Vellayani. The materials used and the methods adopted for the study are briefly described in this chapter.

3.1 Collection and preparation of composting materials

3.1.1 Source of materials

a) Farm yard manure : Good quality FYM was collected from the Dept. of Animal Husbandry at the College of Agriculture, Vellayani. The material was sun dried, powdered and sieved for making it fit for analysis.

b) Ordinary compost : Good quality compost prepared scientifically was collected from the Instructional farm attached to the College of Agriculture, Vellayani. The material was sun dried, powdered and sieved for preparation of sample for analysis.

c) Vermicompost : Good quality vermicompost prepared using *Eudrillus eugineae* in the vermicompost yard attached to the College of Agriculture, Vellayani, was collected and used for analysis.

3.1.2 Analysis of compost materials

The compost samples were analysed for pH, EC, CEC, total organic carbon, total nitrogen, total phosphorus, total potassium and C:N ratio following standard analytical procedures (Jackson, 1973).

Total Ca and Mg were determined in the perchloric acid extract of the sample using atomic absorption spectrophotometer Model PE 3030.

3.2 Laboratory incubation experiment

This experiment was conducted for evaluating different compost materials to assess their relative efficiency in releasing P from soil with and without an added P source (taking rock phosphate as an added source) and to study the changes in electro-chemical characteristics of the soil due to treatment effects.

3.2.1 Collection and preparation of soil sample

Soil for the incubation experiment was collected from the southern part of the block of the Instructional Farm attached to the College of Agriculture, Vellayani. The soil was texturally classified as Fine Loamy Kaolinitic Isohyperthermic Typic Kandiustults as per soil taxonomy. The surface soil collected was air dried and sieved through a 2 mm. sieve.

3.2.2 Design of incubation experiment

The study was programmed in CRD with 9 treatment replicated thrice. The following were the treatments.

T_1 : control (soil alone)

T_2 : soil + super phosphate

T_3 : soil + rock phosphate

T_4 : soil + FYM

T_5 : soil + FYM + rock phosphate

T_6 : soil + ordinary compost

T_7 : soil + ordinary compost + rock phosphate

T_8 : soil + vermicompost

T_9 : soil + vermicompost + rock phosphate

3.2.3 Quantity of treatment materials

The quantity of various treatment materials (per treatment) were as follows.

Soil	: 200 g.
Super phosphate (16 % P_2O_5)	: 0.5 g.
Rock phosphate (22 % P_2O_5)	: 0.5 g.
Farm yard manure	: 20 g.
Ordinary compost	: 20 g.
Vermicompost	: 20 g.

3.2.4 **Filling of containers**

135 plastics containers of uniform size representing 27 samples each (9 treatment replicated thrice) for 5 intervals were cleaned and dried well. 200 g air dried soil (2 mm.) each with the treatment material were filled in the plastics containers. The moisture level was maintained at 60 per cent of field capacity.

3.2.5 **Sampling**

Sampling was done at 30 days interval i.e., 0^{th}, 30^{th}, 60^{th} , 90^{th} and 120^{th} days after incubation by removing 27 containers representing 9 treatments and 3 replications for each observation.

3.2.6 **Chemical analysis**

The following properties were analysed at each of the five intervals.

3.2.6.1 Soil reaction (pH)

The pH was determined in a 1:2.5 soil water suspension using ELICO digital pH meter.

3.2.6.2 Electrical conductivity

Electrical conductivity was determined from the same soil -water suspension prepared for the determination of soil reaction using a conductivity bridge.

3.2.6.3 Organic carbon

The wet digestion method suggested by Walkley and Black (1947) was employed for the estimation of organic carbon using ferroin as indicator.

3.2.6.4 Total nitrogen

Total N was estimated by the modified Micro Kjeldahl method (Jackson, 1973).

3.2.6.5 C:N Ratio

It was calculated as the ratio of total organic carbon to total nitrogen.

3.2.6.6 Cation exchange capacity

A known weight of soil was treated with neutral normal ammonium acetate and kept over night for saturating the exchange sites with ammonium ions. It was filtered and the residue was washed with more of ammonium acetate and then the excess ammonium was removed by washing with ethyl alcohol. The adsorbed NH_4^+ was steam distilled, collected in four per cent boric acid and estimated titrimetrically (Jackson, 1973).

3.2.6.7 Total phosphorus

A known weight of soil sample was digested in constant boiling HCl and the total phosphorus was then estimated colorimetrically by Vanado-molybdo phosphoric yellow colour method using a Klett-Summerson photoelectric colorimeter (Jackson, 1973).

3.2.6.8 Fractionation of soil inorganic P

The method suggested by Chang and Jackson (1957) was followed for the separation of the inorganic soil phosphorus into the following three fractions.

Aluminium phosphate -- extracted with 0.5 N neutral NH_4F.
Iron phosphate -- extracted with 0.1 N NaOH.
Calcium phosphate -- extracted with 0.5 N H_2SO_4.

In the method followed, soil was first treated with N ammonium chloride to remove the negligible amount of water soluble and loosely bound phosphorus which might be present. After this treatment, the soil was extracted with the various reagents and the different phosphorus fractions separated and estimated as follows.

3.2.6.8.1 *Aluminium phosphate*

This fraction was extracted by shaking the soil with 0.5N ammonium fluoride for one hour. The solution was filtered and the extracted P was estimated colorimetrically and reported as aluminium phosphate (Al - P).

3.2.6.8.2 *Iron phosphate*

The soil after treatment with ammonium fluoride was washed with saturated sodium chloride solution and then shaken with 0.1 N sodium hydroxide for 17 hours. The phosphorus extracted was estimated colorimetrically and reported as iron phosphate (Fe - P).

3.2.6.8.3 *Calcium phosphate*

After sodium hydroxide extraction, the soil was again washed with saturated sodium chloride and calcium phosphate (Ca - P) was extracted by shaking with 0.5 N H_2SO_4 for one hour and then estimated colorimetrically.

3.2.6.9 Organic phosphorus

The HCl - NaOH extraction method as suggested by Mehta *et al.* (1954) was followed for the determination of organic phosphorus. The determination was carried out by alkaline extraction in NaOH after acid pre-treatment. The difference between the inorganic phosphorus in the extract before and after oxidation of the organic matter represented the organic P fraction.

3.2.6.10 Available nitrogen

Available nitrogen in soil was determined by alkaline permaganate method (Subbiah and Asija, 1956).

3.2.6.11 Available phosphorus

Available P in soil was extracted using Bray No. 1 reagent and was determined colorimetrically by Chlorostannous - reduced molybdophosphoric blue colour method in hydrochloric acid system (Bray and Kurtz, 1945).

3.2.6.12 Available potassium

The ammonium acetate leachate collected during the determination of CEC was directly used for the determination of available potassium using an EEL flame photometer (Jackson, 1973).

3.2.6.13 Available calcium and magnesium

Available calcium and magnesium were determined from the ammonium acetate leachate collected during the determination of CEC using atomic absorption spectrophotometer. (Jackson, 1973).

3.2.6.14 Available sulphur

Available sulphur was determined adopting the procedure suggested by Chesnin and Yien (1951). It followed turbidimetric determination of sulphate as a barium sulphate suspension stabilised by gum of acacia. The extraction was carried out using Morgan's extraction solution.

3.2.6.15 Oxalate extractable iron and aluminium

Soil was shaken with 0.2 M ammonium oxalate at pH 3.0 for four hours, centrifuged and supernatant fed into an atomic absorption spectrophotometer for the determination of oxalate extractable iron - Fe (o) and oxalate extractable aluminium - Al (o). (McKeague and Day, 1966).

3.2.6.16 Dithionite extractable iron and aluminium

Soil was added with sodium dithionite - citrate - bicarbonate solution and stirred for 15 minutes. Then added sodium chloride solution and acetone, warmed, centrifuged and the supernatant fed to an atomic absorption spectrophotometer for the determination of dithionite extractable iron - Fe (d) and dithionite extractable aluminium - Al (d). (Mehra and Jackson, 1960).

3.2.6.17 DTPA extractable Fe, Mn, Cu, Zn

The micronutrients Fe, Mn, Cu and Zn were extracted with DTPA extracting solution which is a mixture of 0.005 M DTPA, 0.01 M $CaCl_2$ and 0.1 M triethanol amine adjusting the pH to 7.3 with dilute HCl. Air dry soil (2 mm.) was extracted with DTPA extracting solution in 1:2 (W/V) ratio and the micronutrient contents were determined using an atomic absorption spectrophotometer. (Lindsay and Norvell, 1969).

3.2.6.18 Zero point of charge (ZPC)

The procedure described by van Raij and Peech (1972) was used. A series of 4 g H-saturated soil samples was equilibrated with known amounts of acid (HCl) and base (NaOH) in various concentrations of NaCl for 3 days. The pH of the supernatent solution was determined using a pH meter. The amount of H^+ and OH^- ions absorbed at a given pH value was taken as equal to the amount of HCl and NaOH added to the suspension minus the amount of acid or base required to bring the same volume of eletrolyte solution without soil to the pH value. The ZPC of the soil is taken as the pH value where the charge pH curves measured in different electrolyte concentrations intersect one another.

3.2.6.19 Organic matter fractions

The separation of fractions of organic matter was carried out by adopting the following method (Jackson, 1973).

3.2.6.19.1 ***Humic acid***

Soil sample was extracted with 0.5 N sodium hydroxide after repeated periodical shaking and filtration, and the filtrate was precipitated by concentrated hydrochloric acid to determine humic acid.

3.2.6.19.2 ***Fulvic acid***

The acid soluble fraction collected during the separation of humic acid is evaporated and estimated as fulvic acid.

3.2.6.20 Enzyme activity (Phosphatase)

Acid phosphatase activity of the incubated samples was assayed adopting the method suggested by Tabatabai (1982). The enzyme assay was performed on moist samples incubated at 37 ^{0}C.

3.3 Pot culture experiment

This experiment was undertaken with the objective of assessing the agronomic effectiveness of vermicompost, in comparison with FYM and ordinary compost at different doses, using cowpea as a test crop.

3.3.1 Experimental site

The pot culture was carried out in the experimental field attached to the Department of Soil Science at College of Agriculture, Vellayani.

3.3.2 Soil

The soil used for the study was a low activity clay soil collected from the Instructional Farm attached to the College of Agriculture, Vellayani. The soil used was classified as Fine Loamy Kaolinitic Isohyperthermic Typic Kandiustults.

3.3.3 Season

The study was conducted during the period from the first week of January, 1995 to the first week of April, 1995.

3.3.4 Crop and variety

The study was conducted using cowpea as a test crop. The variety used was C - 152. This variety was evolved at IARI and is recommended for cultivation in clay soils of Kerala. It is an erect, tall variety with a duration of about 90 - 100 days.

3.3.5 Source of the seed material

The seeds were obtained from the Regional Office of National Seeds Corporation, Karamana, Thiruvananthapuram.

3.3.6 Fertilizers

The following straight fertilizers were used for the study as N, P and K source

Nitrogen : Urea

Phosphorus : Single super phosphate

Potassium : Muriate of potash

3.3.7 Design of the experiment

The field pot culture experiment was conducted in three replications with the following 11 treatments, programmed in CRD.

T_1 : FYM (At recommended dose of inorganic fertilizers)

T_2 : Ordinary compost („ „)

T_3 : Vermicompost („ „)

T_4 : FYM (10 t ha^{-1}) + Lime + Fertilizer at recommended dose

T_5 : FYM (20 t ha^{-1}) + lime + Fertilizers

T_6 : Ordinary compost (10 t ha^{-1}) + lime + Fertilizers

T_7 : Ordinary compost (20 t ha^{-1}) + lime + Fertilizers

T_8 : Vermicompost (10 t ha^{-1}) + lime + Fertilizers

T_9 : Vermicompost (20 t ha^{-1}) + lime + Fertilizers

T_{10} : Mineral fertilizers alone

T_{11} : No manure, No fertilizer.

3.3.8 Treatment materials

Fertilizers were added as recommended in the package of practices of KAU (N : P : K @ 20 :30: 10 kg ha^{-1} ; Organic manure @ 20 t ha^{-1} ; Lime @ 250 kg ha^{-1}). On per hectare soil weight basis, after accounting for the nutrient contents of the fertilizers, 0.11 g of urea, 0.42 g of single superphosphate and 0.042 g of MOP were added in each pot as equivalent to the recommended dose of inorganic fertilizers. 50 g each of compost materials and FYM were added as equivalent to the treatment dose of organic manures (20 t ha^{-1}) and 25 g each of compost materials were added as equivalent to 10 t ha^{-1}. In the first three treatments, viz., T_1, T_2 and T_3, in addition to 50 g each of the respective organic manures, additional amounts of 15g FYM, 30 g ordinary compost and 25 g vermicompost were added (to the respective treatments, viz., T_1, T_2 and T_3) as equivalent to the recommended dose of inorganic fertilizers. This was done on a phosphorus equivalence basis. Lime was added at the rate of 0.7 g per pot (to correct acidity).

3.3.9 Arrangement of pots

A total number of 99 pots were set for the experiment. 33 pots (representing 11 treatments replicated thrice) were exclusively set apart for taking observation of biometric and yield parameters. Destructive sampling at 20 days after sowing was done in 33 pots to study the plant nutrient status and nodule count. A similar destructive sampling was done in 33 pots at maximum flowering stage to study the same parameters. Plant nutrient status and yield parameters were studied at the time of harvest. The pots were arranged in fields at a spacing of 25 x 25 cm.

3.3.10 Seeds and sowing

Soil from the proposed site was collected and 5 kg soil was mixed with the treatment materials was filled in each pot. Three bold, disease free seeds of cowpea were sown in each pot. Then the pots were irrigated and kept protected from the attack of birds.

3.3.11 After cultivation and irrigation

Gap filling and thinning were done seven days after sowing so that two healthy plants were retained in each pot. All the weeds were removed by hand weeding and the pots were kept completely weed free. The pots were irrigated once in alternate days.

3.3.12 Plant protection

Two spraying were given with Malathion (0.05%) for controlling the pea aphids.

3.3.13 Harvesting

The dry pods from each pot were picked thrice, sun dried, threshed potwise and the yield of grain and husk were recorded separately. The plants were then pulled out from each pot and sun dried.

3.3.14 Observation on growth characters

The growth characters except nodule number were recorded at 3 stages of growth, viz., on the 20th day after sowing, at maximum flowering and at harvest.

3.3.14.1 Height of the plants

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

3.3.14.2 Number of leaves per plant

Each of the trifoliately compound leaf was counted as a single leaf and the number of such leaves in each plant was recorded separately at three stages of growth.

3.3.14.3 Dry weight of plants

The plants were uprooted carefully, sun dried and then oven dried at 80^0C and the weights were recorded separately.

3.3.14.4 Number of nodules per plant

The plants were uprooted, the separated nodules from the roots were washed carefully, counted and the average worked out. Nodule count was taken at two stages of growth, viz., 20 days after sowing and at flowering.

3.3.15 **Yield and yield attributes**

The various observations contributing to yield were recorded at the time of harvest for each treatment separately.

3.3.15.1 Number of pods per plant

Pods collected from the observational plants were counted separately and the average worked out.

3.3.15.2 Length of pods

Length of six pods selected randomly from each pot were measured in cm and the average worked out.

3.3.15.3 Number of seeds per pod

Pods used for measuring the length were threshed separately and the number of seeds in each pod was counted and the average worked out.

3.3.15.4 Grain yield per plant

Dry weight of all the seeds from the observational plants were recorded and the average worked out and expressed in grams.

3.3.15.5 Hundred Grain weight

100 seeds were selected randomly from the bulk of seeds in each pot, weighed and recorded in grams as hundred grain weight.

3.3.15.6 Bhusa yield

After the pods were picked, the plants were uprooted, sun dried uniformly and weighed. This was expressed in grams of bhusa yield per plant.

3.3.15.7 Harvest index

The harvest index was worked out based on the grain, husk and bhusa yield obtained from each plant using the following formula and expressed in percentage.

$$HI\ (\%) = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100.$$

3.3.16 **Plant analysis**

The uprooted plants were washed well, sun dried, oven dried at $80^{0}C$, powdered and used for chemical analysis.

3.3.16.1 Nitrogen content

Total nitrogen of the plant samples were determined by modified MicroKjeldahl method (Jackson, 1973).

3.3.16.2 Phosphorus content

The total phosphorus was determined colorimetrically by Vanado-molybdo phosphoric yellow colour method (Jackson, 1973).

3.3.16.3 Potassium content

The total potassium content was determined by using EEL flame photometer.

3.3.16.4 Calcium and Magnesium

The Ca and Mg contents were determined directly from the extract obtained by the wet oxidation of plant tissue, using an atomic absorption spectrophotometer (Jackson, 1973).

3.3.16.5 Sulphur content

The sulphur content was determined employing the wet oxidation procedure without H_2SO_4. (Jackson, 1973).

3.3.17 **Analysis of the soil after experiment**

The soil samples collected from the pots after the experiment were air dried and analysed for pH, organic carbon, available nitrogen, phosphorus, potassium, calcium, magnesium and sulphur following standard analytical procedures (Jackson, 1973).

3.4 Statistical analysis

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

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RESULTS AND DISCUSSION

4 RESULTS AND DISCUSSION

The present study undertaken to investigate the effect of vermicompost on the electro-chemical properties and nutritional characteristics of a low-activity clay soil, comprised two experiments viz., an incubation experiment and a pot culture experiment. The incubation experiment was designed for the evaluation of different organic manures to assess their relative efficiency in releasing P from soil with and without an added P source. Various properties of the soil as influenced by different organic manures over a period of upto 120 days were periodically analysed and recorded at an interval of 30 days.

Second part of the study, the pot culture experiment, was conducted to investigate the agronomic effectivness of different organic manures, using cowpea as a test crop. Biometric observations and yield parameters were recorded at critical stages of plant growth. Uptake of major and secondary nutrients by the plant at critical stages of growth and the nutrient status of the soil after the experiment were also analysed.

The results thus obtained from the above investigations are presented in this chapter, and are discussed in the light of published information and fundamental theoretical knowledge.

4.1 Analysis of organic manures

The different organic manures were analysed following standard analytical procedures and the data is presented in Table. 1. The vermicompost (VC) used for the study recorded a nutrient composition of 0.9, 0.4, 0.3 per cent of N, P_2O_5 and K_2O respectively. From the data, it is seen that FYM and vermicompost are almost on par with respect to nitrogen and potassium contents but FYM stands slightly superior with respect to phosphorus content. The ordinary compost showed lesser values for all the treatments compared to both FYM and vermicompost. However the nutrient content of VC as reported by Pushpa (1996) (1.69, 0.78, 1.90 per cent of N, P_2O_5, K_2O) did not agree with the results of the present study. The variation observed may be attributed to the possible difference in the source material used for composting. From the data it is clear that the superiority of vermicompost compared to FYM in

Table 1 BASIC ANALYSIS OF ORGANIC MANURES

Properties	Vermicompost	Farm yard manure	Ordinary compost
Nitrogen (%)	0.90	0.80	0.45
Phosphorus (%)	0.40	0.50	0.25
Potassium (%)	0.30	0.30	0.20
Calcium (%)	0.35	0.20	0.23
Magnesium (%)	1.45	1.10	1.15
Organic C (%)	18.00	22.40	13.50
C : N Ratio	20.00	28.00	30.00
CEC (cmol kg^{-1})	27.44	22.00	20.00
Soil reaction (pH)	7.30	6.90	6.80

Table 2 PRELIMINARY ANALYSIS OF SOIL USED FOR THE STUDY

Parameter	Content
Total Nitrogen	0.03 %
Total Phosphorus	0.05 %
Total Potassium	0.09 %
Available Nitrogen	241.05 kg ha^{-1}
Available Phosphorus	28.44 kg ha^{-1}
Available Potassium	116.00 kg ha^{-1}
Available Calcium	1.12 cmol kg^{-1}
Available Magnesium	1.52 cmol kg^{-1}
Available Sulphur	110 ppm
Soil reaction (pH)	5.10
Electrical conductivity	0.044 dS.m^{-1}
Organic carbon	0.83 %
Cation Exchange Capacity	2.51 cmol kg^{-1}
Bulk density	1.51 Mg m^{-3}
Water holding capacity	26.42 %

SOIL TEXTURE		SANDY LOAM
	Coarse sand : 30.00 %	
	Fine sand : 26.00 %	
	Silt : 24.50 %	
	Clay : 19.50 %	

Fine Loamy Kaolinitic Isohyperthermic Typic Kandiustults augmenting crop growth and soil fertility, as reported by several research workers, is attributed mainly to factors other than its own nutrient contents which needs elaboration.

From the data on nutrient composition *per say* of vermicompost and other organic manures no conclusions could be drawn to establish a clear cut superiority for vermicompost. Thus the reported information of the superiority of vermicompost has to be theorised based on analytical details on its growth promoting effects. There are reports to believe that a variety of metabolically active organic compounds are being produced / synthesised while the organic wastes descends through the gut of worms (Edwards and Lofty, 1980). A detailed investigation on these unstudied aspects of vermiculture is beyond the scope of the present study. Emphasis is given more towards the effect of vermicompost on the electro-chemical behaviour of a low activity clay soil having variable charge character.

Further, from the data presented in Table 1, it is evident that vermicompost is basic in reaction with high cation exchange capacity, exchangeable Ca and Mg and comparatively narrow C : N ratio. Hence the role of verimcompost as a suitable soil amendment for modifying the exchange complex of the impoverished, base depleted, humus poor variable charge soils under investigation is theoretically sound.

4.2 Preliminary analysis of soil used for the study

The physical and chemical characteristics of the soil selected for the study are given in Table. 2. From the data presented, it is clear that the soil used is a sandy loam, low in available N, K_2O and medium in available P_2O_5, classified as Fine Loamy Kaolinitic Isohyperthermic Typic Kandiustults according to soil taxonomy. The variable charge nature justifies the selection of the soil as one likely to respond to the various treatments and hence suited for making an overall assessment of the comparative effect of different treatments (Parfitt, 1980).

A close scrutiny of the data reveals that soil is depleted of bases with very low percentage base saturation, rich in sesqui oxides and poor in organic carbon. The soil reaction is distinctly acidic with a pH of 5.1. The soil is texturally sandy loam with low value of clay at the surface which indicates downward migration of clay. The electrical conductivity values are negligibly low showing excessive leaching and downward movement of bases present in the soil. Further, the tropical climate with heavy rainfall alternated with high tempetatures would have enhnaced the solute movement from the surface layers. The impoverished nature of the soil is clearly brought about by the very low available N and K_2O contents. However, the P_2O_5 content was medium. The electro-chemical properties of the soils studied clearly showed that the inorganic components of the soil is of variable charge type with low cation exchange capacity and higher Fe and Al contents. Thus the soil used for the study is likely to interact with organic materials and the clay-organic complexes formed is expected to change the charge behaviour of the soil and the exchange complex to the advantage of cation and anion exchange for better nutrient retention and availability (Barrow, 1985).

4.3 INCUBATION EXPERIMENT

Tables 3 to 31 present data on various investigations done to study the effect of different organic manures with and without rock phosphate as an added P source on the nutritional characteristics and electro-chemical properties of the soil taken for the study. The various soil parameters investigated are grouped into four, viz., fractions of phosphorus, available major and secondary nutrient status, electro-chemical properties and fractions of organic matter ; for convenience in tabulation, comparison and discussion.

4.3.1 **Fractions of Phosphorus**

As vermicompost is reported to have a major influence on phosphorus dynamics in variable charge soils, more emphasis was given to investigate its effects on the occurrence and transformations of various forms of P. Total P, Bray-extractable (available) P, forms of inorganic P (Fe-P, Al-P, Ca-P) and organic P status of soil under various treatments were investigated over five periods of incubation and the data are presented in Tables 3 to 8.

4.3.1.1 Total Phosphorus

Table. 3 (Fig. 1) contains data on the total phosphorus contents under various treatments over an interval of 30 days for a period of four consecutive months. There

Table 3 **Total Phosphorus (ppm)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	500.00	555.33	472.00	472.00	527.67	505.40
T_2	694.00	694.00	666.33	694.00	666.00	682.87
T_3	777.67	777.67	805.33	749.67	777.67	777.60
T_4	1027.67	1055.33	916.33	999.67	972.00	994.20
T_5	1227.67	1277.67	1305.33	1277.67	1249.67	1277.60
T_6	750.00	805.33	7.49.67	777.67	750.00	766.53
T_7	1027.67	1027.67	1000.00	972.00	1027.67	1011.00
T_8	833.00	860.67	805.33	805.33	860.67	833.00
T_9	1160.67	1083.00	1083.00	1055.33	1138.33	1094.07
Mean Pe.	888.70	904.07	867.04	867.04	855.52	

CD. Tr: 31.598 CD. Pe: 29.354 CD. Tr. Pe : 88.063

Table 4 **Available P_2O_5 [Bray extractable] (kg ha^{-1})**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	28.44	26.75	30.84	28.11	31.78	29.18
T_2	187.33	141.52	111.05	97.72	64.42	120.41
T_3	37.44	56.32	71.5	80.50	96.37	68.46
T_4	35.17	41.48	47.39	50.44	55.27	45.95
T_5	48.33	81.05	118.94	147.44	171.13	113.38
T_6	34.22	40.70	45.28	47.50	52.42	44.02
T_7	45.89	75.78	112.55	142.33	162.42	107.79
T_8	45.72	51.15	57.28	71.44	82.80	61.08
T_9	53.61	89.33	129.39	159.61	196.58	125.71
Mean Pe.	57.02	67.12	80.47	91.68	101.47	

CD. Tr: 1.1640 CD. Pe: 0.5912 CD. Tr. Pe : 1.7736

is significant variation between the treatments with respect to total-P. The treatment T_5 representing soil + FYM + rock phosphate(RP) recorded the maximum total P content over all the five periods. The highest value of 1305.33 ppm was recorded by T_5 on the 60th day of incubation. Treatment T_9 representing soil + vermicompost (VC)+ RP recorded the second highest value over all the five periods. The lowest value was observed with respect to treatment T_1 representing soil alone. Eventhough there was significant variation among treatments, no significant variation was noted between various periods of incubations. However Patel *et al.* (1963) and Maurya and Ghosh (1972) have reported an increase in total P contents of the soils due to continuous application of FYM.

A critical evaluation of the data on total P shows no significant variation among various periods of incubation. But total P content in each treatment differed significantly owing to variations in the total P reserve of the incubated system. This variation is acrued due to variations in the P content of fertilizers and organic sources. Thus relative content of FYM, vermicompost and ordinary compost (OC) with respect to phosphorus in combination with the P present in rock phosphate has resulted finally in the change in P status of the incubated system. As there is no removal of P from the system, minor variations noticed is owing to transformations of P and hence no appreciable change is expected in the total P. Thus it is only the absolute sum of P contributed from different sources added to the total P reserve which as per analytical data is maximum for treatment T_5 representing soil + FYM + RP.

