# EFFECT OF VERMICOMPOST/VERMICULTURE ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

By

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## DECLARATION

I hereby declare that this thesis entitled "Effect of vermicompost/vermiculture on physico-chemical properties of soil" 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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# INTRODUCTION

# INTRODUCTION

The growth in agricultural production has to be consistent This becomes possible only when the soil is in good health The primary factor having influence on soil health is the organic matter content of soil Adequate quantity of organic matter is the pre requisite for maintaining soil health and sustained productivity According to Lockeretz (1988) as quoted by Parr et al (1990) sustainable agriculture is one that encompasses a range of strategies for addressing many of the problems that affect soil productivity ground water pollution etc The ultimate goal of sustainable agriculture is to develop suitable farming systems that are productive and profitable and are capable of conserving the natural resources Among the means available to achieve sustainability in agricultural production organic matter plays a key role because it possesses many desirable properties and exerts beneficial effects on physical, chemical and biological characteristics of the soil The organic fraction of cultivated soils is under constant threat of depletion due to environmental factors and inadequate replenishment While appropriate cropping systems and soil conservation measures minimize the hazards of erosion and other forms of soil degradation regular additions of organic manures in sufficient quantities lead to maintenance of organic matter content at optimum levels

The role of organic manures in improving soil structure and soil fertility is well understood Since the sources of farm wastes do not conform to any standards, the waste management has to operate within a wide variety of situations Composting offers an effective method as a waste disposal method The role of earthworms as biological agents in the degradation of organic waste is already recognised They effectively harness the beneficial soil microflora, destroy soil pathogens and convert organic wastes into valuable products such as biofertilizers, biopesticides vitamins enzymes antibiotics growth harmones and proteinaceous worm biomass

Vermitech is an aspect of biotechnology involving the use of earthworms as versatile bioreactors for effective recycling of organic waste to the soil resulting in waste land development and sustainable agriculture The two important components of vermitechnology are vermicomposting and vermiculture Vermicomposting is the bioconversion of organic waste material to nutritious vermicompost through earthworm consumption, while vermiculture is the culturing of earthworms for economic and effective processing of materials to produce value added products By applying vermiculture biotechnology, the time duration for transition of chemical to sustainable agriculture could be curtailed to 3 months from 3 to 6 years Vermicastings, the sustainable effective biofertilizer produced through vermiculture can be applied to the soils to trigger the soil biology so that transition from chemical nutrition to bionutrition is quick and without a significant loss of yield In addition the production of vermicasting right in the field and at low cost makes it very attractive for practical application The trials conducted by Stockdill (1982) led to significant improvement in soil conditions and grass yields by inoculation of earthworms into pasture land

Effect of vermicompost or introducing worms in the field for in situ composting in vegetable cultivations is not well studied in different soil types and climatic conditions of Kerala To assess the importance of vermitechnology, the present study is undertaken with chilli (Capsicum annum L ) as the test crop with the following objectives

1 To study the effect of vermicomposting on availability and uptake of major nutrients

2 To study the effect of vermiculture or in situ application of worms with undecomposed waste on the availability and uptake of major nutrients

3 To find out the changes in physical properties of the soil by vermicomposting and vermiculture

4 To compare the effect of vermicompost and vermiculture in situ on the physico-chemical properties of the soil

5 To find out the effects of vermicompost and vermiculture on growth and yield of the test crop - chilli

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

With the introduction of high yielding varieties, greater emphasis was given on the use of chemical inputs for achieving higher productivity The occurrence of micronutrient deficiencies and overall decline in the productivity of the soil under intense fertilizer use have also been reported These observations as well as the escalating prices of fertilizers has stressed the need for organic farming Kale and Bano (1983) reported the possibility of replacing the chemical fertilizer by organic manures and by earthworms Since long back the effect of earthworms on the structural properties of soils have been studied The relevant literature on the influence of organic manures and vermiculture on physico chemical properties of soils and on the growth and development of different plants are reviewed hereunder

## 2 1 Organic Manures

Organic manures such as green manures, compost, FYM etc constitute a dependable source of major and minor nutrient elements They also have a corrective effect on the adverse soil conditions caused by continuous and excessive use of inorganic fertilizers The judicious use of chemical fertilizers along with organic manures will ensure optimum agronomic conditions for higher crop production under intensive agriculture

2 1 1 Effect of organic manures on soil physical properties

It is well known that a positive relationship exists between soil physical properties and the amount of organic matter, a soil contains Organic manure is capable of increasing soil organic matter level, thereby improving the physical condition of soil The effect of organic manures on soil physical parameters are reviewed below

2 1 1 1 Water stable aggregates

Muthuvel et al (1982 [a]) observed that eventhough the structural indices were not significantly improved by long term fertilizer treatments, the structural parameters like aggregate stability and stability index were considerably improved by NPK and cattle manure treatments

In a field experiment, Bhagat and Verma (1991) observed that the treatment of FYM + straw incorporation had resulted in higher percentage of water stable aggregates (> 0 25 mm diameter - 80 9%) and larger mean weight diameter (0 82 mm) over control

Application of green manures to wetland increased the water stable aggregates between 0 1 and 0 5 mm size by 62%, reduced the bulk density and increased the infiltration rate (Boparai et al , 1992)

Chithra (1993) observed that continuous application of balanced doses of chemical fertilizers do not deteriorate the structural status of the soil

2 1 1 2 Surface compaction

Georges et al (1985) revealed that by using sugarcane by-products as soil amendment in clay and silty clay loam soils, there was a reduction in the penetration resistance and shear strength

Ganai and Singh (1988) observed a significant decrease in soil penetrometer resistance where farmyard manure was applied either in rice or in wheat as compared to control but the treatment farmyard manure to rice was having lower values than farmyard manure to wheat

Pagliai and Antisari (1993) reported that increased porosity in the top soil was accompanied by a reduction in the penetration resistance by addition of organic wastes like livestock effluents and composts from sewage sludge and urban refuse

2 1 1 3 Bulk density

In permanent manurial experiment, the phosphate fertilizers in combination with farmyard manure had shown a tendency in decreasing bulk density, though the difference amongst the treatments were not significant (Das et al , 1966) But Campbell et al (1986) reported that bulk density was not significantly affected by manures or phosphorus treatment in black chernozem soils

Sherry Hsiao Lei Wang et al (1984a) reported that when the mushroom spent compost (MSC) was applied to a fine sandy loam soil at varying doses, the bulk density decreased proportionately as the dose increased

Field experiments conducted by Bhagat and Verma (1991) observed that famyard manure + straw incorporation on a clayey thermic typic hapludalf lowered bulk density

More (1994) noticed decreased bulk density of a sodic Vertisol upon addition of farm wastes and organic manures

2 1 1 4 Porosity

In a green house experiment, Nogales et al (1984) noticed that urban compost increased soil porosity in the presence of rye grass crop but had no significant effect in the absence of the crop

In a long term experiment conducted at Mandya, in a red sandy loam soil, the porosity and volume expansion were much higher in plots where inorganic + organic fertilizers were applied together compared to inorganics alone However application of farmyard manure recorded the highest value (Rabindra et al , 1985) Similar result was also reported by Bhatnagar et al (1992)

Mahimairaja et al (1986) observed that over the years, the continuous application of fertilizer and manure had not changed the total porosity considerably But their influence was observed on non capillary and capillary porespace as it was observed that non capillary porespace decreased and capillary porespace increased Similar work was also reported by Muthuvel et al (1982 [a])

Bhagat and Verma (1991) showed that FYM + rice straw incorporation resulted in higher porosity (54 2%)

2 1 1 5 Water holding capacity

Water holding capacity of soil had improved due to the continuous use of farmyard manure to a good extent, whereas in case of chemical fertilizers, it decreased, except in the case of phosphate fertilizer treatment This was due to the improvement of soil structure in the presence of farmyard manure whereas nitrogenous and potassic fertilizers had a deteriorating action (Das *et al* , 1966)

Continuous application of farmyard manure in combination with chemical fertilizers has proved to be beneficial in increasing the water holding capacity of soil (Bhriguvanshi, 1988)

Sarkar *et al* (1989) suggested that continuous application of farmyard manure increased water holding capacity due to improvement in porosity and soil aggregation but use of inorganic fertilizers increased bulk density and decreased water holding capacity

In a long term fertilizer trial in sandy loam soil under soybean - wheat cropping sequence Bhatnagar *et al* (1992) noticed that water holding capacity of the soil was increased by 26 5 and 32 3% of the initial value under N + FYM and NPK + FYM

Joshi *et al* (1994) revealed that incorporation of green manures in a clay loam soil increased the volumetric water content of unsaturated top soils under rice-wheat cropping system

2 1 1 6 **Hydraulic conductivity**

Khaleel et al (1981) reported that saturated hydraulic conductivity was increased after sludge application, usually explained by parallel decrease in bulk density and increase in porosity

Campbell et al (1986) observed that neither bulk density nor hydraulic conductivity were significantly affected by manures or phosphorus treatments in a black charnozem soil

In a long term fertilizer cum manurial trial conducted at Coimbatore, Mahimairaja et al (1986) observed a significant increase in hydraulic conductivity due to continuous application of inorganic fertilizers and manures

Pikul and Allmaras (1986) found that saturated hydraulic conductivity in the tillage pan was maintained at a high level, only where crop residue additions were increased and soil pH maintained above 5 6

Joshi et al (1994) observed that hydraulic conductivity in a clay loam soil in NPK treated plots was 3 1 cm day$^{-1}$ while it was increased to 4 8 cm day $^{1}$ in the sesbania treated plots

### 2 1 1 7 Infiltration

Khaleel et al (1981) reported that application of organic waste such as sludge improved both initial infiltration rate and steady state infiltration rate

Badanur et al (1990) from their study concluded that incorporation of sorghum stubbles and safflower stalks significantly raised the infiltration rate over the fertilizer treatment

Roberts and Clanton (1992) reported that dairy manure application to a clayey soil with low infiltration raised the infiltration rate The depth of incorporation of manure did not affect the water intake

More (1994) observed an increased infiltration rate due to application of organic waste and manures in rice-wheat grown on sodic Vertisol

### 2 1 1 8 Water retention

Water retention at 1/3 and 15 bars were significantly increased by organic treatments in a lateritic soil (Singh et al , 1976)

Khaleel et al (1981) observed increased water retention (on weight basis) at both field capacity and permanent wilting point when organic wastes such as animal manure, municipal wastes and sewage sludge were added and that relative increase in water retention capacity was greater for coarse textured soils, than for fine textured soils

Studies conducted by Badanur et al (1990) showed that incorporation of organic manures and crop residues in the soil significantly increased the water content at field capacity as compared with fertilizer treatment

Bhatnagar et al (1992) based on their studies reported that the water retention capacity of soils at 15 bar suction did not change much due to long term manuring and fertilization, but it changed appreciably at 0 33 bar suction

Joshi et al (1994) reported that volumetric water content of saturated clay loam soil varied from 0 40 $cm^3$ $cm^{-3}$ in the sesbania treated plots to 0 43 $cm^3$ cm $^3$ in plots receiving no green manure In the unsaturated soils at rice harvest, the corresponding values were 0 32 and 0 27 $cm^3$ $cm^{-3}$

2 1 1 9 **Available water**

Sommerfeldt et al (1987) inferred that in the surface 15 cm of the soil, the mean volume of plant available water retained by the soil between 20 and 1500 kPa tension decreased with increasing rates of cattle manure on both the non-irrigated and irrigated lands

Available water content of the soil was increased by application of NPK fertilizers together with compost or farmyard manure (Patnaik et al , 1989)

Bharadwaj and Omanwar (1992) conducted studies to evaluate long term fertilizer treatments on water content of an Aquic Hapludoll Soils of farmyard manure treated plots showed higher water content at 33 kPa and available water over the fertilizer treated plots which in turn was lesser than that of fallow plots

Hudson (1994) reported that soil organic matter is an important determinant of available water content as it is a significant soil component by volume and it increases the available water content in sandy textured soils only As soil organic matter increased, the volume of water held at field capacity increased at a greater rate than that held at the permanent wilting point

2 1 2 Effect of organic manures on availability of nutrients

Available nitrogen, phosphorus, potassium and exchangeable calcium and magnesium are important nutrients that help in plant growth and involved in many metabolic activities of the plant Many factors like soil moisture, temperature, cation exchange capacity influence the availability of plant nutrients The impact of combined use of organic manures and chemical fertilizers on the nutrient availability is studied by many scientists The literature pertaining to the effect of organic manures on the availability of these nutrients is summarized below

2 1 2 1 Soil reaction

Olsen et al (1970) reported that addition of manures increased the soil pH

Giusquiani et al (1988) observed that city refuse compost improved the pH of the soil

Jankowski and Koc (1992) noticed that the soil pH increase was greatest with the use of compost and fertilizer

Application of manures increased the pH of soil while that of nitrogen tended to decrease it (Patiram and Singh, 1993)

2 1 2 2 Organic Carbon

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% by the continuous application of organic manures and among the organic manures FYM had a significant influence (Udayasoorian et al , 1988)

2 1 2 3 Available nitrogen

Kurumthottical (1982) observed highest available N content in soil supplemented with organic and inorganic sources of nitrogen together with $P_2O_5$ and $K_2O$

An increase in available N content of soil upto 20 days after farmyard manure application and a decrease thereafter was noticed in a long term field experiment with wheat (Gupta et al , 1988)

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

Connell *et al* (1993) found that the composted municipal solid waste application in soil increased the available N content

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

2 1 2 4 Available phosphorus

Kurumthottical (1982) revealed that application of phosphate fertilizer in combination with organics had resulted in higher content of available phosphorus as compared to inorganic fertilizer alone

Phosphorus enrichment in soils with application of balanced or high doses of NPK and combined use of NPK and FYM and P depletion in the absence of phosphorus fertilization was quite evident in the long term fertilizer experiment with wetland rice conducted at various locations in India (Nambiar, 1985)

Badanur *et al* (1990) reported that available phosphorus content of soil was significantly increased with the incorporation of subabul, sunnhemp loppings and with farmyard manure

More (1994) noticed that application of farm wastes and organic manures increased the available phosphorus content of sodic Vertisol

2 1 2 5 **Available potassium**

Debnath and Hajra (1972) observed from their incubation studies, that available K content increased upto sixteenth day, a decrease on thirtieth day followed by an increase and then stabilized when farmyard manure and daincha were added

Comparing the effect of FYM and green manure, it was inferred that there was a build up of available K which was maximal with the use of FYM than green manure (Sharma and Sharma, 1988)

Dhanorkar et al (1994) reported that continuous use of farmyard manure raised the available K by 1 3 to 5 4 folds over control

Among nutrients, the most significant role of organic matter is in supplying K (Bharadwaj, 1995)

2 1 2 6 **Exchangeable calcium and magnesium**

Olsen et al (1970) inferred that the application of manures increased the exchangeable calcium and magnesium particularly at higher rates of their application

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

Udayasoorian et al (1988) noticed that continuous application of compost improved the status of exchangeable calcium but lowered the exchangeable magnesium content in the permanent manurial experiment conducted at Coimbatore

Singh and Tomar (1991) reported that the contents of exchangeable calcium and magnesium in soil decreased with applied K and increased with farmyard manure addition

2 1 3 Effect of organic manures on uptake of nutrients

Studies on soil nutrients alone will not give any inference on the influence of various nutrients on plant growth and development For that, the uptake of nutrients by plant has to be studied Uptake of nutrients is influenced by several soil and plant factors Organic manures greatly influence the uptake of nutrients The impact of organic manures on the uptake of nutrients such as N,P K, Ca and Mg are reviewed hereunder

2 1 3 1 Nitrogen uptake

Nimje and Seth (1988) found that uptake of nitrogen at flowering and harvesting stages of soybean were significantly enhanced due to increased levels of P + FYM

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

Singh and Tomar (1991) observed that application of farmyard manure and potassium had a positive effect on the uptake of nitrogen by wheat crop

2 1 3 2 Phosphorus uptake

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

Kale et al (1989) found significantly higher levels of uptake of phosphorus in rice treated with vermicompost

Minhas and Sood (1994) reported that farmyard manure application was beneficial in enhancing the uptake of phosphorus by potato and maize

2 1 3 3 Potassium uptake

Sherry Hsiao - Lei Wang et al (1984b) inferred that concentration of potassium in seedling tissues of vegetable crops like snap bean, cucumber, raddish, spinash and tomato increased progressively as the levels of mushroom spent compost (MSC) increased

Organic manures applied in conjunction with optimal NPK dose resulted in highest potassium uptake by crops (Sarkar et al , 1989, Singh and Tomar, 1991)

Ammal and Muthiah (1994) reported that application of composted coir pith plus potassium (100 kg $K_2O$ $ha^{-1}$) recorded highest uptake of potassium by rice plants as compared with raw coir pith plus potassium and potassium alone

2 1 3 4 Calcium and magnesium uptake

Virginia et al (1984) reported that concentration of calcium was higher and magnesium was lower in the tissues of transplants (tomato, lettuce and cucumber) grown in mushroom spent compost than those in the peat and vermiculite media Similar report about magnesium was obtained by Sherry Hsiao-Lei Wang et al (1984 a and b)

Lal and Mathur (1989) observed highest removal of calcium by maize grain receiving the treatment NPK + lime than with farmyard manure

Application of farmyard manure and potassium had a positive effect on the uptake of calcium and magnesium by wheat crop ( Singh and Tomar, 1991)

**2 1 4 Effect of organic manures on biometric characters**

Many research works show that addition of organic manures increase the yield of several crops, by enhancing leaf area, shoot root ratio etc Their effects on crop yields were, however, found to be more pronounced when combined with fertilizers The impact of organic manures on biometric characters of plant are reviewed below

**2 1 4 1 Yield**

Studies conducted by Helkiah et al (1981) to evaluate the efficacy of organic manures as compared to chemical fertilizers in a black soil revealed that application of organic manures at different levels in combination with inorganic fertilizers had significantly increased the grain and straw yield of sorghum

Gupta et al (1983) observed 30% higher grain and straw yields of pearl millet with farmyard manure and urea than with farmyard manure alone and nearly equal to that obtained with urea alone

The effect of composts prepared out of water hyacinth paddy straw or mango leaves with or without basic slag either in sunlight or in dark on yield and composition of chilli was studied by Maurya and Dhar (1983) They found that compost prepared in sunlight from water hyacinth and basic slag had the highest nitrogen content and resulted in the highest plant yield (upto 612g from 1 seedling per pot)

The role of increasing levels of mushroom spent compost (MSC) as soil amendment was evaluated by Sherry Hsiao Lei Wang et al (1984a) who reported that the yield of cucumber and soybean increased as the rate of mushroom spent compost increased

Gianquinto and Borin (1990) reported that fertilizer/manure application stimulated plant growth and increased tomato yield but the effects were moderated by soil type

Pooled analysis of the yield data from permanent manurial experiment (PME) with dwarf indica at Pattambi from 1973 to 1985 for the virippu crop season showed the superiority of cattle manure application in increasing the yield over the failure of green leaf application to produce higher yield (KAU, 1991).

