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ORGANIC NUTRITION FOR SOIL HEALTH AND PRODUCTIVITY OF CHILLI (*Capsicum annuum* L.)

by

LEKSHMI.V

(2008 – 11 - 112)

THESIS

submitted in partial fulfillment of the requirement for the degree of

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VELLAYANI, THIRUVANANTHAPURAM - 695 522

KERALA, INDIA

2011

DECLARATION

I hereby declare that this thesis entitled **"Organic nutrition for soil health and productivity of chilli (*Capsicum annuum* L.)"** is a bonafide record of research 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, fellowship or other similar title of any other University or Society.

Vellayani,

Date: 13-9-2011

Lekshmi.V

(2008 – 11 – 112)

CERTIFICATE

Certified that this thesis, entitled **"Organic nutrition for soil health and productivity of chilli (*Capsicum annuum* L.)"** is a record of research work done independently by **Lekshmi.V (2008 – 11 – 112)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

13/9/11

Vellayani,

Date: 13-9-2011

Dr.K.Ushakumari

Chairman

Advisory Committee

Professor

Department of Soil Science and

Agricultural Chemistry

College of Agriculture,

Vellayani

Kerala Agricultural University

Thrissur, Kerala.

CERTIFICATE

We, the undersigned members of the advisory committee of **Mrs.Lekshmi.V (2008 – 11 – 112)** a candidate for the degree of **Master of Science in Agriculture** agree that this thesis entitled **"Organic nutrition for soil health and productivity of chilli (*Capsicum annuum* L.)"** may be submitted by **Mrs.Lekshmi.V (2008 – 11 – 112)**, in partial fulfillment of the requirement for the degree.

13/9/11

Dr.K.Ushakumari
Chairman, Advisory Committee
Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani

13/9/2011

Dr.N.Saifudeen
Professor and Head
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani
(Member)

13/9/11

Dr.Sumam Susan Varghese
Professor
Department of Soil Science and
Agricultural Chemistry
College of Agriculture, Vellayani
(Member)

13/9/11

Dr.V.K.Girija
Professor
Department of Plant Pathology
College of Agriculture, Vellayani
(Member)

External Examiner

Dr. Susan John K
Senior Scientist
Division of Crop Production
CTCRI, TVM

DEDICATED TO

MY FAMILY

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LIST OF ABBREVIATIONS

@	- At the rate of
AM fungi	- Arbuscular Mycorrhizal fungi
B:C	- Benefit – Cost ratio
BD	- Bulk Density
BM compost	- Biomineral compost
CD	- Critical Difference
cm	- Centimeter
DAT	- Days After Transplanting
DAP	- Di Ammonium Phosphate
dS m^{-1}	- deci Siemens per meter
DTPA	- Diethylene Triamine Penta Acetic acid
EM	- Effective Microorganism
EC	- Electrical Conductivity
et al.	- And others
Fig.	- Figure
FYM	- Farm Yard Manure
g	- gram
h	- hour
i.e.	- That is
kg ha^{-1}	- kilogram per hectare
LAI	- Leaf Area Index
lbs	- Pounds
MAT	- Months After Transplanting
Mgm^{-3}	- Mega gram per cubic meter
MOP	- Muriate of Potash
MRP	- Mussorie Rock Phosphate

μg	- Micro gram
ml	- Millilitre
mm	- Millimeter
MSL	- Mean Sea Level
POP	- Package of Practices Recommendation
ppm	- parts per million
%	- Per cent
RBD	- Randomised Block Design
RDF	- Recommended Dose of Fertilizers
RP	- Rock Phosphate
SSP	- Single Super Phosphate
t	- Tonnes
TPF	- Triphenyl Formazan
TSS	- Total Soluble Sugar
viz.	- Namely
WAT	- Weeks After Transplanting
WHC	- Water Holding Capacity
^{0}C	- Degree Celsius

INTRODUCTION

1. INTRODUCTION

Long term field experiments have made clear the negative impact of continuous use of chemical fertilizers on soil health (Yadav, 2003). The occurrence of multi-nutrient deficiencies and overall decline in the productivity of soil under intensive fertilizer use has been widely reported (Chhonkar, 2003). Recognising soil as a dynamic living entity which promotes beneficial biological activities in soil and root zone of plant is central to the theme of organic agriculture.

Organic farming is today's answer not only for higher and sustained productivity but also for safe nutritious food and it is increasingly demanded by enlightened consumers. Organic farming management relies on developing biological diversity in the field to disrupt habitat for pests and pathogens and the purposeful maintenance and replenishment of soil fertility. The organic farmers' aim should be to provide crop nutrition that nurture the soil, stimulate soil life and conserve nutrients. This involves developing strategies to improve soil health and supply nutrition. The growth in agricultural production has to be consistent. This becomes possible only if the soil is in good health. The primary factor having influence on soil health is the organic matter content of the soil which is under constant threat of depletion due to environmental factors and inadequate replenishment. With the increase in need to conserve natural resources and energy, recycling of organic waste assumes major importance. Further, in the wake of serious problems and bio-magnification of toxic chemicals in various biological systems, organic farming is the right approach to present day agriculture. The basic requirement in organic farming is to increase input use efficiency in each step of farm operations. One of the major constraints in popularizing organic farming is the non-availability of good quality organic manures. This is achieved partially through reducing losses and adoption of new technologies for enrichment of nutrient content in manures.

Chilli (*Capsicum annuum* L.) is a tropical and subtropical crop grown all over India. It is one of the most important commercial spice crops, earning valuable foreign exchange for the country. India is the largest producer of chillies in the world. India produces about 10.70 lakh tonnes of chilli from an area of 9.08 lakh hectares (Singhal, 2003). The crop is grown in the homesteads of Kerala throughout the year. Chillies are economically very important for their diverse varieties being used as spice, condiment, vegetable, pickles, sauces and other culinary supplements. The green and ripe red (fresh) as well as dry chilli fruits are consumed in various forms and preparations for their stimulating pungency. Chilli fruits are rich in vitamin C and capsaicinoides, which are used as medicine (Das, 2007). Wood(1987) and Das(2007) stated that chillies contain upto 1.5% capsaicinoides including capsaicin, carotenoid pigments including capsanthin, capsorubin, alpha and beta carotene, proteins and vitamin A. The chilli fruits help in digestion when taken with food as it increases the flow of saliva that contains the enzyme amylase (Verghese et al., 1992). A natural enzyme asparaginase and various alkaloids present in the fruits of chilli have been reported to possess medicinal values (Mahadeviah and Balasubramanyan, 1976). Ascorbic acid content of mature chilli fruits varies between 60-180 mg 100 g^{-1} fresh weight of fruits upto ripening stage after which it declines gradually (Lalithakumari *et al.*, 1998).