4.3.1.2 Available Phosphorus (Bray No. 1)

The quantity of available P_2O_5 is considered to be very important in phosphorus studies, since it directly reflect the immediate P nutrition to plants. Table. 4 (Fig. 2) represents the effect of various treatments and periods of incubation on the Bray extractable (available) phosphorus. In general, there is a gradual increase in available P_2O_5 with advancement of time. There was significant variation among the treatments, the maximum mean value being represented by treatment T_9 (soil + VC + RP) followed by T_2 (soil + SSP). T_9 showed a gradual increase of available P_2O_5 from 0th to 120th day, attaining the highest value of 196.58 on the 120^{th} day. In contrast to this, T_2 showed a peak value of 187.33 on the 0^{th} day followed by a gradual decrease over

Fig. 1. Total phosphorus (ppm)

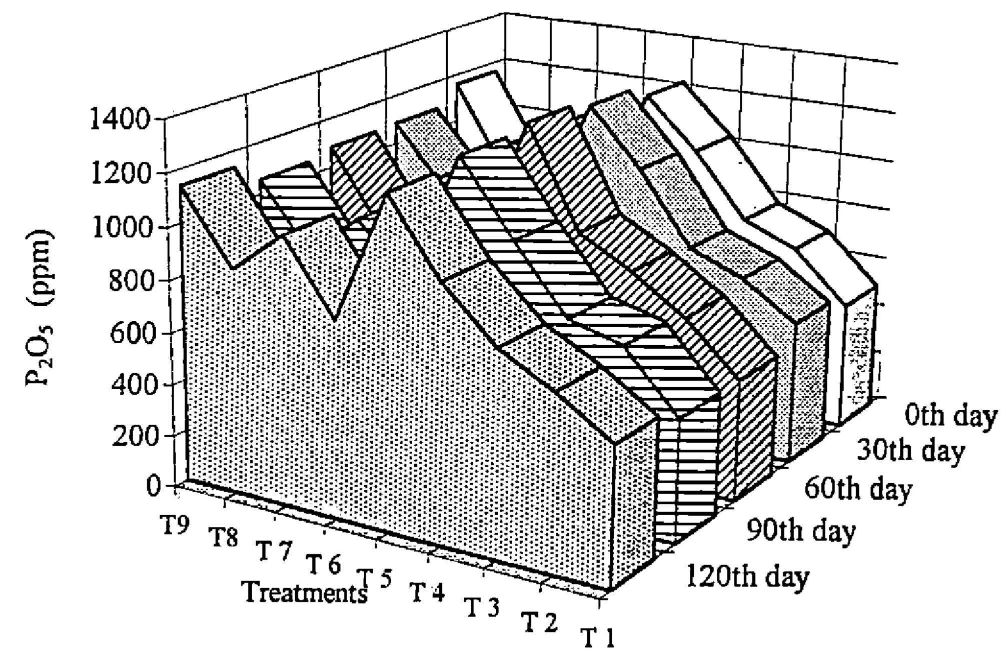
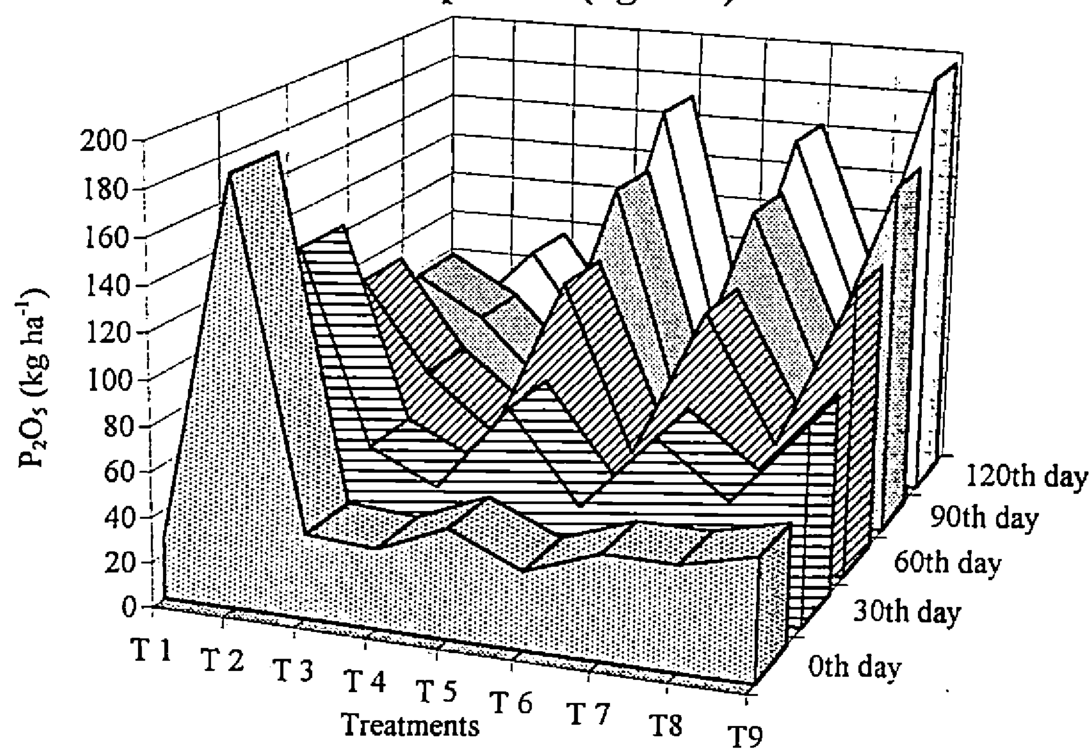


Fig. 2. Available (Bray extractable) **Phosphorus (kg ha^{-1})**



subsequent periods. Treatment T_1 representing control (soil alone) recorded the lowest values over all the five periods. Treatments T_5, T_7 and T_9 receiving both organic manures and rock phosphate showed significantly higher values than treatments T_3, T_4, T_6 and T_8 receiving either of them, over all the five periods. The variation due over all the five periods were significantly different. This result is in consonance with the findings of Mackey *et al.* (1983) who found that incorporation of earthworms to soil incubated with phosphate rock resulted in a 32 per cent increase in Bray - extractable soil phosphorus after 70 days. Similar results had also been reported by Kale *et al.* (1992).

Highest value of available P_2O_5 observed in T_9 is due to the reported effect of vermicompost by releasing inorganic phosphates from insoluble rock phosphates. The high microbial activity and enhanced mineralisation of soil P coupled with high phosphatase and phytase activity might be the reasons for the high Bray extractable P obtained (Alexander, 1978 ; Sharpley and Syres, 1977). Further, the process of solubilisation of added RP by the organic acids and other organic ligands must have played a vital role in releasing insoluble soil P in treatments receiving organic manures (Gaur, 1994). Though the same mechanism is applicable to all treatments with organics, the effectiveness of VC is more pronounced in the process than other organic amendments. The liberation of P by decomposition of organic matter is also one of the mechanisms contributing available P. Hence the easily decomposable vermicompost could build up a high phosphate labile pool in soil than FYM and ordinary compost. The chances of P release by ligand exchange and by anion exchange with silicates, humates, citrates and OH- ions cannot be ruled out in any soil system treated with large doses of organic manures. This view is supported by the findings of Srivastava *et al.* (1969) and Alexander (1978).

Though there is appreciable conversion of soluble P to other forms like Fe-P, Al-P, Ca-P etc., it is presumed that they are Bray extractable initially as evidenced from the high Bray extractable P obtained. More or less the same trend observed with respect to other treatments receiving organic manures are also explained in the same manner. As treatment T_9 continues to maintain Bray extractable P even after the 5^{th} observation it is evident that the processes responsible for P release is still active in treatments receiving vermicompost with an added source of insoluble P like rock phosphate. Thus priming / pelleting of rock phosphate with vermicompost can be suggested as a suitable proposition for improving the efficiency of rock phosphate in variable charge soils.

The high Bray P observed in T_2 initially was expected because of single super phosphate present in the treatment. Peak values of soluble P obtained decreased gradually due to fixation and transformations of P which was chiefly controlled by the Fe and Al suite of the soil system. It is reported that the Fe-P and Al-P formed in the absence of organic anions and humic materials results in stable insoluble crystalline forms at a faster rate. Hence the degradation products of organic matter exercises a profound influence on anion protection with respect to phosphate in soil solution. These views are in conformity with the findings of Moshi *et al.* (1974) and Russell (1975).

4.3.1.3 Inorganic Phosphorus

A close observation of various fractions of inorganic phosphorus, viz., Fe-P, Al-P and Ca-P could present a detailed picture of phosphorus dynamics as influenced by various treatments. The changes in various fractions of inorganic phosphorus due to the effect of treatments over different periods are presented in Tables 5, 6 and 7.

4.3.1.3.1 *Iron phosphate*

Table 5 (Fig. 3) shows data on the pattern of changes in Fe-P due to various treatments. From the data recorded, it is clear that as time advances there is a gradual increase of Fe-P in case of all the nine treatments. Treatment T_9 representing soil + VC + RP recorded the maximum mean value over all the periods, followed by T_5 representing soil + FYM + RP. Treatment pairs T_7, T_8 and T_1, T_3 show insignificant variation among themselves. The highest Fe-P value of 500.67 ppm was recorded by T_9 on 120th day followed by the second highest value of 443.33 by T_5 on the same day. The variation due to effect of incubation time was significant in all the five periods. This result is in consonance with the findings of Sahi *et al.*(1979).

As the soil used for the study is rich in active iron, both Fe(o) and Fe(d), the conversion of soluble P to Fe-P is faster in all treatments where the release of available

Table 5 Iron -Phosphate (ppm)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	149.33	154.33	158.00	160.00	164.00	157.13
T_2	150.00	162.33	171.33	188.33	202.67	174.93
T_3	150.67	156.33	161.67	170.67	177.00	163.27
T_4	152.33	169.00	200.00	243.33	295.00	211.93
T_5	149.33	200.0	291.67	381.67	443.33	293.20
T_6	150.00	162.33	181.67	201.67	220.00	183.13
T_7	151.67	193.33	243.00	295.00	345.00	245.67
T_8	153.33	205.00	275.00	295.00	320.00	249.67
T_9	153.33	241.67	361.67	428.33	500.67	337.13
Mean Pe.	151.11	182.70	227.15	262.67	296.41	

CD. Tr: 6.904 CD. Pe: 2.286 CD. Tr. Pe : 6.857

Table 6 Aluminium - Phosphate (ppm)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	47.67	50.33	54.00	54.33	56.67	52.60
T_2	52.67	60.67	72.67	81.33	87.33	70.93
T_3	50.33	52.33	56.33	59.33	64.67	56.60
T_4	51.67	55.67	59.00	72.67	87.67	65.33
T_5	52.33	64.33	77.33	94.67	131.67	84.07
T_6	50.33	55.67	59.00	66.33	72.67	60.80
T_7	50.33	60.67	68.67	84.33	102.67	73.33
T_8	50.33	59.67	69.00	82.33	92.67	70.80
T_9	52.33	74.33	98.33	117.67	132.33	95.00
Mean Pe.	50.89	59.30	68.26	79.22	92.04	

CD. Tr: 3.321 CD. Pe: 0.614 CD. Tr. Pe : 1.842

Fig. 3. Iron phosphate (ppm)

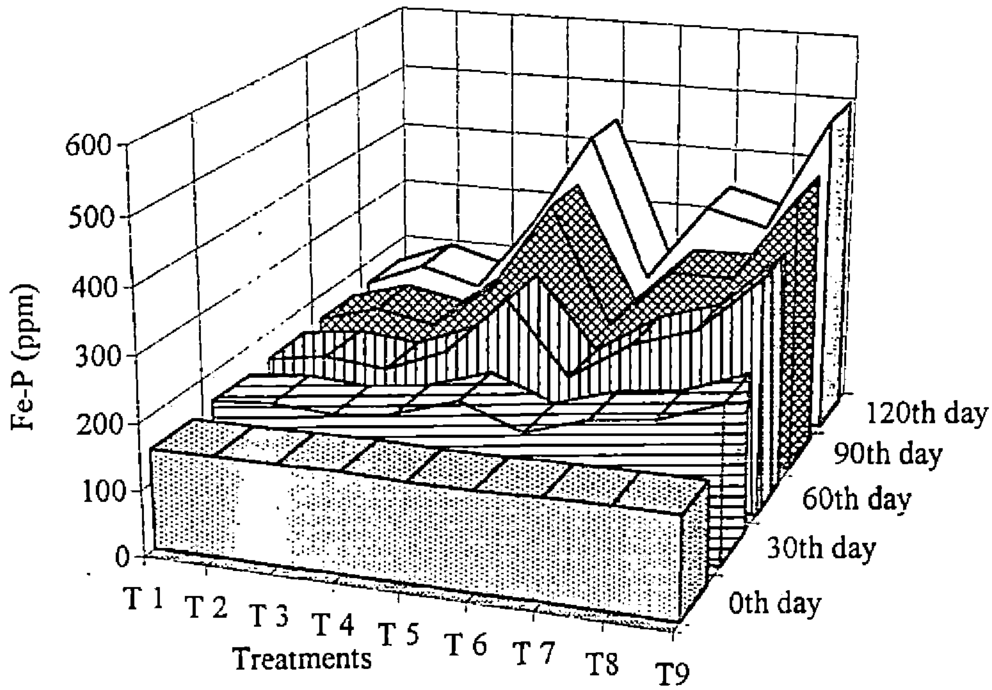
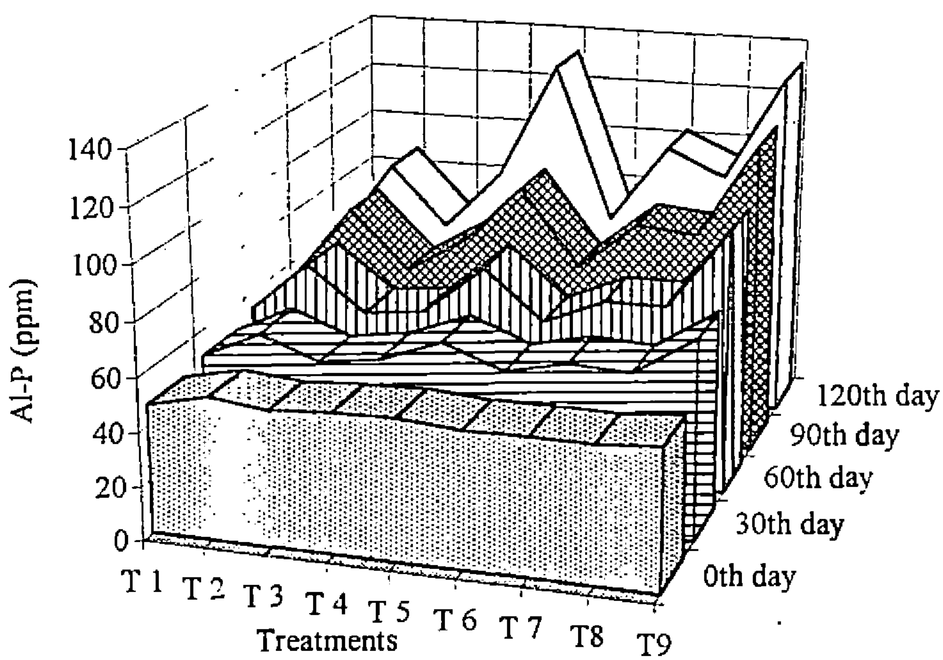


Fig. 4. Aluminium phosphate (ppm)



P is appreciable with time. As this effect is more pronounced in the case of T_9 and continues even after 120 days, it is logical to observe a sustained Fe-P concentration in this treatment throughout the period of incubation. Though there is reaction between humic colloids with metal cations like Fe forming very stable compounds by complex formation or by chelation, the affinity of Fe to soluble phosphate is very high, suppressing the former effect leading to stable compounds of iron phosphates (Russell, 1975). Further, there is no P removal from the incubated system except the negligible microbial immobilisation, thus maintaining a high available P pool, creating an atmosphere conducive for Fe-P formation. Thus it is apparent to believe that the polyvalent cation suit dominated by Fe interacts with the soluble P, as and when it is formed, fixing P temporarily as Fe-P (Bear, 1965). As the capacity of vermicompost to release P from insoluble forms is very high, when compared to other organic sources, it is reasonable to believe that this reaction leading to the formation of Fe-P is also high for treatments receiving VC. Almost similar trend observed in treatments receiving FYM could also be explained in the same manner.

4.3.1.3.2 ***Aluminium phosphate***

From the mean recorded (Table.6 ; Fig. 4), it was observed that as in the case of Fe-P, there is a gradual increase of Al-P over all the five periods. There is significant variation among different treatments, eventhough T_7, T_2 and T_8 are statistically on par. The highest mean value of 95.00 ppm was recorded by treatment T_9 (soil + PC + RP) followed by 84.07 (T_5 : soil + FYM + RP). Treatments T_9, T_5 and T_7 receiving both RP and organic manures showed significantly higher values of Al-P compared to other treatments.

A trend similar to Fe-P was observed in the case of Al-P also since Fe and Al are the dominant cations present in the soil under study. The reported specificity of pH in Fe-P and Al-P formation (Wada and Gunjigake, 1979) is insignificant in an incubated system since the process of precipitation is mostly chemical than microbiological and biochemical as observed in an open system. Thus the observed increase of Al-P throughout the incubation period is theoretically sound.

4.3.1.3.3 *Calcium phosphate*

In contrast to Fe-P and Al-P, a general decreasing trend is noted in the case of Ca-P with the passage of time (Table.7 ; Fig. 5). Treatment T_3 representing soil + RP maintained comparatively higher values over all the five periods taken together. The highest Ca-P value of 264.33 ppm was recorded by T_9 during the first observation which decreased drastically to 88.33 ppm on the 120^{th} day towards the last observation. Treatments T_5, T_7 and T_9 receiving both RP and organic manures registered higher values compared to T_4, T_6 and T_8 receiving organic manures alone, though T_3 superceeded all the treatments with a mean treatment value of 210.27 ppm over all the five periods taken together. The lowest Ca-P value recorded was 28.00 ppm by the treatment T_8 (soil + VC) on the 120^{th} day of incubation. The variation due to different periods was significant. This is in conformity with the reports of Raju and Venkata Rao (1979) in acidic red soils of Bangalore.

The initial high Ca-P values observed for RP containing treatments, as expected, was due to the high tricalcium phosphate introduced into the soil through RP. Except for treatments receiving organics, this Ca-P concentration is maintained at a higher level as evident from the trends of T_3. Treatments T_5, T_7 and T_9 receiving organic amendments showed a gradual decline of Ca-P towards the last observation and maintained a level much lower than T_3. Amongst the treatments receiving organic amendments in presence of RP, the aforementioned effect of suppressing the concentration of Ca-P is more pronounced in the case of vermicompost (T_9). This decline in Ca-P concentration in treatment T_9, on the contrary, is explained by a spurt in Fe-P and Al-P in the same treatment with advancement of time. It is needless to say in this context the anomalous capacity of vermicompost to release P from insoluble forms for various reasons explained above. Thus the Ca-P dynamics in an incubated system is not dependant of Ca concentration alone, but is controlled to a greater extent by active Fe and Al. Hence the increase in Fe-P and Al-P observed in the above treatments must be at the expense of a decrease in Ca-P. This view is in close agreement with the findings of Kothandaraman and Krishnamoorthy (1979) and Puranik *et al.* (1979).

Table 7 Calcium - Phosphate (ppm)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	51.00	49.33	47.00	45.00	40.00	46.47
T_2	127.67	107.33	92.33	68.67	56.67	90.53
T_3	247.67	220.00	200.00	194.33	189.33	210.27
T_4	57.67	49.33	44.67	42.00	39.67	46.67
T_5	259.33	242.33	197.67	160.67	125.00	197.00
T_6	59.00	51.33	46.67	42.67	39.00	47.73
T_7	263.33	236.67	199.33	158.00	138.33	199.93
T_8	62.33	47.00	37.00	30.67	28.00	41.00
T_9	264.33	172.00	129.67	100.00	88.33	150.87
Mean Pe.	154.70	130.59	110.48	93.56	82.70	

CD. Tr: 2.782 CD. Pe: 1.495 CD. Tr. Pe : 4.483

Table 8 Organic - Phosphorus (ppm)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	70.67	70.67	66.33	62.67	59.67	66.00
T_2	69.33	68.67	64.33	60.33	58.67	64.27
T_3	68.33	67.00	63.67	62.00	58.00	63.80
T_4	415.33	355.00	300.00	243.33	205.00	303.73
T_5	419.33	361.67	287.67	251.00	235.00	310.93
T_6	305.33	246.00	200.00	140.00	114.33	201.13
T_7	322.00	260.00	212.33	164.00	143.00	220.27
T_8	440.33	394.33	337.67	331.00	296.67	360.00
T_9	453.33	403.33	259.67	350.00	336.33	380.53
Mean Pe.	284.89	247.41	210.18	184.93	167.41	

CD. Tr: 3.359 CD. Pe: 2.059 CD. Tr. Pe : 6.179

Fig. 5. Calcium phosphate (ppm)

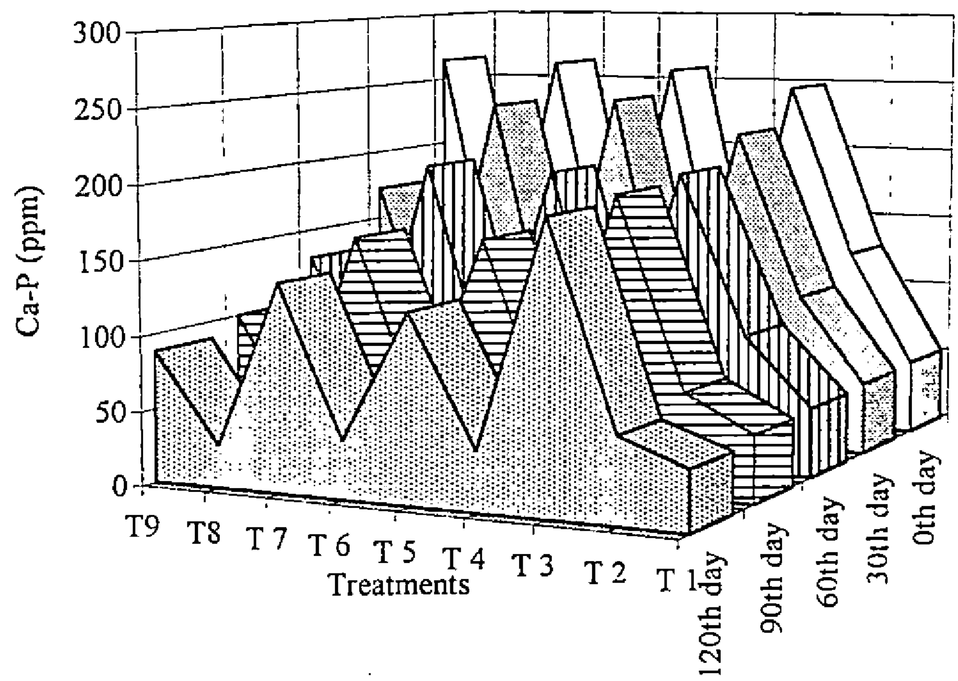
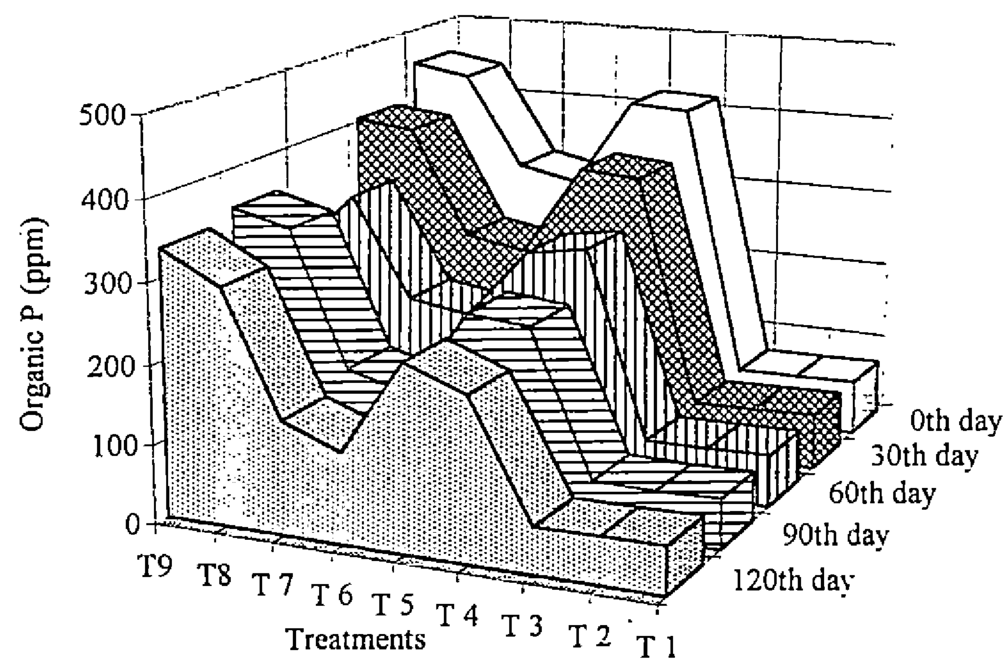


Fig. 6. Organic phosphorus (ppm)



4.3.1.4 Organic Phosphorus

The results indicated (Table. 8 ; Fig. 6) a trend of decreasing values for organic-P over all the five periods. All the treatments receiving any of the organic manures showed significantly higher values compared to those treatments which did not receive organic manures. Among the various treatments, T_9 showed maximum mean value of 380.53 ppm over all the five periods taken together. The highest value of organic-P recorded was 453.33 ppm on the initial day by T_9 followed by T_8 on the same day. Treatments T_8 and T_9 showed minimum variation for organic-P during the entire period of incubation.

The high organic-P content observed in all treatments receiving organic amendments initially is explained by the high content of organically bound P contributed from the source (Singh and Omanwar, 1979; Mukherjee *et al.*,1979). The general decline in organic-P content observed with advancement of time is due to excessive mineralisation of organic matter and transformation leading to the formation of Fe-P, Al-P and other inorganic forms. A close scrutiny of the data clearly indicates lower values for organic-P with respect to treatments T_6 and T_7 receiving ordinary compost in comparision to FYM and vermicompost receiving treatments.

This could be explained by the relative difference in the chemical composition of organic fractions of the source materials. The content of humic acid fraction which is believed to maintain a high organic-P is minimum in the case of ordinary compost. Vermicopmost and FYM contain higher amounts of this fraction and hence the observed increase in organic-P in the experiment for treatments receiving the above is explained. It is interesting to note that treatments receiving VC, FYM and OC along with RP maintain a higher organic-P compared to their counterparts without RP at a later stage. This is probably due to the incorporation of soluble phosphate into the humic fractions of organic matter degradation leading to synthesis of organic-P and organically bound P (Bower, 1949 ; Dalal, 1977).

4.3.2 **Available major and secondary nutrients**

As the plant growth is directly linked to the easy and timely availability of various nutrients, the results in this section have high relevance with respect to plant nutrition. The related data are summarised in Tables 9 to 13.

4.3.2.1 Available Nitrogen

Being the most important nutrient in plant nutrition, the data (Table. 9 ; Fig. 7) on available N need a thorough study and interpretation. From the table it was observed in general, that there is an increasing trend in the available N upto 90 days of incubation and then a decrease. Among the treatments, T_9 (soil + VC + RP) was on the top with a mean value of 773.57 kg ha^{-1} over all the five periods taken together, followed by T_8 (soil + VC) with 765.68 kg ha^{-1}. From this observation it is clear that both the treatments receiving vermicompost are significantly superior in providing available N compared to FYM and ordinary compost. The highest value of 963.83 kg ha^{-1} available N was recorded by T_9 on 90^{th} day of incubation followed by the second highest value of 952.47 kg ha^{-1} by T_8 on the same day. The difference between those treatments receiving organic manures and those without organic manures had been found to be pronounced with the advancement of time. Treatment T_1 representing control (soil alone) showed the lowest value which remained practically unchanged over different periods. Similar results were reported by Syres and Springett (1984) and Shuxin *et al.* (1991). Gupta *et al.* (1988) reported an increase in available N content of soil upto 20 days after FYM application and a decrease thereafter, in a long term field experiment with wheat.