Ferriere and Cruz (1992) reported that compost produced by earthworms from municipal wastes (CPEMW) increased the maize dry matter This increase was statistically significant only when it was used along with lime or fertilizer

Barve (1993) reported increase in the yield on application of vermicompost to grape

Sheshadri <u>et al</u> (1993) conducted an experiment to study the comparative effect of vermicompost, farmyard manure and fertilizer on yield of chilli The results showed that the yield of dry chillies obtained from vermicompost was some what higher than the control and farmyard manure and somewhat lower than the fertilizer treated bed but the yield of fresh chilli was maximum in the vermicompost treated bed

More (1994) suggested that the treatment farmyard manure + pressmud was the best for increasing yields of rice and wheat grown on sodic Vertisol

2 1 4 2 Leaf area

Dietz (1989) observed that when spinash plants were grown in sulphate and phosphate deficient media, the plants showed a reduction in whole plant leaf area by 76% and 69% respectively

Rao and Terry (1989) found that low phosphorus treatment decreased total leaf area by 76%

Brandner et al (1990) reported that plant growth, as measured by leaf area increased with application of phosphorus upto 269 kg ha $^{1}$ but after that plant growth was stable

Muchow (1990) observed increased leaf area index with increasing doses of nitrogen application Similar result was also reported by Andrews et al (1991)

2 1 4 3 Shoot-root ratio

Davidson et al (1985) reported that the grass plants in the swords receiving low nitrogen had high root shoot ratio

Catmak et al (1994) found in an experiment, shoot/root dry weight ratios were 4 9 in the control, 1 8 in P-deficient, 6 9 in K deficient and 10 2 in Mg deficient bean plants

2 2 Earthworms

Earthworms modify soil physical, chemical and biological properties and it is believed that they enhance nutrient cycling by ingestion of soil and humus and by the production of casts

2 2 1 Effect of earthworms on soil physical properties

Earthworm activity can potentially improve soil physical properties It has a major effect on soil structure by promoting macroaggregation (ie , the combination of soil particles into stable compound structures) The aeration and water holding capacity of soil are largely determined by its physical structure With a good crumb structure, water is retained in the capillary spaces within the aggregates, allowing continuous gaseous diffusion between them Mull is characterized by an aggregated structure and in defining mull, Burger and Raw (1967) states, "Practically all the aggregates are earthworm casts or residues of them" The effect of earthworms on water infiltration and the vertical mixing of soil horizon may also be significant, even though it does not build burrow systems and only leaves evenly distributed macropores in the soil it colonizes The literature on the effect of earthworms on various soil physical parameters are presented hereunder

2 2 1 1 Water stable aggregates

Earthworms were found to increase the amount of water stable aggregates in soil, thereby increasing plant growth (Lee, 1985)

Shaw and Pawluk (1986) showed that earthworms can positively or negatively influence the soil structure depending on the species and/or the nature of soil

Earthworms play an important role in the process of soil formation and in the maintenance of soil fertility They incorporate organic matter and turn over large amounts of soil by burrowing, feeding and casting This leads to improved soil structure (Stewart and Scullions, 1988)

In a field experiment in U S A the proportion of water stable aggregates in Ultisol was increased by the presence of earthworms (Kladivko et al , 1986)

Vijayalakshmi (1993) reported that soil aggregation of wormcast fertilized soil was improved as compared with no wormcast amended soil as reflected in the pot experiment of paddy growth

2 2 1 2 Surface compaction

Wormcasts are structurally more stable and they prevent soil crusting and minimize soil erosion (Lal, 1976a)

Syers et al (1984) observed an increase in soil penetrability by the burrowing activity of earthworms thereby increasing soil microbial activity influencing the supply of nutrients etc

Earthworms through their feeding, casting and burrowing activities reduce the surface crusting of soil (Atlavinyte and Zimkuviene, 1985, Kladivko et al 1986)

2 2 1 3 Bulk density

Earthworms decreased the bulk density of soil (Rushton, 1986)

Lal and Akinremi (1983) reported that bulk density of worm cast soil was significantly lower than that of uncast soil

2 2 1 4 Porosity

Ehlers (1975) observed increased transmission porosity in surfaces of zero tilled soils through the development of earthworm channels and other soil faunal pores

Macro-porosity (20 80 mm depth) and number of biopores were higher in the non cultivated system with farmyard manure than in the cultivated control (no farmyard manure added) and number of biopores were directly related to the numbers of earthworms incorporated in the plots with manure (Shinde et al 1992)

Kale (1994) reported that the humus feeder type of earthworms physically mix the contents of the deeper layers and make the soils loose and porous

Manyankusi *et al* (1994) reported that macropores were greater in the 0-5 cm layer of the fertilized plots than in the manured plots They also inferred that macropores were continuous to greater depth (>5 cm layer) in the plots receiving liquid dairy sludge than in the fertilized plots due to the presence of earthworms

2 2 1 5 **Water holding capacity**

Edwards and Lofty (1980) reported that earthworms can breakdown organic wastes produced in intensive agriculture largely into peat like materials with a good moisture holding capacity and porosity

Kale (1994) reported that the body exudates of earthworms improved the water holding capacity of soil and promoted the establishment of microorganisms

2 2 1 6 **Hydraulic conductivity**

Earthworm burrows increase hydraulic conductivity by 80% (Douglas *et al* , 1980)

Urbanek and Dolezal (1984) reported that earthworm channels between drains in the vicinity of drainage contributed substantially to water movement in the soil

Shipitalo *et al* (1994) found water movement in earthworm burrows was less in the tilled than those in no tilled soil

2 2 1 7 Infiltration

The range of water infiltration was increased by six-fold in the presence of earthworm burrows (Stockdill,1966, Rhee, 1969)

A dominant infiltration rate and redistribution of water was observed in a silt loam sub soil with vertical worm channels (Ehlers, 1975, Bouma *et al* , 1982, Edwards *et al* , 1990)

Bezborodov and Khalbaeva (1983) reported that in a dark serozem the infiltration rate was approximately doubled by the activity of earthworms and the high infiltration rate in cotton field soils during irrigation were caused by earthworm activity

Logsdon and Linden (1992) revealed that earthworm channels can increase infiltration and reduce runoff, increasing soil water availability or possibly deep percolation to maintain favourable water status for crop growth

2 2 1 8 Water retention

Lal and Akinremi (1983) found that moisture retention of soil was increased in the presence of earthworms

2 2 1 9 Available water

Earthworm burrowings increased range of available soil moisture by 17 29% (Stockdill, 1966 Rhee, 1969)

Lal and Akinremi (1983) reported that available water holding capacity (AWHC) was significantly higher in cast-soil than non-cast soil samples

2 2 2 Effect of earthworms on availability of nutrients

The role of earthworms in maintaining soil fertility is well recognized Earthworms that burrow deep into the mineral strata and return periodically to cast faecal material at the soil surface facilitate the transport of certain elements to the surface from deep in the profile There is abundant evidence that earthworm casts are rich in plant nutrients than in the surrounding soil (Lee, 1985) In addition to the physical mixing of the soil by burrowing activities, soil enrichment is achieved by speeding up mineralization of organic matter 2-5 times by earthworms The overall effect of earthworms on availability of nutrients is summarized below as reported by various research workers

2 2 2 1 Soil reaction

The worms significantly raised the pH of the leaching water and humus (Haimi and Huhta, 1990)

Bhawalkar and Bhawalkar (1993) opined that earthworms participate in soil forming process by influencing soil pH

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) and Hulugalle and Ezumah (1991)

2 2 2 2 Organic carbon

Shuxin _et al_ (1991) reported that by introducing earthworms and applying organic manure in the red arid soil, the organic carbon in the soil increased from 0 5 to 0 6%

Bhawalkar and Bhawalkar (1993) opined that earthworms participate in soil forming processes by influencing soil pH, promoting humus formation and by enriching the soil

Gaur and Singh (1995) stated that earthworm mediated conservation (Vermiconservation) system as a mechanism in which vermicastings replenish the organic matter content of soils

2 2 2 3 Available nitrogen

Increased availability of nitrogen in earthworm casts compared to the non-ingested soil has been reported by several workers (Scheu 1987 Tomati _et al_ , 1988 Tiwari _et al_ , 1989 Hulugalle and Ezumah, 1991)

Scheu (1987 [d]) found large amounts of mineralised N in the presence of large earthworm biomass

Haimi and Huhta (1990) reported that earthworms increase either directly or indirectly the proportion of mineral N available for plants at any given time, although N was clearly immobilized in the initial stage

Haimi and Einbork (1992) found in an experiment in which the humus was limed, earthworms positively influenced the biological activity and also increased the rate of N mineralisation

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

2 2 2 4 Available phosphorus

Higher concentrations of available phosphorus in earthworm casts compared with the surrounding soil or litter have been observed by Sharpley and Syers (1977) Mansell et al (1981), Vleeschauwer and Lal (1981) and Tiwari et al (1989)

Mackay et al (1983) found that incorporation of earthworms to soil incubated with phosphate rock (PR) resulted in a 32% increase in Bray-extractable soil phosphorus after 70 days and increase ranging from 30-44% in bicarbonate extractable soil phosphorus over the same period

Mouat and Keogh (1987) suggested that the decrease in availability of soluble phosphate from wormcasts with increase in depth may result from an increase in the P-adsorptive capacity of the surrounding soil

Haimi and Huhta (1990) reported that the worms influenced the level of $PO_4{}^3$ P in coniferous forest soil slightly

2 2 2 5 Available potassium

Increased concentrations of available and exchangeable K content in casts compared to surrounding soil was reported by Lal and Vleeschauwer, 1982, Krishnamoorthy and Vajranabhaiah, 1986 Tiwari et al , 1989 Hulugalle and Ezumah, 1991

Basker et al (1992) inferred from his incubation experiment that the exchangeable K content increased significantly due to earthworm activity but nitric acid extractable K did not change significantly

The higher concentratioin 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 (Basker et al , 1994)

2 2 2 6 Exchangeable calcium and magnesium

Kale and Krishnamoorthy (1980) reported that castings of earthworms were rich in soluble forms of calcium The concentration of soluble calcium of castings was 11 8 times more than the surrounding soil but in the case of total calcium it was only 1 3 times more than the surrounding soil

Shinde et al (1992) reported that the concentration of exchangeable calcium and magnesium 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 2 3 Effect of earthworms on uptake of nutrients

There is considerable evidence that earthworms can increase plant growth (Edwards and Lofty 1980, Grapelli et al , 1985, Tomati et al , 1988) This effect has been attributed, in part to the ability of earthworms to influence the soil physical environment by increasing pore volume amount of water stable aggregates, incorporation of organic matter and enhancing pedological process Further, earthworms may modify the rate of release of nutrients through the anecic effect (introduction of litter into the subsoil decomposition system) and storing of nutrients in the casts The impact of earthworms on uptake of nitrogen phosphorus, potassium calcium and magnesium are presented below

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 earthworms increase short-term plant availability of P derived from plant litter by 2 3 fold

Reuter and Robinson (1986) reported that the concentration of potassium in wheat tops was potentially increased in the presence of earthworms

Stephens et al (1994) found that the presence of earthworms caused a significant increase in foliar concentration of N,P K Ca and Mg

2 2 4 Effect of earthworms on biometric characters of plant

Earthworm activity can potentially increase crop growth in many ways such as, by nutrient uptake, improved soil physical properties, better mixing of the soil etc Pot studies often indicate increased plant growth in response to high earthworm inoculation rates But only a few field studies indicate any plant growth increases, mainly for pastures, orchards and cereals The literature pertaining the effect of earthworms on plant characters are reviewed

2 2 4 1 Yield

Rhee (1969) found that grass yields in polders increased upto four times and clover yields upto ten times after inoculation with earthworms

Earthworms are known to increase height and yield of crops (Rhee, 1977, Edwards and Lofty 1978, 1980 )

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

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

2 2 4 2 Shoot root ratio

Earthworms stimulate root biomass and depth of rooting height and biomass of above ground tissue ( Rhee, 1977 Edwards and Lofty 1978 1980)

Haimi and Einbork (1992) showed that shoot-root ratio in birch seedling was not affected either by application of $NH_4^+$-N fertilizer or by mechanical mixing with earthworms

Stephens et al (1994) reported that the presence of earthworms caused a significant increase in shoot and root dry weight of wheat

# MATERIALS AND METHODS

# MATERIALS AND METHODS

The present investigation was undertaken to study the effect of vermicompost/vermiculture on physico chemical properties of soil and yield of chilli crop The materials employed and the methods adopted in this investigation are described in this chapter

## 3 1 Experimental site

The experiment was conducted in the garden land of Agricultural College farm, Vellayani The area selected was uniform in soil conditions and free from any shade The farm is situated at 8 5$^{o}$ N latitude and 76 9$^{o}$ E longitude at an altitude of 29 m above mean sea level

## 3 2 Soil characters

The preliminary analysis of physical and chemical properties of the soil are presented in tables 1 and 2 respectively

As seen from the table 1, the soil is having an optimum porosity condition but the moisture characteristics are not so favourable for cultivation and it belongs to a sandy loam texture (fine loamy kaolinitic isohypothermic Typic Kandiustults)

**Table 1 Preliminary analysis of soil physical properties**

| Sl No | Parameter | Observations | |
|---|---|---|---|
| | | 0 15 cm | 15 - 30 cm |
| 1 | Soil texture | Coarse sand-30 5%<br>Fine sand 27 0%<br>Silt 22 5%<br>Clay -18 6% | - |
| 2 | Surface compaction | 1 30 kg cm$^{-2}$ | |
| 3 | Bulk density | 1 51 Mg m $^{3}$ | 1 58 Mg m$^{-3}$ |
| 4 | Particle density | 2 58 Mg m $^{3}$ | 2 56 Mg m$^{-3}$ |
| 5 | Porosity | 41 47% | 38 28% |
| 6 | Water holding capacity | 25 37% | 22 72% |
| 7 | Water stable aggregates | 32 56% | 28 72% |
| 8 | Moisture content | 8 53% | 9 08% |
| 9 | Hydraulic conductivity | 12 51 cm hr$^{-1}$ | 9 76 cm hr$^{-1}$ |
| 10 | Infiltration | 4 00 cm hr$^{-1}$ | - |
| 11 | Water retention | | |
| a | 33 kPa | 10 77% | 10 53% |
| b | 1500 kPa | 9 01% | 9 58% |

Table 2 P relιmιnary analysιs of soιl chemιcal propertιes

| Sl No | Parameter | Observatιons | |
|---|---|---|---|
| | | 0 - 15 cm | 15 30 cm |
| 1 | pH | 5 20 | - |
| 2 | Organιc carbon | 1 18% | 1 15% |
| 3 | Avaιlable nιtrogen | 240 43 kg ha $^{1}$ | 235 72 kg ha$^{-1}$ |
| 4 | Avaιlable phosphorus | 31 21 kg ha $^{1}$ | 28 53 kg ha$^{-1}$ |
| 5 | Available potassium | 115 48 kg ha$^{-1}$ | 110 24 kg ha$^{-1}$ |
| 6 | Exchangeable calcιum | 1 10 cmol kg$^{-1}$ | 1 06 cmol kg$^{-1}$ |
| 7 | Exchangeable magnesιum | 1 50 cmol kg$^{-1}$ | 1 42 cmol kg$^{-1}$ |

Table 3 Nutrιent analysιs of organιc manures on oven dry basιs

| Sl No | Organιc manures | N (%) | P | K | Ca | Mg |
|---|---|---|---|---|---|---|
| 1 | Farmyard manure | 0 60 | 0 18 | 0 55 | 0 21 | 1 10 |
| 2 | Vermιcompost | 1 61 | 0 65 | 2 71 | 0 30 | 1 34 |
| 3 | Banana wastes | 0.89 | 0 43 | 1.02 | 0 25 | 1 33 |

Table 2 shows that the soil is acidic in reaction, low in available nitrogen and potassium and medium in available phosphorus

3 3 Meteorological parameters

The data on various weather parameters such as ambient temperature rainfall, relative humidity during the cropping period are given in appendix I The mean maximum and minimum temperature during the cropping period ranged from 30 53 to 33 46°C and 21 00 to 25 97°C respectively The mean RH ranged from 69 79 to 81 43% The total rainfall received during the crop period was 150 80 mm and the number of rainy days during the period was 6

The field experiment was conducted during the period from December 1994 to April 1995 under a humid tropical climate

3 4 Variety of crop

The variety used was Jwala mukhi, a newly released high yielding variety of vegetable chilli evolved by Kerala Agricultural University by crossing Pusa Jwala and Vellanotchi It has got high yield potential ideal for culinary purposes and suited for high density planting The maximum yielding period is found to be between 90 to 120 days The seed material was obtained from the Instructional Farm, College of Agriculture, Vellayani

3 5 Manures and fertilizers

Urea, superphosphate and muriate of potash analysing 46 percent N, 18 percent $P_2O_5$ and 60 percent $K_2O$ respectively were applied to chilli crop The nutrient composition of the organic manures used such as farmyard manure, vermicompost and banana waste are given in table 3

Besides the above the local and Eudrillus species of earthworms were also tried as treatments by insitu application

3 6 Design and lay out

The design of the experiment was randomized block design The layout of the experiment is given in Fig 1 The details of the lay out are given below

| | |
|---|---|
| Number of treatments | - 6 |
| Number of replications | 4 |
| Number of plots in a block | 6 |
| Total number of plots | - 24 |

Gross plot size - 1 8 x 1 8 m

Net plot size - 1 4 x 1 4 m

Spacing - 45 x 45 cm

Number of plants per gross plot 16

Number of plants per net plot - 4

The different treatment combinations are as given below

T1 FYM @ 25 t ha $^{1}$ + inorganic fertilizer as per package (75 40 25 Kg NPK ha$^{-1}$)

T2 Vermicompost @ 25 t ha$^{-1}$ + inorganic fertilizer as per package

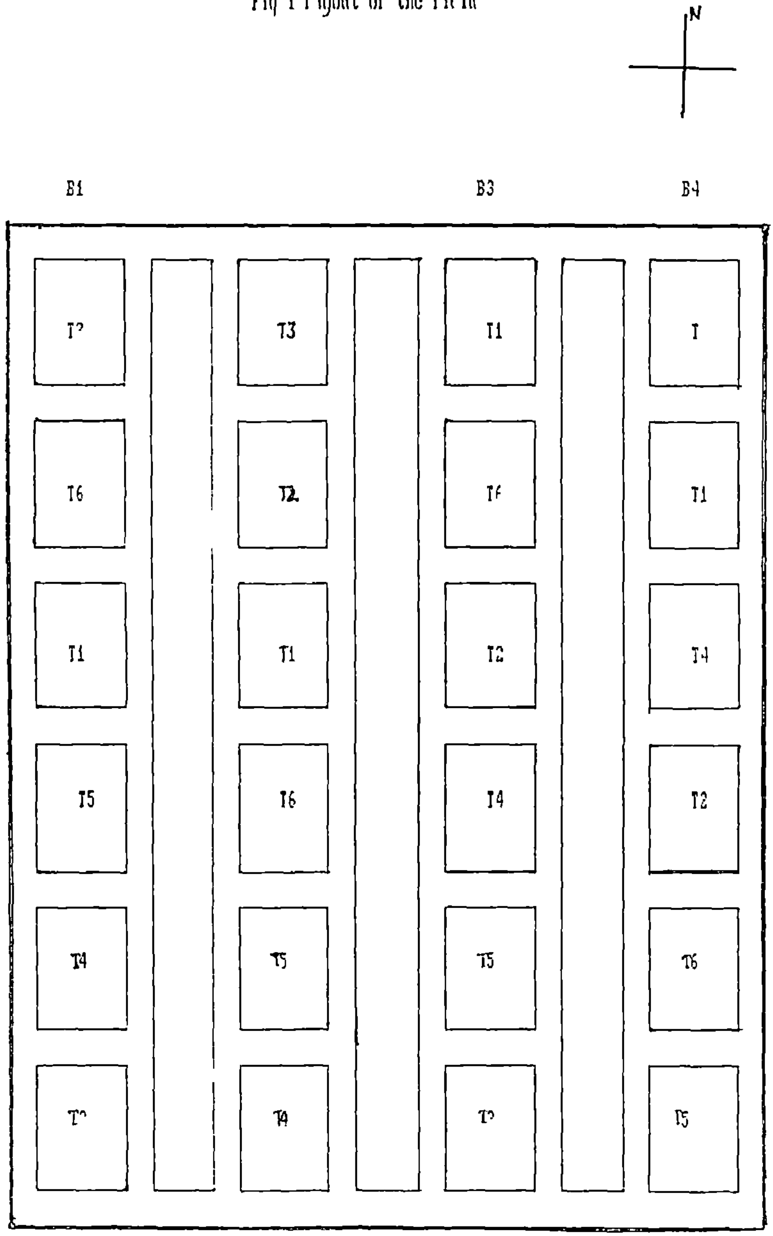
T3 250g local worms plot $^{1}$ + banana waste equivalent to produce vermicompost as in treatment no 2