In the light of the above background, the present study was conducted to assess the physical, chemical and biological properties of soil under organic nutrient management and its effect on growth, yield and quality parameters of the test crop, chilli.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Organic farming is the right approach to the present day agriculture. Increase in the use of organic source of nutrients is important in the context of organic farming and sustainable agriculture. Compost, manures and organic fertilizers are now being recommended and also utilized widely for increasing crop productivity and for improving soil and environmental quality. However the nutrient content of ordinary compost is very low. Degradation of organic wastes by organic additives and bio-inoculants are the recent developments in the composting technology to enrich the nutritional quality of composts. Use of organic additive like rock dust and bio-inoculants such as *Trichoderma* and Effective Micro-organism (EM) were carried out in this experiment. Effect of two growth promoters *viz.* Panchagavya and Vermiwash were also studied in this experiment on chilli. The literature pertaining to enriched manure is scanty. Hence available literature relevant to the present investigation has been reviewed hereunder.

2.1 EFFECT OF ORGANIC MANURES ON SOIL PROPERTIES

Application of some organic waste products such as liquid and dehydrated slurry, keratin bark-urea granule, sewage sludge, FYM and NPK improved the physico-chemical properties except the acidification caused by keratin bark-urea granule (Debicki and Rejman, 1988).

Lal and Mather (1988) reported that application of N, P, K fertilizers reduced the pH from 5.5 to 3.8 but FYM application maintained or increased the pH of the soil, while the combination of fertilizers and manures decreased the pH.

Mbagwu (1989) reported that the application of organic wastes like poultry manure, compost, sawdust, rice shavings and cashew leaves improved the soil structure, water retention property, total porosity, macroporosity and saturation hydraulic conductivity but it decreased the bulk density.

From a long term field experiment in England, Rose (1990) reported that continuous application of farmyard manure increases the total porosity of soil.

Organic manure application resulted in an improvement of physical and chemical soil properties, *i.e.*, porosity, aggregate stability, water exchange and fertility (Tester, 1990).

Shuxin *et al.* (1991) reported that by introducing earthworms and applying organic manure in the soil, improved the soil structure and fertility status.

A decrease in bulk density by the addition of organic matter residues over long time was observed by Rasmussen and Collins (1991).

Compost and compost extracts applied to soil improve its quality by altering the chemical and physical properties, increase organic matter content, water holding capacity and provide macro and micro nutrients essential for plant growth. (Weltzien, 1991; Scheuerell and Mahaffe, 2004; Heather *et al.*, 2006)

Application of organic wastes improved soil structure, water holding capacity and cation exchange capacity. (Latif *et al.*, 1992)

According to Hudson (1994) organic matter is an important determinant of available water content and it increases the available water in sandy textured soils only.

Soils could be sustained through the use of organic amendments like vermicompost and inoculation of earthworms which facilitates humus formation and reduces leaching of nutrients from the soil by their slow release. (Thampan, 1995; Ansari, 2008a)

Ghuman *et al.* (1997) reported that green manuring with sunhemp reduces the soil pH and organic matter content of surface soil. Soil nitrate nitrogen decreases during sunhemp growth. Green manuring increases soil water retention and reduces bulk density in 0-0.1m soil depth, as a result infiltration rate increased.

Application of FYM to soybean crop resulted in significant improvement in soil properties *viz.* organic carbon, total N, available P and K in the soil. (Babhulkar *et al.*, 2000)

Incorporation of organic waste significantly increased the soil pH and nutrient status of an acid soil. (Lal *et al.*, 2000)

Pizzeghello *et al.* (2002) reported that rice straw compost extract improved soil fertility, modified soil physical and chemical conditions directly due to higher nutrient content and humic acids percentage.

Tolanur and Badanur (2003) observed a significant increase in organic carbon content due to organic manure addition. This was due to better root growth and the subsequent decomposition of roots which resulted in increasing the organic carbon content of soil.

In an experiment to study the water retention characteristics under soybean-wheat cropping sequence it was observed that in FYM treated plots, soil water retention was significantly higher in all depths compared to fertilized plots. This is because water retention at lower tension depends primarily upon the profile distribution. (Ranjan *et al.*, 2004)

Bonde and Rao (2004) observed that the application of organic residues significantly lowered the bulk density over control. Among different residues, FYM resulted in greater availability of nitrogen, phosphorus and potassium in soil compared to other treatments (wheat straw and pressmud compost) including control in cotton-soybean cropping system.

Rajshree *et al.* (2005) reported that the application of FYM decreased the bulk density and increased the organic carbon content of soil when applied @ 7.50 t ha^{-1} along with 50 $kgha^{-1}$ nitrogen and 30 kg ha^{-1} phosphorus. The bulk density was lowered to1.56 Mg m^{-3} from an initial value of 1.66 Mg m^{-3} and organic carbon content was increased to 6.20 g kg^{-1} from an initial value (4.81 g kg^{-1}).

Ghuman and Sur (2006) reported that application of FYM @ 18 t ha^{-1} recorded higher organic carbon content (0.33%),lower bulk density(1.36 Mgm^{-3}) and lower pH (7.3) over FYM applied @ 6 t ha^{-1} (0.29% , 1.4 Mg m^{-3} and 7.4, organic carbon, bulk density and pH, respectively) and control (0.17% , 1.43 Mg m^{-3} , 7.5 organic carbon, bulk density and pH respectively) besides increasing yield of crops.

Application of organic wastes with high organic matter content has been reported to improve soil fertility (Tejada *et al.*, 2006; 2009)

According to Singh and Rao (2009) organic manures are nature's best mulches and soil amendments which improve soil structure, aeration and also increase the soil's water holding capacity.

Application of organic manure and FYM improved the soil physico - chemical properties such as soil pH, soil moisture availability, organic carbon and nutrient status of the soil in twenty five years old apple orchards. (Verma *et al.*, 2009)

2.2 EFFECT OF ORGANIC MANURES ON AVAILABILITY AND UPTAKE OF NUTRIENTS

Srivastava (1985) observed that increased use of nitrogenous fertilizers decreased organic matter content and total nitrogen, while FYM increased the above parameters.

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

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

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

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

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

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

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

More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon, available N, P and K of the soil.

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

Balaji (1994) recorded higher levels of total N, available P and K in treatments which received either vermicompost alone or in combination with FYM or chemical fertilizers than control.

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

FYM application resulted in lowest acidity due to the increase in exchangeable or soluble Al in the soil (Patiram, 1996).

According to Meera (1998), use of vermicompost coated seeds produced the maximum uptake of N, P and K at peak flowering stage and harvest. Soil application of vermicompost recorded the highest uptake of Ca, Mg, Cu and Mn during peak flowering stage.

Organic manure is an important source of N, P, Ca and micro-elements such as Zn, Cu, Mg which are essential to crop growth. (Debosz *et al.*, 1999)

Cuevas *et al.* (2000) reported that application of dried composted municipal solid waste to a degraded semi acid shrub land significantly increased the availability of P, K, nitrate nitrogen and EC. It also increased the concentration of total soil heavy metal like Zn, Pb, Cd, Ni, Cr and Cu but the increase is significant only for Zn, Pb and Cu.