The observed increase in available N in treatment receiving organic amendments is due to the enhanced mineralisation of organic matter consequent to high microbial activity. Further, the total addition of N to soil also is more in the above treatments. Vermicompost with the lowest C : N ratio might have contributed more N than the other organic sources (Bohlen and Edwards, 1995). It is reported that vermicompost has a high urease activity than soil and other compost materials (Bremner and Mulvaney, 1978). The processes of aminisation, ammonification and oxidative deamination, all brought about by microbially mediated enzyme systems are believed to be active in vermicompost and other organic amendments thus contributing more of soluble N to the soil N economy. In addition to this, soluble N compounds excreted, secreted and synthesised by microbial population is also more in soils treated with organic amendments. The beneficial microflora present in the alimentary system of earthworms may also contribute to N levels in the case of vermicompost

Table 9 Available Nitrogen (kg ha^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	241.05	244.48	250.43	249.80	243.20	245.79
T_2	24678	291.67	331.77	345.15	330.13	309.10
T_3	248.88	256.25	266.88	270.55	260.40	260.59
T_4	361.25	420.30	754.27	869.28	768.57	634.73
T_5	370.53	426.30	777.70	892.73	762.90	646.03
T_6	395.17	446.30	722.33	842.62	747.82	630.79
T_7	403.70	457.83	725.48	859.98	753.68	640.14
T_8	505.75	606.30	881.63	952.47	852.55	765.68
T_9	510.67	613.30	893.13	963.83	886.90	773.57
Mean Pe.	364.86	418.05	622.63	694.05	626.21	

CD. Tr: 1.446 CD. Pe: 1.463 CD. Tr. Pe : 4.388

Table 10 Available K_2O (kg ha^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	116.00	118.67	123.00	121.67	121.67	120.20
T_2	119.33	121.33	126.33	119.33	119.33	121.13
T_3	120.00	123.00	124.00	121.67	120.67	121.87
T_4	424.67	520.00	741.33	684.33	538.00	581.67
T_5	437.00	524.00	729.00	673.33	546.67	582.07
T_6	384.33	491.67	703.33	654.33	524.33	551.60
T_7	376.00	497.00	703.00	663.33	530.67	554.00
T_8	526.00	682.00	812.67	749.00	686.00	691.13
T_9	533.00	690.00	804.33	755.33	684.67	693.47
Mean Pe.	337.41	418.63	540.78	504.70	430.22	

CD. Tr: 2.7778 CD. Pe: 2.1507 CD. Tr. Pe : 6.4521

Fig. 7. Available nitrogen (kg ha^{-1})

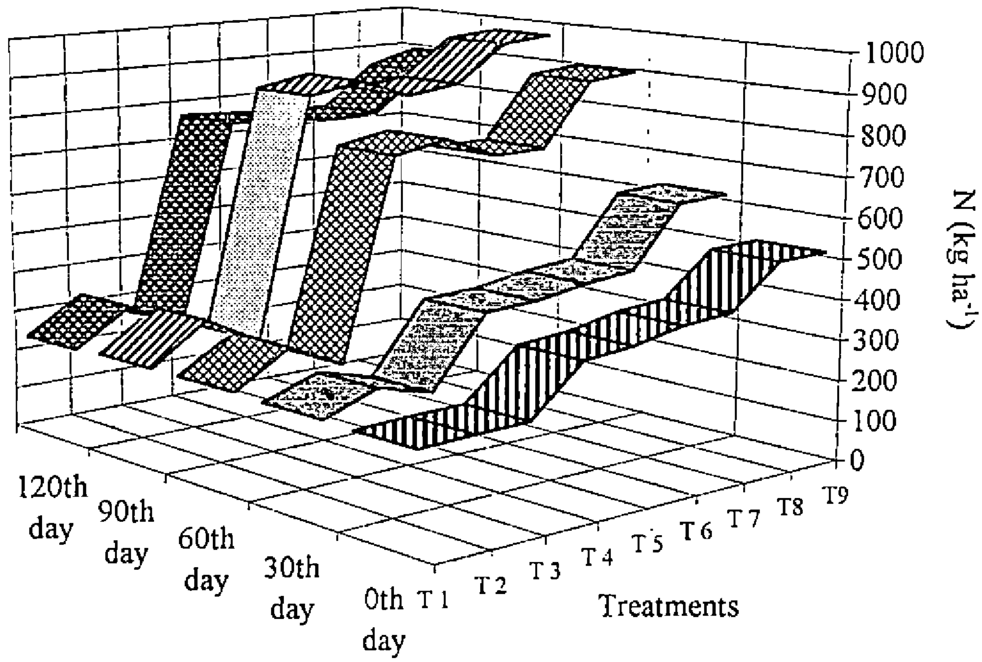
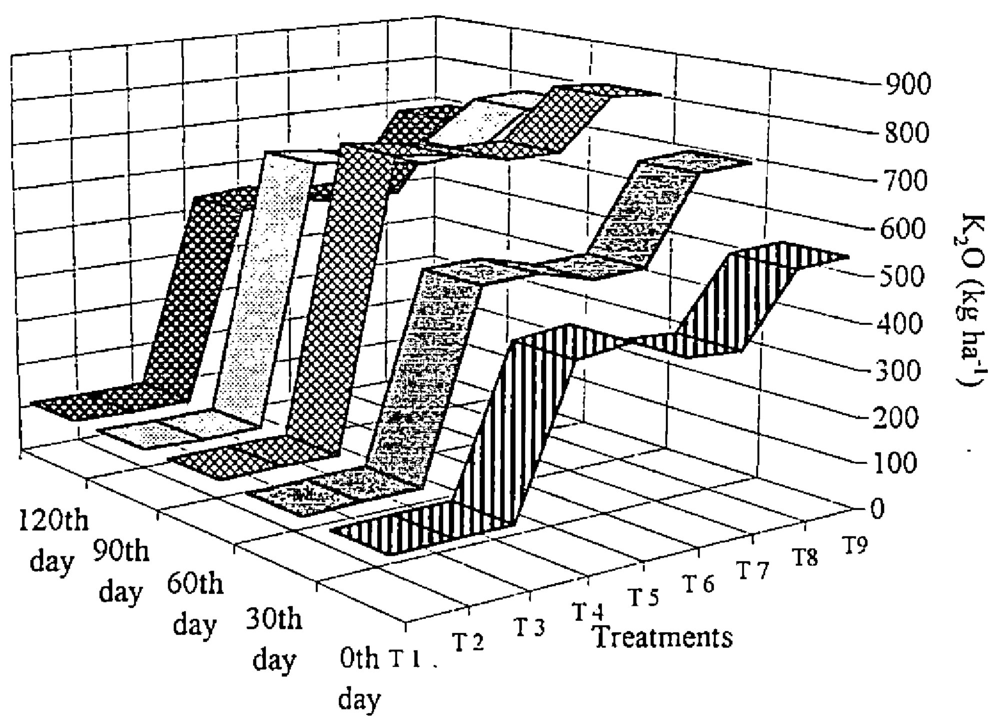


Fig. 8. Available potassium (kg ha^{-1})



(Indira *et al.*, 1986). As the mineralisation of organic amendments get stabilised during the 4th observation, the observed decline in available N content beyond 90 days is well explained.

4.3.2.2 Available Potassium

In Table. 10 (Fig. 8) the details relating to the changes in available K_2O due to the effect of various treatments are presented. The general observation is that, in contrast to other nutrients, available K_2O reaches its peak within a shorter span of time, and then decreases. From the table, it was clear that the availability was maximum at 60th day, after which it gradually decreased. Among the treatments, those receiving vermicompost (T_9 and T_8) registered highest values of treatment means over all the five periods. Other treatments receiving organic manures (T_4, T_5, T_6 and T_8) also showed significantly higher values compared to treatments T_1, T_2, T_3 which did not receive ogranic manures. The highest value for available K_2O recorded was 812.67 kg ha-1 by the treatment T_8 on the 60th day closely followed by T_9 (804.33) on the same day. However, Debnath and Hajra (1972) observed from their incubation studies that available K content increased upto 16th day, decreased on 30th day and then increased and got stabilised when FYM and daincha were added.

Faster degradation of organic matter leading to a better mineralisation pattern consequent to high microbial activity results in an enhanced release of basic cations like K^+ (Ammal and Muthiah, 1994). The total contribution of K to the soil K pool which varies with the organic source is also one of the factors affecting the K availability. As the microbial and enzyme activity is reported to be more in vermicompost, the K build up in the soil solution is also more (Basker *et al.*, 1994). As the major portion of available K_2O is obtained from the mineralisation of organic materials, the peak concentration of available K_2O also synchronises with the peak time of mineralisation i.e., about 60 to 90 days after incubation (Dhanokar *et al.*, 1994 ; Srinivasa Rao *et al.*, 1996).

4.3.2.3 Available Calcium

From the data recorded in Table 11 (Fig. 9) it was observed that there was a general trend of increasing values upto 90th day, which decreased thereafter. Among various treatments, T_9 and T_8 which receive vermicompost showed significantly higher values of available Ca over all the five periods. However, treatment T_2 (soil + SSP) alone has showed a decreasing trend with the passage of time. The highest value of 1.73 cmol kg^{-1} was recorded by T_9 on 90^{th} day. The variation due to different periods was also significant over all the five periods.

Calcium content increased with time generally observed upto 60 to 90 days in treatments receiving organic amendments closely approximates the peak period of organic matter degradation. Increase in concentration of Ca and basic cations due to earthworm activity in soil and vermicompost application has been reported by many workers (Kale and Krishnamoothy, 1980). In the case of treatment T_2, the decreasing trend observed is probably due to a decrease in the content of soluble monocalcium phosphate with time. Microbial immobilisation and reaction with soil components leading to temporary fixation of Ca also contribute to the observed decline in concentration. The findings of Kale and Krishnamoorthy (1980) are in conformation to the present observations.

4.3.2.4 Available Magnesium

Data presented in Table. 12 (Fig. 10) indicate the same trend observed in the case of available Ca which reaches its peak on the 90^{th} day of incubation. As in the case of calcium, here also those treatments receiving vermicompost (T_8 and T_9) show higher values. These treatments maintain their superiority throughout the five periods of observation. The highest value registered was 3.17 cmols kg^{-1} by T_9 followed by 3.15 cmol kg^{-1} by T_8, both on the 90^{th} day. Treatments T_1, T_2 and T_3 which did not receive organic manures showed lower values which were statistically not significant. Though there was significant variation due to different periods, the mean values of 60^{th} and 120^{th} days of incubation did not differ significantly.

The dynamics of Mg closely follows the trend of Ca with peak concentration around 60 to 90 days of incubation. The release of this cation is mainly from the decomposition of organic amendments chiefly by enhanced microbial proliferation. Subsequent decline after the peak concentration is due to various reactions with inorganic soil components, organic fractions and due to microbial immobilisation.

Table 11 Available Calcium (cmol kg^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	1.12	1.17	1.15	1.15	1.13	1.14
T_2	1.42	1.43	1.37	1.30	1.23	1.35
T_3	1.22	1.27	1.33	1.42	1.35	1.32
T_4	1.22	1.28	1.30	1.28	1.23	1.26
T_5	1.25	1.32	1.35	1.42	1.38	1.34
T_6	1.22	1.23	1.28	1.27	1.20	1.24
T_7	1.22	1.28	1.33	1.38	1.37	1.32
T_8	1.42	1.53	1.63	1.67	1.62	1.57
T_9	1.43	1.58	1.68	1.73	1.72	1.63
Mean Pe.	1.28	1.34	1.38	1.40	1.36	

CD. Tr: 0.0366 CD. Pe: 0.0144 CD. Tr. Pe: 0.0433

Table 12 Available Magnesium (cmol kg^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	1.52	1.62	1.63	1.65	1.62	1.61
T_2	1.53	1.63	1.62	1.62	1.62	1.60
T_3	1.53	1.53	1.58	1.63	1.62	1.58
T_4	1.82	1.87	1.93	2.08	1.93	1.93
T_5	1.85	1.92	1.98	2.10	1.98	1.97
T_6	1.73	1.82	1.88	2.02	1.90	1.87
T_7	1.82	1.88	1.95	2.03	1.93	1.92
T_8	2.43	2.67	2.92	3.15	2.92	2.82
T_9	2.47	2.72	2.97	3.17	2.95	2.85
Mean Pe.	1.86	1.96	2.05	2.16	2.05	

CD. Tr: 0.0377 CD. Pe: 0.0169 CD. Tr. Pe: 0.0508

Table 13 Available Sulphur (%)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.011	0.013	0.017	0.015	0.017	0.015
T_2	0.014	0.018	0.021	0.019	0.018	0.018
T_3	0.014	0.018	0.023	0.023	0.027	0.021
T_4	0.026	0.031	0.039	0.035	0.033	0.033
T_5	0.026	0.034	0.049	0.042	0.039	0.037
T_6	0.023	0.025	0.033	0.037	0.033	0.030
T_7	0.026	0.029	0.037	0.037	0.037	0.033
T_8	0.043	0.046	0.059	0.055	0.051	0.051
T_9	0.044	0.049	0.059	0.057	0.051	0.052
Mean Pe.	0.025	0.029	0.037	0.036	0.034	

CD. Tr: 0.0022 CD. Pe: 0.0009 CD. Tr. Pe: 0.0028

Fig. 9. Available calcium (cmol kg^{-1})

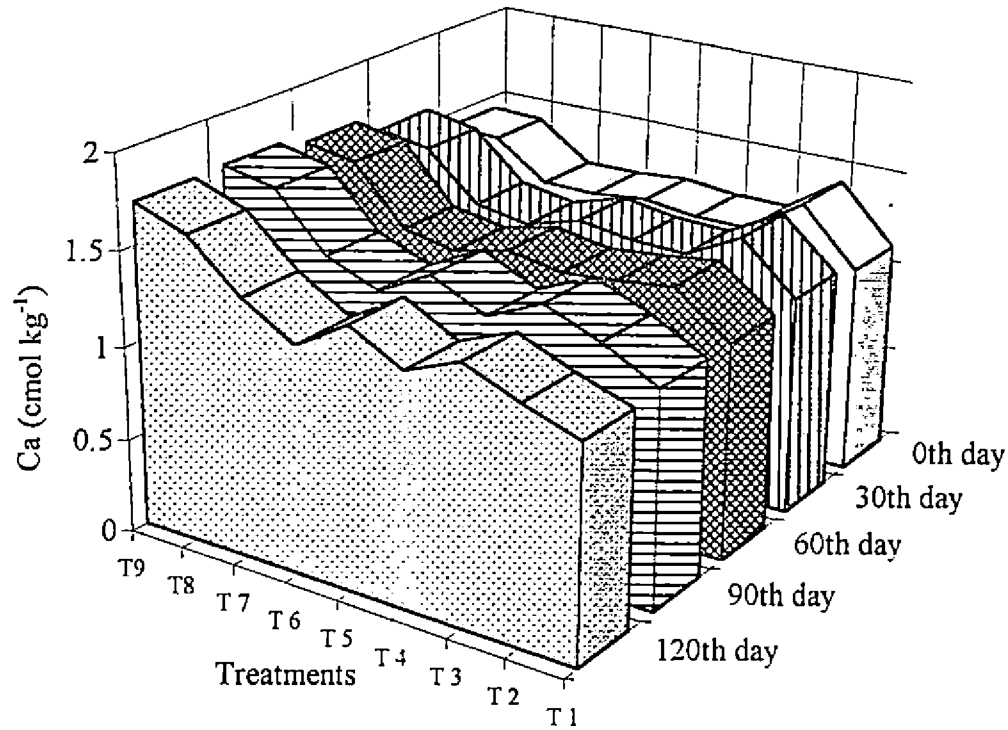


Fig. 10. Available magnesium (cmol kg^{-1})

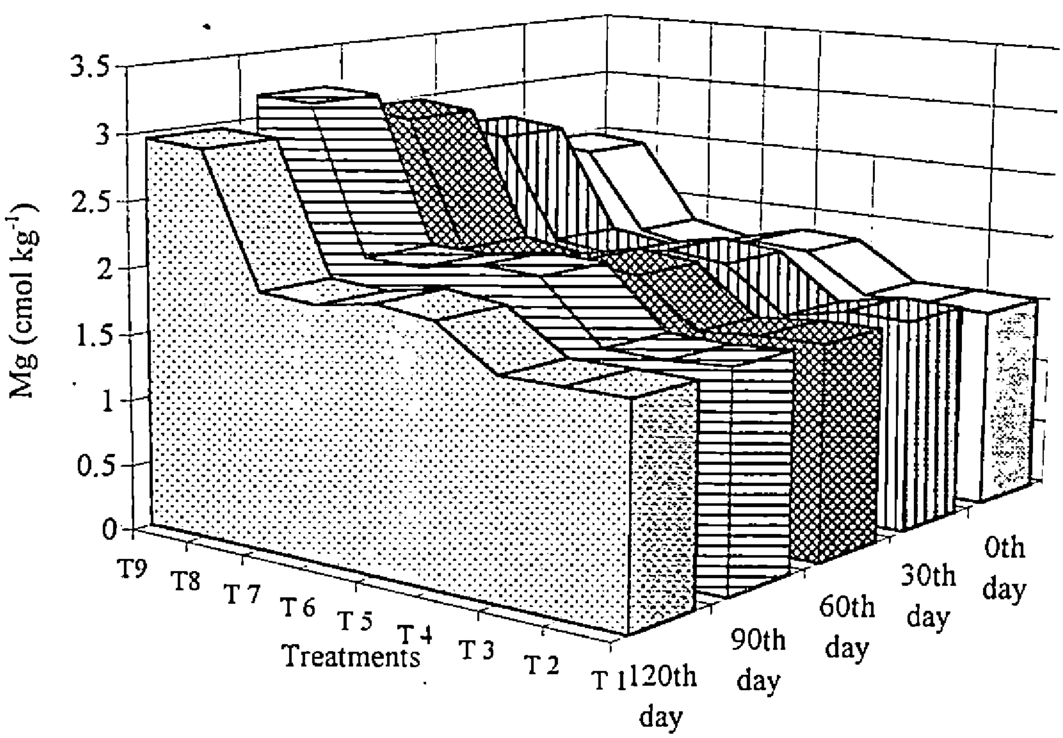
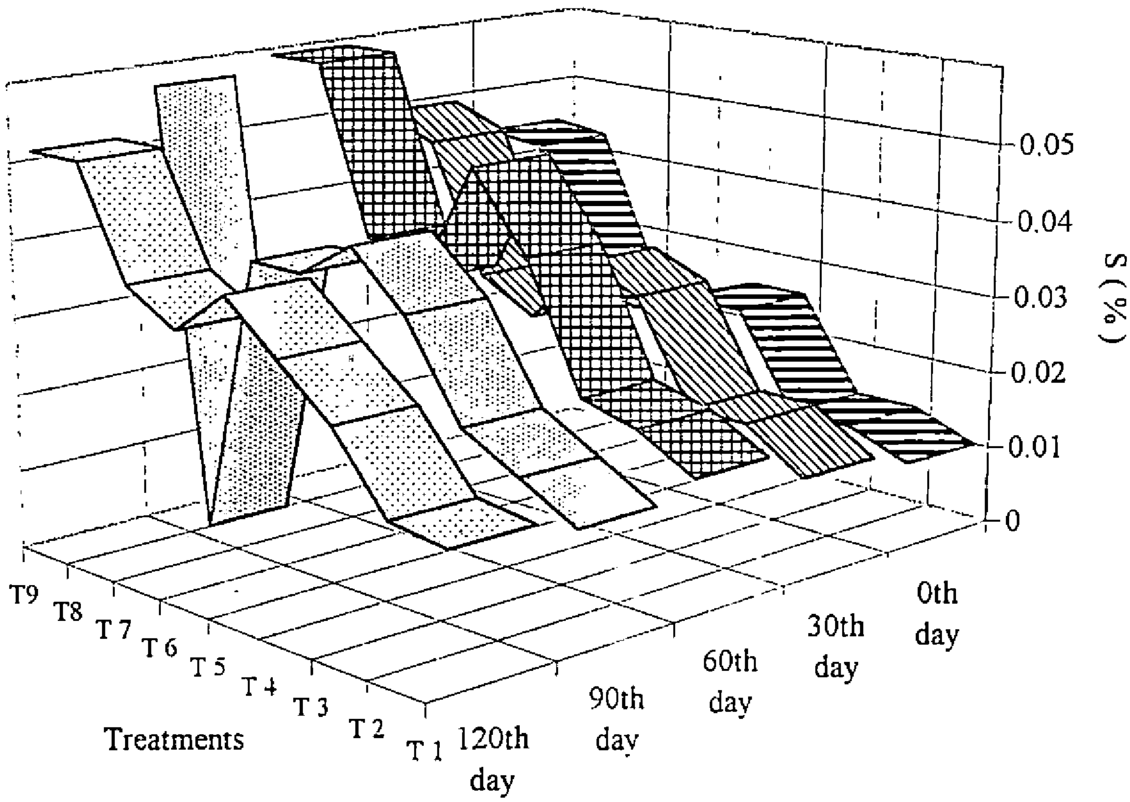


Fig. 11. Available Sulphur (%)



However, Olsen *et al.* (1970) inferred that the application of manures increased the exchangeable Ca and Mg particularly at higher rates of their application.

4.3.2.5 Available Sulphur

A trend similar to that of available K_2O was noticed from the data on available S presented in Table. 13 (Fig. 11). Like available K_2O, available S also showed peak values on the 60th day of incubation which decreased lateron. As in the case of other secondary nutrients, viz., Ca and Mg, here also treatments T_8 and T_9 which received vermicompost recorded maximum values which were significantly different from other treatments. These treatments recorded moreorless stable values over the whole period of incubation. Variation due to different periods of observation was also found to be significant statistically. Shivananda *et al.* (1996) reported similar results in frenchbean.

The observed trend closely resembles the dynamics of potassium. The treatments T_8 and T_9 receiving vermicompost recorded maximum values due to enhanced mineralisation of organic matter. The superiority of treatments receiving organic amendments in augmenting mineralisation is explained earlier. From the results, it is clear that the main source of sulphur is the organics incorporated.

4.3.2.6 DTPA extractable Iron

Table. 14 (Fig. 12) presents data on DTPA extractable Fe, the values of which have high significance in deciding the availability of plant nutrients, especially P, in acidic soils with variable charge components. From the table it was evident that there exist a gradual decreasing trend with the passage of time. Treatments T_1, T_2 and T_3 which received no organic manures showed the highest values over the five periods taken together. They maintained moreorless stable values within a range from 34.83 ppm to 30.20 ppm over the whole period of incubation. But all the other treatments which received some kind of organic manure showed a distinctly decreasing trend, the picture being sharpest in the case of vermicompost treated ones (T_8 and T_9) followed immediately by FYM treated soils (T_4 and T_5) and then by ordinary compost treated samples (T_6 and T_7). Though there was significant variation with respect to different periods, observations after 90 and 120 days were statistically on par which showed

Table 14 **DTPA Extractable Iron (ppm)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	34.40	33.97	35.50	32.40	30.20	33.29
T_2	34.63	34.40	34.17	32.87	31.53	33.52
T_3	34.83	34.20	31.77	31.97	31.97	32.95
T_4	33.93	28.00	16.63	12.20	13.73	20.90
T_5	33.30	28.40	16.20	13.77	14.20	21.17
T_6	36.17	32.17	19.53	15.97	17.30	24.23
T_7	31.17	30.00	19.07	13.30	17.07	22.28
T_8	32.63	16.43	11.77	12.83	11.30	16.99
T_9	36.60	17.50	11.53	12.20	10.20	17.61
Mean Pe.	34.27	28.34	21.80	19.72	19.72	

CD. Tr: 2.458 CD. Pe: 1.024 CD. Tr. Pe : 3.073

Table 15 **DTPA Extractable Manganese (ppm)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	4.57	5.51	6.75	6.59	6.15	5.92
T_2	4.69	6.15	7.69	7.97	7.36	6.77
T_3	5.57	7.19	9.79	8.13	7.17	7.57
T_4	19.30	24.72	33.01	20.87	13.36	22.25
T_5	19.15	26.72	31.52	20.29	12.13	21.69
T_6	11.04	11.89	13.09	8.79	6.55	10.27
T_7	11.25	11.87	14.41	9.97	7.89	11.08
T_8	25.51	50.31	59.69	46.13	25.63	41.45
T_9	27.33	52.75	60.92	47.78	28.85	43.53
Mean Pe.	14.27	21.90	26.32	19.61	12.79	

CD. Tr: 0.8677 CD. Pe: 0.2430 CD. Tr. Pe : 0.7291

Fig. 12. DTPA extractable Iron (ppm)

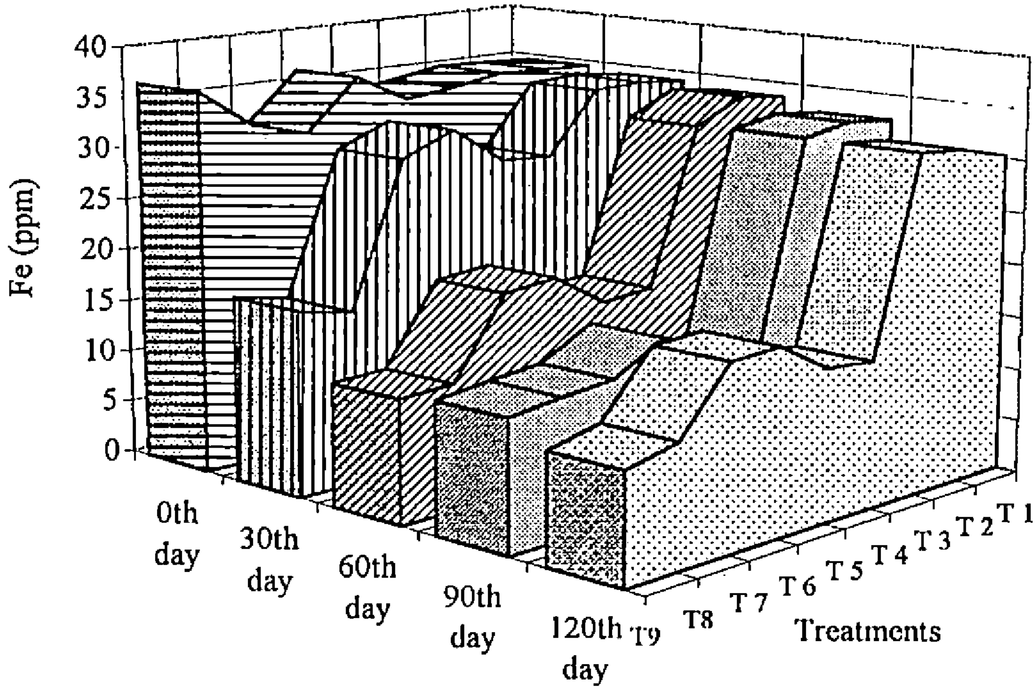
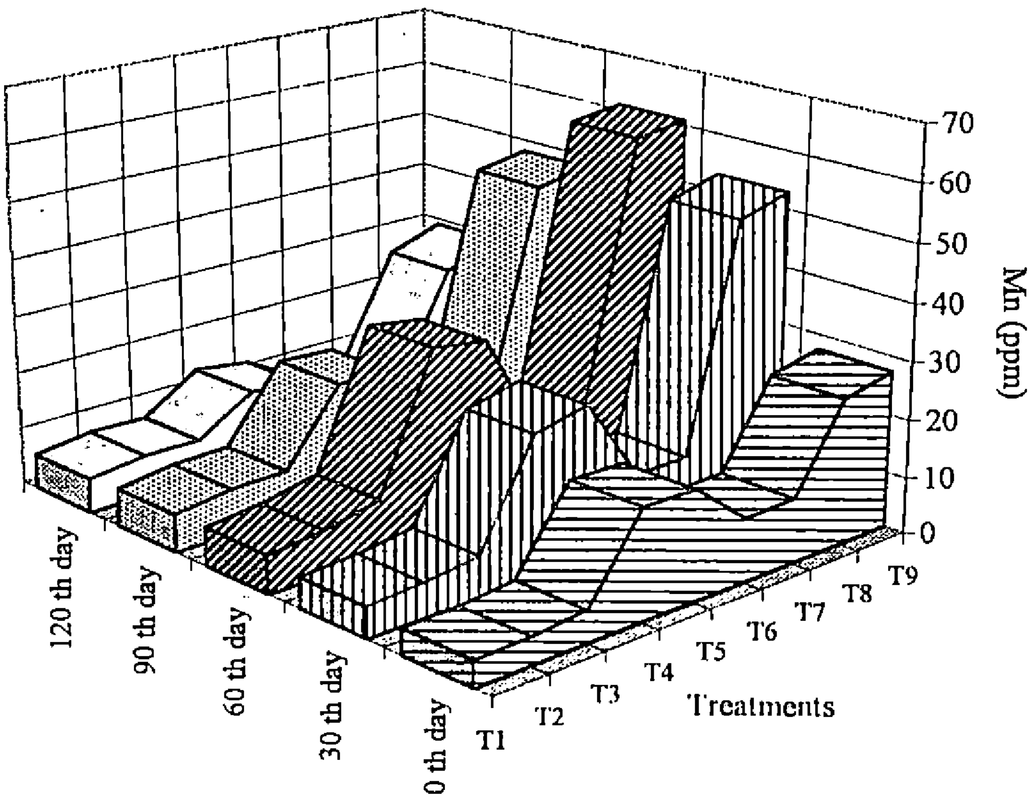


Fig. 13. DTPA extractable Manganese (ppm)



significantly lesser values than the other periods of observation, viz., 0, 30 and 60 days after incubation.