T4 250g Eudrillus plot $^{1}$ + banana waste equivalent to produce vermicompost as in treatment no 2

T5 Basal dose fertilizers as per package + 100g local worms plot $^{1}$ + banana waste equivalent to produce vermicompost as in treatment no 2

T6 Basal dose fertilizers + 100g Eudrillus plot$^{-1}$ + banana waste equivalent to produce vermicompost as in treatment no 2

Fig 1 Layout of the field



3 7 Details of cultivation

3 7 1 Nursery

About 20 g of chilli seeds were sown in pots filled with potting mixture The seeds were sown on 14-12-1994 The seeds were irrigated every day Hand weeding and plant protection measures were undertaken periodically as per KAU Package of practices recommendations (Anon , 1993)

3 7 2 Main field

The main field (an area of about 2 5 cents) was dug twice and plots of size 1 8 x 1 8 m were laid out with bunds of 30 cm width all around

The 28 days old seedlings were planted in each plot with a spacing of 45 x 45 cm on 12 1 1995 Necessary irrigation and shade were provided for the seedlings during the initial periods

3 7 3 Application of fertilizers and manures

Fertilizers were applied as per the schedule of treatments The entire dose of phosphorus, half of nitrogen and potassium were given as basal dressing One fourth of nitrogen and half of potassium were applied 25 days after transplanting The remaining quantity of nitrogen was applied one month after the first top dressing

The entire dose of farmyard manure and vermicompost were also applied as basal dressing Earthworms were applied in the plots containing required dose of banana waste + cattle manure mixture at 8 1 ratio to produce 50 percent vermicompost as in treatment no 2 after 15 days of transplanting The remaining part of the banana waste cattle manure mixture was applied at the time of second top dressing of nitrogen

3 8 Management of the crop

Gap filling was done within 10 days after transplanting The crop was hand weeded thrice at an interval of 25 days The general stand of the crop was good The crop was given irrigation daily Need based plant protection measures were undertaken to control pests and diseases as per Package of practices

3 9 Harvest

The crop was ready for first harvest 61 days after transplanting and subsequent harvests were made at an interval of 8 10 days The matured fruits were harvested five times before the crop dried by last week of April'95

## 3 10 Observations

### 3 10 1 Growth characters

#### 3 10 1 1 Leaf area

Ten leaves from each of the plant in the net plot were taken and their leaf area was measured by using LICOR leaf area meter (model 3100) From this the total leaf area for each plant in the net plot was calculated by knowing the total number of leaves in the plant

The maximum flowering stage for different treatments were noted just before the fruiting started

#### 3 10 1 2 Dry matter production

The total dry weight after harvest for the four plants from observational area were recorded The samples were dried to constant weight in a hot air oven at a temperature of 70°C and then the dry weights were taken

#### 3 10 1 3 Shoot - root ratio

The dried samples from the four plants of observational area were separated into shoots and roots and their weights were recorded separately From this the shoot - root ratio was calculated

3 10 2 Yield of chillies

The total produce from each treatment was recorded by summing up the produce from individual harvest

3 11 Soil analysis

Soils collected from 0 - 15 and 15 30 cm depths at maximum flowering stage and after the experiment were analysed for physico chemical properties

3 11 1 Physical properties

Bulk density, particle density, porosity, water holding capacity and hydraulic conductivity were analysed for undisturbed samples *In situ* determination of surface compaction and infiltration rate were conducted and recorded Aggregate analysis and water retention at 33 and 1500 kPa were also determined for disturbed samples

3 11 1 1 Bulk density, particle density, porosity, water holding capacity and hydraulic conductivity

Core samples were collected from two depths of 0 - 15 cm and 15 30 cm and analysed for bulk density particle density, porosity water holding capacity and hydraulic conductivity as described by Gupta and Dakshinamoorthi (1980)

3 11 1 2 Soil compaction

Using pocket penetrometer, the soil compaction of the surface soil was recorded for each treatment

3 11 1 3 Infiltration rate

Infiltration rates were recorded using the double ring method (Gupta and Dakshinamoorthi 1980) by nullifying angular effect

3 11 1 4 Aggregate analysis

Aggregate analysis was carried out by Yoder's wet sieving method (Yoder 1937) The samples were wetted slowly and using a set of sieves water stable aggregates were determined Mean weight diameter was taken as the structural index (Bavel, 1949)

3 11 1 5 Water retention characteristics

The capacity of retention of soil moisture of the samples at 33 and 1500 kPa were determined by pressure plate and pressure membrane apparatus (Gupta and Dakshinamoorthi, 1980) From this available water for each treatment was calculated

3 11 2 Chemical properties

The soils collected from two depths of 0 15 and 15 30 cm were analysed for available nitrogen, phosphorus, potassium and exchangeable calcium and magnesium The methods followed for the assay of various soil chemical parameters are given in Table-4

3 12 Plant analysis

The nitrogen phosphorus potassium calcium and magnesium in the stems and leaves at maximum flowering stage and in roots of the plants after harvest in each treatment were determined separately The plant parts were dried to constant weight in an electric oven at 70°C powdered and subjected to acid extraction for total nutrient analysis The methods used for the determination of various nutrients are given in Table 5

3 13 Statistical analysis

The data generated in the experiment was statistically analysed according to the procedures of Panse and Sukhatme (1967) Correlation coefficients were also worked out, relating yield with other soil and plant parameters

Table 4 Chemical methods for soil analysis

| Sl No | Parameter | Method | Reference |
|---|---|---|---|
| 1 | Mechanical analysis | International pipette method | Piper, 1966 |
| 2 | $p^H$ | $p^H$ meter with glass electrode | Jackson, 1973 |
| 3 | Organic carbon | Walkley and Black's rapid titration method | Jackson,1973 |
| 4 | Available nitrogen | Alkaline permanganate method | Subbiah and Asija, 1956 |
| 5 | Available phosphorus | Bray colorimetric method | Jackson 1973 |
| 6 | Available potassium | Flame photometer method | Jackson 1973 |
| 7 | Exchangeable calcium | Flame photometer method | Jackson,1973 |
| 8 | Exchangeable magnesium | Atomic absorption spectrophotometer model PE-3030 using ammonium acetate extract | Jackson 1973 |

**Table 5 Analytical methods for plant parameters**

| Sl No | Parameter | Method | Reference |
|---|---|---|---|
| 1 | Total nitrogen | Modified microkjeldahl method | Jackson,1973 |
| 2 | Total phosphorus | Vanado-molybdo phosphoric yellow colour method | Jackson,1973 |
| 3 | Total potassium | Flame phtometer method | Jackson,1973 |
| 4 | Total calcium | Flame phtometer method | Piper, 1966 |
| 5 | Total magnesium | Atomic absorption spectrophotometer model PE-3030 | Piper, 1966 |


EFFECT OF VERMICOMPOST / VERMICULTURE ON PHYSICO-CHEMICAL PROPERTIES OF SOIL AND YIELD OF CHILLI


FYM @ 25 t $ha^{-1}$ + Inorganic Fertiliser (75:40:25 Kg NPK $ha^{-1}$)


ermicompost @ 25 t $ha^{-1}$ +
Inorganic Fertilisers


250g Local worms/plot +
Banana waste


250g Eudrillus/plot +Banana waste


Basaldose fertiliser+
100g Local worms/plot+
Banana waste


100g Eudrilius/plot+Basal dose fertiliser+
Banana waste

# RESULT

# RESULT

The study was under taken at the College of Agriculture, Vellayani to bring about the influence of application of vermicompost / vermiculture on physico-chemical properties of soil and yield of chilli. The experiment was conducted in block number four of Instructional Farm. The result of the study under relevant topics are given below.

## 4.1. Soil physical properties

All physical properties like bulk density, particle density, porosity, mean weight diameter and water stable aggregates, moisture content, water holding capacity, water retention, available water and hydraulic conductivity except surface compaction and infiltration were determined both for the surface and subsurface soils viz., 0-15 cm and 15-30 cm respectively and are presented in Tables 6 to 12.

### 4.1.1. Bulk density and particle density

As seen from table 6, the subsurface soils recorded maximum bulk density as well as particle density over the surface soils. Among the treatments, the highest bulk density was observed under $T_1$ (1.34 Mg $m^{-3}$) followed by $T_2$ (1.30 Mg $m^{-3}$) and the lowest value in $T_3$ (1.11Mg $m^{-3}$). No significant difference in bulk density was observed between soils treated with $T_1$ and $T_2$, $T_3$ and $T_4$ and also between $T_5$ and $T_6$.

In case of particle density, the maximum value was observed under $T_2$ (2.47Mg $m^{-3}$) followed by $T_1$ (2.46Mg $m^{-3}$), however this difference was not significant. Particle density of soil treated with $T_2$ was significantly higher than that of $T_6$, $T_4$ and $T_3$. $T_5$ and $T_6$ was higher than $T_3$ and $T_4$ which were found to be on par.

4.1.2 Porosity

Porosity of the soil obtained for various treatments is given in table 6. The surface soils showed higher porosity when compared to the subsurface soils. $T_3$ and $T_4$ recorded maximum porosity values of 52.25 and 52.64 percent while $T_1$ showed a minimum value of 45.52 percent. Porosity of soils treated with $T_4$ and $T_3$ and also $T_6$ and $T_2$ were on par but that of $T_4$ and $T_3$ was higher than that of soils with other treatments.

4.1.3. Water holding capacity

Table 6 shows the different values of water holding capacity for various treatments. The maximum value of 34.29 percent was recorded under $T_4$ followed by $T_3$ (33.32%) and $T_1$ (32.28%). These

Table 6 Effect of treatments on bulk density particle density porosity and water holding capacity of soil

| Treat ments | Bulk density (Mg m 3) | | | Particle density (Mg m 3) | | | Porosity (%) | | | Water holding capacity (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T/D | 0 15cm | 5 30cm | mean | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean |
| T1 | 1 30 | 1 38 | 1 34 | 2 43 | 2 48 | 2 46 | 46 63 | 44 41 | 45 52 | 33 77 | 30 78 | 32 28 |
| T2 | 1 25 | 1 34 | 1 30 | 2 45 | 2 49 | 2 47 | 48 92 | 46 32 | 47 62 | 32 96 | 31 18 | 32 07 |
| T3 | 1 07 | 1 14 | 1 11 | 2 29 | 2 35 | 2 32 | 53 32 | 51 17 | 52 25 | 34 85 | 31 79 | 33 32 |
| T4 | 1 09 | 1 15 | 1 12 | 2 34 | 2 39 | 2 37 | 53 53 | 51 74 | 52 64 | 35 15 | 33 43 | 34 29 |
| T5 | 1 19 | 1 25 | 1 22 | 2 42 | 2 46 | 2 44 | 50 85 | 49 20 | 50 03 | 30 45 | 29 58 | 30 02 |
| T6 | 1 21 | 1 28 | 1 25 | 2 38 | 2 43 | 2 41 | 49 37 | 47 47 | 48 42 | 33 43 | 30 12 | 31 78 |
| Mean | 1 18 | 1 26 | | 2 38 | 2 43 | | 50 44 | 48 38 | | 33 43 | 31 15 | |
| SE | | | | | | | | | | | | |
| T | | 0 015 | | | 0 019 | | | 0 390 | | | 0 754 | |
| D | | 0 009 | | | 0 011 | | | 0 225 | | | 0 436 | |
| TxD | | 0 021 | | | 0 026 | | | 0 551 | | | 1 067 | |
| CD | | | | | | | | | | | | |
| T | | 0 042 | | | 0 054 | | | 1 123 | | | 2 174 | |
| D | | 0 024 | | | 0 031 | | | 0 648 | | | 1 255 | |
| TxD | | | | | | | | | | | - | |

T Trea ment D Depth

three treatments were found to be on par The minimum value was obtained for $T_5$ (30 02 %) which was on par with $T_2$ and T Surface soils recorded higher values of water holding capacity compared to the subsurface soils for all the treatments

4 1 4 Soil aggregation

The soil aggregation was evaluated using mean weight diameter (MWD) and percent water stable aggregates (WSA) and it is presented in table 7 Mean weight diameter did not appear to be the same at surface and subsurface soils with respect to treatments In the surface soils the highest value of mea weight diameter was recorded by $T_6$ and $T_3$ treated plots (0 87 mm and the lowest value by $T_5$ and $T_2$ treated plots (0 84 mm) Bu in the subsurface soils the highest value was shown by $T_4$ treated plots (1 01 mm) and the lowest by $T_2$ treated plots (0 7 mm) No significant difference in mean weight diameter was observed in surface soils with respect to the treatments while i subsurface soils it was high in soils treated with $T_4$ $T_5$ $T_3$ and $T_6$ which were on par

But with regard to water stable aggregates (WSA) it was not significantly different at different depths on an average while it differed significantly with respect to treatments For both surface and subsurface soils WSA was maximum in $T_4$ (50 76 and

52 06%) and mini m in $T_1$ (45 05 and 42 47%) $T_4$ $T_3$ and $T_5$ we e found to be on par and $T_1$ was significantly different from all other treatments

4 1 5 Moisture content

The gravimetric moist ire content at two different stages viz maximum flowering stage and harvest were determined for two depths and are f irnished in table 8 The moisture content at tle subsurface was significantly higher at maximum flowering stage tho gh no significant difference was observed at harvest During maximum flowering stage the highest moisture content was recorded in $T_5$ (16 52%) whereas after harvest maximum val e was obtained in $T_2$ (19 64 %) The lowest moisture content was showel by $T_1$ in both stages (13 93 and 15 53%) The higher val es observed d iring maxim im flowering stage and harvest we e significantly different from those obtained for other treatment

4 1 6 Water retention

The water retention for maxim im flowering stage and harvest at 33 and 1500 kPa are given in tables 9&10 From the table, t could be observed that water retention of the so l was significantly low at 1500 kPa in comparison with 33 kPa n bo l stages Also no interaction was observed between pressure levels

**Table 7 Effect of treatments on mean weight diameter and water stable aggregates**

| Treatments | Mean weight diameter (mm) | | | Water stable aggregates (%) | | |
|---|---|---|---|---|---|---|
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean |
| $T_1$ | 0 85 | 0 81 | 0 83 | 45 05 | 42 47 | 43 76 |
| $T_2$ | 0 84 | 0 77 | 0 80 | 47 75 | 45 18 | 46 47 |
| $T_3$ | 0 87 | 0 94 | 0 91 | 49 89 | 51 55 | 50 72 |
| $T_4$ | 0 86 | 1 01 | 0 94 | 50 76 | 52 06 | 51 41 |
| $T_5$ | 0 84 | 0 96 | 0 90 | 49 90 | 51 04 | 50 47 |
| $T_6$ | 0 87 | 0 92 | 0 90 | 47 00 | 48 34 | 47 67 |
| mean | 0 85 | 0 90 | | 48 39 | 48 44 | |
| SE | | | | | | |
| T | | 0 026 | | | 0 435 | |
| D | | 0 015 | | | 0 251 | |
| TxD | | 0 037 | | | 0 616 | |
| CD | | | | | | |
| T | | 0 075 | | | 1 254 | |
| D | | 0 043 | | | | |
| TxD | | 0 106 | | | 1 773 | |

T Treatment D Depth

Table 8 Effect of treatments on moisture content at maximum flowering stage and at harvest

| Treatments | Maximum flowering stage % | | | Harvest % | | |
|---|---|---|---|---|---|---|
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean |
| $T_1$ | 13 50 | 14 36 | 13 93 | 15 02 | 16 04 | 15 53 |
| $T_2$ | 13 80 | 14 79 | 14 30 | 19 04 | 20 23 | 19 64 |
| $T_3$ | 13 45 | 14 90 | 14 18 | 15 47 | 16 35 | 15 91 |
| $T_4$ | 14 02 | 14 74 | 14 37 | 15 93 | 17 34 | 16 64 |
| $T_5$ | 15 74 | 17 30 | 16 52 | 16 79 | 17 85 | 17 32 |
| $T_6$ | 14 67 | 15 18 | 14 93 | 16 90 | 17 77 | 17 34 |
| Mean | 14 20 | 15 21 | | 16 53 | 17 60 | |
| SE | | | | | | |
| T | | 0 490 | | | 0 700 | |
| D | | 0 283 | | | 0 404 | |
| TxD | | 0 693 | | | 0 990 | |
| CD | | | | | | |
| T | | 1 413 | | | 2 018 | |
| D | | 0 816 | | | | |
| TxD | | | | | | |

T Treatment D Depth

Table 9 Effect of treatments on water retention at maximum flowering stage (both at 33 and 1500 k Pa)

| Treatments | Maximum flowering stage % | | | | | | |
|---|---|---|---|---|---|---|---|
| | 33 kPa | | | 1500 kPa | | | T x D means over pressure levels |
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | |
| $T_1$ | 14 39 | 13 08 | 13 74 | 13 09 | 12 89 | 12 993 | 13 36 |
| $T_2$ | 13 68 | 12 80 | 13 24 | 12 55 | 12 06 | 12 31 | 12 77 |
| $T_3$ | 19 28 | 18 04 | 18 66 | 17 64 | 16 88 | 17 26 | 17 96 |
| $T_4$ | 16 13 | 14 82 | 15 48 | 15 57 | 13 34 | 14 46 | 14 96 |
| $T_5$ | 15 19 | 14 49 | 14 84 | 13 25 | 12 54 | 12 90 | 13 86 |
| $T_6$ | 14 45 | 13 29 | 13 87 | 3 19 | 12 50 | 12 85 | 13 36 |
| Mean | 15 52 | 14 42 | 14 97 | 14 22 | 13 37 | 13 79 | |
| SE | | | | | | | |
| T | | 0 248 | | | 0 314 | | |
| D | | 0 143 | | | 0 181 | | |
| T x D | | 0 350 | | | 0 444 | | |
| CD | | | | | | | |
| T | | 0 7 4 | | | 0 904 | | 562 |
| D | | 0 411 | | | 0 521 | | |
| T x D | | — | | | — | | |