Das (2000) reported that application of compost, crop residues and other organic wastes increase the water soluble, exchangeable and easily reducible fractions of Mn and increased the availability of Cu in soil.

Sharu (2000) reported that poultry manure recorded higher level of soil nutrients compared to vermicompost, neemcake and POP recommendation. Poultry manures with its low C:N and good nutrient value suits well for all crops especially vegetables.

The higher efficiency of poultry manure is due to large quantities of easily mineralisable N (Meerabai and Raj, 2001)

Sharma *et al.* (2001) reported that conjoint use of N along with FYM markedly influenced NPK uptake.

Patidar and Mali (2002) studied the effect of FYM and biofertilizer on N and P content of soil after harvest of sorghum crop and found significant increase in these parameters over no manure and biofertilizer application.

According to Singh (2002), green manure and FYM get mineralized rapidly and maintain adequate N status of soil. Application of this also supplied K and solubilised K from K bearing minerals and hence increased its availability in soil.

FYM application along with different levels of S, Mo, Fe, Zn and Co increased the uptake of major and micro nutrients by cowpea at harvest (Sharma *et al.*, 2002)

Akbari *et al.* (2002) observed that application of FYM @10t ha^{-1} significantly improved organic carbon, available P, K and S status in soil after harvesting ground nut.

Channabasavanna and Biradar (2002) reported that due to the high content of NPK present in poultry manure, it has been proven that one tonne poultry manure is equivalent to seven tonnes of FYM.

Dikshit and Khatik (2002) found that maximum S uptake was noticed in soybean crop by organic manure application.

After 20 years of continuous intensive cropping under various fertilizers and manurial treatments, Tiwari *et al.* (2002) observed that inclusion of FYM in the treatment schedule improved soil S in a Vertisol.

Application of household compost and solid pig manure showed an increased accumulation of N and P. (Peterser *et al.*, 2003)

2.3 EFFECT OF ORGANIC MANURES ON MICROBIAL PROPERTIES

Many workers reported that application of organic manures increased the soil microbial biomass (Sakamoto and Oba, 1991; Goyal *et al.*, 1993).

The study of microbial biomass, dehydrogenase and alkaline phosphatase activity to obtain a more complete and precise definition of soil fertility was suggested by Beyer *et al.* (1992).

According to Ramamurthy *et al.* (1995) application of organic matter @ 10t ha^{-1} significantly increased the dehydrogenase activity of soils (0.54 μg TPF g^{-1} hr^{-1}) compared to 5 t ha^{-1} of organic matter (0.46 μg TPF g^{-1} hr^{-1}) and control (0.38 μg TPF g^{-1} hr^{-1}).

Manna *et al.* (1996) studied the effect of different levels of FYM on soil microbial biomass and an increased microbial biomass at 4t ha^{-1} FYM was reported, but further increase in FYM caused reduction in biomass turnover.

According to Cooper and Warman (1997) application of compost showed significant increase in dehydrogenase activity in silty clay soil than the application of manures and fertilizers.

Fraser *et al.* (1998) opined that the dehydrogenase activity was linked with the levels of available organic carbon substrates in the soil.

Monreal *et al.* (1998) reported that elevated enzyme activities appear to be associated with conditions promoting microbial synthesis of enzyme and such sensitivity would make soil enzyme activities as effective indicators of changes in soil quality.

Tatento (1998) observed an increase in the activity of dehydrogenase due to poultry manure application in a clay loam soil.

Debosz *et al.* (1999) reported that incorporation of organic manure into the soil increases soil biological activity.

Bhatcharyya *et al.* (2001) reported that application of municipal solid waste compost variably increased the microbial mass.

Manjunatha *et al.* (2006) observed a marked increase in dehydrogenase activity in the soils of organic farms than conventional farms in the selected major cropping systems *viz.,*cotton, sugarcane, jowar and vine yard.

Shwetha (2008) reported that the combined application of fermented organics *viz.*, Beejamrut, Jeevamrut, Panchagavya along with organics such as compost,vermicompost, green leaf manure recorded the highest soil biological activity. Similarly, dehydrogenase activity was higher with combined application of organics and fermented organics than their individual applications and RDF + FYM.

2.4 EFFECT OF ORGANIC MANURES ON QUALITY OF CROPS

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

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

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

Sudhakar *et al.* (1989) reported that seed inoculation with *Rhizobium* increased the seed protein content of black gram.

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

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

According to Rani *et al.* (1997) increase in ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetables.

Anitha (1997) reported that chilli plants treated with poultry manure recorded the maximum ascorbic acid content in fruits as compared to vermicompost and control treatment.

Joseph (1998) observed that in snake gourds, poultry manure treated plants recorded the highest crude protein and lowest crude fibre content as compared to that of FYM and vermicompost treatments.

FYM application increased the drymatter production of Bhindi (Senthilkumar and Sekar, 1998).

According to Sharu (2000) poultry manure application registered maximum keeping quality of fruits compared to vermicompost, neem cake and POP.

Nanthakumar and Veeragavatham (2001) recorded significantly higher ascorbic acid content over control due to application of crop residues.

Bhadoria *et al.* (2001) reported that protein and total mineral content of okra fruit was high when it was treated with FYM.

Omae *et al.* (2003) reported that cattle compost application increased freshness and vitamin C content in Melon (*Cucumis melo* L.)

2.5 EFFECT OF GROWTH PROMOTERS ON GROWTH AND YIELD OF CROPS

Vermiwash contains several enzymes, plant growth hormones, vitamins along with micro and macro nutrients which influence growth. (Shield and Earl, 1982).

Pramoth (1995) found that vermiwash possess an inherent property of acting not only as a fertilizer but also as a mild biocide.

According to Tomati and Galli (1995), growth of ornamental plant after adding vermiwash showed similar growth pattern as with addition of auxins, gibberellins and cytokinins through the soil.

Vermiwash, a liquid nutrient obtained during vermicomposting is known for its crop nourishment, plant growth and pest resistance promoting effects. (Kale, 1998; Giraddi, 2001 ; Giraddi *et al.*, 2003).

Jasmin (1999) reported that application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield in tomato. At higher concentrations (25 and 50%) of vermiwash, inorganic fertilizer could be reduced to half of the recommended dose without any yield reduction.

Buckerfield *et al.* (1999) reported that weekly applications of vermiwash increased radish yield by 7.3%.

Presence of naturally occurring and beneficially effective microorganisms (EM) predominately lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), actinomycetes (*Streptomyces*), photosynthetic bacteria and certain fungi besides biofertilizers such as *Azotobacter*, *Azospirillum* and *Phosphobacterium* were detected in panchagavya which improved soil quality, growth and yield of crops especially in corn (Xu and Xu, 2000).