The observed decrease in DTPA extractable Fe in treatments receiving organic manures could be explained by chelation process leading to specific metal complex formation (Schnitzer and Khan, 1978). Humic colloids form very stable compounds with Fe which reduces the available Fe concentration drastically in soils. This effect is clearly manifested in all treatments receiving organic manures. As the humic acid fraction is more in the vermicompost, more of active Fe is locked up through chelation in soils receiving vermicompost. The same mechanism is operating in the case of other treatments also. It is evident from the observations that this process is very active throughout the incubation period, showing maximum values around 90 days of incubation which synchronises with the peak stage of mineralisation.

4.3.2.7 **DTPA Extractable Manganese**

Table 15 (Fig. 13) present data on DTPA extractable Mn. It is evident from the table that their exist a gradual increase in concentration of DTPA extractable Mn with time upto 60 days of incubation in all the treatments. Subsequently the concentration decreases to lower values slightly above the initial starting values except for treatments receiving ordinary compost (T_6 and T_7). Treatments T_1, T_2 and T_3 which received no organic manures showed the minimum increase over the five periods taken together and maintained moreorles stable values towards the last two observations. Other treatments which received some kind of organic manures registered drastic increase in concentration starting from the second observation, the picture being most spectacular in the case of treatments receiving vermi compost (T_8 and T_9) followed by those receiving FYM (T_4 and T_5) and then by ordinary compost treated samples (T_6 and T_7). There was significant variation with respect to various treatments and also due to different periods of incubation. A maximum mean value of 43.53 ppm was recorded by T_9 cotaining VC with rock phosphate, closely followed by T_8 (41.45 ppm) containing VC without rock phosphate. These two treatments recorded significantly higher values compared to other treatments. Vermi compost treated samples maintained the concentration more or less uniformly upto 90 days and registered higher values even after 120 days of incubation, slightly more than the initial values. All the the organic amendments registered the highest concentration during the 3rd observation (after 60 days) which indicate the stage of maximum decomposition and release of manganese.

The observed increase in DTPA extractable Mn in treatments receiving organic manures could be explained by the direct contribution of this element from the incorporated organic matter (Debnath and Hajra, 1972). Further chelation by the humic colloidal fractions of native soil Mn also contribute to this effect. Unlike DTPA-Iron, Mn dosen't form stable chelation complexes with organic fractions, thus registering a higher concentration in the DTPA extract. This might be due to preferential chelation of Fe compounds present in larger concentrations by the organic colloidal fraction which form comparatively stable Fe-Organic-Metal complexes, which survives DTPA extraction (Schnitzer and Khan, 1978). Further, metal-organic complexes of Mn appear to be less stable and amenable to DTPA extraction. This effect is manifested in all the treatments receiving organic manures. As the soluble humic fractions are more in the vermi compost, more of the Mn-humate fractions formed were available for DTPA extraction. A preferential interaction of the humic fractions from VC with Fe also would have restricted the reaction of Mn with the less soluble fractions of VC forming stable complexes with Mn. The stability of Fe-organic complexes and Mn-organic complexes formed through metal chelation warrants detailed investigation to have a deeper insight into this aspect. Further, the soulbility of the above two complexes in the DTPA extract also needs detailed study.

4.3.2.8 **DTPA Extractable Copper**

A critical examination of Table. 16 (Fig. 14) indicate only marginal increase in DTPA extractable Cu content with time in all the observations including those receiving organic manures except treatments T_6 and T_7 receiving ordinary compost. Ordinary compost without Rock Phosphate registered a higher Cu content of 24.65 ppm compared to FYM and VC. This initial higher concentration is reflected throughout the incubation period for treatments T_6 and T_7. This higher absolute value of Cu must have obtained from the materials used for composting either by contamination or by relative enrichment over long periods of accumulation. Treatments receiving FYM and VC are more or less on par throughout the period of

Table 16 **DTPA Extractable Copper (ppm)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.17	0.22	0.33	0.31	0.29	0.26
T_2	0.21	0.26	0.37	0.35	0.31	0.29
T_3	0.17	0.23	0.32	0.28	0.25	0.25
T_4	0.35	0.45	0.57	0.53	0.33	0.45
T_5	0.37	0.39	0.43	0.38	0.33	0.38
T_6	24.65	30.96	36.16	33.87	30.42	31.21
T_7	22.93	27.35	33.59	33.29	30.20	29.47
T_8	0.41	0.60	0.74	0.66	0.37	0.55
T_9	0.48	0.60	0.85	0.72	0.50	0.63
Mean Pe.	5.53	6.78	8.15	7.821	7.00	

CD. Tr: 0.3905 CD. Pe: 0.3916 CD. Tr. Pe : 1.1747

Table 17 **DTPA Extractable Zinc (ppm)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	1.13	1.33	1.47	1.80	1.87	1.52
T_2	1.27	1.33	1.47	1.67	1.80	1.51
T_3	1.13	1.27	1.53	1.80	1.87	1.52
T_4	2.07	4.67	7.80	11.87	11.93	7.67
T_5	2.27	5.27	7.87	12.07	12.13	7.92
T_6	2.27	5.07	7.47	7.13	6.00	5.59
T_7	2.07	4.53	7.53	6.60	6.13	5.37
T_8	2.13	10.33	16.87	26.73	35.33	18.28
T_9	2.13	11.00	17.00	26.73	36.00	18.57
Mean Pe.	1.83	4.98	7.67	10.71	12.56	

CD. Tr: 0.1752 CD. Pe: 0.1443 CD. Tr. Pe : 0.4330

Fig. 14. DTPA extractable Copper (ppm)

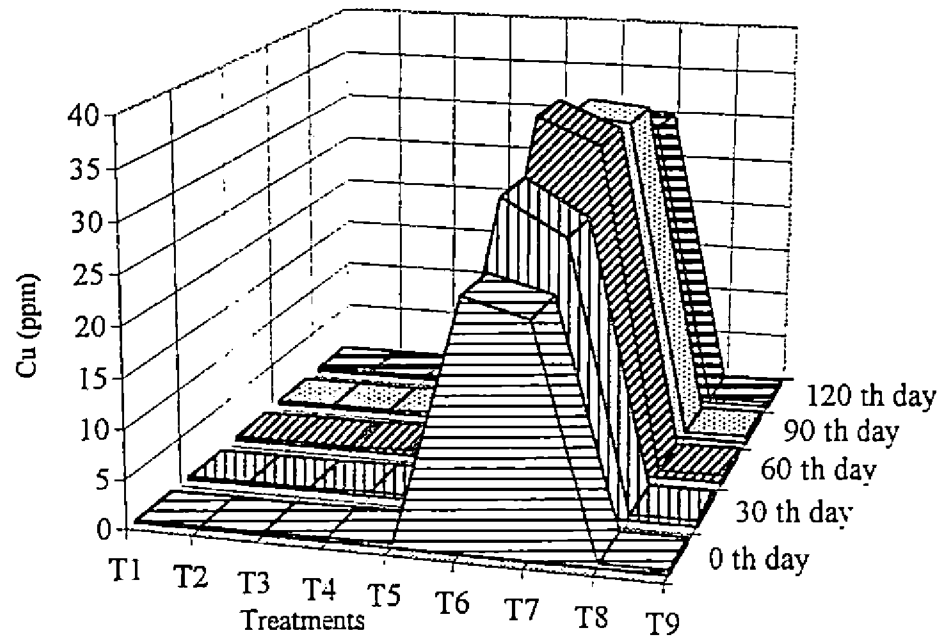
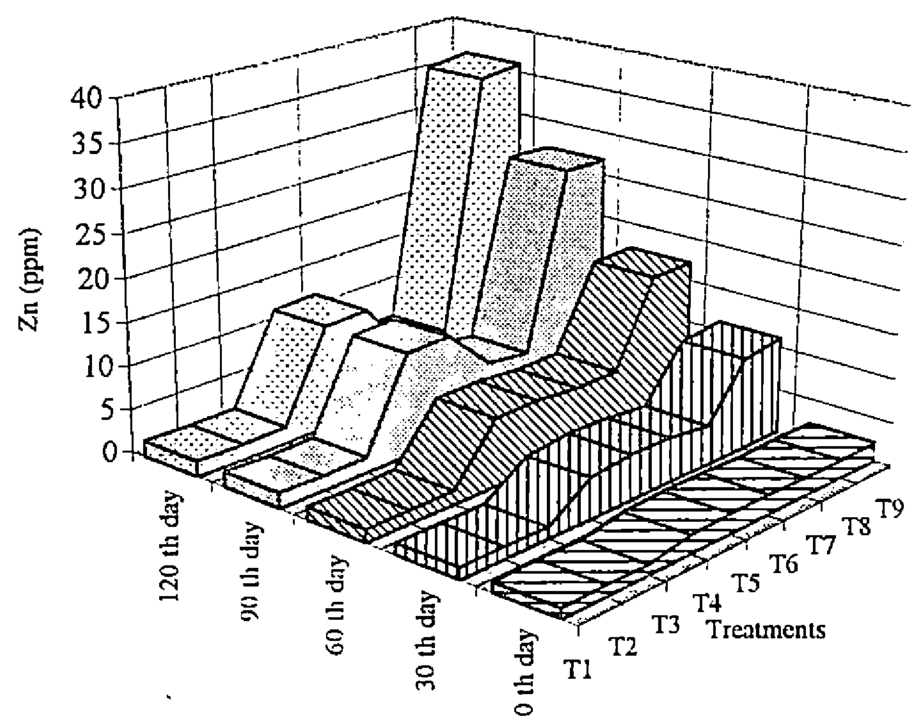


Fig. 15. DTPA extractable Zinc (ppm)



incubation. These observations indirectly indicates the very low DTPA-Cu status in the inorganic mineral fraction of the soil used for the study.

4.3.2.9 **DTPA Extractable Zinc**

Data on DTPA extractable Zn presented in Table. 17 (Fig. 15) revealed that there was significant variation due to treatments and also due to different periods. The highest mean value of 18.57 ppm was recorded by T_9 receiving vermi compost with rock phosphate which was significantly different from T_8 (18.28 ppm) receiving VC without rock phosphate. These two treatments containing VC recorded significantly very high values compared to FYM treated samples (T_4 and T_5) and ordinary compost treated samples (T_6 and T_7).

A close scrutiny of the mean value indicated a steady increase in available Zn content of all the samples, receiving organic amendments. Treatments T_4 and T_5 receiving FYM, after 120 days of incubation registered a six fold increase in available Zn concentration. Unlike Mn, the increase was steady throughout the period of incubation even after 120 days. However for treatments T_6 and T_7 receiving ordinary compost recorded only a three fold increase towards the last observation and values were almost half when compared to treatments T_4 and T_5 (6.0 and 6.1 ppm) in the last observation (120 days). Maximum values were registered in these treatments (T_6 and T_7) during the third observation corresponding to 60^{th} day of incubation. Treatments T_8 and T_9 receiving VC showed a steady increase in available Zn content throughout the incubation period and resulted in maximum mean DTPA extractable Zn of 35.3 and 36.0 ppm respectively for T_8 and T_9. This correspond to an increase in concentration by 15 fold over the initial starting concentration (2.1 to 35.3 ppm and 2.1 to 36.0 ppm respectively for treatments T_8 and T_9).

The observed increase in DTPA extractable Zn content for treatments receiving organic manures is attributed to a direct contribution from the decomposing organic sources and release of soluble chelates from the soil inorganic mineral sources (Debnath and Hajra, 1972). It is presumed from the observation that the cheleated forms of Zn formed with organic fractions during the course of incubation is soluble in DTPA extract, which resulted in an increase in DTPA-Zn for all the samples receiving organic manures (Schnitzer and Khan, 1978). The higher efficiency of vermi compost in releasing Zn in this context could be explained by the higher absolute content of Zn when compared to other organic sources. This may also be due to the higher solubility of the Zn-organic complexes formed from VC in DTPA compared to those formed from other organic sources.

4.3.2.10 Dithionite extractable Iron and Aluminium

The data presented in Table. 18 (Fig. 16) shows the changes in dithionite extractable iron [Fe(d)] which is an index of the crystalline forms of Fe, the greater values of which indicate the inferiority of treatments in supporting plant nutrition. The maximum mean value over all the five periods was shown by the treatment T1 which represented control (soil alone). Treatments T_2 (soil + SSP) and T_3 (soil + RP) also showed similar values both of which were statistically on par with T_1. In general, all the treatments showed a decreasing trend with the advancement of time. On the 0^{th} day, all the treatment showed higher values within a range from 16.97 to 18.63 g kg^{-1}. However those treatments receiving organic manures have shown drastic decrease in their values, the extent of which was more pronounced in the case of treatments T_8 and T_9, both of which received vermicompost. The decreasing trends of all the treatments receiving FYM and ordinary compost (T_4, T_5, T_6 and T_7) were on par statistically.

From Table. 19 (Fig. 17) it was clear that dithionite extractable Al [Al (d)] also showed similar trends as noticed in the case of Fe (d). The treatment T_1 representing control recorded the highest mean value. All the treatments receiving no organic manures recorded only slight decrease in Al (d) values over the five periods of incubation. However those treatments receiving organic manures have shown drastic decrease in their values, the extent of which was more pronounced in those treatments receiving vermicompost (T_8 and T_9). This was followed by treatments receiving FYM (T_4 and T_5) and then by those receiving ordinary compost (T_6 and T_7).

The reported effect of organic colloids in suppressing the crystal knitting process of Fe compounds in an environment dominated by humic and fulvic fractions is very clearly indicated in the present study. Further Al also is complexed with the organic fractions and hence a substantial amount of active Al is made unavailable for dithionite extraction (Schnitzer and Khan, 1978). These are evident from the drastic decline in Fe(d) and Al(d) concentrations in all the treatments receiving organic

Table 18 **Dithionite extractable Iron (g kg^{-1})**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	18.63	18.13	16.93	16.60	15.20	17.10
T_2	18.13	17.47	16.77	16.07	14.53	16.59
T_3	18.13	17.63	16.77	16.07	14.70	16.66
T_4	17.63	14.70	12.03	7.77	5.33	11.49
T_5	18.30	14.70	11.53	7.10	5.00	11.33
T_6	18.13	15.53	12.20	6.77	5.23	11.57
T_7	17.97	14.70	12.20	6.77	5.50	11.43
T_8	16.97	12.70	10.70	5.17	3.70	9.85
T_9	17.47	12.37	10.53	4.93	3.63	9.79
Mean Pe.	17.93	15.33	13.30	9.69	8.09	

CD. Tr: 0.7165 CD. Pe: 0.3109 CD. Tr. Pe : 0.9329

Table 19 **Dithionite extractable Aluminium (g kg^{-1})**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	5.61	5.60	5.59	5.55	5.50	5.57
T_2	5.60	5.57	5.56	5.55	5.52	5.56
T_3	5.60	5.57	5.57	5.55	5.51	5.56
T_4	5.57	5.02	3.93	2.99	2.41	3.98
T_5	5.56	5.02	3.93	2.97	2.41	3.98
T_6	5.58	5.02	4.03	3.26	2.99	4.22
T_7	5.59	5.19	4.03	3.26	3.00	4.22
T_8	5.54	4.60	2.82	1.92	0.99	3.17
T_9	5.52	4.62	2.82	1.92	1.00	3.10
Mean Pe.	5.58	5.16	4.25	3.66	3.26	

CD. Tr: 0.0085 CD. Pe: 0.0058 CD. Tr. Pe : 0.0175

Fig. 16. Dithionite extractable Iron (g kg^{-1})

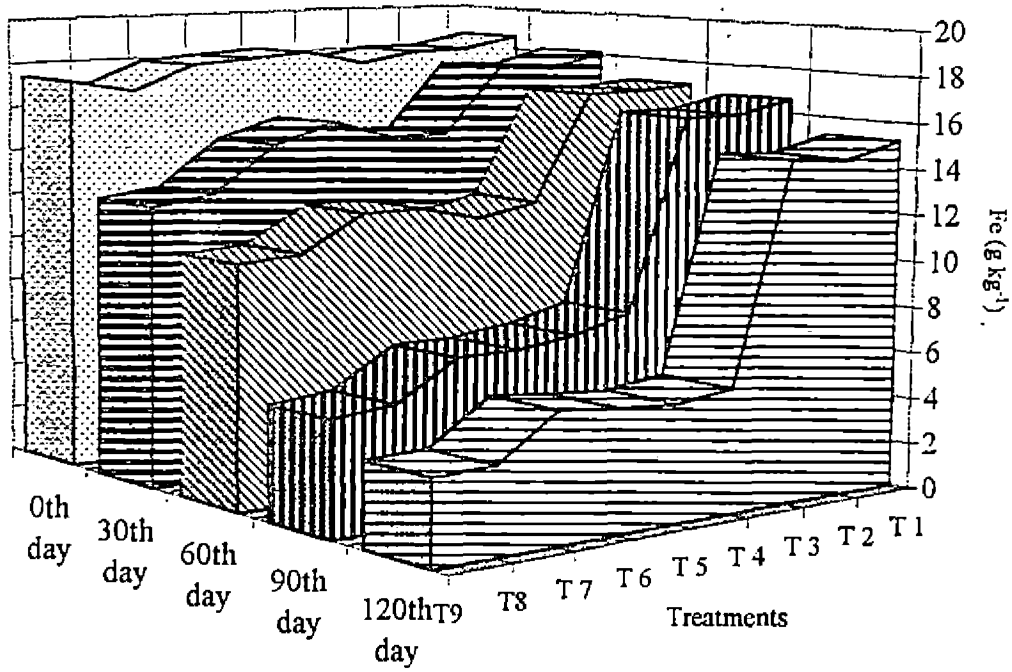
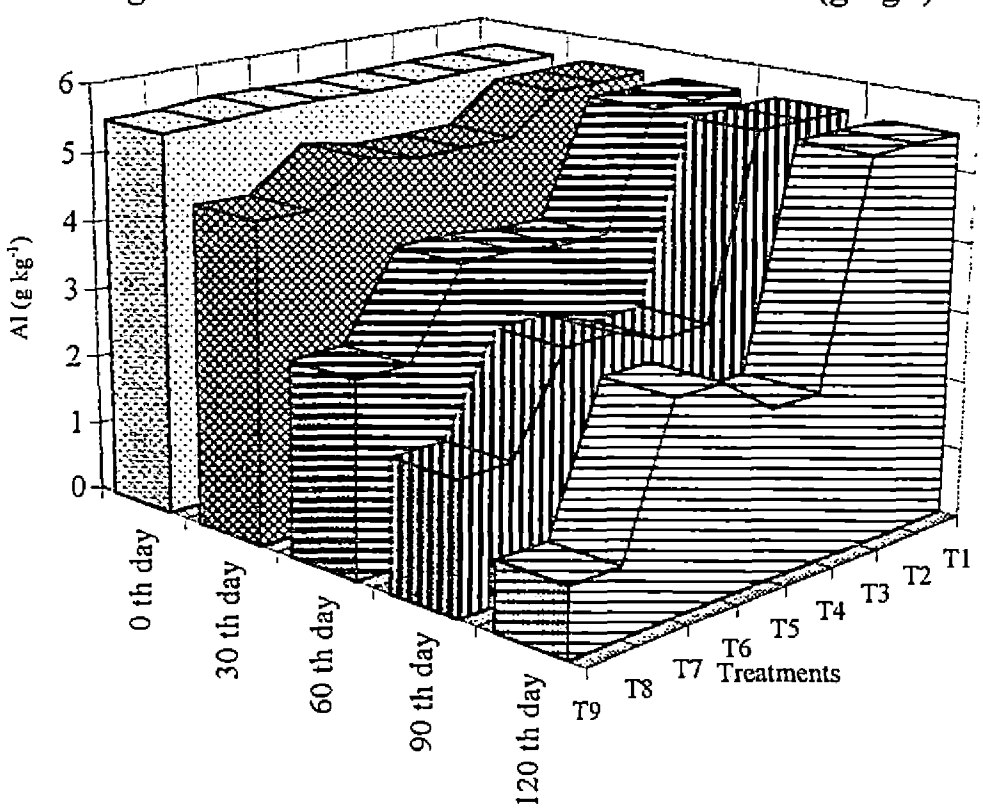


Fig. 17. Dithionite extractable Aluminium (g kg^{-1})



amendments. Though the mechanism is the same for all the above treatments, significant variation has been observed for individual treatment, T_9 imparting maximum effect followed by T_8. Thus the beneficial effects of organic amendments in alleviating Fe and Al toxicity and problems of P fixation in ultisols rich in sesqui oxides is highlighted.

4.3.2.11 Oxalate extractable Iron and Aluminium

As an index of amorphous forms of Fe, mean values presented in Table. 20 (Fig. 18) has high relevance in giving a vivid picture of the transformations and thus the forms, nature and availability of this particular nutrient element, namely Fe. From the table it was revealed that the treatments receiving vermicompost (T_8 and T_9) recorded maximum mean values. In general, all the treatments showed an increasing trend over different periods, though the effect was less pronounced with respect to those treatments which did not receive any kind of organic manures. Among those receiving organic manures, treatments T_8 and T_9 which received vermicompost showed spectacular increase in the content of Fe(o) right from 30^{th} day onwards. These treatments maintained their superiority over all the subsequent periods. This was followed by those treatments receiving FYM and ordinary compost (T_4, T_5, T_6 and T_7) which were statistically on par among themselves. The effect of periods were significant statistically.

Similar trends are also shown by Al (o) as evidenced from Table. 21 (Fig. 19). As in the case of Fe (o), all the treatments showed an increasing trend over different periods with pronounced effect shown by those receiving organic manures. Even among these treatments receiving organic manures, T_8 and T_9 receiving vermi compost showed significantly higher values compared to others. This was followed by those treatments receiving FYM and ordinary compost.

Oxalate extractable iron [Fe(o)] and aluminium [Al(o)], representing mostly the amorphous form clearly showed an increase with period of incubation. This is supposedly due to conversion of parts of the crystalline and inactive oxide forms to colloidal amorphous forms. The effect of organic fractions in breaking the continuity of crystallinity in Fe and Al compounds by metal complexation and chelation is well documented (Schnitzer and Khan, 1978). This mechanism considerably reduces the

Table 20 **Oxalate Extractable Iron (g kg^{-1})**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.64	0.62	0.60	0.69	0.81	0.67
T_2	0.62	0.62	0.68	0.71	0.82	0.69
T_3	0.63	0.67	0.65	0.73	0.82	0.70
T_4	0.61	0.79	1.05	1.31	1.54	1.06
T_5	0.65	0.77	1.01	1.32	1.54	1.06
T_6	0.65	0.79	1.06	1.28	1.55	1.07
T_7	0.66	0.82	1.07	1.30	1.52	1.08
T_8	0.67	1.17	1.52	1.69	1.76	1.36
T_9	0.65	1.23	1.49	1.68	1.75	1.36
Mean Pe.	0.64	0.83	1.01	1.19	1.35	

CD. Tr: 0.0366 CD. Pe: 0.0206 CD. Tr. Pe : 0.0620

Table 21 **Oxalate Extractable Aluminium (g kg^{-1})**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.58	0.57	0.58	0.60	0.61	0.59
T_2	0.56	0.58	0.59	0.61	0.62	0.59
T_3	0.57	0.58	0.60	0.61	0.63	0.60
T_4	0.60	0.64	0.68	0.72	0.80	0.69
T_5	0.59	0.65	0.67	0.72	0.81	0.69
T_6	0.58	0.62	0.67	0.70	0.75	0.67
T_7	0.60	0.63	0.67	0.69	0.75	0.67
T_8	0.61	0.73	0.89	0.94	1.00	0.84
T_9	0.60	0.74	0.89	0.93	1.02	0.84
Mean Pe.	0.59	0.64	0.69	0.72	0.78	

CD. Tr: 0.0099 CD. Pe: 0.0034 CD. Tr. Pe : 0.0101

Fig. 18. Oxalate extractable Iron (g kg^{-1})

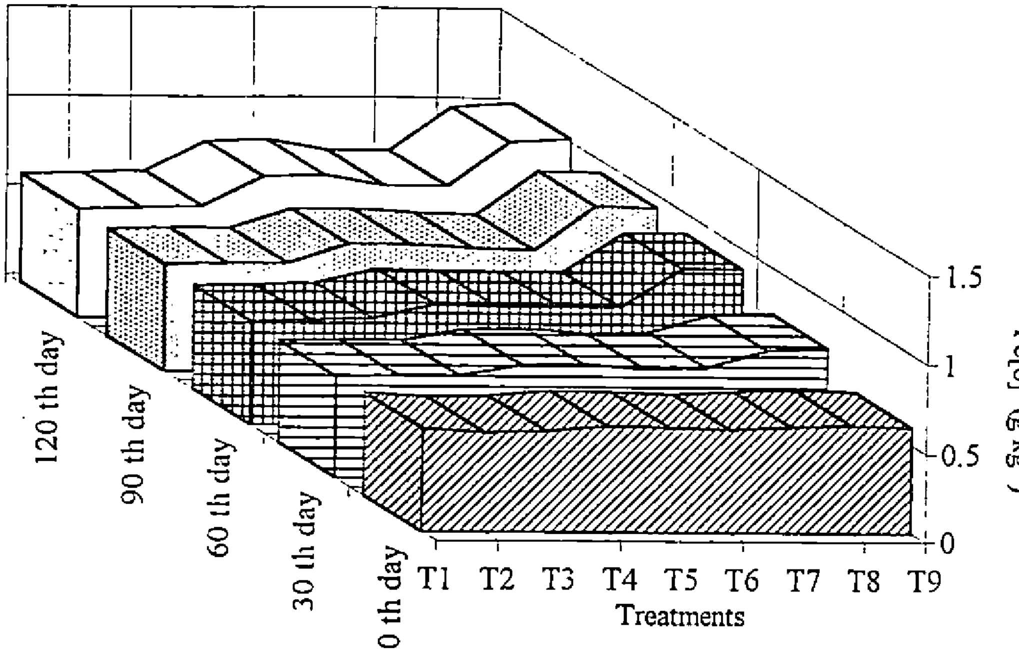
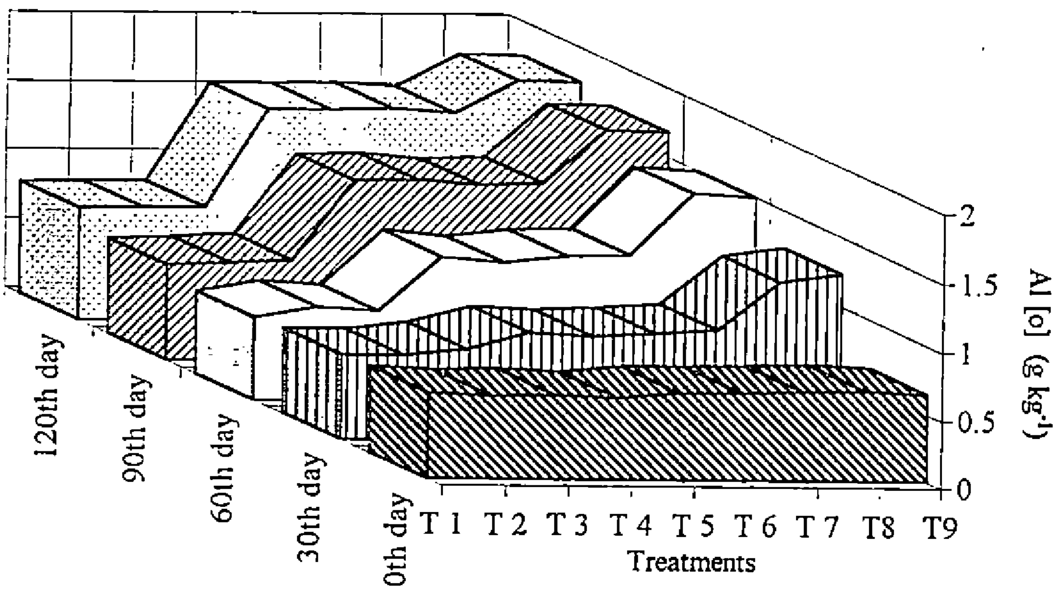


Fig. 19. Oxalate extractable Aluminium (g kg^{-1})



crystalline forms of Fe and Al in an environment dominated by organic anions. Further, the organic acids produced and the enhanced microbial proliferation will also have desirable effects in converting Fe and Al compounds to amorphous forms in soil environment. Thus higher values of amorphous Fe and Al registered by treatments receiving organic amendments like FYM and VC stand substantiated.