T Treatment D Depth

Table 10 Effect of treatments on water retention at harvest (at 33 and 1500 k Pa)

| Treatments | Harvest % | | | | | | |
|---|---|---|---|---|---|---|---|
| | 33 kPa | | | 1500 kPa | | | T x D means over pressure levels |
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | |
| $T_1$ | 11 56 | 13 48 | 12 52 | 10 68 | 11 61 | 11 15 | 11 83 |
| $T_2$ | 11 62 | 13 27 | 12 45 | 9 39 | 10 60 | 10 00 | 11 22 |
| $T_3$ | 12 57 | 13 79 | 13 18 | 9 66 | 10 89 | 10 28 | 11 73 |
| $T_4$ | 18 95 | 19 33 | 19 14 | 14 31 | 14 75 | 14 53 | 16 84 |
| $T_5$ | 18 86 | 20 02 | 19 44 | 15 43 | 17 62 | 16 53 | 17 98 |
| $T_6$ | 13 67 | 14 18 | 13 93 | 9 63 | 10 59 | 10 11 | 12 0 |
| Mean | 14 54 | 15 68 | 15 11 | 11 52 | 12 68 | 12 10 | |
| SF T | | 0 447 | | | 0 445 | | |
| D | | 0 258 | | | 0 257 | | |
| T x D | | 0 632 | | | 0 630 | | |
| CD T | | 1 286 | | | 1 280 | | 927 |
| D | | 0 742 | | | 0 740 | | |
| T x D | | — | | | — | | |

T Treatment D Depth

and treatments At maximum flowering stage water retention was high in $T_3$ (18 66 and 17 26%) followed by $T_4$ (15 48 and 14 46% and low in $T_2$ (13 24 and 12 31 %) at 33 kPa and 1500 kPa respectively No significant difference was observed among $T_2$ $T_1$ and $T_6$ Water retention was significantly high in surface soils than subsurface soils However no interaction was observed between treatments x depths

The results on treatments at harvest were not in agreement with maximum flowering stage Here $T_5$ recorded maximum water retention (19 44 and 16 53 %) followed by $T_4$ (19 14 and 14 53 % and minimum by $T_2$ (12 45 and 10 00%) at 33 k Pa and 1500 k Pa respectively Also water retention was high at subsurface tha at surface of the soil

4 1 7 **Available water**

Table 11 shows available water content in soil At maximum flowering stage available water was highest in $T_5$ (1 94%) which was on par with $T_3$ (1 40%) but at harvest it was highest in $T_4$ (4 61%) which was on par with $T_6$ (3 82%) The lowest available water content was recorded by $T_1$ in both stages (0 75% and 1 38% respectively)

## 4 1 8 Hydraulic conductivity

As seen from table 12 the values of hydraulic conductiv ty for different treatments and at the two depths var ed significantly Cenerally the hydraulic cond ictivity was fo d to increase with depth For both surface and subs irface so s maximum hydra ilic conductivity was observed in $T_5$ with values of 22 37 and 40 86 cm hr $^{1}$ respectively But the minimum value was showed by $T_2$ at surface (14 76 cm hr $^{1}$) and $T_1$ at subsurface (19 98 cm hr $^{1}$) $T_5$ was significantly different from othe treatments where as $T_1$ and $T_2$ and also $T_3$ and $T_4$ were on par r both surface and si bs irface soils

## 4 1 9 Surface compaction

S rface compact on at maxim m flowering stage and a harvest for the different treatments were recorded and i presented in table 12 For both the stages the maxim m val i was observed in $T_3$ (1 17 and 0 87 kg cm $^{2}$ respectively) Thi was closely followed by $T_4$ (1 14 and 0 84 kg cm $^{2}$) The lowes values of 0 76 and 0 60 kg cm $^{2}$ were recorded by $T_2$ at max mu flowering stage and at harvest respectively At max mi flowering stage the value obtained for $T_2$ treated plots wa significantly different from all the other values However treatments like $T_5$ and $T_6$ and also $T_4$ and $T_5$ were fo nd to be o par at both stages

Table 11 Effect of treatments on available water at maximum flowering stage and at harvest

| Treatments | Maximum flowering stage % | | | Harvest % | | |
|---|---|---|---|---|---|---|
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean |
| $T_1$ | 1 30 | 0 19 | 0 75 | 0 88 | 1 87 | 1 38 |
| $T_2$ | 1 13 | 0 74 | 0 94 | 2 23 | 2 67 | 2 4 |
| $T_3$ | 1 64 | 1 16 | 1 40 | 2 91 | 2 90 | 2 9 |
| $T_4$ | 0 56 | 1 48 | 1 02 | 4 64 | 4 58 | 4 61 |
| $T_5$ | 1 94 | 1 95 | 1 94 | 3 43 | 2 40 | 2 9 |
| $T_5$ | 1 26 | 0 80 | 1 03 | 4 04 | 3 59 | 3 8 |
| Mean | 1 31 | 1 05 | | 3 02 | 3 00 | |
| SE | | | | | | |
| T | | 0 197 | | | 0 333 | |
| D | | 0 114 | | | 0 192 | |
| TxD | | 0 278 | | | 0 471 | |
| CD | | | | | | |
| T | | 0 567 | | | 0 959 | |
| D | | | | | | |
| TxD | | | | | | |

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Table 12 Effect of treatments on hydraulic co d ct v ty compaction and infiltrat on ir oil

| Treatments | Hydrauli o ductivity cm h 1 | | | Surface co k o kg n | | f t |
|---|---|---|---|---|---|---|
| | 0 15cm | 1 0cm | mean | maximum flowering stage | st | |
| $T_1$ | 17 30 | 1 98 | 18 64 | 0 93 | 0 5 | |
| T | 14 76 | 37 | 18 57 | 0 76 | C | |
| $T_3$ | 18 6 | 4 | 44 | 1 17 | C | |
| $T_4$ | 1 9 9 | 35 | 4 07 | 1 14 | 0 | |
| T | | 4 86 | 31 62 | 1 03 | 0 | |
| $T_6$ | 18 79 | 5 9 | 2 29 | 1 00 | C | |
| Mean | 18 5 | 01 | | 1 05 | 0 | |
| SE T | | 0 663 | | 0 045 | 0 5 | |
| D | | 0 383 | | | | |
| TxD | | 0 937 | | | | |
| CD T | | 1 910 | | 0 136 | 0 6 | 6 |
| D | | 1 102 | | | | |
| T D | | 2 701 | | | | |

T Treatment D Depth

### 4 1 10 Infiltration

The surface entry of water determined as infiltration rate is given in table 12 The maximum value of 44 25 cm hr $^{-1}$ was recorded for $T_5$ This was followed by $T_6$ (34 50 cm hr $^{-1}$) and $T_4$ (25 50 cm hr $^{-1}$) $T_5$ and $T_6$ differed significantly from each other as well as from other treatments The minimum value of 9 30 cm hr $^{-1}$ was observed for $T_1$ and it was found to be on par with $T_2$

### 4 2 Soil chemical properties

Soil chemical properties such as organic carbon soil reaction and available nutrient contents in soil were a alysed and are presented in tables 13 to 16 Organic carbon and soil reaction were determined only after the harvest of the crop while the nitrient contents in soil viz available nitrogen phosphorus potassium and exchangeable calcium and magnesium were determined at maximum flowering stage and after harvest of the crop

### 4 2 1 Soil reaction

The preliminary analysis of soil showed that the soil was having a pH of 5 20 But after the harvest of the crop the pH ranged from 5 48 5 80 as seen from table 13 The max m m pH valıe was obtaıned for $T_6$ treated plot (5 80) followed by $T_2$ (5 78) and $T_5$ treated plots (5 68) The mınımum pH was showı ły $T_3$ treated plots (5 48) Values for $T_2$ $T_5$ and $T_6$ were on par and they were sıgnıfıcantly dıfferent from $T_1$ and $T_3$

4 2 2 Organıc carbon

As seen from table 13 organıc carbon was hıghest ın $T_2$ (1 42%) followed by $T_1$ (1 38%) The lowest organıc carbon content was showed by $T_3$ (1 23%) Only $T_5$ and $T_6$ were found to be on par whıle others were sıgnıfıcantly dıfferent from ea h other

4 2 3 Avaılable nıtrogen

The maxımım avaılable nıtrogen was recorded for $T_2$ at maxımum flowerıng stage (314 48 kg ha $^{1}$) and ıs gıven ın table 14 Thıs was followed by $T_1$ (303 35 kg ha $^{1}$) $T_6$ (272 52 kg ha $^{1}$) $T_5$ (268 33kg ha $^{1}$) $T_4$ (258 59 kg ha $^{1}$) and $T_3$ (254 07 kg ha $^{1}$) $T_1$ and $T_2$ d ffered sıgnıfıcantly from other treatments whıle $T_5$ and $T_6$ were found to be on par The same trend was observed at harvest stage also Avaılable nıtrogen recorded at harvest stage for all the treatments were lesser than those observed at maxımım flowerıng stage Further ıt was found to łe sıgnıf cantly łıgh n s rface soıl at maxımum flowerıng stage ł t

**Table 13 Effect of treatments on soil reaction and organic carbon in soil**

| Treatments | Soil reaction | Organic carbon % | | |
|---|---|---|---|---|
| | | 0 15cm | 15 30cm | mean |
| $T_1$ | 5 50 | 1 40 | 1 36 | 1 38 |
| $T_2$ | 5 78 | 1 44 | 1 40 | 1 42 |
| $T_3$ | 5 48 | 1 25 | 1 21 | 1 23 |
| $T_4$ | 5 58 | 1 29 | 1 26 | 1 28 |
| $T_5$ | 5 68 | 1 34 | 1 29 | 1 32 |
| $T_6$ | 5 80 | 1 35 | 1 31 | 1 33 |
| Mean | 5 63 | 1 35 | 1 31 | |
| SE | | | | |
| T | 0 052 | | 0 008 | |
| D | | | 0 004 | |
| TxD | | | 0 011 | |
| CD | | | | |
| T | 0 156 | | 0 022 | |
| D | | | 0 012 | |
| TxD | | | | |

T Treatment D Depth

**Table 14 Effect of treatments on available nitrogen in soil at maximum flowering stage and at harvest**

| Treatments | Maximum flowering stage (kg ha $^{1}$) | | | Harvest (kg ha $^{1}$) | | |
|---|---|---|---|---|---|---|
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean |
| $T_1$ | 306 86 | 299 83 | 303 35 | 277 35 | 272 98 | 275 16 |
| $T_2$ | 316 48 | 312 47 | 314 48 | 286 41 | 283 07 | 284 74 |
| $T_3$ | 256 48 | 251 66 | 254 07 | 252 93 | 249 92 | 251 43 |
| $T_4$ | 259 66 | 257 52 | 258 59 | 257 54 | 256 09 | 256 82 |
| $T_5$ | 271 84 | 264 82 | 268 33 | 268 52 | 266 56 | 267 54 |
| $T_6$ | 274 26 | 270 77 | 272 52 | 269 18 | 268 57 | 268 88 |
| Mean | 280 93 | 276 18 | | 268 65 | 266 20 | |
| SE | | | | | | |
| T | | 2 355 | | | 1 680 | |
| D | | 1 359 | | | 0 970 | |
| TxD | | 3 330 | | | 2 376 | |
| CD | | | | | | |
| T | | 6 787 | | | 4 842 | |
| D | | 3 918 | | | | |
| TxD | | | | | | |

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no significant difference was observed at harvest stage in both surface and subsurface soils

4 2 4 **Available phosphorus**

As seen from table 15 the available phosphorus was found to be maximum in $T_2$ treated plots for both the stages (59 71 and 48 38 kg ha$^{1}$) At maximum flowering stage this was followed by $T_1$ (51 75 kg ha$^{1}$) and at harvest by $T_5$ treated plots (45 23 kg ha$^{1}$) The maximum value obtained for $T_2$ treated plot was significantly different from all the other values in both the stages The minimum values of 39 05 and 39 21 kg ha$^{1}$ were recorded by $T_3$ treated plots at maximum flowering stage and at harvest respectively The minimum value was significantly different from all the other values at harvest stage

4 2 5 **Available potassium**

As seen in the case of available nitrogen and phosphorus the maximum value for available potassium was shown by $T_2$ at maximum flowering stage (225 34 kg ha$^{1}$) and at harvest (196 04 kg ha$^{1}$) and are presented in table 15 This was followed by $T_1$ (209 67 and 183 66 kg ha$^{1}$) The $T_3$ showed minimum values of 142 27 and 138 87 kg ha$^{1}$ at maximum flowering stage and at harvest respectively At both the stages all the treatments were significantly different from each other

Table 15 Effect of treatments on available phosphorus and potassium in soil at maximum flowering stage and harvest

| Treatments | Available phosphorus (kg ha$^{-1}$) | | | | | | Available potassium (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum flowering stage | | | Harvest | | | Maximum flowering stage | | | Harvest | | |
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | 0-15cm | 15-30cm | mean |
| $T_1$ | 52 68 | 50 82 | 51 75 | 46 97 | 43 41 | 45 19 | 211 43 | 207 90 | 209 67 | 186 55 | 180 77 | 183 66 |
| $T_2$ | 60 87 | 58 55 | 59 71 | 49 44 | 47 31 | 48 38 | 227 01 | 223 67 | 225 34 | 198 02 | 194 06 | 196 04 |
| $T_3$ | 40 46 | 37 63 | 39 05 | 40 19 | 38 22 | 39 21 | 143 70 | 141 24 | 142 47 | 140 86 | 136 87 | 138 87 |
| $T_4$ | 42 85 | 40 88 | 41 87 | 42 54 | 41 09 | 41 82 | 154 88 | 152 77 | 153 83 | 152 50 | 146 70 | 149 60 |
| $T_5$ | 47 91 | 46 34 | 47 13 | 46 57 | 43 88 | 45 23 | 164 66 | 160 90 | 162 78 | 174 16 | 169 62 | 171 89 |
| $T_6$ | 47 09 | 45 49 | 46 29 | 45 53 | 42 74 | 44 04 | 177 04 | 173 79 | 175 42 | 161 81 | 158 64 | 160 23 |
| Mean | 48 64 | 46 62 | | 45 17 | 42 78 | | 179 79 | 176 71 | | 168 98 | 164 44 | |
| SE | | | | | | | | | | | | |
| T | | 1 163 | | | 0 710 | | | 2 092 | | | 1 812 | |
| D | | 0 672 | | | 0 410 | | | 1 208 | | | 1 046 | |
| T x D | | 1 645 | | | 1 003 | | | 2 958 | | | 2 563 | |
| CD | | | | | | | | | | | | |
| T | | 3 353 | | | 2 045 | | | 6 028 | | | 5 223 | |
| D | | 936 | | | 1 181 | | | | | | 3 016 | |
| T x | | — | | | | | | | | | | |

T ea e Dep h

4 2 6 **Fxchangeable calcium and magnesium**

Table 16 shows the different values of exchangeable calcium and magnesium in soil recorded at maximum flowering stage and at harvest In both the stages $T_2$ treated plots showed highest exchangeable calci m and magnesium The exchangeable calc m ranged between 1 29 to 1 77 cmol kg 1 at maxim m flowering stage and from 1 23 to 1 61 cmol kg 1 at harvest The minimum val e of exchangeable calci m in soil was recorded for plots nder T (1 29 and 1 23 cmol kg 1) at both stages Fxcepting th exchangeable calcium at maximum flowering stage for $T_1$ and T all other treatments differed significantly

Tle val es of exchangeable magnesi m ranged from 2 03 3 10 cmol kg 1 at maxim m flowering stage and f m 1 95 to 2 85 cmol kg 1 at harvest stage As far as he exchangeable magnesium is concerned $T_3$ and $T_4$ and also $T_5$ and $T_6$ were found to be on par $T_1$ and $T_2$ were significantly different from other treatments for exchangeable magnesium

As observed in the case of available nitrogen avail bl phosphorus and potassium exchangeable calcium and magnes were also found to be less in the s bs rface when compared t t surface layer in both stages

Table 16 Effect of treatments on exchangeable calcium and magnesium in soil at maximum flowering stage and harvest

| Treatments | Exchangeable calcium (cmol kg$^{1}$) | | | | | | Exchangeable magnesium (cmol kg$^{1}$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum flowering stage | | | Harvest | | | Maximum flowering stage | | | Harvest | | |
| T/D | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | 0 15cm | 15 30cm | mean | 0-15cm | 15 30cm | mean |
| $T_1$ | 1 73 | 1 69 | 1 71 | 1 57 | 1 52 | 1 55 | 2 83 | 2 73 | 2 78 | 2 65 | 2 61 | 2 63 |
| $T_2$ | 1 78 | 1 75 | 1 77 | 1 63 | 1 59 | 1 61 | 3 19 | 3 00 | 3 10 | 2 88 | 2 81 | 2 85 |
| $T_3$ | 1 30 | 1 27 | 1 29 | 1 24 | 1 21 | 1 23 | 2 05 | 2 00 | 2 03 | 1 95 | 1 95 | 1 95 |
| $T_4$ | 1 38 | 1 35 | 1 37 | 1 33 | 1 26 | 1 30 | 2 11 | 2 07 | 2 09 | 2 00 | 1 96 | 1 98 |
| $T_5$ | 1 60 | 1 55 | 1 58 | 1 38 | 1 33 | 1 36 | 2 36 | 2 29 | 2 33 | 2 31 | 2 24 | 2 28 |
| $T_6$ | 1 50 | 1 51 | 1 51 | 1 31 | 1 23 | 1 27 | 2 42 | 2 33 | 2 38 | 2 34 | 2 27 | 2 31 |
| Mean | 1 55 | 1 52 | | 1 41 | 1 36 | | 2 49 | 2 40 | | 2 35 | 2 31 | |
| SE | | | | | | | | | | | | |
| T | | 0 023 | | | 0 021 | | | 0 067 | | | 0 052 | |
| D | | 0 013 | | | 0 012 | | | 0 039 | | | 0 030 | |
| T x D | | 0 033 | | | 0 030 | | | 0 094 | | | 0 074 | |
| CD | | | | | | | | | | | | |
| T | | 0 067 | | | 0 062 | | | 0 193 | | | 0 150 | |
| D | | — | | | 0 036 | | | — | | | — | |
| T x D | | | | | — | | | — | | | | |

T Treatment D Depth

## 4 3 Nutrient content in plant parts

The nutrient contents of leaf and shoot were analysed during the maximum flowering stage of crop growth to see the effect of nutrient content on growth The root was analysed for plant nutrient only after harvest of the crop Percent content of nitrogen phosphorus potassium calcium and magnesium were analysed and presented in Tables 17 and 18

### 4 3 1 Nitrogen

The nitrogen content in leaf and shoot are presented in table 17 The leaf nitrogen content ranged from 0 83% to 1 57% The maximum nitrogen content was recorded for $T_7$ (1 57%) and minimum was obtained for $T_3$ (0 83%) There was no significant difference obtained between $T_3$ and $T_4$ and also between $T_5$ and $T_6$

The nitrogen content in shoot varied from 0 74 to 1 30% and that in root (Table 18) from 1 20 to 1 91% The effect of treatments on nitrogen content of shoot and root followed the same trend as that of the nitrogen content in leaf

### 4 3 2 Phosphorus

The phosphorus content in leaf and shoot are presented in table 17 In leaf the phosphorus content varied between 0 26 to

0 68% $T_2$ showed the maximum phosphorus content (0 68%) followed by $T_1$ $T_5$ $T_6$ and $T_4$ The minimum value of 0 26% was observed in $T_3$ The maximum value of 0 68% in $T_2$ was significantly different from all the other treatments $T_4$ $T_5$ and $T_6$ were found to be on par and they differed significantly from other treatments

The shoot phosphorus content had also the highest value in $T_2$ (0 55%) and the lowest value in $T_3$ (0 17%) $T_2$ and $T_1$ were on par and they were significantly different from other treatments