Sathiyabama and Selvakumari (2001) studied the effect of humic acid with and without NPK fertilizers on growth, yield and nutrient content of *Amaranthus* (Co– 5). The results showed that application of 10 kg humic acid ha^{-1} along with 75 percent recommended NPK found to influence the green matter production.

Fuhua *et al.* (2002) reported that the application of sewage sludge improved the physico-chemical properties of soil.

Dhevagi *et al.* (2003) reported that application of papermill effluent along with amendment increased BD, pH, EC and organic matter content in groundnut.

According to Thangavel *et al.* (2003) vermiwash will be beneficial for crop production. It will provide macro and micronutrients and growth promoting substances which stimulate plant growth. Increases in organic matter content, uptake of N, P, K , growth and yield also were noticed.

In a study conducted by Somasundaram *et al.* (2003) it was found that increase or decrease the levels of Panchagavya from 3% level decreased the yield At higher concentration, scorching was observed resulting in reduced photosynthetic activity and yield. They also observed increased number of seeds pod^{-1}, higher grain weight and grain yield by the application of panchagavya in green gram. Additional revenue and higher B:C was also reported.

Sundararaman (2004) observed that natural preparations like panchagavya will be of much help in the conversion from chemical farming to organic farming. Panchagavya acts 75% as manure and 25% as pest controller. It stimulates plants growth, rectifies micro nutrient deficiencies and helps plants to develop resistance against diseases.

Reddy (2004) reported that promoting use of Panchagavya as a nutrient and a hormone can help to get better yield at very cheap cost.

Manjunatha *et al.* (2004) evaluated panchagavya as foliar spray and as soil drenching, found that soil drenching or foliar spray of 3% panchagavya improved growth and yield.

Somasundaram and Sankaran (2004) reported that Panchagavya contains growth regulators such as IAA, GA and Cytokinin, essential plant nutrients, naturally occurring beneficial Effective Micro-organisms predominantly lactic acid bacteria, yeast, actinomycetes, photosynthetic bacteria and certain fungi besides *Azotobacter*, *Azospirillum* and *Phosphobacterium* and plant protection agents such as *Pseudomonas* and saprophytic yeasts. Total productivity in terms of total dry matter production, NPK uptake and crude protein yield were higher for panchagavya treated plants.

Hannah *et al.* (2005) observed that the Panchagavya spray produced with tastier banana fruits and sprayed to banana crop @ 3 per cent resulted in improvement in quality of fruits *viz.,* total soluble sugars, total sugars and reduced the negative quality character like acidity.

Louduraj *et al.* (2005)reported that application of panchagavya @ 3 per cent spray 4 times for bhindi augmented the yield level in poultrymanure (10.27t ha^{-1}) treated plot which was comparable to inorganic supplementation (10.39tha^{-1}) with pesticide spray.

According to Ismail (2005) vermiwash is a collection of excretory and secretory products of earthworms, along with major and micro nutrients of soil and organic molecules that are useful for plants.

Application of vermiwash increased the resistance power of crops against various diseases and enhanced the growth and productivity of crops. (Suthar *et al.*, 2005, Yadav *et al.*, 2005)

Panchagavya has been used in many applications as growth promoter, bio-enhancer and immunostimulant in plants and animals. It was found that Panchagavya at 30 days of age recorded better proposition of chemical and microbial composition favourable for utilization as a growth promoter and it did not have direct antibacterial activity. (Mathivanan *et al.*, 2006)

Panchagavya applied @ 3 percent spray along with different organic manures at 0, 30, 50 days after sowing in rice recorded significantly higher grain yield (5.43t ha^{-1}) over no panchagavya spray (4.99 t ha^{-1}) (Ramanathan, 2006).

In an experiment it was reported that foliar application of 3% panchagavya increased plant height, Leaf Area Index and dry matter production which was close to 0.05% humic acid application in increasing the plant height, LAI, dry matter production, maximum weight of mother rhizomes and highest yield. (Satish *et al.*, 2006)

George *et al.* (2007) reported the positive effect of vermiwash on crop growth and yield. Application of vermicompost @ 2.5 t ha^{-1} along with vermiwash (1:1 sprays) registered significantly maximum dry chilli yield.

In an experiment to find out the effect of vermicompost and vermiwash on the productivity of spinach, onion and potato it was found that yield of spinach was significantly higher in plots treated with 5% vermiwash spray whereas yield of onion was higher when treated with 10% vermiwash spray. (Ansari, 2008b)

According to Chandrakala (2008) the combined application of liquid manures, Beejamrut + Jeevamrut + Panchagavya recorded significantly higher fruit length, number of fruits per plant and chilli yield over control.

Shwetha (2008) conducted an experiment to know the effect of nutrient management through organics in soybean wheat cropping system at Main Agricultural Research Station, Dharwad on a medium deep black clay loam soil reported that significantly higher leaf area index (LAI), plant height, number of branches, dry matter accumulation, seed yield and yield parameters like number of pods plant $^{-1}$ with the application of organic manures in combination with fermented organics *viz.,* Beejamrut, Jeevamrut, Panchagavya over organics alone application.

Venkataramana *et al.* (2009) reported that application of Panchagavya along with organic manures influenced the growth and production of Mulberry.

In an experiment it was found that 1:20 ratio vermiwash application influenced the growth of plants. Application of vermiwash along with enriched vermicompost increased the yield and quality of crops. (Masils *et al.*, 2009)

According to Sangeetha and Thevanathan (2010) application of panchagavya registered higher rate of growth of roots and shoots and also enhanced the yield and shelf life of fruits.

2.6 EFFECT OF ENRICHED MANURES ON SOIL PROPERTIES AND SOIL FERTILITY

Hamaker and Weaver (1982) reported that application of rock dust for corn crop resulted in an increase of 57% P, 90% K, 47% Ca and 60% Mg. They also reported that if the rock is finely ground, the microorganisms will access to the minerals more readily.

Satchel *et al.* (1984) reported that earth worm activity stimulate the microbial phosphate production.

Fragstein and Vougtmann (1987) observed an improvement in water holding capacity and cation exchange capacity of soil.

An incubation study conducted by Prasad and Singhamia (1989) showed that the application of manures enriched with urea or single super phosphate maintained higher level of N and P in the soil for longer period than when the soil is treated with fertilizer alone.

Increase in total and available P_2O_5 content in soil due to vermicompost application was reported by Gaur (1990). This may be due to greater mineralization of organic matter.

Lertola (1991) stated that compost and rock dust is a symbiotic combination where compost can provide an excellent medium for the microorganism population explosion and rock dust can increase the soil microbial activity .

Basker *et al.* (1992) reported increased concentration of available and exchangeable K by vermicompost application.

Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in nitrogen fixation and phosphate mobilization leading to higher nutrient uptake by plants.