4.3.3 Electro-chemical properties

Tables 22 to 28 present data on the changes in electro-chemical properties due to the effect of various treatments over five periods.

4.3.3.1 Soil Reaction (pH)

As a key factor in deciding the availabililty of various nutrients, the data on changes in pH under various treatment conditions require a detailed examination (Table. 22 ; Fig. 20). The initial pH of the soil under study was determined to be 5.10. There was slight change in pH following no specific trends, with the passage of time in soil receiving no treatments (T_1). In general, there was an increasing trend with the advancement of time, for the entire 120 days of incubation. A maximum pH value of 6.77 was shown by T_8 at 120^{th} day followed by a value of 6.73 by T_9 on the same day, both the treatments receiving vermicompost. Only these two treatments attained pH values greater than 6.00 by the 60^{th} day of incubation. Treatment T_2 receiving SSP without an organic source recorded a drastic decline in pH from 0^{th} to 30^{th} day, however the normal increasing trend was observed thereafter. All the treatments receiving organic manures had crossed a pH value of 6.00 by 90^{th} day of incubation which indicated an environment suitable for better plant nutrition. The effect of different periods of incubation was significantly different. Similar changes in soil reaction have been reported by Olsen *et al.* (1970) and Jankowski and Koc (1992).

The observed enhancement of pH in all the treatments receiving organic components might be due to a suppression of the activity of Fe and Al oxides and hydroxides which play a vital role in the protonation-deprotonation mechanism controlling the H^+ ion concentration in soil solution. Thus the proton source sites are temporarily blocked and the exchange complex is modified by the degradation products of organic manures. This process considerably reduces the proton

Table 22 Soil reaction (pH)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	5.10	5.13	5.20	5.17	5.23	5.17
T_2	5.03	4.43	5.23	5.47	5.83	5.20
T_3	5.07	5.30	5.73	6.00	6.17	5.65
T_4	5.23	5.53	5.87	6.30	6.47	5.88
T_5	5.30	5.57	5.97	6.37	6.53	5.95
T_6	5.23	5.50	5.87	6.23	6.50	5.87
T_7	5.30	5.57	5.87	6.27	6.53	5.91
T_8	5.53	5.93	6.37	6.67	6.77	6.25
T_9	5.50	5.97	6.40	6.63	6.73	6.25
Mean Pe.	5.26	5.44	5.83	6.12	6.31	

CD. Tr: 0.0595 CD. Pe: 0.0255 CD. Tr. Pe: 0.0767

Table 23 Electrical conductivity (dS m^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.044	0.044	0.044	0.044	0.044	0.044
T_2	0.044	0.059	0.089	0.148	0.178	0.104
T_3	0.044	0.059	0.089	0.089	0.089	0.074
T_4	0.044	0.089	0.089	0.178	0.267	0.133
T_5	0.044	0.059	0.089	0.208	0.267	0.133
T_6	0.044	0.044	0.074	0.089	0.089	0.068
T_7	0.044	0.044	0.044	0.059	0.089	0.056
T_8	0.044	0.059	0.119	0.237	0.326	0.157
T_9	0.044	0.074	0.119	0.267	0.356	0.172
Mean Pe.	0.044	0.059	0.084	0.147	0.189	

CD. Tr: 0.0275 CD. Pe: 0.0131 CD. Tr. Pe: 0.0394

Fig. 20. Soil reaction (pH)

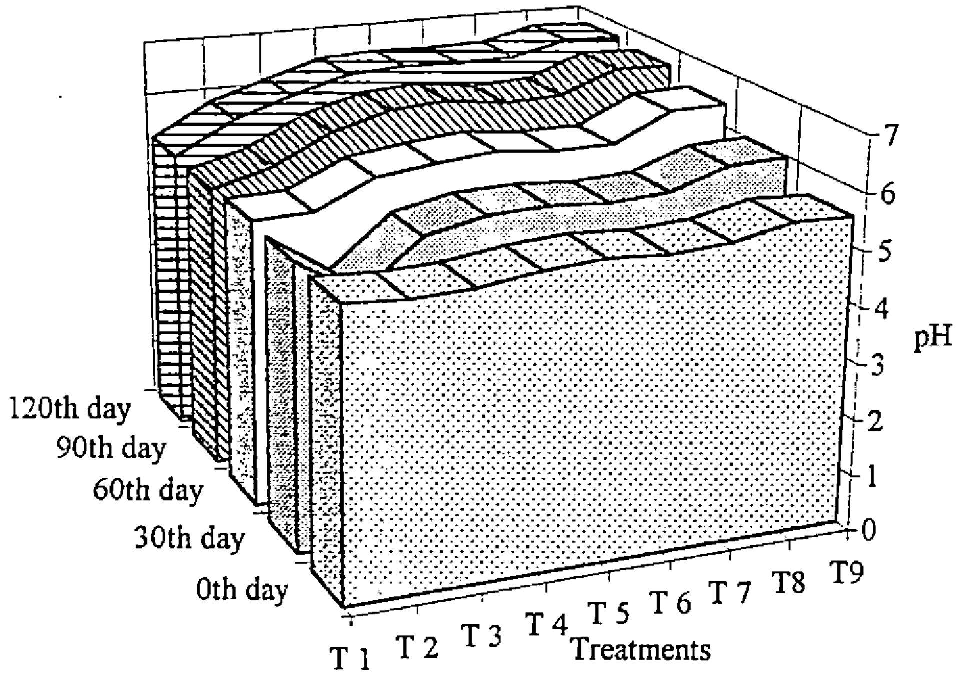
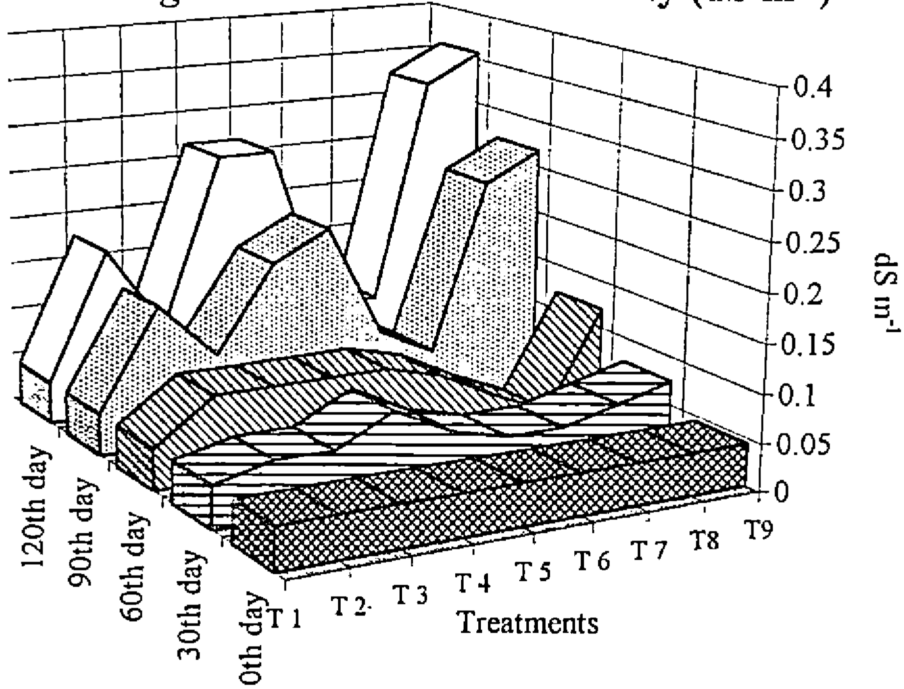


Fig. 21. Electrical conductivity (dS m^{-1})



concentration in soil solution by suppressing the step-wise hydrolysis of Fe and Al compounds (Wiklander, 1964). Hence a substantial portion of the potential acidity is rendered inactive which resulted in a relative enrichment of soil solution with OH^- ions. Further, a sudden release of bases by the active degradation of organic matter also contributes to the observed increase in pH.

4.3.3.2 Electrical conductivity

Table. 23 (Fig. 21) revealed that there was significant variation in electrical conductivity due to various treatments as well as periods of incubation. Though there is a general increasing trend with respect to this parameter, a spectacular increase with the advancement of time was shown by the treatments receiving vermicompost, viz., T8 and T_9. The highest value of 0.356 dS m^{-1} was recorded by T_9 on the 120th day of incubation, closely followed by a value of 0.326 dS m^{-1} by T_8 on the same day, both of which treatments receiving vermicompost. On the 0th day, all the treatments including control showed exactly the same value of 0.044 dS m^{-1}, which remained steady with no change for the treatment T_1 (control) alone, over all the five periods. Apart from those treatments receiving vermicompost, significantly higher values were registered by treatments T_4 and T_5 which received FYM. Treatments T_6 and T_7 which received ordinary compost were on par with T_3 receiving rock phosphate alone. The effect due to different periods of incubation was significant over the whole duration of the experiment.

The electrical conductivity of treatments receiving organic amendments registered a sudden increase owing to faster release of bases and soluble organic fractions into the soil system. Thus the total ionic concentration of the system is likely to give an increase in such treatments leading to higher ionic mobility expressing enhanced EC values (Thompson *et al.*, 1989). The effect was more pronounced in the case of vermicompost which is fully humified and calcium rich when compared to treatments receiving other organic amendments. High concentrations of Ca and Mg observed in the case of vermicompost treated samples also explain partly this observed effect.

Table 24 Cation Exchange capacity (cmol (+) kg^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	2.51	2.49	2.51	2.50	2.50	2.50
T_2	2.54	2.51	2.54	2.52	2.54	2.53
T_3	2.54	2.52	2.54	2.52	2.52	2.53
T_4	7.02	8.81	7.08	5.58	4.03	6.50
T_5	7.04	8.83	7.07	5.64	4.08	6.53
T_6	8.54	7.37	6.10	5.36	5.07	6.49
T_7	8.56	7.44	6.18	5.34	5.03	6.51
T_8	9.90	8.99	8.54	7.40	6.46	8.26
T_9	9.91	9.03	8.63	7.43	6.49	8.30
Mean Pe.	6.51	6.44	5.69	4.92	4.30	

CD. Tr: 0.0494 CD. Pe: 0.0183 CD. Tr. Pe : 0.0550

Table 25 Organic Carbon (%)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.83	0.83	0.81	0.82	0.85	0.83
T_2	0.80	0.80	0.79	0.79	0.77	0.79
T_3	0.82	0.82	0.81	0.80	0.76	0.80
T_4	2.71	2.64	2.17	1.85	1.52	2.18
T_5	2.76	2.59	2.20	1.89	1.62	2.21
T_6	2.58	2.50	2.12	1.66	1.42	2.06
T_7	2.67	2.54	2.17	1.76	1.34	2.10
T_8	2.85	2.75	1.84	1.60	1.67	2.14
T_9	2.92	2.70	1.81	1.54	1.60	2.11
Mean Pe.	2.10	2.02	1.64	1.41	1.28	

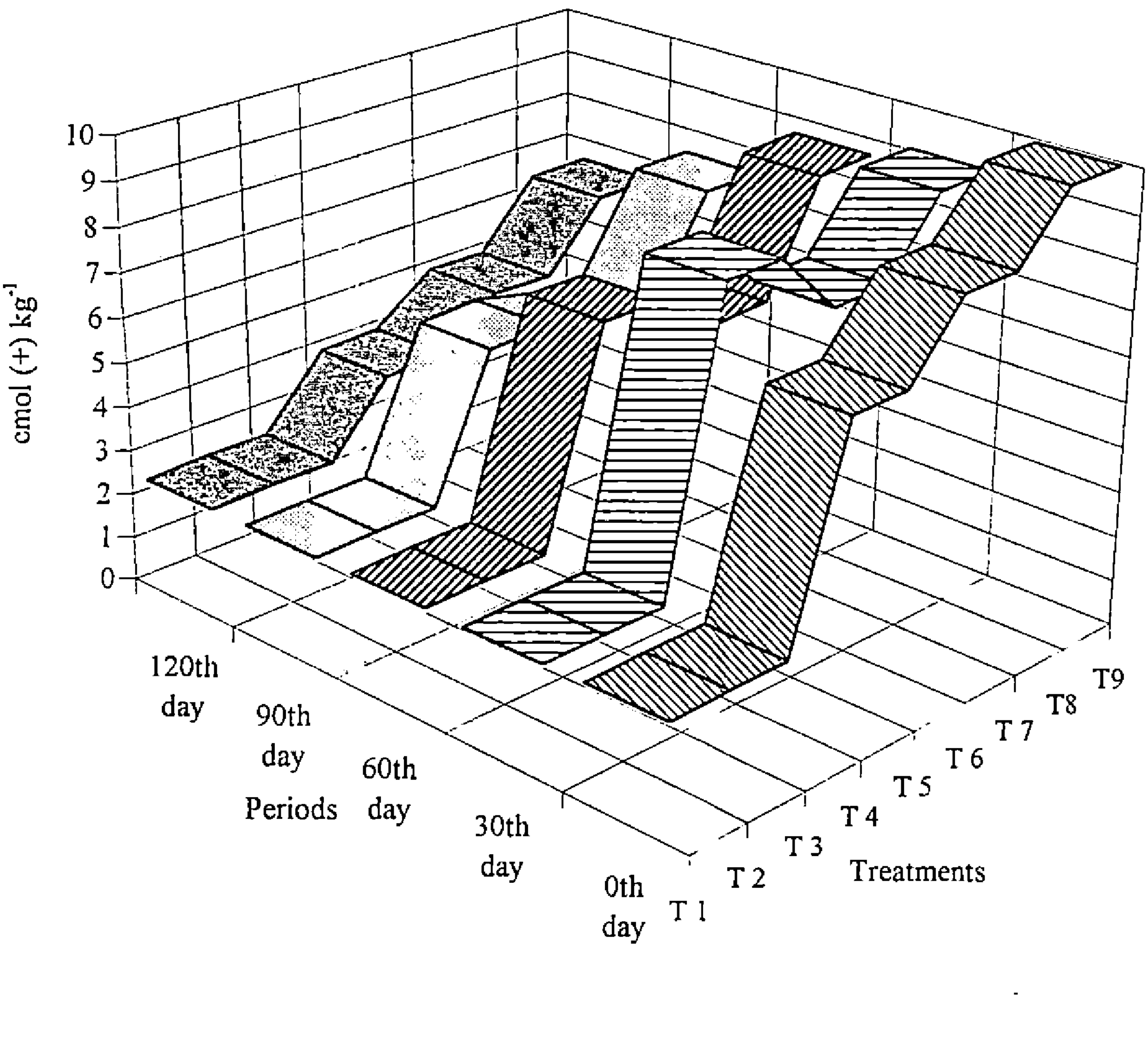
CD. TR: 0.0855 CD. Pe: 0.0338 CD. Tr. Pe : 0.1015

Table 26 C : N ratio

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	11.10	10.72	10.29	10.28	10.84	10.65
T_2	11.05	10.71	10.33	10.21	10.32	10.52
T_3	11.32	10.97	10.61	10.33	10.51	10.75
T_4	19.68	18.50	14.89	12.85	10.33	15.25
T_5	20.05	18.15	15.12	12.71	10.68	15.34
T_6	22.56	21.28	17.46	13.24	10.50	17.01
T_7	22.87	21.04	17.55	13.54	10.09	17.02
T_8	19.07	17.79	11.67	9.90	10.23	13.73
T_9	19.24	17.16	11.29	9.74	9.93	17.47
Mean Pe.	17.44	16.26	13.25	11.423	10.38	

CD. Tr: 0.3339 CD. Pe: 0.1595 CD. Tr. Pe : 0.4785

Fig. 22. Cation exchange capacity [cmol (+) kg^{-1}]



4.3.3.3 Cation Exchange Capacity

The change in cation exchange capacity as shown in Table. 24 (Fig. 22) indicated a general decreasing trend with the advancement of time. A maximum mean value of 8.30 over the five periods was recorded by T_9 (soil + VC ÷ RP), followed by T_8 (soil + VC) with 8.26. The initial CEC of 2.51 remained moreorless unchanged for treatment T_1 (soil alone) which was on par with T_2 (soil + SSP) and T_3 (soil + RP). Compared to these three treatments (T_1, T_2, T_3) which did not receive organic manures, all other treatments which recieved any of the organic manures have shown significantly higher values of CEC over the entire period of incubation. Of this, the highest values were recorded by those treatments receiving vermicompost (T_8 and T_9). However those treatments receiving FYM and ordinary compost (T_4, T_5, T_6 and T_7) did not differ significantly among themselves.

Cation exchange capacity of treatments receiving organic amendments registered higher values expected than other treatments without organics.. The degradation products of organic matter with high CEC and surface area has directly contributed to this observed increase (Wiklander, 1964 ; Thompson *et al.*, 1989). Vermicompost with higher amounts of active humic fractions having high CEC has thus resulted in maximum enhancement of this parameter. A slight decline in CEC values observed with the advancement of time might be due to the interaction of the active organic fractions with the inorganic constituents of the soil blocking some of the exchange sites.

4.3.3.4 Organic Carbon

The mean values of organic carbon expressed in percentage are presented in Table.. 25 (Fig. 23). As in the case of CEC, values on organic carbon also showed a general decreasing trend with the passage of time. As expected, the data showed significantly lower values for treatments which did not receive any organic manures (T_1, T_2 and T_3) during the entire course of time. Among the treatments receiving organic manures, T_5 (soil + FYM + RP) was on the top with a mean value of 2.21 over all the five periods. This was on par with T4 (soil + FYM) and T_8 (soil + VC) having values 2.18 and 2.14 respectively. Upto 30^{th} day, treatments receiving vermicompost (T_8 and T_9) showed highest values compared to other treatments,

Fig. 23. Organic carbon (%)

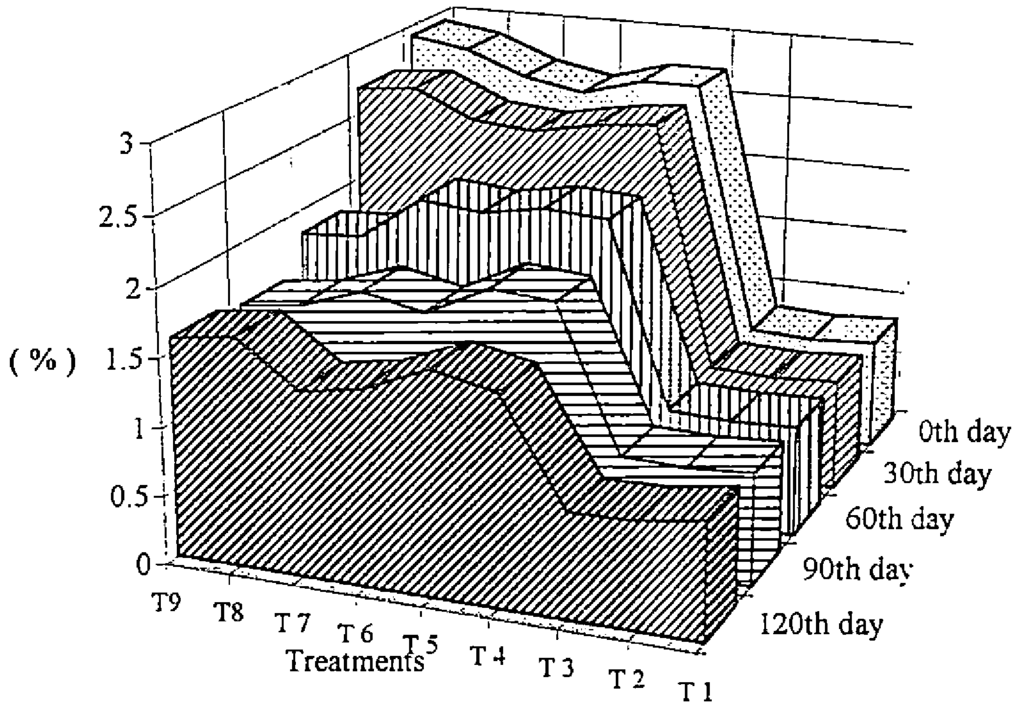
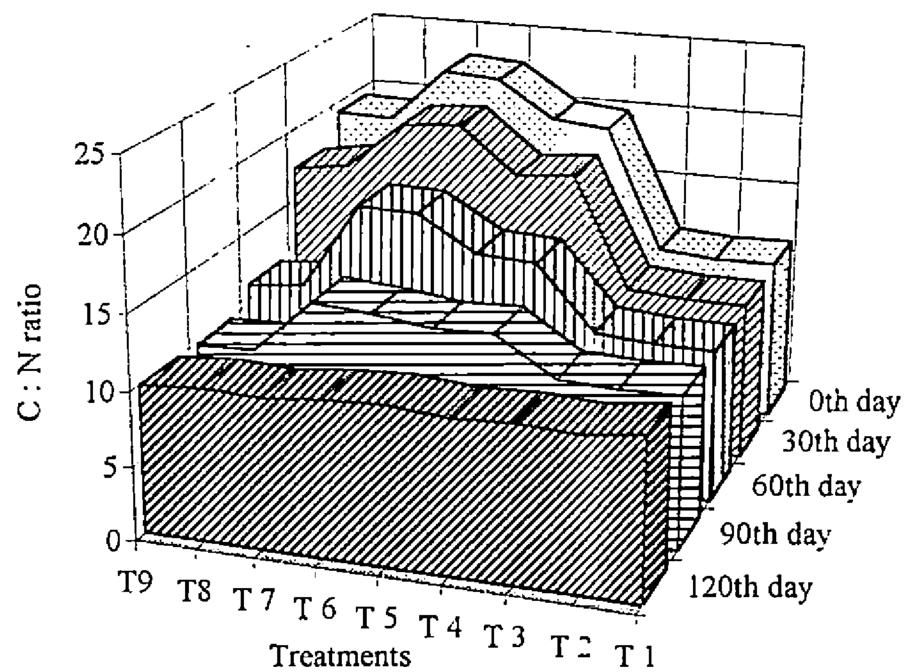


Fig. 24. C : N ratio



however, the treatments receiving FYM (T_4 and T_5) recorded higher values from the 60th day onwards. The variation due to different periods was noted to be significant. An increase upto 52 days after application and a decrease thereafter in carbon content, irrespective of the levels of FYM used was reported by Gupta *et al.* (1988). Udayasoorian *et al.* (1988) reported that carbon content of soil increased from 0.91 to 1.58 per cent by the continuous application of organic manures and among the organic manures, FYM had a significant influence.

The observed decrease in organic carbon content with time after a peak is due to active mineralisation and loss of carbon as CO_2. Thus a substantial amount of carbon is gasified and lost through metabolic activities by microbial proliferation. Treatments receiving FYM and ordinary compost retained more carbon towards the last phase of incubation than vermicompost treated samples. This could be explained by the relative difference in the mineralisation rate of carbon, which is more in the latter case.

4.3.3.5 C : N ratio

Being an index to determine the optimum availability of nitrogen, the C:N ratio has an important role in plant nutrition. A close scrutiny of the results presented in Table. 26 (Fig. 24) on C: N ratio showed a decreasing trend with advancement in the period of incubation for almost all the treatments. Maximum mean values over the entire period of incubation was shown by treatments T_7 and T_6 which received ordinary compost (values 17.02 and 17.01 respectively). This was followed by treatments T_5 and T_4 where FYM was incorporated. Though the mean treatment values were less, treatments T_8 and T_9 receiving vermicompost had shown a desirable trend by recording moreorless stable values starting from the 30th day of incubation till the end. Treatments receiving no organic manures (T_1, T_2 and T_3) had not shown any significant difference among themselves. The variation due to various periods of incubation were also significant.

The general decrease in C : N ratio observed in samples treated with organic amendments with time is theoretically sound as decomposition of bulky organic matter always register a decrease in C : N ratio (Gaur, 1994). The moreorless stable values recorded by vermicompost treated samples in this case clearly indicated the desirable rate of mineralisation and faster decomposition.

4.3.3.6. Zero point of charge (ZPC)

Data on point of zero charge of the samples representing various treatments as determined by potentiometric titrations are summarised in Table. 27 (Fig. 25).

As the number of titrations involved in the calculation of ZPC are plenty, composite samples representing all the three replications alone was considered for this estimation. Thus the data was not analysed statistically.

The ZPC values obtained are invariably lower for treatments receiving organic amendments when compared to control. Not much variation was observed among these treatments with respect to ZPC with advancement of incubation time. In all samples ZPC obtained was shifted towards the acid side. In the case of control ZPC values remained more or less steady (3.8 to 4.1) throughout the period of incubation. The lowest values recorded were in the case of T_4 and T_5 receiving FYM with and without rock phosphate.