The root phosphorus content varied from 0 38% to 0 77% (Table 18) The treatment effects on phosphorus content of root also followed the same trend as that in leaf and shoot

4 3 3 **Potassium**

Table 17 shows that leaf potassium content was higher tha that in shoot as in case of nitrogen and phosphorus The value ranged from 1 27% to 2 10% in leaf and 1 06% to 1 90% in shoot $T_3$ treated plots showed the minimum value of potassium content both the plant parts $T_1$ and $T_2$ were on par both in leaf a d shoot and they were found to be significantly different fr m other treatments

The root potassium content varied from 1 39% to 2 48% (Table 18) It also followed the same trend as that in leaf and shoot But here $T_1$ and $T_2$ differed significantly from eac other and also from other treatments

4 3 4 Calcium

The calcium content in the leaf shoot and root followed the same trend (Table 17 and 18) The maximum calcium content was obtained in $T_2$ (0 19 0 17 and 0 23%) for leaf shoot and root respectively This was followed by $T_5$ $T_6$ $T_4$ and $T_3$ The values obtained for $T_1$ and $T_2$ were significantly different from other treatments In all the cases $T_3$ and $T_4$ and also $T_5$ and $T_6$ were found to be on par

4 3 5 Magnesium

The magnesium content in leaf shoot and root are presented in table 17 and 18 As in the case of calcium the maximum value of magnesium for leaf shoot and root was obtained for $T_2$ (0 26 0 23 and 0 27%) and the minimum value was shown by $T_3$ (0 16 0 3 and 0 16% respectively) $T_1$ and $T_2$ were significantly different from all other treatments able 17 Eff t of treatments on nutrient content in l af and shoot at maximum flowering stage

| ea t | N og (%) | | Pho phor (%) | | Iota sium (%) | | Calc um (%) | | Magnes um (% | |
|---|---|---|---|---|---|---|---|---|---|---|
| | f | } ot | Leaf | Sh | Leat | Shoot | eaf | Shoot | Leaf | Shoo |
| T | 1 3 | 1 17 | 0 61 | 0 50 | 00 | 1 85 | 0 17 | 0 15 | 0 24 | 0 2 |
| T | 1 5 | 1 30 | 0 68 | 0 5 | 10 | 1 90 | 0 19 | 0 17 | 0 26 | 0 2 |
| T | 0 8 | 0 74 | 0 26 | 0 17 | 1 2 | 1 06 | 0 05 | 0 04 | 0 16 | 0 13 |
| | 0 89 | 0 75 | 0 34 | 0 23 | 1 | 1 15 | 0 06 | 0 05 | 0 16 | 0 1 |
| T | 1 0 | 0 99 | 0 37 | 0 8 | 1 42 | 1 26 | 0 08 | 0 07 | 0 17 | 0 1 |
| $T_6$ | 1 00 | 0 89 | 0 35 | 0 32 | 1 49 | 1 29 | 0 07 | 0 06 | 0 17 | 0 1 |
| c | 0 0 | 0 025 | 0 019 | 0 01 | 0 048 | 0 034 | 0 005 | 0 005 | 0 003 | 0 0 |
| | 0 110 | 0 075 | 0 0 8 | 0 048 | 0 145 | 0 101 | 0 015 | 0 0 | 0 009 | 0 009 |

Table 18 Effect of treatment͜ on nutrient co tent ı roo harvest

| Treatments | Nitrogen (%) | Pho pl orus (%) | Potassium (%) | Calc u (%) | Ma |
|---|---|---|---|---|---|
| T1 | 1 70 | 0 72 | 37 | 0 | |
| T2 | 1 91 | 0 77 | 2 48 | 0 23 | |
| T͜ | 1 20 | 0 38 | 1 39 | 0 06 | 0 1 |
| T4 | 1 2 | 0 41 | 1 45 | 0 0 | |
| T5 | 40 | 0 48 | 1 54 | 0 09 | |
| T6 | 1 35 | 0 4͜ | 1 56 | 0 09 | |
| S | 0 041 | 0 020 | 0 023 | 0 00͜ | 0 |
| CD | 0 123 | 0 060 | 0 071 | 0 01 | |

## 4 4 Plant biometric parameters

### 4 4 1 Yield

As seen from table 19 the treatment effects on the yield of chilli varied significantly $T_2$ treated plots recorded maximum yield (8 36t ha $^{1}$) This was closely followed by $T_1$ treated plots (7 41 t ha $^{1}$) These two treatments were on par and were significantly different from other treatments The lowest yield was recorded for $T_3$ treated plots (2 38 t ha $^{1}$) $T_5$ and $T_6$ and also $T_3$ and $T_4$ were found to be on par

### 4 4 2 Dry matter production (DMP)

The dry matter production was recorded at the harvest stage of the crop and is furnished in table 19 The maximum DMP was obtained in $T_2$ (41 91g plant $^{1}$) and the minimum in $T_3$ (23 60g plant $^{1}$) Though $T_1$ and $T_2$ were on par they were significantly different from other treatments However no significant difference was observed between $T_3$ and $T_4$ and also between $T_5$ and $T_6$

### 4 4 3 Shoot root ratio

The values of shoot root ratio presented in table 19 shows that the maximum shoot root ratio was obtained for $T_2$ (4 23)

Table 19 Effect of treatn ɪ t on plant bıometrıc ɪar net r

| Treatments | Yield(t ha 1) | DMP(g plant 1) | Shoot root ratio | Le f |
|---|---|---|---|---|
| $T_1$ | 7 41 | 38 57 | 3 34 | 1 19 |
| $T_2$ | 8 36 | 41 91 | 4 23 | ɒ 1 |
| $T_3$ | 2 38 | 23 60 | 5 | 4 |
| $T_4$ | 3 69 | 24 95 | 73 | 0 |
| $T_5$ | 5 30 | 29 33 | 2 15 | |
| $T_6$ | 4 28 | 25 93 | 1 80 | |
| SE | 0 535 | 1 845 | 0 2 1 | |
| CD | 1 612 | 5 561 | 0 696 | 48 |

followed by $T_1$ (3 34) and the minimum in $T_6$ (1 80) The maximum value was significantly different from all othe treatments Though $T_6$ was found to be recorded minimum value i was on par with $T_3$ and $T_5$

4 4 4 Leaf area

Table 19 shows that the leaf area was maximum in $T_2$ plot (23 84 $m^2$) followed by $T_1$ plots (18 19 $m^2$) and it was minimum i $T_3$ plots (4 49$m^2$) $T_2$ was significantly different from all othe treatments However no significant difference was observed between $T_3$ $T_4$ and $T_5$

4 5 Coefficient of correlation between different physico chemical properties of soil

Correlation coefficients are worked out between different physico chemical properties of soil and the results are presented in table no 20

Bulk density of soil had positive significant correlation with particle density and negative significant correlation with porosity water holding capacity mean weight diameter and water retention at 33 kPa and 1500 kPa at maximum flowering stage It was also positively and significantly correlated with all the nitrient conte ts of soil

Particle density of soil was significantly and negatively correlated with porosity water holding capacity and water retention at 33 kPa and 1500 kPa at maximum flowering stage It had positive significant correlation with nutrient contents of soil

Porosity of the soil was positively and significantly correlated with mean weight diameter water holding capacity and water retention at both pressures at max m m flowering stage and with 33 kPa at harvest It had significant negative correlation with all the nutrient contents of soil at both stages viz maximum flowering stage and harvest

Mean weight diameter of the soil had significant negative correlation with all the nutrient contents in soil at both stages It was positively and significantly correlated with hydraulic conductivity

Moisture content had significant positive correlation with water retention at both pressures at maximum flowering stage and with nutrient content of soil

Water holding capacity of the soil had significant negative correlation with hydraulic conductivity With all othe properties it had no significant correlation

Table 20   Coefficient of correlation between different physico-chemical properties of soil

| Physical properties | Bulk density | Particle density | Porosity | Mean weight diameter | Moisture content | Water holding capacity | Hydraulic conductivity | Water retention A 33 k Pa | Water retention A 1500 k Pa | Water retention B 33 k Pa | Water retention B 1500 k Pa |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulk density | 1 | 0 8655** | 0 9552** | 0 3300* | 0 2796 | 0 3521* | 0 0646 | -0 5585** | -0 5083** | -0 2607 | -0 0831 |
| Particle De sity | | 1 | 0 6797** | 0 1863 | 0 2968* | 0 3103* | 0 1514 | 0 4916** | -0 4659** | -0 0404 | -0 1235 |
| Porosity | | | 1 | 0 3684** | 0 2393 | 0 3437* | 0 0170 | 0 5341** | 0 4807** | 0 3495* | 0 1875 |
| Mea weight diameter | | | | 1 | -0 1478 | 0 0394 | 0 4743** | 0 0504 | 0 0854 | 0 3014* | 0 1957 |
| Moisture co tent | | | | | 1 | 0 0150 | 0 1732 | 0 2884* | -0 3365* | 0 1256 | 0 0618 |
| Water hold ng capacity | | | | | | 1 | 0 3977** | 0 2287 | 0 3189** | -0 1479 | -0 2716 |
| Hydra lic cond ctivity | | | | | | | 1 | 0 1167 | -0 1702 | 0 4543** | 0 4900** |
| Water reten tion A 33 k Pa | | | | | | | | 1 | 0 8875** | -0 1023 | -0 0649 |
| 1500 k Pa | | | | | | | | | 1 | -0 1113 | -0 1384 |
| B 33 k Pa | | | | | | | | | | 1 | 0 7989** |
| 15 Pa | | | | | | | | | | | 1 |

B    Ha vest

Table 20 Contd

| Physico chemical properties | Available nitrogen | | Available phosphorus | | Available potassium | | Exchangeable calcium | | Exchangeable magnesium | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | A | B | A | B | A | B |
| Bulk density | 0 6380** | 0 6730** | 0 6254** | 0 3993** | 0 7388** | 0 6698** | 0 7343** | 0 5210** | 0 6101** | 0 6885** |
| Particle density | 0 4614** | 0 5668** | 0 5929** | 0 4012** | 0 5923** | 0 5813** | 0 6254** | 0 4131** | 0 4705** | 0 5723** |
| Porosity | 0 6608** | 0 6544** | 0 5668** | 0 3569** | 0 7314** | 0 6406** | 0 7092** | 0 5165** | 0 6166** | 0 6702** |
| Mean weight diameter | 0 4970** | 0 3949** | 0 2817 | 0 3707** | 0 449[illegible]** | 0 4656** | 0 5065** | 0 5652** | 0 4734** | 0 4255** |
| Mo sture content | 0 3161* | 0 3905** | 0 3004* | 0 2612 | 0 3025* | 0 3296* | 0 3463* | 0 2872* | 0 4182** | 0 4225** |
| Water holding capac ty | 0 0442 | 0 1794 | 0 1408 | 0 1669 | 0 0696 | 0 0799 | 0 2577 | 0 0134 | 0 0325 | 0 0920 |
| Hyd a l c ond ctiv ty | 0 4331** | 0 2412 | 0 3330* | 0 2985* | 0 3909** | 0 2468 | 0 2514 | 0 4636** | 0 3674* | 0 3059 |
| Wate e en t on A 33 k Pa | 0 5492** | 0 6608** | 0 5757** | 0 5004** | 0 5710** | 0 5485** | 0 5935** | 0 4463** | 0 4552** | 0 5494** |
| 500 k Pa | 0 5260** | 0 6174** | 0 5825** | 0 6376** | 0 5491** | 0 5968** | 0 6455** | 0 4938** | 0 5006** | 0 5980** |
| B 33 k Pa | 0 4950** | 0 9 2* | 0 3092* | 0 1292 | 0 4902** | 0 2699 | 0 2605 | 0 3153* | 0 4319** | 0 4014** |
| 00 k Pa | 0 3619* | 0 2424 | 0 2772 | 0 0980 | 0 3486* | 0 0759 | 0 0485 | 0 1903 | 0 2766 | 0 2278 |

a ves

Table 70 Contd

| Chemical properties | Available nitrogen | | Available phosphorus | | Available potassium | | Exchangeable calcium | | Exchangeable magnesium | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | A | B | A | B | A | B |
| Available ni rogen A | 1 | ** 0 8987 | ** 0 8448 | ** 0 6932 | ** 0 9428 | ** 0 8473 | ** 0 8657 | ** 0 8523 | ** 0 9151 | ** 0 8804 |
| B | | 1 | ** 0 8778 | ** 0 7320 | ** 0 8604 | ** 0 8309 | ** 0 8585 | ** 0 7256 | ** 0 8220 | ** 0 8127 |
| Available phospho s A | | | 1 | ** 0 8137 | ** 0 8810 | ** 0 8177 | ** 0 7817 | ** 0 7368 | ** 0 8285 | ** 0 8444 |
| B | | | | 1 | ** 0 6706 | ** 0 6860 | ** 0 7065 | ** 0 6290 | ** 0 7126 | ** 0 7126 |
| Ava lable potass m A | | | | | 1 | ** 0 8980 | ** 0 8910 | ** 0 8574 | ** 0 9115 | ** 0 9023 |
| B | | | | | | 1 | ** 0 9080 | ** 0 8886 | ** 0 8744 | ** 0 8858 |
| Exchangeable Calcium A | | | | | | | 1 | ** 0 8509 | ** 0 8271 | ** 0 8739 |
| B | | | | | | | | 1 | ** 0 8495 | ** 0 8589 |
| Exchangeable magnesium A | | | | | | | | | 1 | ** 0 9270 |
| B | | | | | | | | | | 1 |

Max mum flowe ng stage B Ha ve

Hydraulic conductivity was negatively correlated with water retention at both pressures It had significant negative correlation with nutrients in soil

Moisture retention characteristics of soil at FC and PWP at maximum flowering stage had significant negative correlation with nutrient contents of soil

**4 6 Coefficient of correlation between physico chemical properties of soil along with nutrient content in plant and yield of chilli**

Among the soil physical properties bulk density and particle density had significant positive correlation with yield All other properties like porosity water holding capacity hydraulic conductivity infiltration mean weight diameter surface compaction and water retention (at 33 kPa and 1500 kPa) at maximum flowering stage and at harvest were negatively correlated with yield (Table 21) Among these porosity mean weight diameter water retention at maximum flowering stage at both tensions surface compaction and infiltration had significant negative correlation

Table 7 Coeff c ent of c relat on betwee phy o hem cal properties of so l along with nutrient content in plant parts and yield of chilli

| o e | M n e ma we ng stage | ha ve | B | P e den | | W e h d ol apa | hyd a nd v | Mean we n d ame ter | Wate reten on max m m flowering stage 33 k Pa | 1500 k Pa | harve t 33 k Pa | 1500 k Pa | S fa e compact on max m m flower ng stage | harvest | Inf l trat on |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y e | 0 0500 | 0 349 | 6855** | 0 5** | 5 9** | 868 | 0 2767 | 0 5168** | 0 5595** | 0 5576** | 0 2612 | 0 1528 | 0 7066** | 0 6596** | 0 4665* |

| hem al p ope e | Ava lable n t ogen A | B | Ava lab e phosphor s A | B | Available potassium A | B | Exchangeable calcium A | B | Exchangeable magnesium A | B |
|---|---|---|---|---|---|---|---|---|---|---|
| Y eld | 0 8291** | 0 7861** | 0 7500** | 0 5856** | 0 8656** | 0 8940** | 0 8640** | 0 8650** | 0 7671** | 0 7643** |

| Plan chem cal pa ame e | N ogen eaf | Sl oo | Root | Phosph ea | Shoot | Roo | Po ass m Leaf | Shoot | Roo | Calc um Leaf | Shoot | Root | Magnes um Leaf | Shoot | Root |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| e d | 875** | 0 8954** | 0 84** | 0 8** | 0 87 4** | 0 24** | 0 8168** | 0 8426** | 0 84 7** | 0 84** | 0 8495** | 0 8478** | 0 8574** | 0 8958** | 0 8576** |

A m m f owe age h e

Yield was positively and significantly correlated with all the available nutrient content of soil The available potassium in soil had maximum correlation (0 8940) with yield Significant positive correlation was also observed between yield and nutrient content in plant Among them the phosphorus content in root was highly correlated with yield (r value being 0 9024)

# DISCUSSION

DISCUSSION

The results obtained during the present study were discussed and the interpretations made are presented below

## 5 1 Influence of application of vermicompost/vermiculture on soil physical properties

### 5 1 1 Bulk density and particle density

As seen from table 6 and figure 2 the subsurface soils recorded higher bulk density as well as particle density This increase at subsurface irrespective of treatments shows that mass per unit volume of the soil at surface was less than that at subsurface The organic matter present in the surface soil either by addition of FYM vermicompost or waste material might have reduced the surface bulk density and particle density The findings of Khaleel et al (1981) corroborate with the present result

In the case of treatments the highest bulk density was observed under treatment FYM + NPK (1 34 Mg m $^{3}$) and that of particle density with vermicompost + NPK fertilizers (2 47 Mg m $^{3}$) but the lowest of both was found the vermiculture treatment with local worms (1 11 and 2 32 Mg m $^{3}$

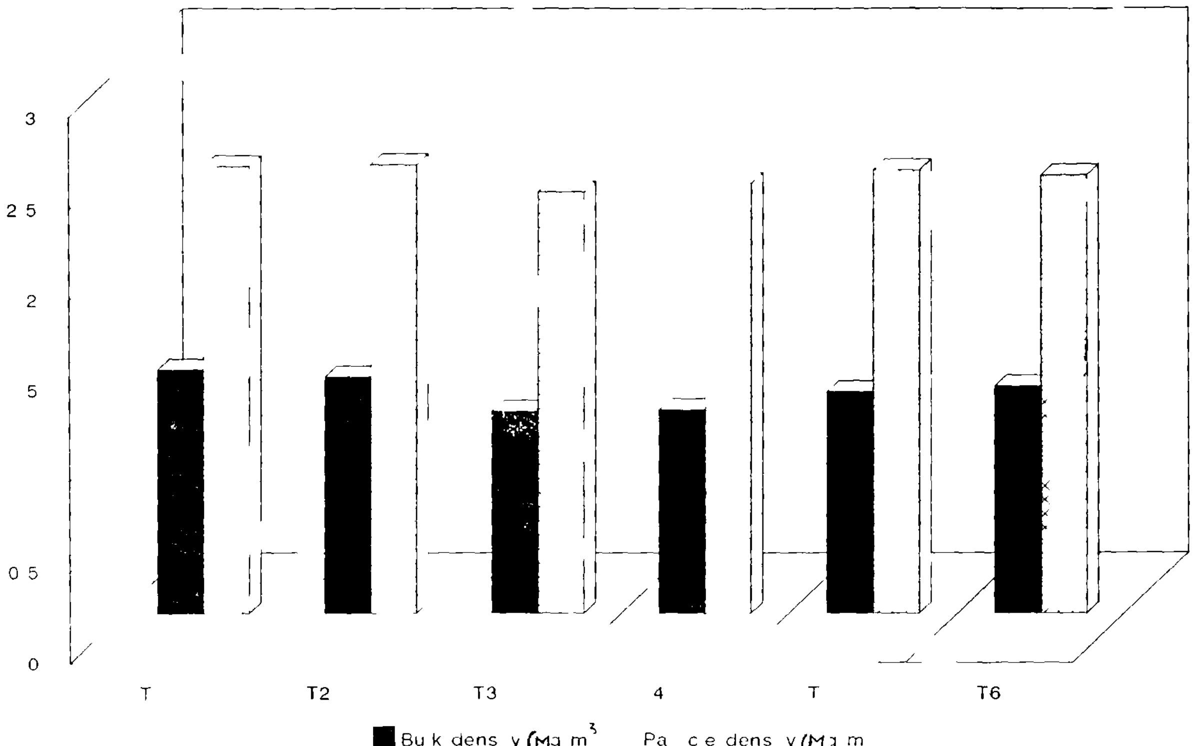


Fig 2 Bulk density and particle density of soil

respectively) The *in situ* application of earthworms and their higher population had produced more wormcasts and they were brought to the surface This process had significantly reduced the bulk density as well as particle density in the upper layers of the soil Similar observations were made by Lavelle (1988) who had reported that wormcasts were deposited on the soil surface or within it and this changed the surface physical properties of soil especially the soil structure The burrowing capacity of these macro animals would have also helped in decreasing bulk density and particle density of the soil (Rushton 1986)