Logsdon and Linden (1992) reported that earthworms create channels that allow deeper root penetration through hard pan. These channels can increase infiltration and reduce run off, increasing soil water availability.

Bhawalkar and Bhawalkar (1993) found that earthworms involve in soil forming process by influencing soil pH by acting as an agent of physical decomposition, promoting humus formation and improving soil structure there by enriching the soil.

Vijayalekshmi (1993) reported that soil physical properties such as porosity, soil aggregation, soil transmission, conductivity were improved with worm cast amended soil.

Chattopadhyay *et al.* (1993) and Rasal *et al.* (1996) found that, plant P uptake was significantly enhanced by the application of compost amended with *T. viride* compared with non-amended compost.

Mahimairaja *et al.* (1994) examined dissolution of phosphate rock during composting with poultry manure which was enhanced by the addition of S to the compost.

Vermicompost increased availability of N in soil had been reported by Parkin and Berry(1994).

Zachariah (1995) reported that enrichment of compost with N fixing *Aspergillus* and P solubilising micro-organisms along with 1% rock phosphate increased the uptake of nutrients by plants.

Scott (1995) found that the application of sedimentary rocks increased the uptake of Ca and Mg in natural forest of North Carolina, USA.

Coroneos (1995) reported that application of granite increased the plant dry weight, K uptake and soil moisture in clover, rye grass and tomato in Western Australia.

Campe *et al.* (1996) reported that rock dust neutralized the soil to a great degree in forest soil where limestone is not recommended.

Vasanthi and Kumaraswami (1996) reported highest concentration of micronutrients in the treatment that received vermicompost along with NPK fertilizer compared to the treatment that received NPK alone.

Kramer (1996) reported that application of rock dust was best for total soil management.

From the experiments with scrap grade phlogopite from a Sri Lankan mica processing centre Hisinger *et al.* (1996) reported that upto 65% of the K and Mg contained in the phlogopite could be recovered.

Ghandour *et al.* (1996) studied the effect of *Rhizobium* inoculation, VAM fungi on growth, 'P', N and Fe uptake by bean plants grown in virgin sandy soil treated with rock phosphate and found that P, N and Fe uptake increased due to inoculation and dual inoculation results in the highest effect.

Bijulal (1997) reported that the major effect of vermicompost application in soil was a reduction in P fixation and this increased the P availability in acidic soils.

Combined application of poultry manure and phosphate fertilizer increases the 'P' availability in soil. (Toor and Bahl, 1997)

Increase in number of nitrogen fixing fungi and bacteria in the soil when earth worms were introduced into experimental plots was observed by Kale *et al.* (1992).

Experiments on co-utilization of rock dust and compost by SEER centre (1998) revealed that addition of rock dust to compost not only increased mineral content but also accelerated microbial activity, heat build up and thus increased the rate of break down.

Thakur and Sharma(1998) studied the effect of inoculation of *Azotobacter* and addition of varying levels of rock phosphate on N and P transformation. During composting inoculation with *Azotobacter* at 30 days of composting increased NH_4^+, NO_3^- ,total nitrogen content and decreased water soluble P and CN ratio. Rock phosphate enrichment accelerated the decomposition and improved the nitrogen mineralization. Phosphorus from rock phosphate was solubilized during composting and transformed into available form.

In Bhindi, N and P uptake were highest for FYM plus neemcake whereas K uptake was maximum for FYM plus poultry manure at N_3 level of N (150 kg ha^{-1}) and with *Azospirillum* inoculation. The available N, P and K status of the soil was highest in FYM plus neemcake, FYM plus enriched compost and FYM alone treated plots respectively at N_3 level of nitrogen (150 kg ha^{-1}) and *Azospirillum* inoculation (Raj, 1999).

Rekha (1999) reported a significant increase in the uptake of nutrients like N, P, K, Ca and Mg by enriched vermicompost application.

Application of vermicompost enriched with rock phosphate increased the available N, P_2O_5 and K_2O status of the soil (Sailajakumari, 1999)

Srikanth *et al.* (2000) studied the direct and residual effect of enriched compost, FYM, vermicompost and fertilizers on the properties of Alfisol. According to him soil nutrient value was found to be high in enriched compost amended soil after the harvest of first and second crop. Slight decrease in bulk density after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment alone was noticed.

Latha *et al.* (2001) reported that the enrichment of manures with $ZnSO_4$ resulted in increased Zn availability in all stages of maize crop. It may be due to the direct addition of Zn by the organic matter besides the involvement of decomposition products in solubilization and complexation reaction.

Garcia *et al.* (2002) found that application of rock dust increased the microbial activity in the initial period of composting, the mesophilic phase resulting in increased temperature.

According to Senthilkumar and Surendran (2002) vermicompost influenced the physical, chemical and biological properties of soil. They also reported that it improved the WHC of soil and acted as a mineral for various plant essential nutrients such as N, P, K, S and trace elements.

Dahia *et al.* (2003) observed that application of sugarcane trash enriched with Mussorie rock phosphate and photosynthetic bacteria decreased bulk density, increased nutrient use efficiency mainly 'N' and 'P', increased the availability of N, P, Ca, Fe, Mn, Zn, enzyme activity, pH, EC and Hydraulic Conductivity and favored soil conditioning, aggregate stability and nutrient recycling.

According to Sheeba (2004), enriched vermicompost *i.e.,* vermicompost enriched with neemcake and bone meal reduced bulk density, CN ratio and increased pH, EC and organic carbon status of the soil.

Observations made by Deepa (2005) include increased P and K uptake by cowpea after the application of enriched vermicompost.

Maximum amount of soluble P was produced in composts prepared using rice straw, rock phosphate, *A.niger, T.viride* and FYM. (Zayed and Abdel-Motaal, 2005)

Application of composts amended with saw dust was found to increase the microbial population thereby increased the enzymatic activities and soil respiration. (Lovieno *et al.*, 2009)

Battikopad *et al.* (2009) reported that application of cattle dung enriched with rock phosphate along with Effective Micro - organisms (0.5 ml kg^{-1}) improved the microbial activities and enhanced the health and productivity of soil.

Poultry manure amended paddy straw compost improved microbial biomass and different enzymatic activities responsible for nutrient cycling. It was also noticed that highest grain yield of rice may be due to improved biological parameters of soil thereby improving soil health and productivity. (Gaind and Nain, 2010)

2.7 EFFECT OF ENRICHED MANURE ON GROWTH AND YIELD OF CROPS

Hamaker and Weaver (1982) reported that application of gravel dust in an organic garden @ 2 to 4 lbs per square feet resulted in an increased yield of 2 to 4 times.

Banergee and Das (1988) reported that application of enriched compost improved the growth attributes of potato as compared to uninoculated control.

From the experiments in various trees in Australia using granite and diorite @ 12 t to 20 t ha^{-1},Oldfield (1992) found that application of rock dust increased plant growth and nitrogen fixation capacity.