In all the samples studied, representing various treatments the ZPC was displaced towards the acid side. This is attributed to the presence of permanent negative charge balanced mainly by Al^{3+} ions (van Raij and Peech. 1972). As the soil used for the study is rich in sesqui oxides, appreciable amount of aluminium is present in the cation suite of the colloidal fraction. The variation in ZPC values for soil samples receiving different treatments indicate the influence of organic amendments As the mineralogical properties of these samples are the same the observed differences in ZPC may be attributed to the effect caused by the interaction of organic fractions with the colloidal mineral components (Rajendran, 1992). In all the six treatments receiving organic matter the tendency observed was to lower the zero point of charge. The presence of Fe and Al oxides tend to increase the ZPC towards higher pH values while the presence of clay minerals with permanent or structural negative charge as well as the presence of organic matter tend to shift the ZPC to lower pH values (van Raij and Peech, 1972). Thus the lower ZPC values observed for soil receiving treatments T_4 to T_9 with organic amendments, inspite of considerable amounts of Fe and Al oxides, is due to the dominance of kaolinite in the clay fraction and the

Table 27 **Zero Point of Charge (ZPC)**

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	3.8	4.1	3.9	3.8	3.8	3.88
T_2	3.8	3.6	3.7	3.8	3.8	3.74
T_3	3.6	3.8	4.0	3.9	3.8	3.82
T_4	3.4	3.1	2.8	3.1	3.1	3.10
T_5	2.9	3.1	3.1	2.8	3.2	3.02
T_6	3.4	3.4	3.2	3.1	3.1	3.24
T_7	3.2	3.4	3.1	3.3	3.4	3.28
T_8	3.4	3.3	3.1	3.4	3.5	3.34
T_9	3.4	3.4	3.6	3.4	3.4	3.44
Mean Pe.	3.43	3.47	3.39	3.40	3.46	

Table 28 **Phosphatase activity** (μg p-nitrophenol g $soil^{-1}$ h^{-1})

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	482.1	476.7	496.0	468.0	481.4	480.8
T_2	532.3	561.5	559.4	538.8	600.0	558.4
T_3	496.0	523.0	560.0	576.0	546.0	540.2
T_4	1050.0	1150.0	1125.0	1210.0	1186.0	1144.3
T_5	1186.0	1210.0	1218.6	1310.4	1278.0	1240.7
T_6	1080.4	1140.6	1120.8	1128.4	1140.6	1122.2
T_7	1210.0	1320.7	1260.8	1240.0	1340.0	1274.3
T_8	1320.4	1410.8	1420.6	1270.0	1310.0	1346.4
T_9	1278.7	1420.6	1490.4	1480.8	1437.0	1421.5
Mean Pe.	959.5	1023.8	1027.9	1024.7	1035.4	

Fig. 25. Zero point of charge

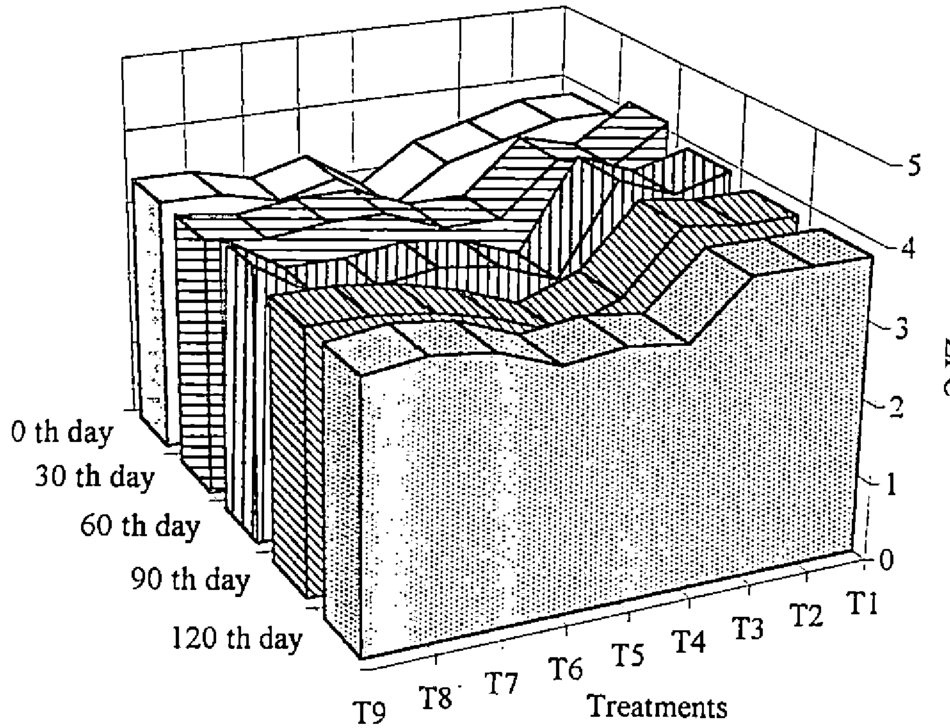
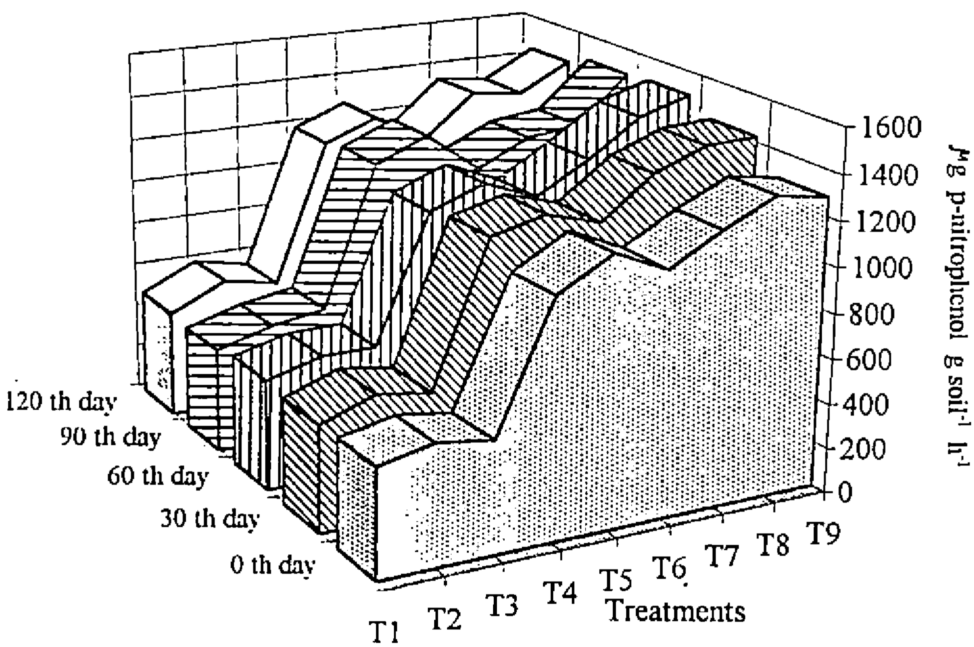


Fig. 26. Phosphatase activity



influence of organic colloids masking the effect of sesqui oxides. Similar results have been repoted by Herbillon (1988) and Rajendran (1992). Comparative efficacy of the organic amendments used in influencing the variation in ZPC is not clearly evident from the present study. However, treatments receiving FYM have shown slightly lower values than treatments receiving other organic manures. This aspect could be explained only by studying the nature of organo-mineral complexes formed from these organic sources and their influence on ZPC.

4.3.3.7 Phosphatase activity

Table. 28 (Fig. 26) shows the results on acid phosphatase activity changes due to various treatments. Acid phosphatase activity was studied in composite samples representing three replications and hence no statistical analysis was done for this parameter. From the results it was clear that the phosphatase activity of the treatment T_1 representing the control registred the lowest values throughout the period of incubation. Treatment T_9 representing soil + VC + RP recorded the maximum value at 60 days of incubation which remained more or less same with advancement of time. Treatments T_4, T_5, T_6, T_7 and T_8 receiving FYM, OC and VC with and without RP also showed comparatively higher values throughout the incubation period. Treatments T_2 and T_3 receiving SSP and RP respectively without organics registered slightly higher values over the control with advancement of time. Combinations of organic manures with RP registered a substantial increase in phosphatase activity over their counter parts without RP.

Enzyme assay indicated wide variation among treatments over the period of incubation. This might be due to variation in the amount of this endoenzyme in the viable microbial population and variation in the levels of accumulated phosphatase in the soil matrix. As the phosphatase activity had shown to be highly correlated with both microbial respiration and total biomass in soil (Frankenberger and Dick, 1983), it is logical to observe greater activity in samples treated with organic amendments. Bare soils with low organic matter represented by control thus have shown the lowest values. Addition of rock phosphate in treatments (T_2 and T_3) without organic amendments registered marginal increase over control presumably due to temporary microbial proliferation of the sensitive flora. Significant positive relationship reported between enzyme activities and soil organic carbon by Bremner and Mulvaney (1978) is in conformity with observations obtained in the present study. Addition of organic manure must have stimulated microbial activity and therefore phosphatase production and accumulation. Further, higher organic carbon levels in soils may also provide substrate for the protection of these enzymes in the soil matrix since soil organic constituents are thought to be important in forming stable complexes with free enzymes (Burns, 1982). The superiority of VC over other organic amendments in exhibiting a higher phosphatase acitvity might be due to the higher microbial load that the vermicompost supports.

4.3.4 **Fractions of organic matter**

The changes in various fractions of organic matter, viz., humic acid and fulvic acid due to the effect of various treatments over five periods are presented in Tables 29 to 31.

4.3.4.1 Humic acid

The changes in humic acid (HA) content, expressed in percentage, due to the effect of various treatments are presented in Table. 29 (Fig. 27). In general, there was an increasing trend with advancement of time. The maximum mean value for treatment over the whole period was shown by the treatment T_8 (soil + VC) followed by T_9 (soil + VC + RP). Over all the periods, except for 60th day, T_8 superceeded T_9 ; however T_9 recorded a slightly higher value over T_8 on 60th day. Treatments receiving organic manures registered significantly higher values over those treatments which did not receive any organic matter (T_1, T_2 and T_3). Among the various treatments receiving organic manures, those with FYM have shown significant differences which were superior to ordinary compost treatments, but inferior to those treatments with vermicompost. The highest percentage of HA (59.67) was shown by treatment T_8 on 120th day of incubation whereas T_1 (soil alone) registered the lowest value of 21.33. There was significant variation due to different periods of incubation. This result is in agreement with the findings of Senesi *et al.* (1992). However Bano and Suseela Devi (1996) have reported comparatively higher HA fraction in cowdung based composts than in vermicompost.

Table 29 Humic acid (%)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	21.33	22.67	22.33	23.00	23.00	22.47
T_2	21.67	21.33	22.33	23.00	23.00	22.47
T_3	22.00	22.67	21.33	23.00	22.67	22.33
T_4	45.67	48.67	50.33	52.33	54.33	50.27
T_5	45.67	47.67	48.33	50.33	52.67	48.93
T_6	41.67	43.67	45.33	46.67	47.33	44.93
T_7	43.67	43.67	45.33	46.33	47.00	45.20
T_8	49.33	52.67	55.67	58.33	59.67	55.13
T_9	48.33	51.67	56.33	57.00	59.33	54.53
Mean Pe.	37.70	39.41	40.82	42.22	43.22	

CD. Tr: 0.4383 CD. Pe: 0.3560 CD. Tr. Pe : 1.0680

Table 30 Fulvic acid (%)

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	42.67	39.67	4133	39.33	38.33	40.27
T_2	41.67	39.67	41.33	38.67	39.67	40.20
T_3	42.67	39.67	39.33	38.33	39.33	39.87
T_4	42.00	40.33	37.67	37.33	35.33	38.53
T_5	40.00	39.33	37.67	36.67	36.67	38.07
T_6	40.00	39.67	37.67	35.67	35.33	37.67
T_7	40.00	40.33	36.67	36.33	35.67	37.93
T_8	38.33	35.67	35.00	35.33	33.67	35.60
T_9	38.33	34.33	36.67	34.67	33.67	35.53
Mean Pe.	40.70	38.74	38.15	36.93	36.41	

CD. Tr: 0.6086 CD. Pe: 0.3271 CD. Tr. Pe : 0.9813

Table 31 H A / F A ratio

Treatment	0 th day	30 th day	60 th day	90 th day	120 th day	Mean Tr.
T_1	0.49	0.57	0.54	0.58	0.60	0.56
T_2	0.52	0.53	0.54	0.60	0.58	0.55
T_3	0.51	0.57	0.54	0.60	0.57	0.56
T_4	1.08	1.21	1.33	1.40	1.54	1.31
T_5	1.14	1.21	1.28	1.37	1.44	1.29
T_6	1.04	1.10	1.20	1.30	1.34	1.20
T_7	1.07	1.08	1.23	1.27	1.32	1.19
T_8	1.28	1.47	1.59	1.65	1.77	1.55
T_9	1.26	1.50	1.54	1.64	1.76	1.54
Mean Pe.	0.93	1.03	1.09	1.16	1.21	

CD. Tr: 0.0174 CD. Pe: 0.0131 CD. Tr. Pe : 0.0393

Fig. 27. Humic acid (%)

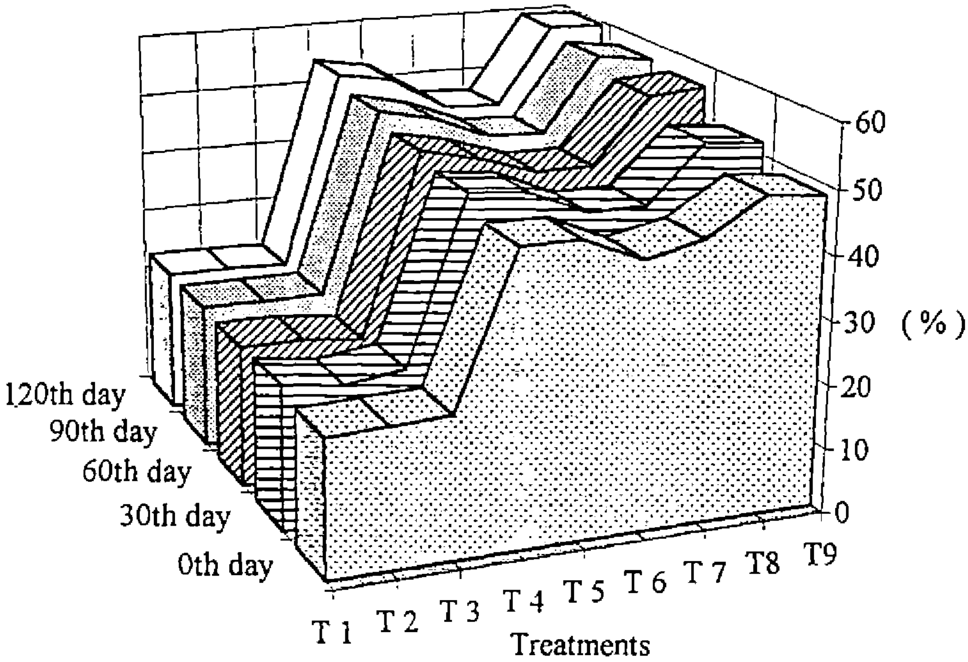
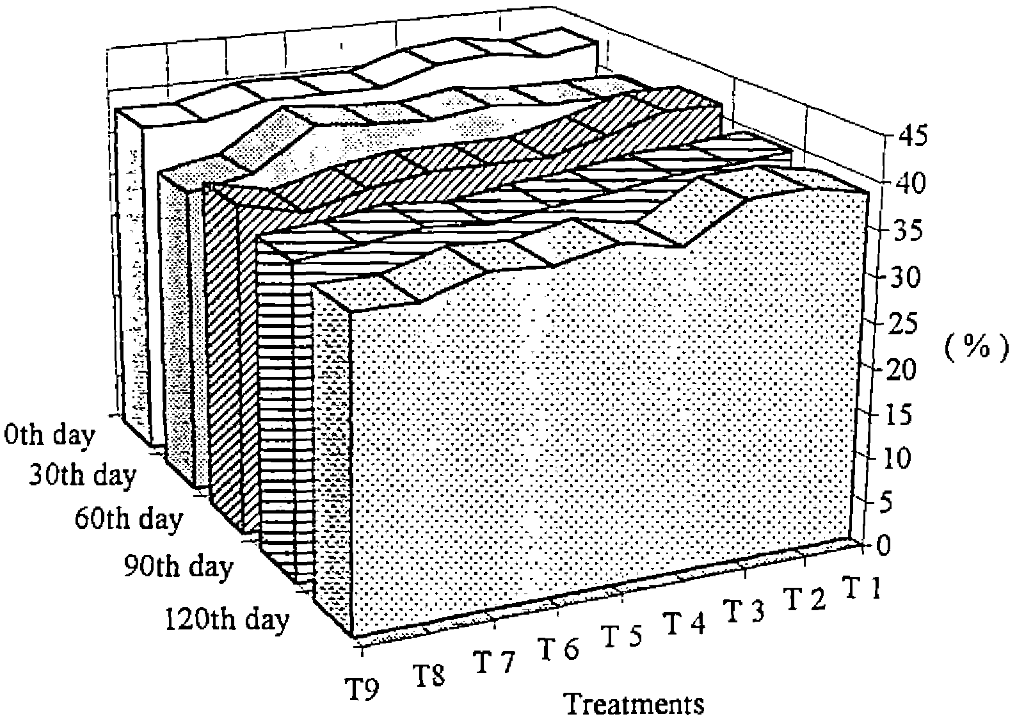


Fig. 28. Fulvic acid (%)



Treatments with organic amendments had shown a gradual increase in humic acid fraction in all the cases. However, treatments receiving organic manures without chemical fertilizers have registered higher values for HA compared to their counterparts with chemical fertilizers. This might be due to the decreased rate of carbon mineralisation and microbial immobilisation observed in the absence of chemical fertilizers. HA fraction being more stable than fulvic acid fraction, it is logical to observe the accumulation of the former at higher amounts in all treatments receiving organic amendments. Vermicompost with higher amounts of humic acid like fraction (HAF) accounts to higher values of HA extracted from vermicompost containing treatments in all the observations. This view is in agreement with the findings of Fontes *et al.* (1992) in some Oxisols from Brazil. In contrast to this, Bano and Suseela Devi (1996) reported higher humic acid fraction in cowdung based compost than in vermicompost, which they attribute to the presence of cellulose decomposing enzymes of cattledung apart from the action of earthworms.

4.3.4.2 Fulvic acid

Table. 30 (Fig. 28) presents the mean values of fulvic acid (FA) expressed in percentage. A critical observation of the data reveals that, in general, there is a slight decreasing trend with the advancement of time of incubation. Treatment receiving no organic manures (T_1, T_2 and T_3) have shown slightly higher values than those treatments receiving organic manures. Maximum mean value over the whole period of incubation was recorded by the treatment T_1 representing soil alone. Treatments receiving vermicompost (T_8 and T_9) had shown the lowest values over the whole period. Significantly higher values were recorded by ordinary compost in comparison to vermicompost and by FYM to ordinary compost.

The general decrease in FA content observed in all treatments with time is attributed to the disappearence of this less stable fraction at a faster rate than HA. Thus comparatively lower values exhibited by treatments containing vermicompost is mainly due to the low absolute values of this fraction present in it. This view is supported by the reported information of a lower value of fulvic acid like fraction in well decomposed organic manures based on analytical data (Schnitzer and Poapst, 1967).

4.3.4.3 Humic acid / Fulvic acid ratio

From the data presented in Table. 31 it was observed that, in general, the ratio gets widened with the advancement of time. The soil taken for study showed an initial value of 0.49 which increased to 0.60 during the 5th observation in the case of control. Treatments which received any of the organic manures have shown significantly higher values compared to those without organic manures (T_1, T_2 and T_3). Among the treatments, those receiving vermicompost, T_8 and T_9 recorded the highest ratio of 1.55 and 1.54 respectively. This was followed by T_4 and T_5 which received FYM. Among those treatments receiving organic manures, ordinary compost treated ones (T_6 and T_7) recorded the lowest ratio. However, the variation due to periods were significant.

The observed incresase in HA / FA ratio in treatments receiving organic amendments is well explained in the earlier discussions under HA and FA fractions. The relative enrichment of HA with faster disappearence of FA clearly substantiate the widening of the ratio, particularly in vermicompost receiving treatments, with inherently high HA contents.

4.4 POT CULTURE EXPERIMENT

The agronomic effectiveness of various organic manures were compared under pot culture experiment using cowpea as a test crop. The various observations are grouped into four, viz., biometric observations, yield parameters, plant analysis at crirical stages of plant growth and analysis of soil nutrient status after experiment. The data obtained are presented in Tables 32 to 38.

4.4.1 Biometric observations

Various growth characters of the crop at three critical stages of plant growth, viz., 20 days after sowing, maximum flowering stage and harvest were recorded and presented in Tables 32 to 34.

4.4.1.1 Height of plants

The mean height of plants at critical stages of plant growth are presented in Table. 32 (Fig. 29). A critical observation of the mean values revealed that there was

Table 32 HEIGHT OF PLANTS

Treatments	Mean values (cm)		
	20 DAS	Flowering	Harvest
T_1	18.87	33.67	45.67
T_2	18.53	33.53	45.50
T_3	20.63	37.60	48.27
T_4	21.97	37.57	50.00
T_5	22.63	39.77	53.73
T_6	22.13	37.73	50.77
T_7	23.00	39.67	53.53
T_8	23.13	41.57	53.10
T_9	23.43	43.23	57.20
T_{10}	18.93	33.47	45.83
T_{11}	14.07	22.27	34.37
CD (0.05)	1.077	1.016	1.207

Table 33 NUMBER OF LEAVES

Treatments	Mean values		
	20 DAS	Flowering	Harvest
T_1	3.17	7.33	9.33
T_2	3.33	7.33	9.00
T_3	4.00	8.00	9.67
T_4	4.33	8.67	10.17
T_5	4.83	9.00	11.17
T_6	4.67	8.50	10.17
T_7	4.83	9.00	10.67
T_8	4.83	9.00	10.83
T_9	6.00	11.00	12.50
T_{10}	3.67	7.50	9.33
T_{11}	2.67	6.83	8.17
CD (0.05)	0.571	0.779	0.807

Table 34 NUMBER OF NODULES

Treatments	Mean values	
	20 DAS	Flowering
T_1	3.17	20.00
T_2	3.50	19.50
T_3	8.83	25.67
T_4	4.67	27.17
T_5	4.83	27.33
T_6	4.67	27.00
T_7	4.33	26.83
T_8	9.50	33.17
T_9	9.50	40.50
T_{10}	7.50	19.17
T_{11}	1.67	9.83
CD (0.05)	1.621	3.370

significant variation due to treatments at all the three stages of plant growth. Treatment T_9 representing vermicompost (20 t ha^{-1}) + lime + chemical fertilizers recorded maximum height at all the three stages of growth. Treatment T_8 representing vermicompost (10 t ha^{-1}) + lime + fertilizers recorded the second highest values at different stages of growth.

At 20 DAS, T_8 receiving 10 t ha^{-1} of vermicompost recorded no significant difference with treatments T_5 and T_7 receiving 20 t ha^{-1} each of FYM and ordinary compost respectively. So also, at this period, treatment T_3 receiving vermicompost alone has shown significantly higher value compared to treatments T_1 and T_2 receiving FYM and ordinary compost alone. Here T_1 and T_2 were statistically on par with T_{10} which received mineral fertilizers alone.

At maximum flowering stage T_8 recorded a significantly higher value compared to T_5 and T_7 which again established the superiority of 10 t ha^{-1} of vermicompost over 20 t ha^{-1} each of FYM and ordinary compost. At this stage only those treatments receiving vermicompost (T_8 and T_9) attained heights above 40 cm. Here T_3 receiving vermicompost alone was significantly on par with T_4 and T_6 receiving 10 t ha^{-1} each of FYM and ordinary compost along with lime and recommended inorganic fertilizers.

At the time of harvest also, the significant effect of vermicompost was pronounced. The maximum mean plant height of 57.2 cm was recorded by T_9 at this stage which received 20 t ha^{-1} of VC. Treatment T_8 which received 10 t ha^{-1} of VC was statistically on par with T_5 and T_7 which received 20 t ha^{-1} each of other organic manures. T_3 receiving VC alone was statistically superior over its counterparts receiving FYM and ordinary compost alone without lime and chemical fertilizers. Howerer T_{11} (control) receiving no manures / fertilizers showed lowest values during all the stages of plant growth. Similar observations were made in sugarcane and soyabean by Shuxin *et al.* (1991). The enhanced plant height on VC application was in conformity with the findings of Ismail *et al.* (1993 a) in Zinnea and Stephens *et al.* (1994) in wheat.

From these observations it is evident that T_9 receiving 20 t ha^{-1} of VC along with lime and inorganic fertilizers is far superior over all other treatments. Treatment T_8 receiving 10 t ha^{-1} of VC along with lime and fertilizers is equivalent in all respects to T_5 and T_7 receiving 20 t ha^{-1} each of FYM and ordinary compost. So also T_3

Fig. 29. Height of plants

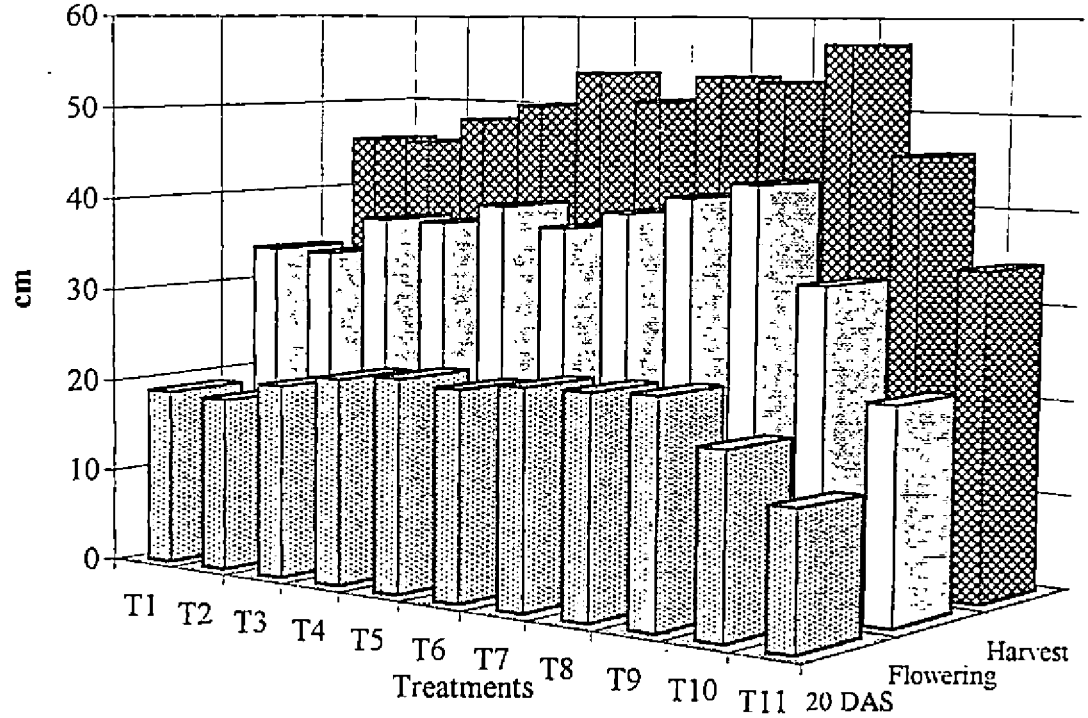
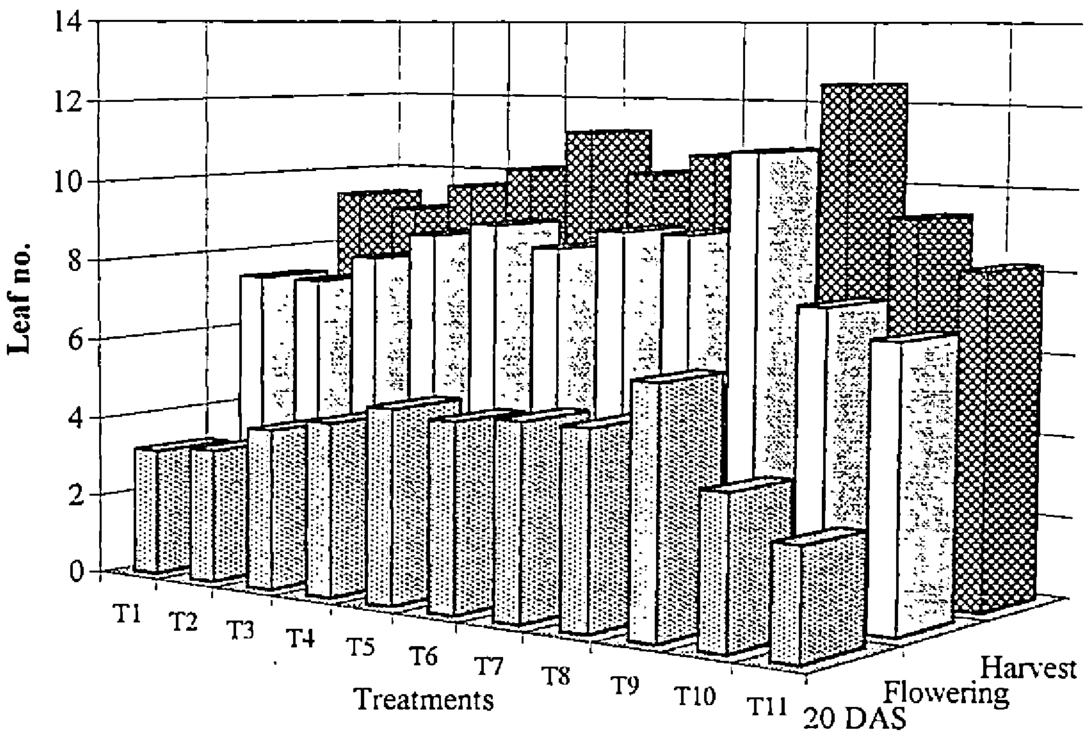


Fig. 30. Number of leaves



receiving VC alone is superior over its counterparts, T_1 and T_2 receiving only FYM and ordinary compost. Moreover T_1 and T_2 were statistically always on par with T_{10} receiving mineral fertilizers alone. As expected, the control (T_{11}) showed the lowest values over all the stages of growth.