5 1 2 Porosity

The results presented in table 6 shows that the effect of various treatments on porosity of the soil at 0 15 cm and 15 30 cm depths were significant Porosity was highest in the plot treated with local worms + banana waste (52 64%) and least for the treatment receiving FYM + NPK fertilizers (45 52%) (Fig 3) It is reported by several authors that earthworms have the capacity to churn the soil through the alimentary canal by mixing with gastric juices and wormcast produced is having an optimum structure The burrowing habit of earthworms produced microchannels whereby increase the porosity of soil The present study is supported by the view of Knight *et al* (1989) who reported that earthworms through burrowing activity resulted in the formation of fewer but larger pores

The effect of earthworms on physical characteristics of so l is attributed to the fact that as they dig burrows deposit casts on soil surface and within it mix the horizons and burry above ground litter A general increase in porosity and aeration of soil was also reported by Lavelle (1988) in the presence of earthworms

The reduced values of porosity in plots treated with FYM or vermicompost together with NPK fertilizers might be due to the absence of earthworms in these plots But an optimum porosity was observed in these plots also

Bulk density and particle density of soil were negatively correlated with the field capacity water When all the pores were filled with water at field capacity the pore distributio was not in a uniform pattern and the general porosity of soil was decreased

5 1 3 **Water holding capacity**

When the values obtained for water holding capacity in the present study were analysed from table 6 and Fig 3 it could b observed that the mean values obtained for various treatment were not much different This shows that the influence o organic matter either decomposed or undecomposed would definitely influence the water holding capacity ranging from 30 02% t

34 29% This resılt ıs ın support of the vıew of Khaleel et al (1981) who stated that as a result of organic manure applıcatıon soıl organıc carbon content was ıncreased This might be the reason for ıncrease ın water holdıng capacity The role of organıc matter on the water holdıng capacıty was maınly by ıts ınfluence on porosıty of the soıl Organıc matte addıtıon resulted ın unıform dıstrıbutıon of mıcropores

The aeratıon and water holdıng capacıty of the soıl are largely determıned by ıts physıcal structure Wıth a good crumb structure water ıs retaıned ın the capıllary spaces wıthın the aggregates allowıng contınuous gaseous dıffusıon between them It has also been stated that practıcally all aggregates are earthworm casts or resıdues of them (Burger and Raw 1967) The present study also shows that the physıcal structure under treatments wıth vermıculture alone was optımum for pla t growth Maxımum waterholdıng capacıty was also shown by these treatments

5 1 4 Soıl aggregatıon

It ıs seen from the results that the mean weıght dıameter f soıl was ınfluenced by the effect of vermıcompost/vermıculture From the Table (Table 7) the values of mean weıght dıameter raı ged from 0 77 to 1 01 mm whıch shows that the soıl had kept a fairly good graded structure The water stability of aggregates in this range would provide an optimum physical condition in the soil as far as water holding capacity porosity and water movement are concerned Percentage of water stable aggregates greater than 0 25 mm diameter was reported to be a good index f soil structure as it is related with several soil physical parameters (Biswas 1982)

The treatments in which earthworms were applied _in situ_ showed a higher content of water stable aggregates than other treatments (Fig 3) Considering the effect of vermiculture n water stable aggregates from the evidence of wet sieving and water drop stability tests it has been generally agreed by numerous workers that wormcasts contain more water stable aggregates than non cast soil Further the result shows that the subsurface soil was having more water stable aggregates than surface soil where worms were applied _in situ_ This might be due to wormcasts produced in the subsurface The direct effect of wormcasts was observed by Blanchart _et al_ (1990) and they opined that in the humified tropical soils with high endogeic earthworm activity casts deposited in the subsoil were the component units of stable macroaggregate structures and such macroaggregates might comprise 50 to 60% of the soil

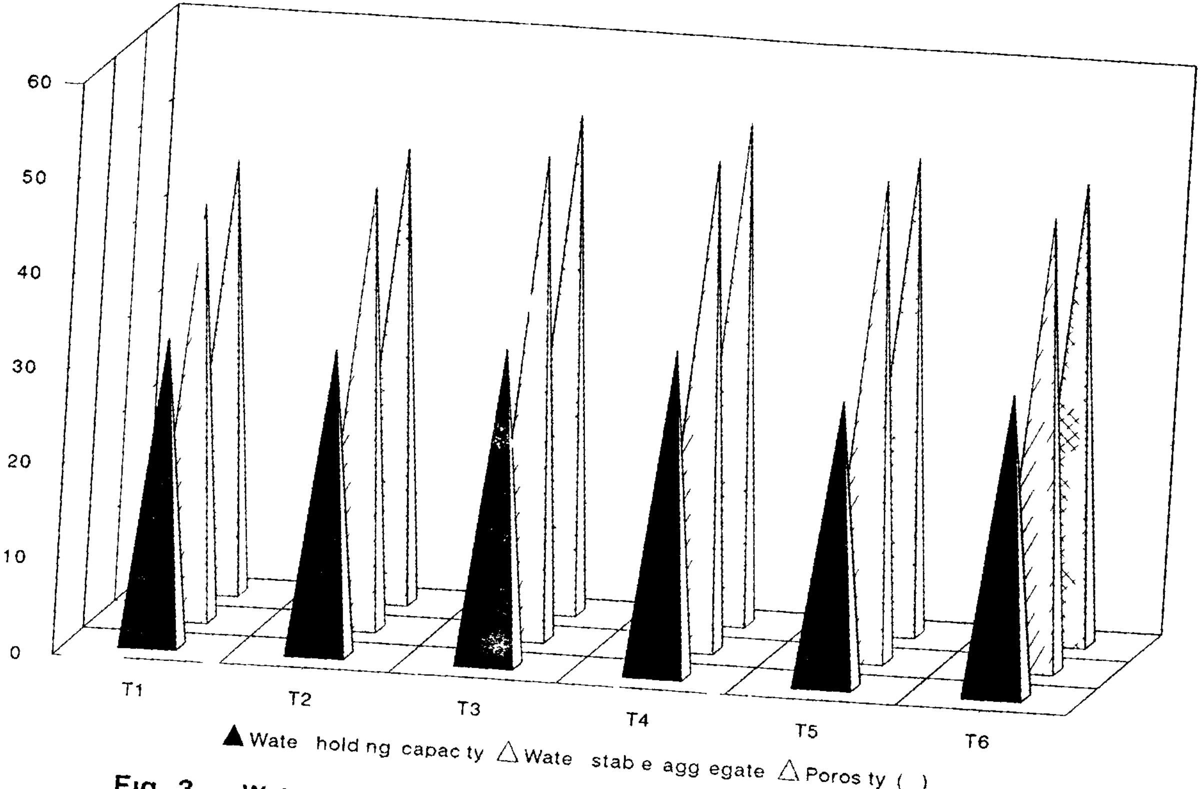


**Fig 3 Water holding capacity water stable aggregates and porosity of soil**

In treatments $T_1$ and $T_2$ where FYM and vermicompost were applied directly the top soil had shown a higher aggregate stability than the subsoil This shows that the effect of organic materials was predominant on the surface layer This is supported by the view of Tisdall and Oades (1982) who reported that organic materials played a major role in the structural stability of top soil Decreasing organic matter content has been correlated with a loss of stability

Table 19 shows that mean weight diameter was negatively correlated with water holding capacity As the MWD increased the number of large sized particles were increased in the soil thereby decreasing the capacity to hold water and increasing the conductivity of water Hence hydraulic conductivity was increased

5 1 5 Moisture content

As revealed from table 8 moisture content was maximum in plot treated with basal dose of NPK fertilizers + vermiculture with local worms at maximum flowering stage $T_5$ (16 52%) and in plot treated with vermicompost + NPK fertilizers at harvest $T_2$ (19 64%) The minimum moisture content was shown by $T_1$ which is FYM + NPK fertilizers in both stages

Ir plots with $T_5$ treatments the canopy coverage d r maximum flowering stage was found to be higher/ or almost eq a to that of plots with $T_2$ and $T_1$ and evaporation rate was reduce by this canopy coverage This could be attributed to tl increased moisture content in this plot

During harvest time almost all leaves were shed in all treatments and the soil was exposed to sunligl t A rainfall of 138 40 mm was received during this period But the conservat o of moisture was found to be more in plots treated w tl vermicompost + inorganic fertilizers It might be due to tle higher content of humus present in the soil which can hold greater amount of moisture than the soil with low humus conte t

5 1 6 Water retention

As seen from tables 9 and 10 and Fig 4 comparatively higler values of moisture retention were obtained in the plots trea ed with worms either alone or with basal dose of NPK fertilize s At maximum flowering stage the higher values for 33 and 1500 kPa were recorded for plots with local and Eudril us earthworms alone but at harvest stage worms along w th fertilizers recorded maximum values In these plots wormca ts were produced which helped in better aggregation of the so l Tl is could be attributed to the increased moisture retention in these plots The microaggregates have the capacity to retain water in the intra aggregate spaces due to the surface te io forces The interparticle attraction by vander Waal s forces are also much helpful in the retention of water by adsorption Lal and Akinremi (1983) had also viewed the effect of wormcasts i producing greater moisture retention in soils at different matric potentials

Irrespective of the treatments the moisture retained at surface was higher at maximum flowering stage and during harvest it was more in the subsurface soil It was obvious that at maximum flowering stage the crop canopy reduced the evaporation rate thereby conserving the moisture in the surface soil whereas at the time of harvest the surface soil acted as a mulch and the subsurface soil retained more water

The increased water retention at field capacity is partly attributed to the increase in number of small pores (Khaleel et al 1981)

A significant relation between water retention characteristics of soil and WSA was noted This is supported by the reports of Tamhane and Datta (1965)

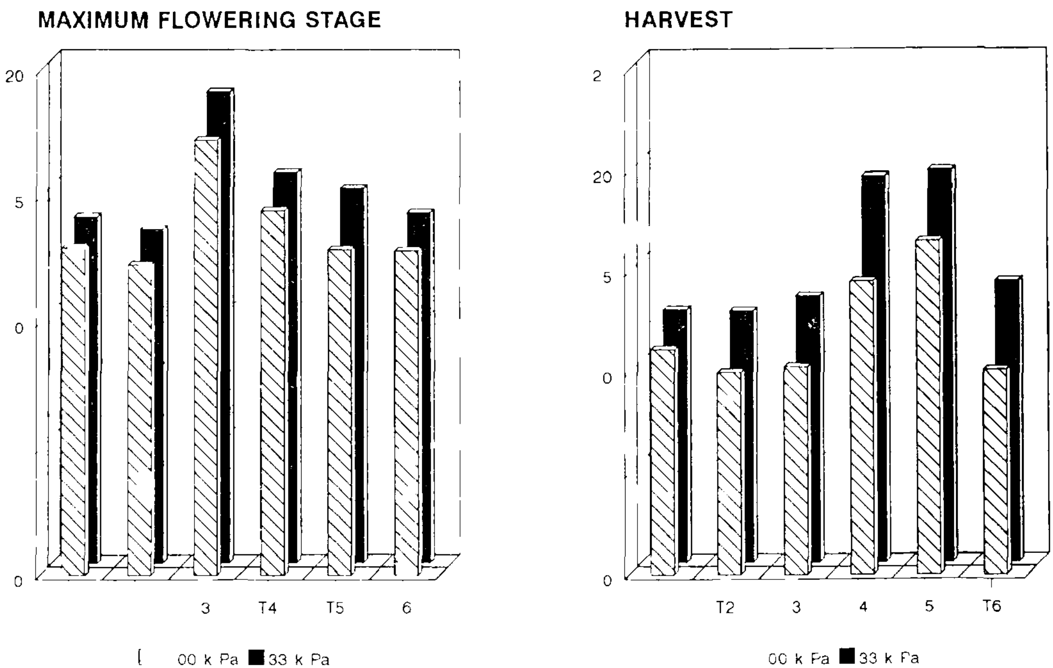


Fig 4 Water retention at maximum flowering stage and at harvest

5 1 7 Available water

The results presented in table 11 shows that available water was highest in plots in which earthworms were applied insitu and was lowest with treatment which received FYM + NPK fertilizers

Probably the surface coverage by organic wastes earthworm treated plots might have reduced the evaporation ra e and increased the available water present in soil The view f Khaleel et al (1981) supports this result who showed tl at so l without surface cover dried faster and essentially all availatle water was removed where as residue covered soil still retained 50 to 70 mm available water at that time

5 1 8 Hydraulic conductivity

The table 12 shows that the plots treated with vermicult re with local worms + basal dose of NPK fertilizers showed maxi num values of hydraulic conductivity (40 86 cm hr 1) and minimum ı plots treated with vermicompost + NPK fertilizers (14 76 cm hr 1)

When earthworms are present in soil they dig burrows a create cl annels and this makes a suitable medium for tl conductance of water Tl is process would have increase hydraulic conductivity in the plots treated with worms The results of Lavelle (1988) also substantiate the results obtain d in the present study

The result also shows that hydraulic conductivity was higher in the subsurface than the surface soil (Fig 5) This might be due to the presence of macropores in the subsurface soil compared to that of the surface soil But the surface soil had increased porosity due to the presence of capillary pores Khaleel et al (1981) had also reported that better aggregation caused by the addition of organic matter would result in increased hydra il c conductivity Lee (1985) observed an 80% increase in hydraul c conductivity in the presence of earthworms usually exists in the subsoil condition

5 1 9 Surface compaction

The results on surface compaction (Table 12) at t different stages viz maximum flowering stage and harvest shows that the surface soils were loose with less particle contact The treatment which received vermiculture alone with local worms ($T_3$) was found to have the highest surface compaction (1 17 and 0 84 kg cm $^{2}$) whereas the lowest values (0 76 and 0 60 kg cm $^{2}$) were shown by the treatment with vermicompost + NPK fertilizers ($T_2$) The capillary pores helped in the transit of water which was less in this case than that of other treatments w earthworms So the total porosity and also the hydraul conductivity was found to be less in these plots Since t e nutrient contents were concentrated and found to be more these treatments the yield values were also found to be h gh in treatments with vermicompost or FYM So we can say that far as the crop yield is concerned an optimum surface compacti was maintained in these treatments throughout the crop growth

5 1 10 Infiltration

The present experiment shows that the presence of worms the soil had definite influence in the improveme t f infiltration rate which is evident from table 12 and Fig Infiltration was highest in the plots treated with basal dose norganic fertil zers + vermiculture with local wo ms (T showing a value of 44 25 cm hr $^{-1}$ The treatment with FYM vermicompost provided low infiltration compared to the soils w h local or Eudrillus worms applied insitu The crea ed infiltration rate with insitu application of worms to s l indicated the improvement in water permeability of the so l as compared to plots without worms This view is agreed by he reports of Vimmerstedt (1969) who found that when earthw ms were present a layer of dung and dead plant material would t

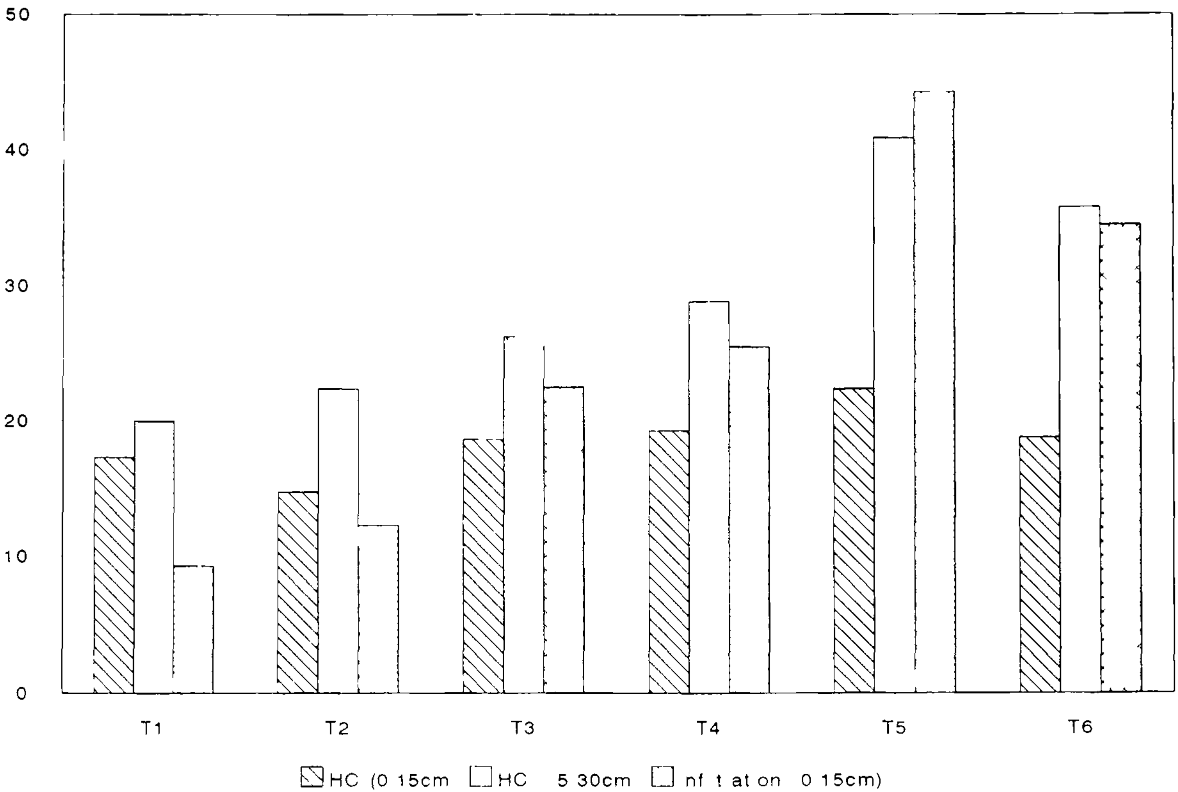


**Fig 5 Hydraulic conductivity and infiltration of soil**

be accumulated at the soil surface thus increasing the infiltration capacity of the soil This influence was found to be more in undisturbed and aerable soil as reported by Lee (1985) and Logsdon and Linden (1992) They showed that burrows could persist for a long time in undisturbed soil and large diamete burrows below the plough layer could be important in providing channels for root growth and water infiltration in compacted aerable soil

When worms were present in the soil the surfac accumulation of plant residues or soil crusting was inhibited because they were passed through the intestine of worms and brought back to the surface soil This is supported by the results obtained in case of water stable aggregates Beno t et al (1962) also opined that there was an improvement n infiltration rate when aggregate stability was improved Sometimes higher infiltration rate would lead to the loss f plant nutrients by percolation