Edward (1993) found that application of volcanic dust increased the yield of banana by 80% in Australia.

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

Application of *Eudrillus* compost inoculated with *Azospirillum* and photosynthetic bacteria recorded highest plant height, number of leaves and shoot root ratio in chilli (Zachariah, 1995).

Becker (1995) found that application of granite, basalt, glacial silt along with compost increased the grain yield of maize.

In Australia, Bolland (1995) observed that application of granite increased the plant growth in wheat.

Campe *et al* (1996) reported that application of granite, basalt, sand silt increased 50% growth in maize.

In North Carolina, Scott (1995) observed that in natural forest, the application of sedimentary rock lowered plant mortality by 39%.

Dinakaran and Savithri (1995) reported that the effect of Vesicular Arbuscular Mycorrhizal fungi (VAM) in increasing dry matter production was positive and it was more pronounced at higher levels of P application in onion.

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

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

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

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

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

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

According to Newsham *et al.* (1995) compost inoculated with AM fungi led to an increase in plant growth.

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

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

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

Stoffella and Graetz (1996) reported that the total tomato yield was larger in plots amended with sugarcane filter cake compost as compared to control plots without compost.

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

Requena *et al.* (1996) reported that inoculation of composts with *Trichoderma* or *Streptomyces* improve plant growth and consequently uptake of nutrients from soil.

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

Mahimairaja and Perumal (1995) revealed that combined with organics or biofertilizers MRP performed equally good to that of DAP but gave significantly higher rice yield than control.

Yarrow (1997) found that application of granite increased the yield of potato and sugar beet in USA.

Meera (1998) reported that coating seeds with vermicompost combined with application of full inorganic fertilizers and FYM as organic source recorded the highest grain yield.

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

Vermicompost and phosphobacteria in combination with two inorganic P sources namely single superphosphate and Tumis rock phosphate (TRP) were verified in a calcareous black soil for their effect on yield parameters of black gram (Co-5) and cotton (LRA 5155). The application of TRP (100 percent) along with vermicompost and phosphobacteria in black gram recorded the highest grain and haulm yield. In cotton, effect of SSP and TRP on Kapar yield and Stover yield were on par (Thiyageswhwari and Perumal, 1998)

Improved plant growth and establishment through the application of basalt was reported from an experiment conducted at Scotland in *Brassicas* by Szmidt (1998).

Yarrow (1998) reported that the application azomite clay (rock dust) increased the plant height and earliness of flowering in tomatoes.

Bruck (1998) found that the application of rock dust increased the plant height of mahogany by 33.6%.

Addition of effective micro organisms to organic amendments enhance nutrient elements availability thereby influences plant growth. (Ni and Li, 1998)

Madeley (1999) conducted pot experiments using rock dust in lettuce, cress and *Brassicas* using perlite as medium. It was found that the initial growth rate of the rock dust applied lettuce plant were higher, when compared to control. He also reported that the shoot height, root length and plant weight were significantly higher in the rock dust applied plants. In the same study, it was also found that the application of rock dust increased plant growth and establishment in *Brassicas*.

Vermicompost application along with full recommended dose of NPK increases the growth and yield of okra (Ushakumari *et al.*, 1999)

Vasanthy and Kumaraswamy (1996) reported that application of vermicompost increased the rice grain yield.

Raj (1999) reported that growth characters like plant height, LAI, dry matter production, yield attributes like fruit number per plant, fruit weight, fruit length and fruit yield were higher in organic manure treated plots. FYM + neem cake recorded maximum number of fruits plant $^{-1}$, FYM+ neem cake and FYM+ green leaf recorded comparable and maximum yield of 158 and 153 q ha^{-1} respectively.

According to Sailajakumari (1999), application of enriched vermicompost (vermicompost enriched with RP) increased the plant height, number of branches, nodule number and yield in cowpea.

Sharanappa (2002) showed that application of FYM enriched with 10 percent by weight each of rock phosphate and gypsum maximized the grain yield of maize.

Sreenivas and Narayanasamy (2002) observed that enriched compost made out of *Trichoderma viride* (500g t^{-1}), 2% RP and 1% pyrite leads to better growth and higher yield.

Paddy straw compost prepared using *Trichoderma viride* along with rock phosphate increased the yield of crops. (Misra *et al.*, 2002).

Namdeo *et al.* (2003) reported that application of 60kg P_2O_5 ha^{-1} or Jhabua rock phosphate charged phosphocompost 2.5 t ha^{-1} or 25 percent Jhabua rock phosphate charged phosphocompost 1.5 t ha^{-1} showed statistically identical performance for growth and yield parameters of soybean and it was found to be superior than control (without P).

Dahia *et al.* (2003) observed that sugarcane trash enriched with MRP increased ratoon yield of sugarcane.

Deepa (2005) observed that application of enriched vermicompost increased number of flowers, number of pods and length of pod in cowpea.

Zayed and Abdel-Motaal (2005) reported that application of compost made using rice straw, *Trichoderma viride* and *Aspergillus niger* @ 300g along with 1% RP recorded highest grain yield in cowpea.

Field experiment conducted by Sahai *et al.* (2006) found that Zn enriched organic manures increase the grain and straw yield of rice and wheat.

The response of cassava to rock dust viz. khondalite was studied during 2001-2003 at FSRS, Kottarakara, Kerala by conducting field experiments. The results revealed that application of rock dust @ 1 t ha^{-1} along with 75% of the recommended dose of chemical fertilizer registered the highest yield of 21.32t ha^{-1} and it was on par with full and 50% of chemical fertilizers along with 1 t ha^{-1} rock dust (Shehana *et al.*, 2006).

Madhuri *et al.* (2006) conducted studies on the effect of organic manure and biofertilizers on growth and yield of turmeric at the College of Agriculture, Nagpur during 2003-2004. Application of $N:P_2O_5:K_2O$ @ 120:60:60 kg ha^{-1} recorded higher plant height, number of leaves, size and surface area of leaves, girth of pseudostem, number of tillers $plant^{-1}$ and fresh yield (t ha^{-1}) of turmeric over FYM applied @ 10 t ha^{-1} in combination with bio-fertilizer.

Rajamoni *et al.* (2006) observed highest rhizome yield, increased plant height and LAI of turmeric after the application of enriched manure.

According to Biswas and Narayanasamy (2006) compost made out of rice straw, RP and *Aspergillus awamori* recorded highest yield and P uptake in vegetables.

Sable *et al.* (2007) conducted studies on tomato var. Parbhani Yashshri at MAU, Parbhani during 2002-03 to study the effect of organic sources of nutrients on growth and yield of tomato on a slightly alkaline soil. Results revealed that organic mode of plant nutrition through various combinations of neemcake and vermicompost was found superior to chemical fertilizers alone. A higher number of branches and fruit yield with the combination of 50 per cent N through neem cake and 50 per cent N through vermicompost were recorded.