4.4.1.2 Number of leaves

Table. 33 (Fig. 30) presents the mean number of leaves at critical stages of plant growth. It was observed that there was significant difference in the number of leaves due to various treatments at all the three stages of growth. From the table, it is evident that, as in the case of height of plants, the treatment receiving 20 t ha^{-1} of VC (T_9) stands superior to all the treatments at different stages of growth.

At 20 DAS,only T_9 showed a mean leaf number of more than 5.0. Here, treatments receiving 10 t ha^{-1} of VC (T_8), 20 t ha^{-1} of FYM (T_5), 20 t ha^{-1} of OC (T_7), 10 t ha^{-1} of FYM (T_4) and 10 t ha^{-1} of OC (T6) have shown no significant difference statistically. At maximum flowering stage also, these five treatments (T_8, T_5, T_7, T_4 and T_6) were stastistically on par. At this stage T_9 recorded a maximum mean value of 11.0 number of leaves whereas the mean values shown by the aforesaid five treatments ranged between 8.5 and 9.0. At the time of harvest a maximum mean leaf number of 12.5 was recorded by T_9 receiving 20 t ha^{-1} of VC. Here T_8 was statistically on par with T_5 and T_7 which indicated that the lower dose (10 t ha^{-1}) of VC is equally efficient like the higher doses (20 t ha^{-1}) of FYM and ordinary compost. Moreover, T_3 (VC alone) being seen statistically on par with T_4 (FYM 10 t ha^{-1} + lime + fertilizer) and T_6 (OC 10 t ha^{-1} + lime + fertilizer) again establishes the superiority of vermicompost over other organic manures. The control (T_{11}) showed the lowest values at all the stages of growth except at the time of maximum flowering, where it was statistically on par with treatments T_1, T_2 and T_{10}. Similar observations of increased plant growth by the application of vermicompost have been reported by Edwards and Lofty (1980) and Tomati *et al.* (1988).

From the aforementioned results, it is evident that application of vermicompost at 20 t ha^{-1} with lime and inorganic fertilizers have significantly contributed plant nutrients and growth promoting substances which in turn have increased the uptake of nutrients and the metabolic activity of the plant (Nielson, 1965). This enhancement of the general growth of plant coupled with high utilisation efficiency has resulted in better plant growth indicated by plant height and number of leaves. Further, nutrient loss from the soil especially of cations is also reduced considerably due to an improvement in CEC. Other related aspects like high moisture retention, better aeration and microbial activity leading to enhanced enzyme activity in soil also has to be taken into consideration.

4.4.1.3 Number of nodules

The mean number of nodules at early critical stages of plant growth ,viz., 20 DAS and at maximum flowering , are presented in Table. 34. From the table, it is evident that at 20 DAS all the treatments receiving VC (T_3,T_8 and T_9) had shown significantly higher values compared to other ones.This was closely followed by T_{10} receiving mineral fertilizers alone. All treatments containing different doses of FYM and ordinary compost (T_4, T_5, T_6 and T_7) were statistically on par, but significantly inferior to those receiving VC. However at this stage T_2(ordinary compost alone)was found significantly superior to T_1 (FYM alone).

At the time of flowering also treatments containing VC registered significantly higher number of nodules. The maximum mean 40.50 number of nodules was recorded by T_9 (20 t ha^{-1} of VC), followed by a mean of 33.17 by T_8 (10 t ha^{-1} of VC),both of which were significantly superior than all other treatments. Treatments T_4, T_5, T_6 and T_7 which contain different doses of FYM and OC with lime and fertilizers were statistically on par, but all being inferior to T_9 and T_8 containing VC. However these four treatments (T_4, T_5, T_6 and T_7) were statistically on par with T_3 which contained VC alone without lime and chemical fertilizers. Treatment T_{11}(control) recorded the minimum mean number of nodules, both at 20 DAS (1 67) and at flowering stage (9.83).

Vermicompost and other organic manures have contributed significantly for the multiplication of Rhizobium indirectly through the better plant growth acrued consequent to their application. Thus the rhizobial population is able to derive large amounts of metabolic fuel from the actively growing cowpea plants which resulted in better nodulation. 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).

4.4.2 **Yield parameters**

To compare the agronomic effectiveness of various organic manures, the yield parameters including number of pods per plant, lengh of pods, number of seeds per pod, grain yield per plant, hundred grain weight, bhusa (vegetative) yield and harvest index were recorded and presented in Table. 35.

4.4.2.1 Number of pods per plant

From the observation on the number of pods per plant, it is found that T_9 (VC 20 t ha^{-1}) was superior over all other treatments. T_8 (VC 10 t ha^{-1}) was also found to be significantly different from the rest of the treatments. T_9 and T_8 recorded mean numbers of pods of 8.50 and 6.83 respectively. T_3 receiving VC alone without chemical fertilizers had showed a spectacular equivalence with T_5 (FYM 20 t ha^{-1}) and T_7 (OC 20 t ha^{-1}) both with lime and chemical fertilizers. Treatments T_6, T_4, T_2, T_{10} and T_1 did not differ significantly among one another. Control (T_{11}) recorded the lowest value significantly lower than the rest of the treatments.

4.4.2.2 Length of pods

There was significant difference among the treatments. Treatment T_9 (VC 20 t ha^{-1}) ranked first among all the other treatments. T_8(VC 10 t ha^{-1}) was also significantly different from the rest of the treatments. T_9 and T_8 recorded mean pod lengths of 16.32 and 15.90 cm respectively. Treatments T_5 and T_7 receiving 20 t ha^{-1} each of FYM and ordinary compost respectively had shown no significant difference. T_3 receiving VC alone without chemical fertilizer was superior to both T_4 and T_6 receiving 10 t ha^{-1} each of FYM and OC with lime and chemical fertilizers. Treatment receiving mineral fertilizers alone (T_{10}) was found to be inferior to treatments receiving FYM or OC alone (T_1 and T_2). T_{11} (control) recorded the minimum mean pod length (8.34 cm).

Table 35 **YIELD PARAMETERS**

Treatments	mean values						
	Number of pods per plant (no.)	Length of pods (cm)	Number of seeds per pod (no.)	Grain yield per plant (g)	100 grain weight (g)	Bhusa yield (g / plant)	Harvest index
T_1	5.00	13.58	9.94	3.55	7.38	11.64	30.54
T_2	5.17	13.60	10.06	3.54	7.43	11.53	30.74
T_3	5.83	14.99	12.45	6.03	9.95	13.39	45.06
T_4	5.50	14.51	10.84	5.95	9.46	15.06	39.52
T_5	6.17	15.32	12.11	6.82	9.31	19.09	35.71
T_6	5.50	14.49	10.78	5.98	9.42	15.24	39.25
T_7	5.83	15.34	12.11	6.78	9.30	19.61	34.56
T_8	6.83	15.90	13.34	8.64	9.59	17.48	49.47
T_9	8.50	16.32	14.00	10.91	9.51	19.71	55.35
T_{10}	5.17	13.11	9.22	3.52	7.20	12.76	27.60
T_{11}	3.50	8.34	7.56	1.89	7.37	7.18	26.41
CD (0.05)	0.571	0.116	0.396	0.042	0.039	0.406	1.193

4.4.2.3 Number of seeds per pod

From the table, it was evident that there was significant difference among treatments with respect to the number of seeds per pod. Treatments receiving VC at different doses showed its superiority in this aspect also. T_9 (VC 20 t ha^{-1}) recorded the maximum mean seed number of 14.00 per pod followed by T_8 (VC 10 t ha^{-1}) with 13.34, both of which significantly differed from the rest of the treatments. As in the case of number of pods per plants, here also the treatment T_3 receiving VC without chemical fertilizers has proved to be equally efficient, with T_5 (20 t ha^{-1} FYM) and T_7 (20 t ha^{-1} OC) both with lime and chemical fertilizers, in deciding the number of seeds per pod. Similar treatments containing FYM and OC, viz., T_4 - T_6 and T_1 - T_2 did not differ significantly among each other. A minimum mean seed number of 7.56 per pod was recorded by T_{11} (control).

Yield parameters like number of pods per plants, length of pods and number of seeds per pod are all growth related aspects, which obviously express desirable effects in a healthy, actively growing cowpea plant having adequate nutrient supply. Hence it is needless to say that the aforementioned parameters are expressed in a manner which is most desirable for higher yields in treatment receiving VC. Application of vermicompost as an organic source stimulates microbial activity and enhances nitrogen fixation (Parkin and Berry, 1994). This enrichment of soil nitrogen due to N fixation, leads to increased N uptake and result in increased yield. The increased yield cannot be explained by effect of N alone, but it may be due to several factors like improved soil physical, chemical and biological properties (Bezdicek and Granatstein, 1989). This effect is pronounced even at lower doses of VC with and without chemical fertilizers.

The results obtained in the present study are in consonance with the findings of Ismail *et al.* (1993 b) who reported an increase in the number of fruits in chilli due to VC application . Sheshadri *et al.* (1993) and Rajalekshmi (1996) both in chilli and Pushpa (1996) in tomato have also reported similar effect of VC on yield parameters. The present observations are also supported by the findings of Jiji *et al.* (1996) who reported that vermicompost along with full inorganic fertilizers increased the yield of cowpea by 19 per cent. Thus it is concluded that application of VC must have enhanced nutrient availability and modified the rhizosphere environment to the advantage of the plant. In this context it is remembered that the growth promoting substances reported to be present in VC must also have played a role to achieve this effect.

4.4.2.4 Grain yield per plant

The difference among various treatments were highly significant with respect to grain yield per plant. T_9 is found to be superior, with a mean grain wieght of 10.91 g followed by T_8 with 8.64 g, both of which differ significantly from the rest of the treatments. This was followed by the treatments T_5 and T_7 receiving highest doses of FYM and OC with chemical fertilizers. However, T_3 receiving VC without chemical fertilizers has shown superiority over those treatments (T_4 and T_6) receiving 10 t ha^{-1} each of FYM and OC with lime and chemical fertilizers. T_{10} receiving chemical fertilizers alone was found to be statistically on par with T_1 and T_2 receiving FYM and OC alone. Control (T_{11}) recorded the lowest value of 1.89 g of grain per plant.

4.4.2.5 Hundred grain weight

In contrast to other yield parameters, here T_3 receiving VC alone without any chemical fertilizers had proved to be significantly superior over all other treatments, with a mean weight of 9.95 g for 100 grains. This was followed by treatments receiving VC at different doses with lime and chemical fertilizers. Of this, T_8 (VC 10 t ha^{-1}) and T_9 (VC 20 t ha^{-1}) recorded values 9.59 and 9.51 g respectively. T_4 and T_6 receiving 10 t ha-1 each of FYM and OC showed no significant difference, but proved to be significantly superior over T_5 and T_7 receiving 20 t ha^{-1} each of FYM and OC. The noted difference from other yield parameters is that the lowest mean value for 100 grain weight (7.20 g) was recorded by treatment T_{10} receiving mineral fertilizers alone which was found to significantly lower than the control (T_{11}).

4.4.2.6 Bhusa (vegetative) yield

With respect to vegetative yield also there was significant difference among treatments. The maximum mean of 19.71 g per plant was recorded by T_9 receiving 20 t ha-1 VC along with lime and chemical fertilizers, which was statistically on par with T_7 receiving the similar doses of ordinary compost. This was followed by T_5 (20 t ha^{-1}

FYM) and T_8 (10 t ha^{-1} VC) which differed significantly each other. Treatments T_4 and T_6 receiving 10 t ha^{-1} each of FYM and OC were statistically on par. Treatment T_3 receiving VC alone recorded significantly higher values over T_{10} (mineral fertilizers alone), T_1 (FYM alone) and T_2 (OC alone). Control plots recorded the minimum mean bhusa yield of 7.18 g per plant.

4.4.2.7 Harvest index

The data on harvest index once again confirmed the superiority of VC receiving treatment in deciding the yield attributes of crop. While T_9 with 20 t ha^{-1} of VC with lime and fertilizers recorded the maximum mean harvest index of 55.35, both the other treatments T_8 and T_3 receiving VC, showed significantly supaerior values over the rest of the treatments. It is very important to note that T_3 receiving vermicompost alone without lime and chemical fertilizers had proved its unchallengeable superiority over the highest dose of FYM and ordinary compost along with lime and recommended dose of chemical fertilizers. It was also interesting to note that the treatments T_4 and T_6 receiving 10 t ha^{-1} respectively of FYM and OC along with lime and chemical fertilizers was proved to be superior over T_5 and T_7 receiving similar treatments with 20 t ha^{-1} organic manures, with respect to harvest index. The other important observation with respect to this parameter is that, both control (T_{11}) as well as the treatments receiving solely mineral fertilizers (T_{10}) have not shown any statistically significant difference.

Data on grain yield per plant, 100 grain weight, bhusa yield and harvest index, all show results significantly superior in support of treatments receiving VC with and without chemical fertilizers. The higher availability of plant nutrients created due to improved physical environment brought about by vermicompost can be cited as the major reason for the above desirable effects. Though an integration of organics, particularly VC, with fertilizers have shown complementary effects with respect to grain yield and bhusa yield, the 100 grain weight was shown to be favourably influenced by the application of vermicompost without chemical fertilizers. This probably may be due to a better partitioning of photosynthates and a modification of the sink-source relation within the plant brought about by a balanced nutrient ratio in the vermicompost as compared to other treatments receiving chemical fertilizers.

4.4.3 Chemical analysis of plant at critical stages of growth

The whole plant samples were analysed for N, P_2O_5, K_2O, Ca and Mg at three critical stages of plant growth, viz., 20 DAS, at flowering and at harvest. The results thus obtained is presented in Tables 36 and 37.

4.4.3.1 Nitrogen

The nitrogen content of the plants receiving various treatments at different stages of growth are presented in Table. 36 (Fig. 31). In general, it is seen that in all the treatments, the N contents at 20 DAS and at flowering are nearly equal which showed a decline at the time of harvest. At all the three stages of growth, T_9 showed highest content of nitrogen in plants followed by T_8, both of which receiving VC, differed significantly from rest of the treatments.

During the first stage (20 DAS), T_9 recorded a maximum mean value of 2.85 per cent followed by T_8 with 2.79 per cent. These were followed by T_5 (FYM 20 t ha^{-1}) which, in turn showed significantly higher values compared to T_7 (OC 20 t ha^{-1}) and T_4 (FYM 10 t ha^{-1}). T_3 receiving VC alone was significantly superior over T_1 (FYM alone) and T_2 (OC alone). At flowering stage, T_9 and T_8 recorded highset values of 2.88 and 2.82 per cent respectively. Here T_5 receiving 20 t ha^{-1} of FYM was found to be significantly superior over T_7 receiving 20 t ha^{-1} of OC, both in the presence of lime and chemical fertilizers. However, T_{10} (mineral fertilizers alone) was found to be superior over T_3 (VC alone). At harvest, though T_9 itself recorded the highest per cent of N, the content was slightly reduced to 2.65, compared to its N contrnt at flowering. T_8 also showed a similar trend, recording 2.53 per cent N. This was followed by the other treratments which differ significantly among one another, viz., T_{10}, T_5, T_4 and T_7. Treatment T_3 (VC alone) showed statistically insignificant difference with T_6 (OC 10 t ha^{-1}). Throughout the growth stages, T_{11} (control) recorded lowest value for N content. Significant enhancement in the uptake of N at flowering and harvesting stages due to increased levels of P + FYM have been reported by Nimje and Seth (1988). The results obtained in the present study are in agreement with the findings of Shuxin *et al.* (1991) in soybean and Sagaya Alfred and Gunthilagaraj (1996) in amaranthus who reported increased uptake of N in the respective crops on vermicompost application.

Table 36 NUTRIENT ANALYSIS OF COWPEA PLANTS

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	20 DAS	Flowering	Harvest	20 DAS	Flowering	Harvest	20 DAS	Flowering	Harvest
T_1	2.11	2.11	1.91	1.04	0.79	0.68	0.94	0.87	0.57
T_2	2.08	2.07	1.89	1.01	0.73	0.63	0.93	0.83	0.51
T_3	2.24	2.26	2.16	1.13	0.83	0.73	0.99	0.89	0.60
T_4	2.63	2.61	2.30	1.10	0.83	0.73	1.00	0.87	0.59
T_5	2.72	2.75	2.34	1.18	0.85	0.77	1.11	0.89	0.63
T_6	2.56	2.60	2.16	1.09	0.79	0.63	0.96	0.83	0.57
T_7	2.64	2.67	2.24	1.15	0.83	0.65	1.01	0.85	0.61
T_8	2.79	2.82	2.53	1.19	0.86	0.75	1.12	0.91	0.61
T_9	2.85	2.88	2.65	1.25	0.93	0.85	1.20	0.95	0.65
T_{10}	2.42	2.47	2.37	1.18	0.91	0.80	0.89	0.79	0.55
T_{11}	1.91	1.81	1.51	0.82	0.31	0.33	0.88	0.87	0.51
CD (0.05)	0.0278	0.0294	0.0308	0.0294	0.0235	0.0228	0.0335	0.0230	0.0244

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Fig. 31. Nitrogen (%)

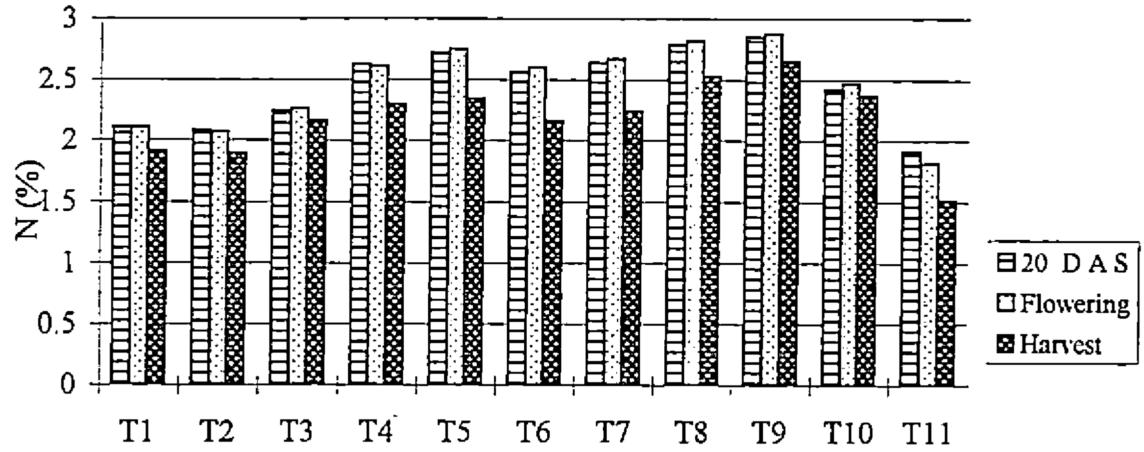


Fig. 32. Phosphorus (%)

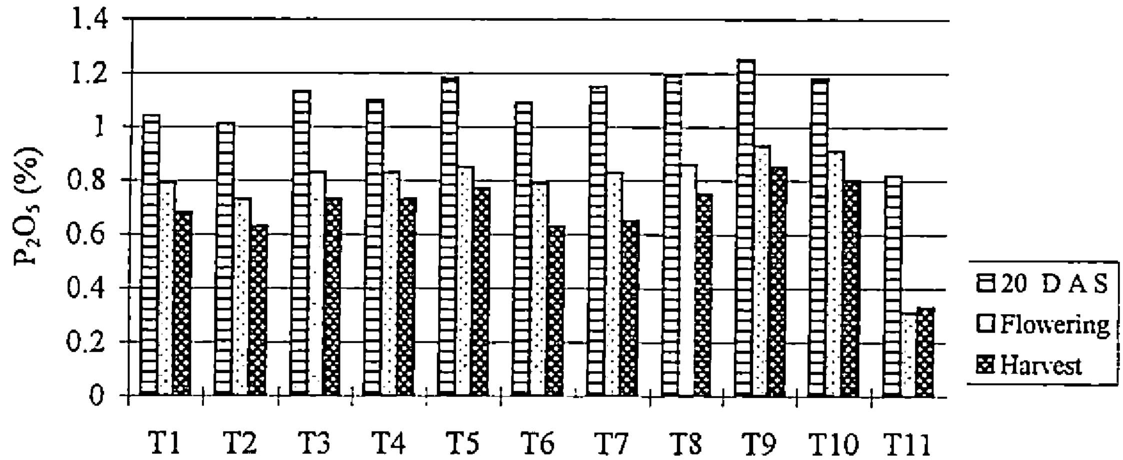
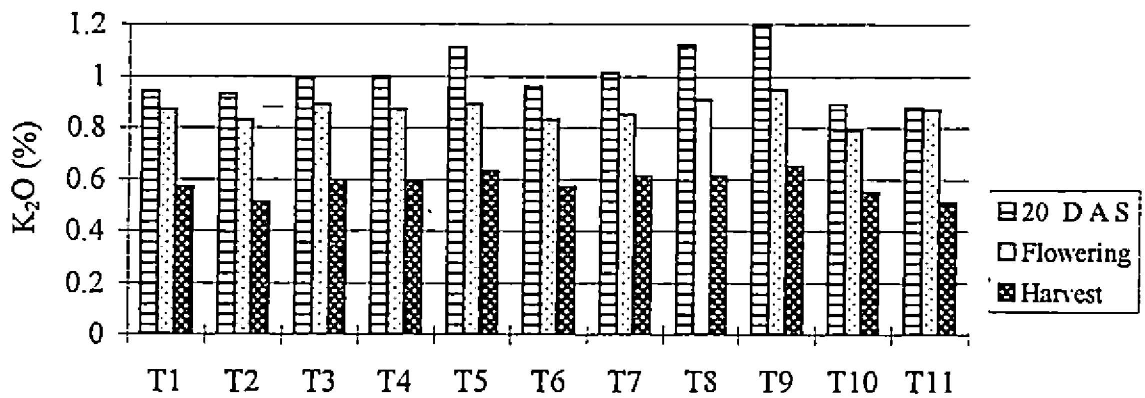


Fig. 33. Potassium (%)



4.4.3.2 Phosphorus

A critical observation of the per cent P_2O_5 showed that there was a general decrease in P_2O_5 content with the advancement of growth stages (Table 36 ; Fig. 32). All of the treatments including control recorded maximum P_2O_5 content at 20 DAS. At this stage, T_9 receiving 20 t ha^{-1} of vermicompost with lime and chemical fertilizers recorded the highest value of 1.25 per cent P_2O_5. This was followed by T_8, T_5, T_{10} and T_7 which were statistically on par among one another. Treatment T_3 receiving vermicompost alone, recorded a statistically non significant difference with T_7 receiving 20 t ha^{-1} of OC with lime and chemical fertilizers. At flowering, it was noted that the superior treatment T_9 showed a non significant difference with T_{10} receiving mineral fertilizers alone. Following this, T_8 and T_5 recorded P_2O_5 values which were statistically on par. However, T_3 receiving VC alone, showed its equality with T_5 (20 t ha^{-1} FYM), T_7 (20 t ha^{-1} OC) and T_4 (10 t ha^{-1} FYM), all the three with lime and fertilizers. At harvest, the highest P_2O_5 content recorded was 0.85 per cent by T_9 which was followed by a significantly lower value of 0.80 by T_{10}. Treatment receiving 10 t ha^{-1} of VC (T_8) was found to be on par with the treatment of 20 t ha^{-1} of FYM (T_5). However, T_3 receiving VC alone, was found to give values moreorless same as T_8 receiving 10 ha^{-1} of VC along with lime and fertilizers. Control (T_{11}) receiving no manures / fertilizers showed significantly lowest value throughout the entire growth period. Kale *et al.* (1989) found significantly higher levels of uptake of phosphorus in rice treated with VC. Minhas and Sood (1994) reported that FYM application was beneficial in enhancing the uptake of P by potato and maize.

4.4.3.3 Potassium

A gradual decrease in per cent K_2O content was observed (Table. 36 ; Fig. 33) with the passage of time. At all the three growth stages, the superiority of T_9 was pronounced. At 20 DAS, maximum K_2O per cent was registered by T_9 (1.20). This was followed by T_8 and T_5 which did not show significant difference in between. Treatment T_3 receiving VC alone, was found to be statistically on par with T_7 (OC 20 t ha^{-1}) and T_4 (FYM 10 t ha^{-1}), both with lime and chemical fertilizers. Treatment T_{10} receiving mineral fertilizers alone was found to show statistically non significant difference with the control (T_{11}) at 20 DAS. At flowering the highest K_2O per cent of

0.95 was registered by T_9. At this stage, T3 receiving vermicompost alone, was found statistically on par with T_8 (VC 10 t ha^{-1}) and T_5 (FYM 20 t ha^{-1}) both with lime and chemical fertilizers. However, it was interesting to note that the control (T_{11}) recorded non significant difference with T_5 (FYM 20 t ha^{-1}), T_4 (FYM 10 t ha^{-1}) (both with lime and fertilizers), T_3 (VC alone) and T_1 (FYM alone). At this stage, T_{10} receiving solely mineral fertilizers recorded the lowest content of K_2O (0.79 %). At harvest, the per cent of K_2O in plants receiving all the treatments showed a decrease, compared to their respective values at flowering stage. Though T_9 recorded the highest content of 0.65 per cent at this stage, it was statistically on par with T_5 receiving 20 t ha-1 of FYM + lime + fertilizers. This was followed by T_8 which showed an insignificant difference with T_7. Treatment T_3 receiving VC alone was found to be statistically on par with T_8 (VC 10 t ha^{-1}), T_7 (OC 20 t ha^{-1}) and T_4 (FYM 10 t ha^{-1}) all of which receiving lime and fertilizers, in addition. The control (T_{11}) recorded the lowest value of 0.51 per cent of K_2O at harvest.

The results presented with respect to N, P_2O_5 and K_2O content of plants clearly bring out an increase in the content upto the flowering stage and then a decline to lower values towards senescence. Though the latter part of the observation could be substantiated by nutrient immobilisation and translocation to the storage organs, namely seeds, through destructive senescence, the initial increase in the nutrient content may be attributed to their enhanced availability through faster mineralisation especially in an environment dominated by vermicompost (Stephens *et al.*, 1994). Further, the increase in N concentration consequent to fixation, increased nitrate reductase activity and better cation protection by humic colloids for NH_4^+ ions, all operate for better N utilisation efficiency and availability.

Activation of phosphatase leading to higher P availability, increased mineralisation of soil and added P by the organic acids produced, and direct immobilisation of P by microbial population, all contribute to the total phosphorus economy of the soil plant continuum in a desirable manner. The increased mineralisation of native soil P as a result of production of organic acids during decomposition of organic matter might be the reason for increased P content of plant parts. The solubilisation of P by the micro organisms was attributed to the excretion of organic acids like citric, glutamic, succinic, lactic, oxalic, glyoxalic, maleic, fumaric and tartaric acid (Rao, 1983). The micro organisms present in the VC helped in the mineralisation of organic P in a soluble form. These reaction had taken place in the rhizosphere and since the organisms rendered more P into the solution than that required for their own growth and metabolism, the surplus was made available for the plant parts thereby increasing the P content. This view is supported by Syres and Springett (1984) and Shuxin *et al.* (1991) who had reported that the increased P availability was by an increase in solubility of phosphorus by higher phosphatase activity in the presence of VC application.

Faster decomposition of organic manures releasing the bases including K brought about by application of vermicompost and FYM thus results in an increase in K^+ concentration in soil solution leading to higher uptake. Release of occluded and co-precipitated forms of K in the soil by the organic acids also would have resulted in the higher availability of K. The increase in K content due to VC application might be due to the increase in K availability by shifting the equilibrium forms of K from relatively unavailable forms to more available forms in the soil. This finding of Basker *et al.* (1994) is in consonance with the present result obtained. In the presence of VC, the K fixation might have reduced thereby releasing more of K in the soil. The enhanced proliferation of roots had helped in the increased uptake of K.