## 5 2 Influence of application of vermicompost/vermiculture on soil chemical parameters

### 5 2 1 Soil reaction

Irrespective of the treatments pH was increased from t e value obtained from the preliminary analysis (Table 13) Bef re starting the experiment the pH was 5 20 which was ranged fr m 5 48 to 5 80 after the experiment The soils which receiv l vermicompost or wormcast had reduced their acidic reactio o some extent By analysis it was observed that vermicompost (pH being 7 34) and wormcast were neutral to alkaline in reactio So by incorporation of these to soils would increase the pH values of the soil

The observation by Lee (1985) that earthworm ca ts are closer to neutral pH range than those of the surrounding soil a l the possible factors that act on pH are $NH_4^+$ excretion a d o excretion from the calciferous glands also supports the presen result Any how there was not much significant difference between $T_1$ and $T_3$ The increase in soil pH or decrease in soi acidity in the presence of earthworms is attributed to vari u reasons by different authors as given below

The calciferous glands present in earthworms fix $CaCO_3$ and prevent any fall in pH (Kale and Krishnamoorthy 1980) Haimi and Huhta (1990) and Basker et al (1992) reported that conversion of organic nitrogen to ammonia and further to $NH_4^+$ with consequent consumption of $H^+$ ions as the material passes through gut of earthworms temporarily reduced the pool of H ions i the soil thereby reducing the acidity

5 2 2 Organic carbon

As seen from table 13 the organic carbon conte t was maximum in treatments treated with NPK + organic manures such as vermicompost and FYM (1 42 and 1 38%) respectively This result is in agreement with the view of Khaleel et al (1981) wl o reported that as a result of organic manure application so l organic carbon content was increased

5 2 3 **Available nitrogen**

Tl e data on available nitrogen of the soil at maxim flowering stage and at harvest are presented in table 14 a d Fig 6

The result shows that $T_2$ (Vermicompost + NPK fertilizers) recorded the maximum value for available nitrogen (314 47 kg ha $^{1}$) and $T_3$ with vermiculture alone ie local worms recorded minimum value (254 07 kg ha $^{1}$)

The analysis of vermicompost indicated that it contaired 1 61% of N (Table 3) The higher degree of decompositior and mineralisation in vermicompost might be one of the reasons for the higl nitrogen content in vermicompost (Shuxin et al 1991) and subsequently high nitrogen content in soil also Th s also supported by the view of Bhawalkar (1993) that l e incorporation of worm casts enriched in nitrogen also increased the nitrogen content in vermicompost

The increased decomposition and mineralisation of nitrogen in vermicompost was attributed to the higher microbial population and the enzyme activities in casts as reported by several authors Another reason for the high mineral nitrogen excretion is the rapid turnover of nitrogen in earthworm biomass as shown by Ferriere and Bouche (1985) Moreover the high efficiency of organic matter assimilation by earthworms and their associated micro organisms had resulted in huge production of readily available organic matter (Lavelle *et al* 1983)

5 2 4 **Available phosphorus**

Table 15 and Fig 6 shows that available phosphorus content of soil was significantly higher for the plots treated with vermicompost + NPK fertilizers at maximum flowering stage and at harvest (59 71 and 48 38 kg $ha^{-1}$) and it was least for the plots with vermiculture with local worms (39 04 and 39 20 kg $ha^{-1}$)

Initial analysis showed that phosphorus content of the vermicompost was higher than that in FYM (Table 3) To support the view of the present study Sharpley and Syers (1977) reported that the higher phosphorus content in vermicompost was due to the greater mineralisation of organic matter with the aid of microflora associated with earthworms Thus the dissolution of phosphorus in the presence of worms has increased the availability of phosphorus in soil They also observed that there was an enhanced microbial phosphatase activity in the presence of vermicompost

The addition of casts in the treatments where earthworms were applied <u>in situ</u> ($T_3$ to $T_6$) had definitely influenced the physical properties of soil But the decomposition of waste material added was rather slow in these treatments The fully decomposed organic material reduced the phosphorus fixation because they formed stable complexes or chelates with cations which were responsible for the phosphorus fixation process This was observed by Stanford and Pierre (1953) Probably this might be the reason for increased availability of phosphorus in plots where vermicompost or FYM were added directly

5 2 5 Available potassium

The results of the present study shows that availabl potassium in soil (Table 15) was maximum in plots receivin vermicompost + NPK fertilizers at maximum flowering stage and a harvest (225 34 and 196 04 kg ha $^{-1}$) and it was minimum in plot with local worms applied insitu + banana waste (142 47 and 138 8 kg ha $^{-1}$)

From the nutrient analysis of vermicompost and FYM (Table 3 it was observed that the vermicompost contained about four time of potassium than that of FYM This had influenced the availabl potassium in the soil with vermicompost (Fig 6) Bano et al (1987) observed considerable variation in the $K_2O$ content o compost when earthworms were used as biological agents f degradation of wastes Since the vermicompost was neutral t alkaline in reaction much of the $NH_3$ in organic matter was converted to $NH_4^+$ ion by accepting protons According to Alday and Graff (1975) $K^+$ ions from edge wedge or interlayer sites within clay minerals could possibly be replaced by $NH_4^+$ ions f similar ionic radius the concentration of which was increased in the presence of vermicompost Results of the present study involving available potassi im supports this proposition

Further it could be seen from results that there was on y slight difference in available potassium between maximum flowering stage and harvest in treatments with worms whereas n treatments with organic manures there was a considerab e variation To support this result Basker et al (1992) al o reported that there was an increase in the availability f potassium by shifting the equilibrium among the forms f potassium from relatively unavailable forms to more availab e forms in the presence of earthworms

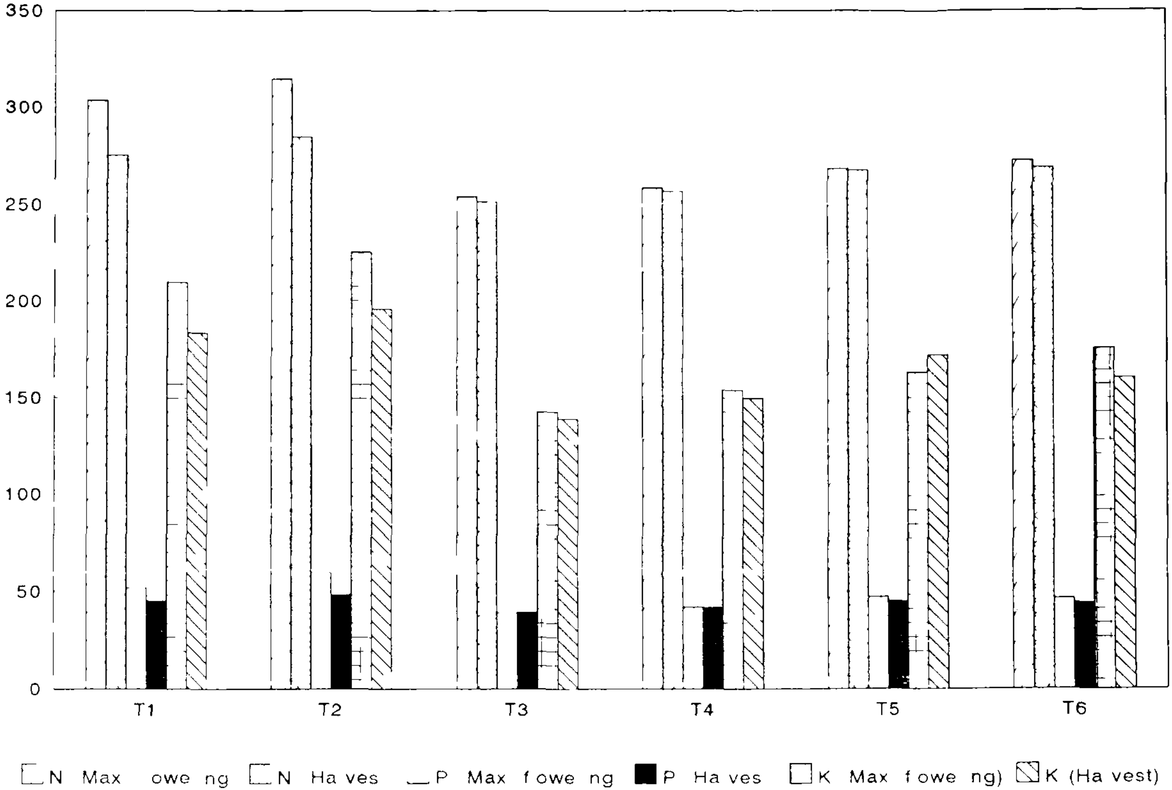


**Fıg 6 Avaılable nıtrogen phosphorus and potassıum ın soil**

5 2 6 **Exchangeable calcium**

As seen from the results (Table 16 and Fig 7) exchangeable calcium content of the soil was highest in treatment with vermicompost + inorganic fertilizers both at maximum flowering stage and at harvest (1 76 and 1 61 cmol $kg^{-1}$) and it was leas with vermiculture with local worms (1 28 and 1 23 cmol kg respectively)

The high calcium content of vermicompost was reported by Kale and Krishnamoorthy (1980) and Shuxin et al (1991) They found that earthworms were of relative feeding of calcium ri h materials thereby the total calcium in castings was considerab y increased As per the report of the Pierce (1972) species w h the active calciferous glands absorbed excess calcium from the diet and transfered it to calciferous glands from which it was excreted via the digestive tract thereby increasing t e exchangeable calcium content in the soil

5 2 7 **Exchangeable magnesium**

As evident from the table 16 and fig 7 the exchangeable magnesium was also found to be higher when vermicompost + NPK were applied together (3 09 and 2 84 cmol $kg^{-1}$) followed by the plot receiving FYM + NPK

From the nutrient analysis as given in table 3 th percentage of magnesium was 1 34 and 1 10 in vermicompost and FYM respectively Probably this might have increased the exchangeable magnesium content in soils treated with these organic manures The original soil sample had a magnesium content of 1 5 and 1 42 cmol kg 1 at 0 15 and 15 30 cm respectively By the addition of vermicompost the residual exchangeable magnesium content of the soil was found to be 2 88 and 2 81 cmol kg 1 for the two depths This shows that the nutrient content in soil was increased by the addition of vermicompost

As seen from the nutrient analysis of soil it could be inferred that the general fertility of the soil was increased by the addition of vermicompost This was reflected in the yield of the crop Sharpley and Syers (1977) view agree with the present result that earthworms or vermicompost could not increase the total amount of nutrients in the soil but could make them more available and they might increase the rate of nutrient cycling thereby increasing the quantity of nutrients available at any one time

**5 3 Influence of application of vermicompost/vermiculture on nutrient content of plant parts**

The increased nutrient content in plant parts following application of organic manures (Fig 8) was probably due to the

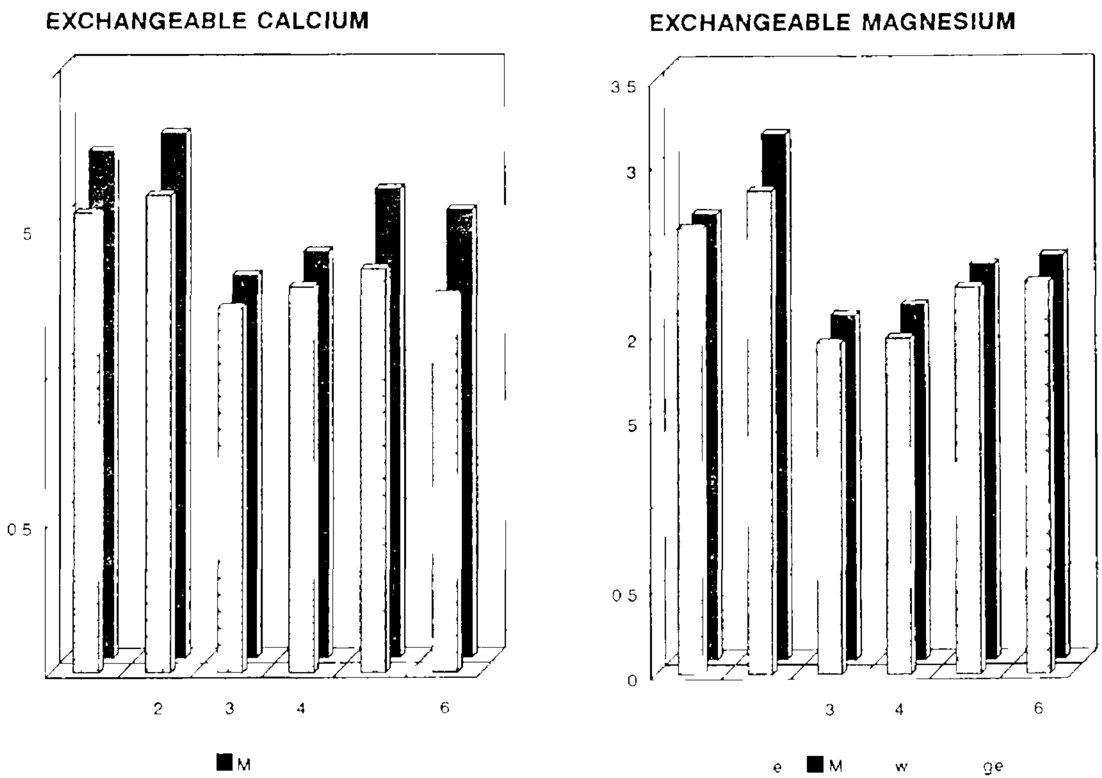


Fig 7 Exchangeable calcium and magnesium in soil

soil environment which encouraged proliferation of roots which in turn derived more water and nutrients from larger volumes of soil

5 3 1 Nitrogen

As in the case of available nitrogen content present in the soil the content of nitrogen in the plant parts viz leaf and shoot (Table 17) was maximum for the treatment with vermicompost (1 57 and 1 30%) followed by the application of FYM (1 33 and 1 17%) In the other treatments in which earthworms were applied insitu the plant wastes are applied freshly and it took time for decomposition by the action of earthworms At the same time the nitrogen decomposition and release were faster in case of vermicompost and FYM applied plots The mineralisation of nitrogen was supposed to be faster in the presence of vermicompost as reported by Shuxin et al (1991) also This had led to the increase in leaf area as well as early flowering i these plots Subsequently the yield also was increased The results of the present study is supported by the findings of Aldag and Graff (1975) and Grappelli et al (1987)

5 3 2 Phosphorus

The phosphorus content of leaf and shoot followed the same trend as that of nitrogen (Table 17) The maximum phosphor s content of 0 68% in leaf and 0 58% in shoot were recorded for vermicompost + NPK treatment

The release of phosphorus was lower in case of other four treatments where earthworms were applied in situ The increased mineralisation of native soil phosphorus as a result of production of organic acids during decomposition of organic matter might be the reason for increased phosphorus content of plant parts The solubilisation of phosphorus by the microorganisms was attributed to the excretion of organic acids like citric glutamic succinic lactic oxalic glyoxalic maleic fumaric tartaric and a keto butryic acids This was observed by Rao (1983)

The micro organisms present in the vermicompost helped in mineralisation of organic phosphorus in the soluble form These reactions had taken place in the rhizosphere and since the organisms rendered more phosphorus into the solution than that required for their own growth and metabolism the surplus was made available for the plant parts thereby increasing the phosphorus content This view is supported by Syers and Springett (1984) and Shuxin et al (1991) who had reported that the increased phosphorus availability was by an increase in solubility of phosphorus by higher phosphatase activity in the presence of vermicompost application

### 5 3 3 Potassium

The potassium content of shoot and leaf was much influenced by the treatments with organic manures along with inorganic fertilizers The maximum value of potassium 1 90% in shoot and 2 10% in leaf were recorded in vermicompost treated plots

The nutrient analysis showed that the potassium content was comparably higher in vermicompost (Table 3) than in other organic manures The increase in potassium content due to vermicompost application might be due to the increase in potassium availability by shifting the equilibrium forms of K from relatively unavailable forms to more available forms in the soil This finding of Bhaskar et al (1992) is in consonance with the present result obtained In the presence of vermicompost the K fixation might have reduced thereby releasing more of potassium in the soil The enhanced proliferation of roots had helped in the increased uptake of potassium

### 5 3 4 Calcium and magnesium

As seen from table 17 it is inferred that vermicompost or FYM application along with inorganic fertilizers influenced the plant content of calcium and magnesium also Both these nutrients were higher in leaf compared to the shoot part of the

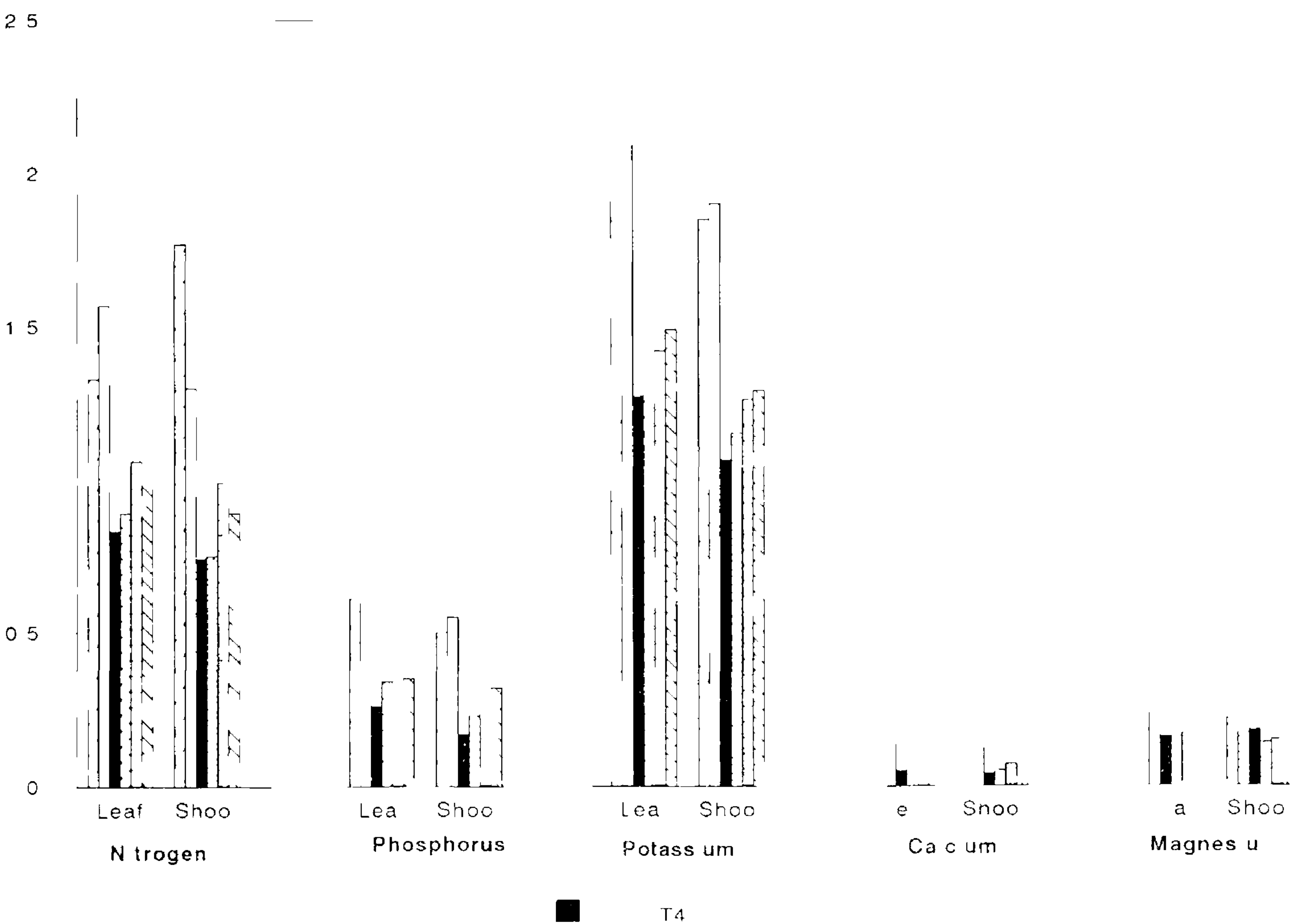

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Fig [illegible]

plant The higher values for exchangeable calcium and magnesiu in soil had enhanced the content of these nutrients in the plant parts Probably the organic manures like vermicompost or FYM might have helped in the easy release of these nutrients thereby making it available for the plants