The increase in grain and straw yield in sweet sorghum by the combined use of urban compost and sewage - sludge in combination with FYM was reported by Reddy and Singh. (2007).

Pseudonumas and *Trichoderma* sp are promising bio- enhancers promoting the growth of tomato plants by synthesizing growth promoting substances. (Kumar *et al.*, 2007)

According to Siddiqui *et al.* (2008) Okra crops receiving rice straw compost extract fortified with *Trichoderma harzianum* gave significantly better growth performance and yield due to stimulation of growth by improving the nutrient efficiency.

Singh *et al.* (2009) observed that yield of coriander increased after the application of P and S enriched vermicompost.

Pandhare *et al.* (2009) found that enriched compost made using *Azotobacter chroococcum* and PSB increased the number of leaves, height of plant and number of days required for the emergence of spike in tuberose.

According to Dheware and Waghmare (2009) compost prepared using *Azospirillum, Bacillus polymyxa, B. subtilis* and *Pseudomonas striata* increased number of fruits per tree and average weight of fruit in sweet orange.

Singh *et al.* (2009) reported that maximum plants height, number of tillers plant^{-1} and fresh rhizome yield of ginger were recorded after the combined application of FYM, neemcake and RP.

Highest rhizome yield was recorded with the application of poultry manure enriched with microbial inoculant followed by *Trichoderma viride*-banana pseudostem compost @ 750kg ha^{-1} along with 75% of the recommended dose of fertilizer (Thenmozhi and Paulraj, 2009).

Yadav *et al.* (2009) observed 44.5 % yield increase in rice after the application of a combination of poultry manure, FYM and pressmud each @ 5t ha^{-1}.

Amendment of paddy straw with fungi like *Aspergillus, Trichoderma* and *Phanerochaete* recorded highest yield in rice. (Gaind and Nain, 2010)

2.8 EFFECT OF ENRICHED MANURES ON QUALITY OF CROPS

Tomati *et al.* (1990) reported that incorporation of vermicompost increased protein content in lettuce and radish.

Pushpa (1996) reported that an increase in protein content in tomato fruits after the application of vermicompost.

Vermicompost application increased the sweetness of njalipoovan fruit (Ushakumari *et al.*, 1997)

Starch content of sweet potato tuber was maximum when N was given as vermicompost. (Sureshkumar, 1998)

Gollagi (1999) noticed an improvement in quality parameters of *chilli* with combined application of micronutrients and growth regulators.

Raj (1999) reported that crude protein content and ascorbic acid content were maximum for FYM in combination with poultry manure and FYM along with enriched compost respectively in bhindi. FYM+enriched compost and FYM+neemcake recorded comparable and lowest crude fibre content and highest keeping quality of fruits.

Jasmin (1999) found that soil application of vermiwash produced fruits with more shelf life and produced positive influence on the lycopene content of tomato but no influence on the ascorbic acid and crude fibre content.

Sailajakumari (1999) found the superiority of vermicompost enriched with rockphosphate on the quality of cowpea.

Arunkumar (2000) reported that application of vermicompost to *Amaranthus* recorded significantly high ascorbic acid and low fibre content.

Shashidhara (2000) found that the combined application of both organics and inorganics significantly increased the ascorbic acid compared to 100 per cent RDF alone.

Protein content of cowpea grains were more in vermicompost treated plants compared to FYM. (Sailajakumari and Ushakumari, 2001)

In an experiment it was noted that combination of FYM, organic manure and Neemax (biopesticide) gave higher yield, protein and vitamin C content with prolonged shelf life in fresh beans (Singh, 2002).

The palatability and quality of vegetable crops were enhanced by a combination of poultry manure along with weed compost. (Berry *et al.*, 2003).

Renu (2003) reported that texture, odour and keeping quality of bittergourd were well pronounced with vermicompost application.

Sheeba (2004) showed that application of vermicompost enriched with neemcake and bone meal improved β carotene, protein and reduced fibre content in *Amaranthus.*

Significantly higher crude protein content was recorded in treatments that received vermicompost in blackgram. (Vasanthi and Subramanian, 2004)

Patil *et al.* (2004) reported that application of FYM (50 %) along with half RDF recorded maximum number of fruits plant^{-1} and the highest fruit yield, fruit juice, TSS and ascorbic acid content over 100 per cent RDF in tomato.

According to Deepa (2005) application of enriched vermicompost increased shelf life and crude protein content of cowpea pods.

According to Thimma (2006),the quality parameters like oleoresin per cent increased by 13.89, 6.60, 3.70 and 2.30 percent with application of poultry manure @ 7.50 t ha^{-1}, vermicompost @ 10 t ha^{-1}, FYM (50 %) + vermicompost (50 %), FYM (50 %) + neem cake (50 %), respectively over RDF alone in chilli.

Santoshkumar and Shashidhara (2006) reported that the application of FYM @ 10 t ha^{-1} along with RDF increased oleoresin content and yield by 16.97 per cent and 124.23 kg ha^{-1}, respectively over 100 per cent RDF alone (14.53 per cent and 87.50 kg ha^{-1}, respectively) in chilli.

Rajamoni *et al.* (2006) reported that application of enriched manure increased curcumin content, oleoresin, essential oil and chlorophyll content of leaves in turmeric.

According to Chandrakala (2008) the combined application of Beejamrut + Jeevamrut + Panchagavya and Panchagavya alone increased ascorbic acid, oleoresin and colour value by 8.02 and 6.74, 7.89 and 7.00 and 8.25 and 7.17 per cent, respectively over control .

Singh *et al.* (2009) observed that oleoresin and essential oil content in coriander increased after the application of 'P' and 'S' enriched vermicompost.

Ascorbic acid content of sweet orange increased due to the application of compost inoculated with *Azospirillum, B. polymyxa, B. subtilis* and *P. striata* (Dheware and Waghmare, 2009)

Singh *et al.* (2009) observed an enhancement in quality of ginger by the use of a combination of FYM, neemcake and rockphosphate.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Organic nutrition for soil health and productivity of Chilli (*Capsicum annuum* L.) has been carried out at College of Agriculture, Vellayani during 2009-2010. The main objective of the study was to assess the effect of enriched composts on physico-chemical and biological properties of soil and to study its impact on crop performance. The investigation consisted of two parts (1) preparation of enriched composts and growth promoters and (2) field experiment. The materials used and the methods adopted for the studies are briefly discussed in this chapter.

3.1. MATERIALS

3.1.1. Location

The field experiment was laid out in the Vth block of Instructional Farm, College of Agriculture, Vellayani. Geographically the area is situated at 8^0 30' North latitude and 76^0 54' East longitude and at an altitude of 29m above MSL.

3.1.2. Season

The period of crop growth was from June 2009 to November 2009. Average rainfall, temperature, evaporation and relative humidity at monthly intervals collected from meteorological observatory attached to the College of Agriculture, Vellayani during the cropping period were given in Appendix II and graphically presented in Fig.1.