4.4.3.4 Calcium

Difference in Ca content (%)due to the effect of various treatments is presented in Table.37 (Fig. 34). In general, it could be observed that the Ca content at 20 DAS, and at flowering recorded moreorless equal values, which got reduced drastically at the time of harvest. At all the growth stages, T_9 receiving vermicompost 20 t ha-1 + lime + fertilizer showed highest content of Ca. At 20 DAS, T_9 recorded a maximum Ca content of 1.31 per cent followed by T_8 (1.29 %) and T_3 (1.24 %). It is important to note that the first three superior treatments were those receiving vermicompost at different doses with (T_9, T_8) and without (T_3) chemical fertilizers. This was followed by treatments T_5, T_4 and T_7 which did not differ statistically. Treatment T_6 receiving 10 t ha-1 of ordinary compost with lime and chemical fertilizers was on par with FYM and OC (T_1 and T_2) without chemical fertilizers.

Table 37 NUTRIENT ANALYSIS OF COWPEA PLANTS (contd.)

Treatments	Calcium (%)			Magnesium (%)		
	20 DAS	Flowering	Harvest	20 DAS	Flowering	Harvest
T_1	0.91	0.91	0.37	0.52	0.66	0.59
T_2	0.91	0.91	0.35	0.52	0.64	0.57
T_3	1.24	1.22	0.40	0.79	0.83	0.63
T_4	0.93	0.90	0.38	0.70	0.70	0.60
T_5	0.94	0.93	0.39	0.72	0.77	0.63
T_6	0.91	0.89	0.36	0.64	0.69	0.57
T_7	0.93	0.91	0.39	0.69	0.72	0.60
T_8	1.29	1.23	0.44	0.83	0.92	0.82
T_9	1.31	1.29	0.46	0.93	0.98	0.89
T_{10}	0.82	0.82	0.41	0.63	0.89	0.77
T_{11}	0.80	0.81	0.41	0.49	0.71	0.63
CD (0.05)	0.0174	0.0169	0.0158	0.0174	0.0188	0.0156

Fig.. 34. Calcium (%)

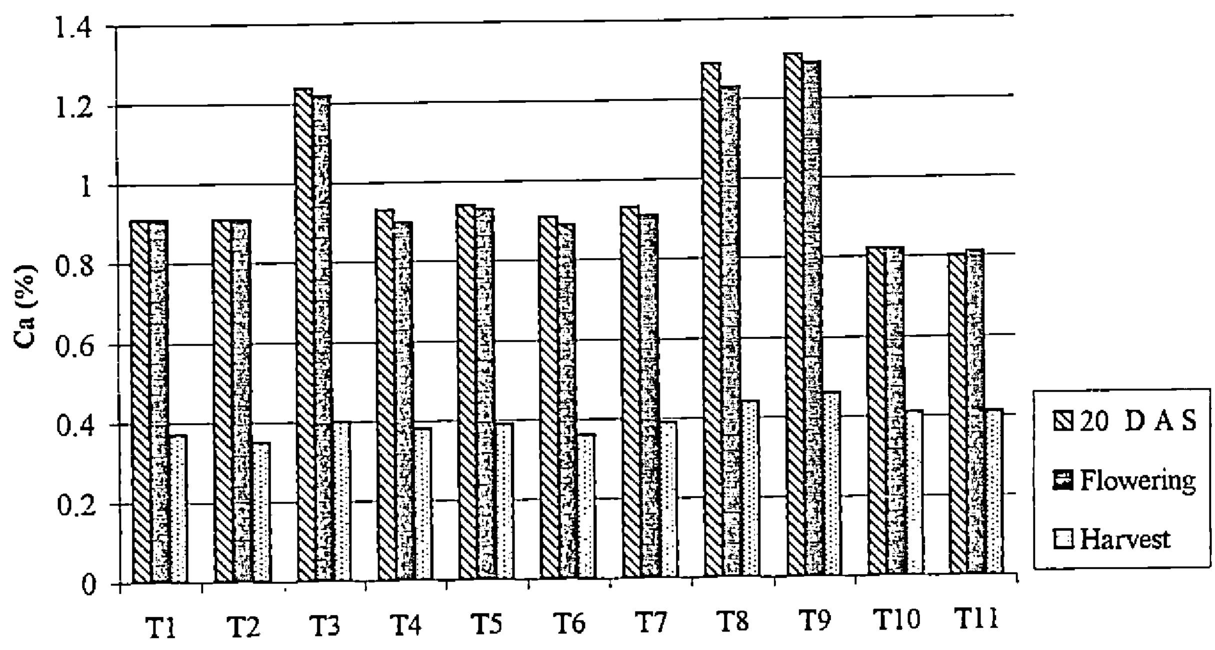
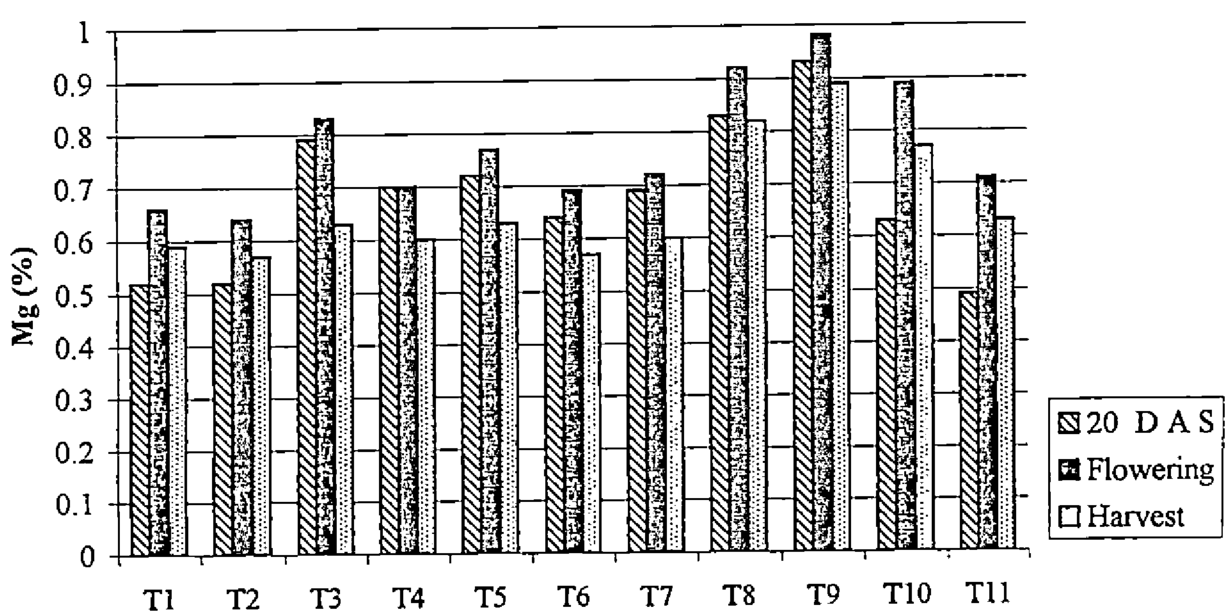


Fig. 35. Magnesium (%)



At flowering stage, T_9 recorded a maximum Ca content of 1.29 per cent. This was followed closely by T_8 and T_3 receiving vermicompost with and without chemical fertilizers. Here also the superiority of vermicompost in supplying Ca to crops is well documented. The superior vermicompost treatments were followed by T_5 and T_1 which received FYM. The lowest Ca content recorded at this stage was 0.81 per cent by control (T_{11}) which was statistically on par with T_{10} receiving mineral fertilizers alone. At the time of harvest T_9 recorded a maximum mean Ca content of 0.46 per cent. Here also T_8 recorded the second highest value of Ca, as in the case of earlier stages. However, at this stage, it was interesting to note that T_3 receiving vermicompost alone, came statistically on par with T_{10} (mineral fertilizers alone) and T_{11} (control), all of which showed superiority over rest of the treatments containing different doses of FYM and ordinary compost. The lowest content of Ca at the stage of harvest (0.35 %) was shown by T_2 receiving ordinary compost without chemical fertilizers.

4.4.3.5 Magnesium

From the data on the content of Mg as persented in Table. 37 (Fig. 35) it was observed that, in general, the Mg content is increased from 20 DAS to the time of flowering which again decreased at the time of harvest. At all the growth stages, T_9 and T_8, both receiving vermicompost, showed significantly higher values over the rest of the treatments. At 20 DAS, the maximum Mg content (0.93 %) was recorded by T_9, followed by T_8 (0.83 %) and T_3 (0.79 %) ; all the three receiving vermicompost at different doses. This was followed by T_5 receiving 20 t ha^{-1} of FYM. Treatment T_6 receiving 10 t ha^{-1} of ordinary compost was statistically on par with T_{10} (mineral fertilizers alone).

At the time of flowering the maximum Mg content (0.98 %) was registered by T_9 followed by T_8 (0.92 %), both receiving vermicompost. Here the third highest value was recorded by T_{10} receiving mineral fertilizers alone, which was significantly superior to T_3 receiving vermicompost alone. Here, T_7 receiving 20 t ha^{-1} of ordinary compost was found to be statistically on par with T_{11} (control). The lowest Mg content of 0.64 per cent was recorded by T_2 receiving OC without chemical fertilizers. At the time of harvest also, vermicompost treated plants showed highest content of

Mg. Though there occured a decline in Mg content at harvest compared to flowering stage, T_9 recorded a maximum value of 0.89 per cent followed by T_8 with 0.82 per cent. Treatment T_{10} receiving mineral fertilizers alone had recorded a significantly higher content of Mg compared to all the FYM and OC receiving treatments. Treatment T_3 receiving VC alone showed no statistical difference with T_{11} (control) and T_5 (20 t ha^{-1} of FYM). As in the case of Ca content, here also, the lowest value at the time of harvest was shown by T_2 receiving ordinary compost with on chemical fertilizers.

A critical study of the data on Ca and Mg contents showed an initial increase in Ca and Mg contents in early vegetative phase of the crop upto flowering, and a gradual decline in the reproductive phase ending towards harvest. These observations are in conformity with the findings of Vasanthi and Kumaraswamy (1996) and Pushpa (1996) in rice and tomato respectively. The peak period of Ca and Mg levels in plants synchronises moreorless with the active stage of organic matter degradation which is characterised by a faster release of basic cations during mineralisation. This trend was observed in all the treatments receiving organic amendments with highest correlation for treatments T_9, followed by T_8 and T_3, all receiving vermicompost. Hence the enhanced availability of Ca and Mg from vermicompost must be the reason for high content of these two elements recorded at all the stages of growth. The superiority of VC over other organic amendments used for the study is evident from the analytical data presented in Table.1 also. The higher amounts of Ca and other bases present in wormcast, vermicompost and vermiwash has been reported by many workers. Thus the higher content of these two cations in plants treated with VC may be due to increased uptake through enhanced availability from the soil.

4.4.4 Analysis of soil nutrient status after pot culture experiment

The soil after the harvest of the crop was subjected to chemical analysis for the parameters, viz., pH, organic carbon and available nutrients. The results obtained are presented in Table. 38.

Table 38

NUTRIENT STATUS OF SOIL AFTER THE EXPERIMENT

Treatments	pH	Org. Carbon (%)	Av. Nitrogen (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})	Av. Calcium (cmol kg^{-1})	Av. Magnesium (cmol kg^{-1})	Av. Sulphur (%)
T_1	6.17	1.54	280.37	34.78	160.00	1.23	1.92	0.029
T_2	6.03	1.43	262.40	32.44	147.67	1.12	1.88	0.027
T_3	6.53	1.79	314.40	37.67	174.00	1.45	2.55	0.047
T_4	6.43	1.75	341.40	40.78	177.33	1.30	2.17	0.037
T_5	6.47	1.87	361.50	45.33	191.00	1.42	2.33	0.045
T_6	6.37	1.67	318.90	37.39	168.67	1.23	2.17	0.034
T_7	6.43	1.74	340.23	41.39	173.33	1.33	2.32	0.043
T_8	6.67	1.87	394.40	49.28	222.00	1.48	2.87	0.059
T_9	6.77	1.99	422.23	59.44	247.67	1.63	3.18	0.064
T_{10}	5.93	0.85	276.13	36.33	131.33	1.18	1.70	0.015
T_{11}	5.47	0.77	256.50	28.33	118.33	1.02	1.63	0.011
CD (0.05)	0.0980	0.0339	3.500	1.572	3.866	0.0625	0.0571	0.0039

4.4.4.1 Soil reaction (pH)

The soil receiving different treatments were analysed for determining soil reaction (pH) after the experiment. From the data it was observed that treatment T_9 recorded the maximum value for pH (6.77). This was statistically on par with the value 6.67 obtained in the case of T_8. The third highest value of 6.53 was shown by T_3. It may be remembered that all the above three treatments were receiving vermicompost at different doses. However the treatments T_5 (FYM 20 t ha^{-1}), T_4 (FYM 10 t ha^{-1}) and T_7 (OC 20 t ha^{-1}) were statistically on par with T_3. The pH of the control (T_{11}) remained at 5.47 after the experiment which showed the lowest value.

It is evident from the data that treatments receiving vermicompost has caused a substantial increase in pH, nearing neutrality. This increase in pH is attributed to the higher amounts of bases contributed from vermicompost compared to other organic sources. Further, loss of bases from the experimental material was also restricted since the treatments were contained in pots. Moreover, cowpea, being a crop with high root cation exchange capacity, must have exercised better cation protection with respect to Ca and Mg , which in turn must have increased the percentage base saturation to maintain the pH.

4.4.4.2 Organic carbon (%)

Treatment T_9 receiving 20 t ha^{-1} of vermicompost with lime and chemical fertilizers recorded the maximum value of 1.99 per cent of organic carbon after the experiment. This was significantly superior to the treatment T_8 (VC 10 t ha^{-1}) which in turn was statistically on par with T_5 (FYM 20 t ha^{-1}). This was followed by T_3 receiving vermicompost without chemical fertilizers. Treatment T_4 (FYM 10 t ha^{-1}) and T_7 (OC 20 t ha^{-1}) recorded no significant difference. Treatment T_{10} receiving only mineral fertilizer showed significantly higher organic carbon content of 0.85 per cent over the control (T_{11}) which recorded the lowest value (0.77 %).

The data reveals the importance of organic amendments in maintaining the organic carbon content of soils. The highest dose of vermicompost represented by T_9 (with mineral fertilizers) has shown the highest level of residual organic carbon even after the experiment. This is attributed to the high amount of organic carbon contributed by the compost material added. This observation is true with respect to other organic amendments also, but the contribution of easily oxidisable organic carbon (as determined by Walkley-Black method) was more from vermicompost. Thus it is clear that the carbon present in vermicompost is more easily oxidisable than the carbon present in other organic amendments.

4.4.4.3 Available Nitrogen

From Table. 38, it is observed that T_9 recorded the highest value of 422.23 kg ha^{-1} of available N after the experiment. This was followed by T_8 (394.40 kg ha^{-1}) which was significantly superior to T_5 with a N content of 361.5 kg ha^{-1}. Treatments T_4 (FYM 10 t ha^{-1}) and T_7 (OC 20 t ha^{-1}) were statistically on par. Treatment T_{10} receiving mineral fertilizers alone, recorded a value (276.13 kg ha^{-1}) which was significantly higher than those of T_2 (262.4 kg ha^{-1}) receiving OC alone. Control (T_{11}) showed the lowest value of 256.5 kg ha^{-1}.

4.4.4.4 Available Phosphorus

The maximum available P_2O_5 content was recorded by T_9 receiving 20 t ha^{-1} of vermicompost along with lime and chemical fertilizers (59.44 kg ha^{-1}). This was followed by T_8 receiving a lower dose of vermicompost (49.28 kg ha^{-1}). Treatment T_5 receiving 20 t ha^{-1} of FYM recorded the third highest value of 45.33 kg ha^{-1}. As in the case of available N, treatments T_7 and T_4 showed no significant difference. Treatment T_3 receiving vermicompost alone (37.67 kg ha^{-1}) recorded non significant difference with T_6 receiving 10 t ha^{-1} of OC with lime and fertilizers (37.39 kg ha^{-1}) and T_{10} receiving mineral fertilizers alone (36.33 kg ha^{-1}). The lowest available P_2O_5 value of 28.33 kg ha^{-1} was recorded by the control (T_{11}).

4.4.4.5 Available Potassium

As in the case of available N and P_2O_5, here also the vermicompost receiving treatments, viz., T_9 and T_8 recorded their superiority over the rest of the treatments. A maximum value of 247.67 kg ha^{-1} of available K_2O was recorded by T_9, whereas T_8 recorded the second highest value of 222.00 kg ha^{-1}. Treatment T_5 receiving 20 t ha^{-1} of FYM showed significantly higher value (191.00 kg ha^{-1}) compared to T4 receiving the lower dose of FYM. However, T_3 receiving VC alone, showed no significant differnce with T_4. For the rest of the treatments, available K_2O was recorded in a decreasing order: T_7, T_6, T_1, T_2 and T_{10}. The treatment receiving mineral fertilizers alone (T_{10}) showed significantly higher value (131.33 kg ha^{-1}) than the lowest value of 118.33 kg ha^{-1} registered by control (T_{11}).

4.4.4.6 Available Calcium

Treatment T_9 recorded the highest value of 1.63 cmol kg^{-1} of available Ca after the experiment. This was followed by T_8 (1.48 cmol kg^{-1}) and T_3 (1.45 cmol kg^{-1}). It is to be noted that all the three said treatments receive vermicompost at different doses. However, T_5 was found statistically on par with T_3 and T_8. Treatment T_7 (OC 20 t ha^{-1}) was found to be statistically on par with T_4 (FYM 10 t ha^{-1}). Treatment T_{11} (control) recorded the lowest value of 1.02 cmol kg^{-1} of available Ca.

4.4.4.7 Available Magnesium

The three treatments receiving vermicompost at different doses (T_9, T_8 and T_3) stood superior over the rest of the tratments in the case of available Mg also. The maximum value of 3.18 cmol kg^{-1} was recorded by T_9 followed by T_8 (2.87) and T_3 (2.55), all of which differed significantly ampng one another. Treatments T_5 and T_7; and T_6 and T_4 were statistically on par. Tretment T_{10} receiving mineral fertilizers alone recorded a significantly higher value (1.70) over the control (T_{11}) which recorded the lowest value of 1.63 cmol kg^{-1}.

4.4.4.8 Available Sulphur

As in the case of Ca and Mg, here also the vermicompost receiving treatments (T_9, T_8 and T_3) showed significantly higher values over other treatments. Treatment T_9 receiving 20 t ha^{-1} of VC with lime and chemical fertilizers showed the highest value of 0.064 per cent available S. This was followed by T_8 (0.059 %) and T_3 (0.047 %). However, the treatments T_5 and T_7 which received 20 t ha^{-1} each of FYM and OC with lime and chemical fertilizers were statistically on par with T_3 receiving vermicompost alone. Treatment T_{10} receiving mineral fertilizers alone, showed no significant difference with the control (T_{11}).

A close scrutiny of the data (Table. 38) on available N, P, K, Ca, Mg and S once again established the superiority of vermicompost receiving treatments in contributing available plant nutrients which are in agreement with the findings of Scheu (1987), Tomati *et al.* (1988), Tiwari *et al.* (1989), Srinivasa Rao *et al.* (1996), Haimy and Huhta (1990), Shuxin *et al.* (1991), Pushpa (1996) and Rajalekshmi (1996). The analysis of residual soil after the pot experiment clearly reflects this superiority in terms of the absolute values of the above nutrients which is always higher for the treatments receiving VC. Thus the effect is manifested in terms of available nutrients, not only during cropping period but continues further after harvest as residual effects.

Thus in the light of the aforementioned discussion it is proved beyond doubt, the unchallengeable superiority of vermicompost over other organic amendments studied in releasing nutrients, in modifying the soil environment and physico-chemical properties, microbial and enzyme activity and the overall growth promoting effects on plant growth. However, there are certain missing links to fully substantiate the above statement and to have a deeper insight into the exact mechanism by which vermicompost imparts superiority over other organic amendments with more or less equivalent nutrient status. This aspect has to be investigated further through experimentation, without which a scientific study on vermicompost would remain incomplete.

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SUMMARY AND CONCLUSION

5. SUMMARY AND CONCLUSION

The salient findings of the present investigation are summarised hereunder.

Incubation experiment

* Vermicompost influenced almost all electrochemical properties of the soil significantly compared to other organic manures.

* Available N status was found to increase upto 90 days of incubation which recorded a decline thereafter, with respect to all the treatments. The treatments receiving vermicompost have shown significantly higher effects in providing available N compared to other organic manures.

* The release of different forms of P, viz., Bray extractable P, Fe-P and Al-P from rock phosphate was highest in the presence of vermicompost compared to other organic manures. All these three forms were found to increase steadily even upto the last observation (120 days). However, Ca-P and organic P contents got reduced with the advancement of time.

* In contrast to other nutrients, available K reached its peak with in a shorter span of 60 days which decreased thereafter. Both the treatments receiving vermicompost recorded highest values of available K over all the five periods of incubation, eventhough there was a general decreasing trend after 60 days of incubation.

* Available Ca and Mg recorded peak values on 90th day whereas available S was maximum on 60th day, both of which decreased gradually after the peak. Treatments receiving vermicompost recorded highest values for available Ca, Mg and S, compared to other organic manures, over different periods of incubation.

* While DTPA extractable and dithionite extractable (crystalline) forms of Fe showed a decreasing trend over different periods of incubation, the amorphous form of Fe represented by the oxalate extractable fraction had shown a gradual increasing trend over different periods. Vermicompost receiving treatments showed comparatively higher contents of amorphous Fe, indicating lesser chances of Fe toxicity.

* A gradual rise in pH has been noted with the advancement of time. Vermicompost treated samples showed a marked change in soil reaction, buffering it near neutrality, and thus assuring a conducive atmosphere for better plant nutrition.

* The marked difference obtained in electrical conductivity values shown by the vermicompost receiving treatments, especially towards the last periods of incubation, indicated a fairly release of bases into the soil system by vermicompost, compared to other organic manures.

* Though there occurred a gradual decrease in CEC with the passage of time, vermicompost treated ones showed highest values of CEC, during all the five periods, compared to treatments receiving FYM and ordinary compost.

* In the case of organic matter fractions also, vermicompost receiving treatments had shown a desirable trend by registering progressively higher values for humic acid fraction keeping the fulvic acid values more or less stable, thus gradually widening their ratio with the advancement of time.

* It is evident that processes responsible for P release is still active even after 120^{th} day of incubation in treatments receiving vermicompost with an added source of insoluble P like rock phosphate. Thus priming / pelleting of rock phosphate with vermicompost can be suggested as a suitable proposition for improving the efficiency of rock phosphate in variable charge soils.

Pot culture experiment

* Highest dose of VC (20 t ha^{-1}) with lime and chemical fertilizers maintained its superiority over all the other treatments.

* Lower dose of VC (10 t ha^{-1})with lime and fertilizer was equally effective as higher doses (20 t ha^{-1}) of other organic manures studied.

* Biometric observations at critical stages of growth and yield parameters recorded at the time of harvest indicated clearly the superiority of vermicompost over other organic manures studied.

* In contrast to all other yield parameters, the 100 grain weight was maximum with respect to the treatment receiving VC alone without chemical fertilizers.

* Analysis of plant samples at critical stages of growth revealed that all the nutrients studied, viz., N, P_2O_5, K_2O, Ca and Mg have shown their highest content with vermicompost receiving treatments at all growth stages, compared to treatments receiving other organic manures.

* Analysis of nutrient status of the soil after the pot culture experiment clearly indicated that the beneficial effects of vermicompost application was obvious even after the harvest of the crop. Values of available N, P_2O_5, K_2O, Ca, Mg and S of the soil after experiment once again established the superiority of vermicompost receiving treatments over other organic manures. However FYM could be rated moreorless on par with vermicompost in respect of certain parameters.

* All the observations summarised above clearly proved the superiority of vermicompost over other organic amendments studied with respect to release of plant nutrients, improvement of physico-chemical properties and soil environment, enhancement of microbial and enzyme activity and the overall growth promoting effects to sustain plant life.

* As the inherent nutrient make-up of vermicompost is moreorless similar to that of FYM, the added advantage of vermicompost is to be attributed to some other factors which could not be elucidated clearly, so far. This make it necessary to have deeper studies in this field covering areas which encompasses the beneficial effect of VC in enhancing microbial activity, especially in N-fixation and P-release. Further, the possibility of reducing the dose of vermicompost, without affecting the economic yields of various crops need be studied in detail through experimentation.

* The present study, being a pot culture experiment under controlled conditions may not be applicable to field situations as such. Thus detailed studies in this respect under actual field conditions are essential for drawing final conclusion.

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EFFECT OF VERMICOMPOST ON THE ELECTRO-CHEMICAL PROPERTIES AND NUTRITIONAL CHARACTERISTICS OF VARIABLE CHARGE SOILS

By

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ABSTRACT OF THE THESIS
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ABSTRACT

The study entitled "**Effect of vermicompost on the electrochemical properties and nutritional characteristics of variable charge soils**" has been carried out during 1994-95 which comprised of two experiments, viz., an incubation study and a pot culture experiment.

The incubation experiment was carried out at the laboratory attached to the Department of Soil Science and Agrl. Chemistry, College of Agriculture, Vellayani which was intended to study the effect of vermicompost (VC) in comparison with two other organic manures, viz., FYM and ordinary compost, on the electro-chemical properties and nutritional characteristics of a low activity clay soil taken from Vellayani. The pot culture experiment was conducted using the same soil used for the incubation study, to compare the agronomic effectiveness of various organic manures including vermicompost using cowpea as a test crop.

Both the experiments were laid out in Completely Randomized Design. The incubation experiment was conducted with nine treatments consisting of various organic manures with and without rock phosphate. Periodical sampling and analyses of soil incubated with various treatment materials were done at 30 days' interval to study the comparative effect of treatments on the electo-chemical properties and nutritional characteristics of the soil.

The pot culture experiment was conducted with eleven treatments containing different organic manures with and without chemical fertilizers, to study the comparative effect of different treatments on crop growth using cowpea. Observations on various biometric and yield parameters have been recorded and analyses of plant samples were done at three stages of growth of the plant, viz., 20 DAS, maximum flowering and at harvest. The nutrient status of the soil after the experiment was also analysed.

From the incubation experiment it was made clear that the effect of various organic manures differed significantly in influencing the electro-chemical and nutritional properties of variable charge soils.

In general, vermicompost maintained its superiority over other organic manures, especially in the presence of chemical fertilizers, in influencing various soil

properties. The effects were statistically significant in the order vermicompost > FYM> ordinary compost.

From the experiment it was proved that lower doses of vermicompost could be equated with higher doses of FYM and ordinary compost. Vermicompost established its superiority over other organic manures by influencing many of the soil properties favourably. The major effects were the reduction in P-fixation and increased P solubility in presence of vermicompost. The increased mineralisation of other major and secondary nutrients in the presence of VC caused an enhancement in the availability of these nutrients on an equivalent weight basis. A substantial increase in base status and pH, caused by vermicompost improved the overall plant nutrient status and soil environment compared to other organic manures. The organic matter fractions and other colloidal fractions were found to be favourably influenced by vermicompost. Organic colloids, being the most active and reactive phase of the soil, its contribution towards the total base exchange capacity and cation protection was more pronounced in the case of vermicompost.

Biometric observations at critical stages of growth of the crop and yield parameters recorded when analysed statistically have proved the superiority of VC over other organic amendments studied. Vermicompost application in combination with chemical fertilizers was proved to be the best among treatments tested. Lower doses of VC (10 t ha^{-1}) with lime and fertilizers was equally effective as higher doses (20 t ha^{-1}) of other organic manures studied. Analysis of plant samples at critical stages of growth also revealed the same effect. Soil analysis data after the pot experiment has further established the superiority of VC over other treatments. This is indicative of the ability of VC to sustain a higher level of soil fertility for a sufficiently longer period of time.

However, the present study being an experiment under controlled conditions, further research involving detailed field experimentation with selected crops is needed for drawing final conclusions.