The major and secondary nutrients present in the root were analysed at the harvest stage and it is presented in table 18 As in the case of leaf and shoot the maximum content of all the nutrients in root was also observed under treatment with vermicompost + NPK fertilizers The percent content of all nutrients were higher in root compared to leaf and shoot It might be because the root was analysed at a later stage The influence of vermicompost was predominant in this case also The increased root density and proliferation might have also helped in more absorption of all the plant nutrients

**5 4 Influence of application of vermicompost / vermiculture on biometric observations of plant**

**5 4 1 Yield**

The highest yield of chilli ie about 8 4t ha$^{1}$ was obtained for the treatment with vermicompost + NPK fertilizer (Fig 9 The lowest yield was recorded under vermiculture with local worms alone (2 40 t ha$^{1}$)

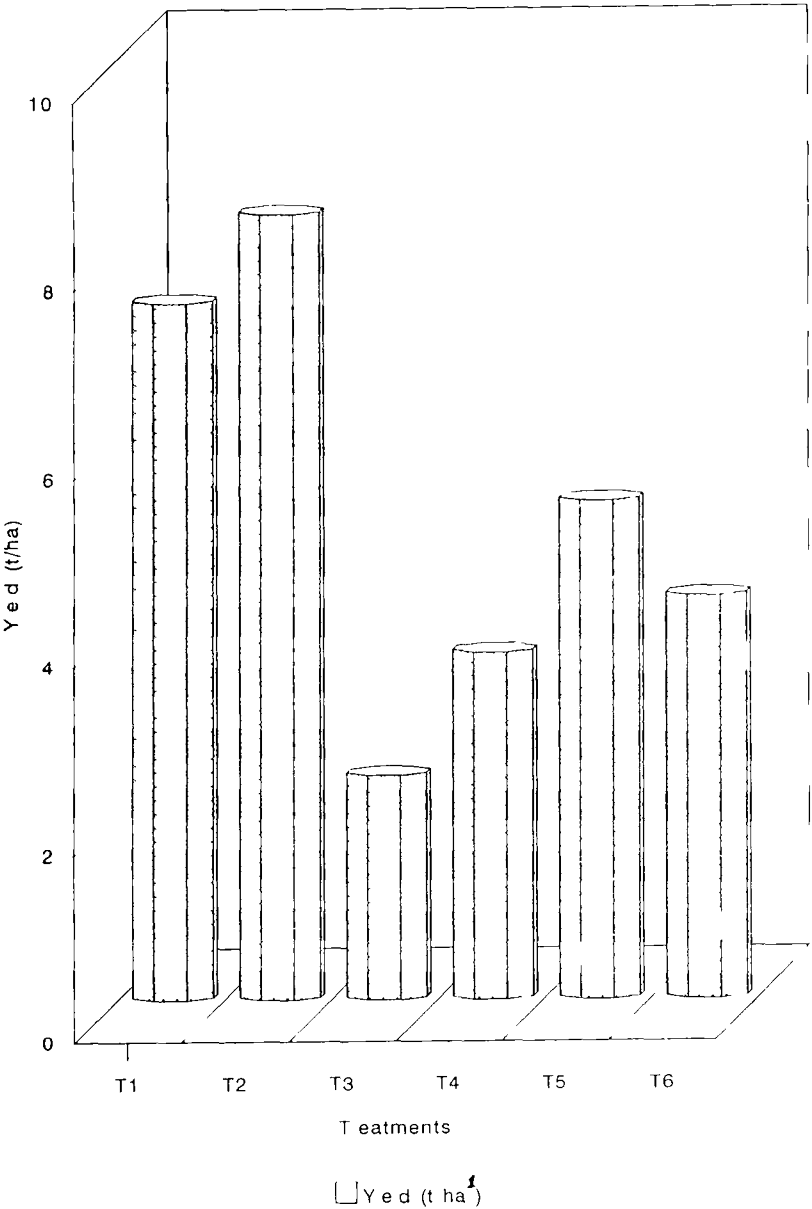


**Fig 9 Effect of treatments on yield of chilli**

All the available nutrients were higher in treatments with organic manures + NPK fertilizers which indirectly increased the yield of produce As far as the physical fertility of the soil was concerned vermiculture with either local worms or Eudrillus sps had profound influence on the various physical properties But the decomposed organic manures like vermicompost or FYM improved the chemical fertility of the soil thereby increasing the available plant nutrients in soil and nutrient content in the plant parts This was the main reason for the increased yield with these treatments But in some other cases increased yield was also noted by improvement of the physical environment in the presence of worms by Mo e (1994) In support to the present result influence of vermicompost on the yield of soybean and sugar cane was also reported by Sl uxin <u>et al</u> (1991) It has been observed that a large number of growth promoting substances excreted by earthworms had beneficial influence on crop growth and vegetable growth in the presence of vermicompost than the chemical fertilizers

Further it could be observed from table 21 that a significant positive correlation existed between yield and available nutrients in soil and also with nutrient content in plant From the strength of correlation it could be observed that all the nutrients were influencing the yield to the maximum level Beneficial effects of higher levels of potassium in soil in increasing the nitrogen and phosphorus uptake there by increasing the yield was reported by John (1989)

5 4 2 Dry matter production (DMP)

The data pertaining to the dry matter production i presented in table 19 The treatment with vermicompost + NPK recorded the highest DMP (41 91 g plant $^{-1}$) and the least by vermiculture treatment with a value of 23 6 g plant $^{-1}$ The DMP also showed a linear response to the high nitrogen level in so and content in plant parts

An increase in dry weight of plants as a result of manure additio was due to the productio of humus substances whi improved the physical and chemical properties of the soil as well as to the increased nutrient release and hence the r availability to the growing parts (Sakr 1985) These resul s are in agreement with the findings of the present study

5 4 3 Shoot root ratio

A signif cant variation in shoot root rat o was observ d in plants grown in various treatments However the highe t hoot root ratio (table 19) was observed in plants where t e organic o rce is vermicompost (4 23) Pla ts w th FYM as orga ic source showed the second highest value for shoot roo ratio (3 34) and the least by vermiculture treatment

When vermicompost or FYM was applied the available nitrogen content in the soil was increased thereby development of shoot and other plant parts also were influenced This had led to an increase in the shoot weight with a higher value for shoot root ratio Many authors have supported this view that higher levels of nitroge increa e the shoot weight compared to the root we ght thereby increasing the shoot root ratio Logsdon and Linden (1992) had opined from their study that improved root growth d d not always result in increased crop growth in earthworm treated plots This view is in agreement with the present result

5 4 4 Leaf area

From table 19 it could be observed that largest leaf area was recorded by the plants treated with vermicompost + NPK fertilizer (23 84 $m^2$) and the smallest one by vermiculture treatment with local worms (4 49 $m^2$)

Leaf area index (LAI) is a fu ction of leaf number and s ze Obviously higher levels of nitrogen prese t in the soils tr ated with orga ic man res favoured the above two aspects and there by increased the leaf area

Naturally u der lower levels of nitrogen the lea production rate and leaf expansion is lesser Russel (1973 reported that as the nitrogen supply increased the extra protei content produced allowed the plant leaves to grow larger a l le ce to have more s rface area available for photosynthesis I was also found from the result that there is 91% correlatio betwee leaf area and nitrogen content present in leaf Th higher levels of nit ogen release from vermicompost had resulted in higher leaf area Increase in leaf area through highe nitrogen application in solanaceous vegetables was reported ly Joshi and Nankar (1992) These works are in agreement with the results of the present study

Thus from the results it could be observed that the physical properties of soil was influenced mainly by applying f vermiculture in situ But the application of vermicomp st lal enhanced the nutrient content in soil and plant Hence long te m effects of vermicompost/vermiculture on the physical properties of soil with perennial crops could be further studied to achieve letter res lts

# SUMMARY AND CONCLUSION

# SUMMARY AND CONCLUSION

The investigation was carried out at the College of Ag i u t Vellayani to find out whether the applicat on f vermicompost/vermiculture had brought about any changes n physico chemical properties of soil and also on yield of ch ll The variety used was Jwalamukhi a high yielding var e y recommended for cultivation in Kerala The so l of he experimental site was sandy loam (fine loamy kaol n t isohypothermic Typic Kandiustults) medium in available n trogen and phosphorus and low in available potassium The experimen was laid o it in a randomized block design with four replicat ons

From the experimental site core samples were collected f om two depths of 0 15 cm and 15 30 cm The observat ons on l l density particle density porosity water holding capac ty and hydraulic conductivity were made from these samples D st bed samples were also collected from same depths for the analy s of structural nd ces water retention characterist cs and also f r available macro and secondary nutrients Soil compactness and infiltrat on rate of the s irface soil were also dete m ne Plant samples were collected and were analysed for nut e content present in them The biometric characters of plant we e also recorded

The results obtained and the salient conclusions drawn are summarised below

1 The farmyard manure + inorganic fertilizer treated plots recorded higher values of bulk density and particle density and also lowest values of porosity Bulk density and particle density values of soil were reduced and porosity was increased considerably by the application of vermicompost/vermiculture However in case of earthworm introduced plots <u>in</u> situ application of earthworms with basal inorganic fertilizer produced a higher bulk density over the <u>in situ</u> application of earthworms alone Bulk density and particle density were positively and significantly correlated with yield

2 The application of vermicompost/vermiculture had considerable effect on structural indices viz mean weight diameter and percent water stable aggregates The treatments in which earthworms were applied <u>in situ</u> showed higher mean weight diameter and per cent aggregates than other treatments Per cent of water stable aggregates > 0 25 mm in these treatments was found to be more than 47 percent but an optimum mean weight diameter of above 0 5 mm was recorded by all treatments Subsurface soils recorded higher mean weight diameter and water stable aggregates in earthworm treated plots whereas in case of FYM and vermicompost treated plots it was maximum in surface soils

3 Soil moisture content was also affected by application of vermicompost/vermiculture The presence of earthworms and also the organic wastes retained more soil moisture in the field at maximum flowering stage of chilli crop where as at harvest it was found to be maximum in vermicompost + NPK treated plots Surface evaporation was also prevented by organic wastes

4 Water holding capacity and hydraulic conductivity in the experimental site were also found to be much affected by the presence of earthworms There was a significant difference observed between two depths in case of hydraulic conductivity and it was found to be maximum in plots treated with local earthworms + basal dose of NPK fertilizers in the subsurface (ie at 15 30 cm) But water holding capacity was higher in surface soil in plots with vermiculture alone with Eudrillus worms

5 <u>In situ</u> application of earthworms to chilli crop had influenced the water retention characteristics of soil also Moisture retention capacity of surface soil (0 15 cm) was slightly higher than that of subsurface soil (15 30 cm) at maximum flowering stage where as at harvest it was found to be reverse

6 Infiltration rate of soil is also improved in the presence of earthworms The increased infiltration rate with insitu application of worms to soil indicate the improvement in water permeability of the soil as compared to plots without worms

7 Earthworm introduction shows negative correlation with surface compaction The values of surface compaction at harvest is found to be slightly decreased compared to that at maximum flowering stage

8 Influence of application of vermicompost/vermiculture on soil reaction and organic carbon content of soil is significant But the addition of compost or earthworms in soil has only slightly changed the $P^H$ values from 5 50 to 5 80 Organic carbon content is found to be increased with increasing nitrogen rates at both depths of 0 15 cm and 15 30 cm It is highest in the treatment receiving vermicompost + NPK and lowest in the vermiculture treatment with local worms alone

9 Available nutrient contents of the soil viz available nitrogen phosphorus and potassium and exchangeable calcium and magnesium are influenced significantly due to different treatments at maximum flowering stage and at harvest Application of organic manure in the form of vermicompost in soil records the

highest value for all available nutrients which is followed by application of farmyard manure with inorganic fertilizer. At all stages lowest availability is associated with the introduction of earthworms alone. Available nutrients in soil has positive significant correlation with yield. Among them available potassium in soil is found to have maximum correlation.

10 With respect to the content of nutrients viz nitrogen phosphorus potassium calcium and magnesium in the plant part such as leaf shoot and root they show significant variation by the different treatments. The treatment which has given the highest yield (treated with vermicompost + NPK) also record the highest values for all the nutrient contents. The nutrient content in all plant parts is positively correlated with nutrient content in soil and yield.

11 With regard to the yield and dry matter production of chilli crop the treatment receiving application of vermicompost + NPK records highest yield while the treatment with vermiculture alone using local worms records lowest yield. Application of organic manure either as vermicompost or farmyard manure is significantly superior to all other treatments. The shoot root ratio and leaf area also are increased by these treatments.

shoot root ratio and leaf area also were increased by these treatments

The result obtained in the present study shows that vermiculture improved the physical condition of the soil in the long run Its effect on chemical fertility and the yield parameter would be reflected only after a considerable time The yield of crop was increased by 12 per cent by application of vermicompost over the Package of practices with farmyard manure and inorganic fertilizers The cost involved in using farmyard manure could also be reduced by applying vermicompost Thus vermicompost or vermiculture practices help to improve the inherent physical and chemical condition of the soil

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# APPENDIX

## Appendix I
### Weather data during the cropping period
### (from 11 12 94)

| Week | Period | | Rainfall (mm) | Average maximum temperature ($^{o}C$) | Average minimum temperature ($^{o}C$) | Average relative humidity (%) |
|---|---|---|---|---|---|---|
| | From | To | | | | |
| 1 | Dec 11 | Dec 17 | | 30 53 | 21 00 | 76 07 |
| 2 | Dec 18 | Dec 24 | | 31 68 | 23 08 | 81 22 |
| 3 | Dec 25 | Dec 31 | | 31 83 | 22 26 | 77 93 |
| 4 | Jan 1 | Jan 7 | | 31 70 | 22 6 | 80 79 |
| 5 | Jan 8 | Jan 14 | 8 4 | 31 83 | 23 18 | 74 72 |
| 6 | Jan 15 | Jan 21 | | 31 00 | 23 17 | 81 43 |
| 7 | Jan 22 | Jan 28 | | 30 87 | 21 43 | 73 79 |
| 8 | Jan 29 | Feb 4 | | 31 65 | 22 83 | 70 94 |
| 9 | Feb 5 | Feb 11 | | 32 18 | 23 03 | 69 93 |
| 10 | Feb 12 | Feb 18 | | 31 34 | 23 29 | 73 79 |
| 11 | Feb 19 | Feb 25 | | 31 95 | 23 06 | 73 36 |
| 12 | Feb 26 | Mar 4 | | 32 07 | 22 83 | 72 19 |
| 13 | Mar 5 | Mar 11 | 4 | 32 30 | 23 11 | 74 72 |
| 14 | Mar 12 | Mar 18 | | 32 57 | 23 57 | 70 79 |
| 15 | Mar 19 | Mar 25 | | 33 43 | 23 69 | 69 79 |
| 16 | Mar 26 | Apr 1 | 1 | 33 46 | 25 97 | 72 92 |
| 17 | Apr 2 | Apr 8 | 38 6 | 32 79 | 24 94 | 76 36 |
| 18 | Apr 9 | Apr 15 | 6 8 | 32 4 | 24 71 | 74 50 |
| 19 | Apr 16 | Apr 22 | 68 6 | 32 29 | 24 26 | 75 65 |
| 20 | Apr 23 | Apr 29 | 23 4 | 32 26 | 25 39 | 78 86 |

# EFFECT OF VERMICOMPOST/VERMICULTURE ON PHYSICO-CHEMICAL PROPERTIES OF SOIL

By

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ABSTRACT OF THE THESIS
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A study was undertaken to assess the effect of applicat on of vermicompost/vermiculture on physico chemical properties of soil and yield of chilli making use of the soil and plant samples taken from the trial conducted at College of Agricult ıre Vellayani The experiment was conducted during the per od f om December 1994 to April 1995 The soil of the experimental s te was sandy loam (fine loamy kaolinitic isohypothermic Typi Kandiustults) The experiment was laid out in randomized block design with four replications and six treatments

The treatments consisted of FYM + NPK fertil zers vermicompost + NPK fertilizers vermiculture with local worms and with Fudrillus sps vermiculture with above sps of worms + basa dose of NPK fertilizers

Soil samples were collected from all the replications of the various treatment before planting at maximum flowering stage and at harvest Plant samples were also collected at the above growth stages Soil and plant samples were analysed in the laboratory to find out the effect of applicat on of vermicompost/vermiculture on physico chemical properties of and content of nutrients in plant parts viz leaf shoot and root

Results of prel minary analys s of so l samples colle ted before the experiment revealed the beneficial effe t f application of vermicompost/vermiculture on physico chem a properties of soil

Physical properties of soil such as bulk dens ty and particle density were found to be much educed in plots t eated with earthworms while porosity was increased n them Percent f water stable aggregates in plots with insitu application of wo m was found to be more than 50 percent but an optimum mean weight diameter of above 0 50 mm was recorded by all treatments Wa e stable aggregates with greater than 0 25 mm size had helped retain more moisture due to the increased intraggregate space The moisture content in soil was found to be more due to the coverage of organic wastes on soil surface Water hold ng capac ty and hydraulic conductivity were also much influenced by the presence of earthworms The increased infiltration ate w h insitu applicat on of worms to so l ndicated the mprovement water permeability of the soil as compared to plots withou worms But surface compaction of soil was found to be not m affected by the application of vermicompost/vermiculture and showed negative correlation

Application of organic manures either as farmyard manure or vermicompost with inorganic fertilizers had significant influence on soil reaction and organic carbon content of the soil. Organic carbon content was found to be increased with increasing nitrogen rates at both depths of 0-15 cm and 15-30 cm. Available nutrient contents of the soil viz. available nitrogen, phosphorus and potassium and exchangeable calcium and magnesium were influenced significantly due to different treatments at maximum flowering stage and at harvest. Application of vermicompost+ NPK increased the availability of nutrients in soil while application of vermiculture alone with local worms or Eudrillus sps. had resulted in a lower value.

Regarding the nutrient content in plant parts such as leaf, shoot and root, all the nutrient contents were highest in the plot treated with vermicompost + NPK fertilizers followed by farmyard manure + NPK. Significant correlation existed between available nutrient in soil and plant nutrient content.

Maximum yield and growth parameters were also recorded by the treatment receiving application of vermicompost +NPK fertilizers and the results thus clearly indicate that application of vermicompost along with NPK is essential to maintain high yields. Application of vermiculture alone with local worms or Eudrillus sps. or together with basal dose of fertilizers also failed to give higher yields. Thus by adopting vermiculture technique only the physical properties of soil can be improved while its effect on chemical properties is negligible. So combined application of vermicompost/vermiculture with inorganic fertilizers is found to be better for improving the soil productivity and fertility.