3.1.3. Soil

The soil of the experimental site was sandy clay loam belonging to the family of Loamy Kaolinitic Isohyperthermic Typic Kandiustult. The initial data on physical, chemical and biological properties of soil where the field experiment conducted are given in Table 1.

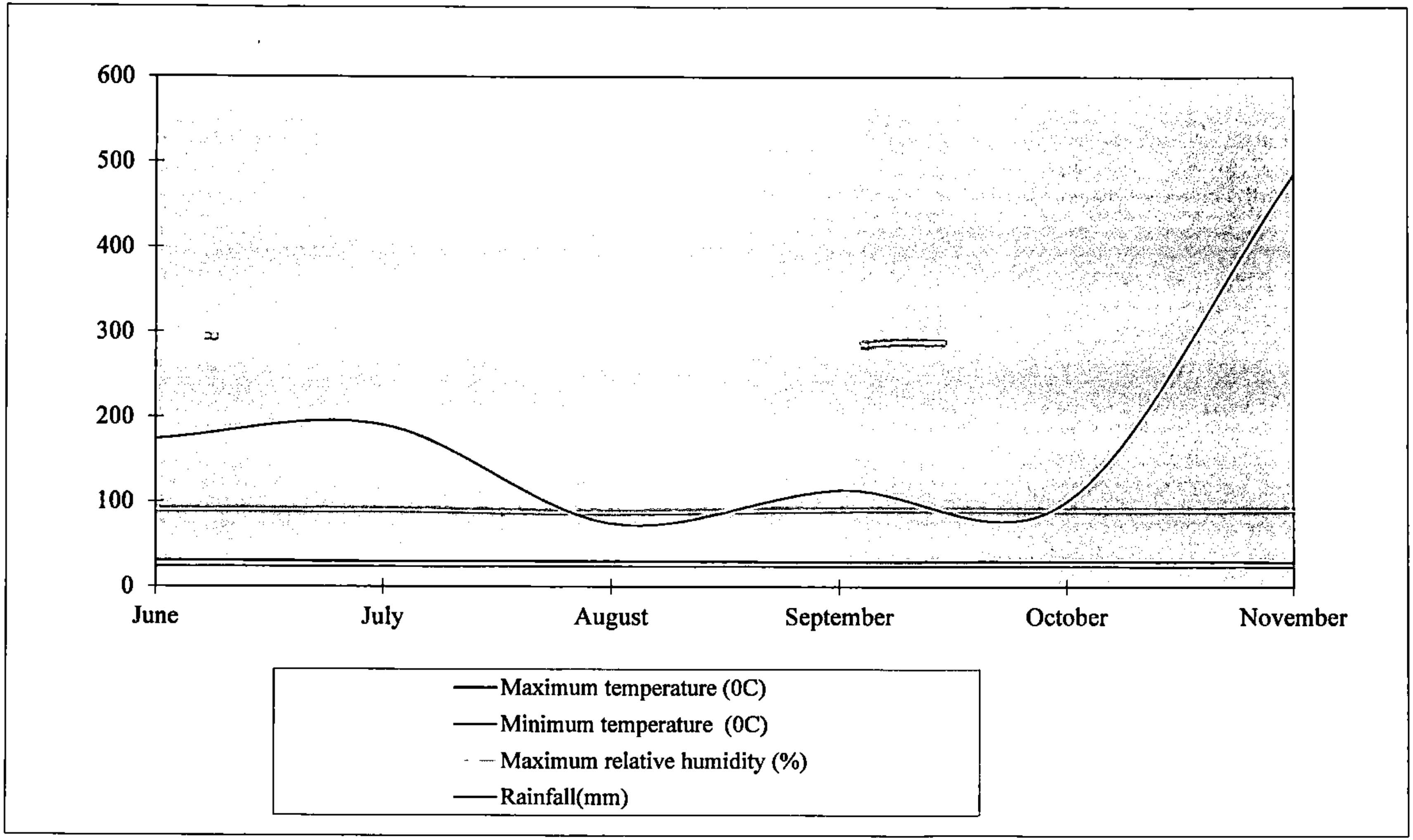

Fig.1. Weather parameters during field experiment

Table 1 Physical, chemical and biological properties of soil of the experimental site

Sl No.	Parameters	Content
	A. Physical properties	
1	Mechanical composition	
	Sand	63.09%
	Silt	10.38%
	Clay	26.53%
2	Texture	Sandy clay loam
3	Bulk Density	1.47 Mg m^{-3}
4	Particle Density	2.56 Mg m^{-3}
5	Porosity	42.58%
6	WHC	23.89%
7	pH	5.50
8	EC	169.90 µS m^{-1}
	B. Chemical Properties	
9	Organic carbon	0.41% (low)
10	Available N	244.60 kg ha^{-1} (low)
11	Available P	41.43 kg ha^{-1} (high)
12	Available K	114.89 kg ha^{-1} (medium)
13	Exchangeable Ca	1.09 c mol(+) kg^{-1}
14	Exchangeable Mg	1.32 c mol(+) kg^{-1}
15	Micronutrients	
	Fe	16.10 ppm
	Mn	9.70 ppm
	Zn	1.40 ppm
	Cu	0.52 ppm
	C. Biological Properties	
16	Dehydrogenase	76.70 µg TPF g^{-1} h^{-1}
17	Microbial count	
	Fungi	12.7×10^{4} CFU g^{-1} soil
	Bacteria	21×10^{6} CFU g^{-1} soil
	Actinomycetes	4.3×10^{8} CFU g^{-1} soil

3.1.4. Crop

Chilli variety 'Vellayani Athulya' was used as test crop for the experiment. The seed material was obtained from the Department of Olericulture, College of Agriculture, Vellayani.

3.1.5. Manures

Two composts *viz.* Biomineral compost (BM compost), Effective Micro-organism compost (EM compost) and two growth promoters (liquid organic manures) namely Panchagavya and Vermiwash were applied as per the treatments.

3.1.5.1. Preparation of Manures

3.1.5.1.1. Preparation of Biomineral Compost (BM compost)

Pits of size 2.5×1×0.5 m were used for the preparation of compost and the biowastes used were banana pseudostem and dried leaves of banana. The biowastes were collected, chopped and mixed with cowdung in the ratio of 10:1 on volume basis. Natural additive *viz.* rockdust @ 5% was added initially to the biowaste-cowdung mixture. After two weeks microbial inoculant *Trichoderma* spp. @ 0.2% was added. The pit was watered daily to ensure optimum moisture level *i.e.*, 60-70% and compost was ready for application at 80^{th} day.

3.1.5.1.2. Preparation of EM Compost

The raw materials used and the methods adopted were the same as that in the preparation of BM compost. Two weeks after filling the pit, activated EM solution was sprayed @ 2ml L^{-1} on the biowaste-cowdung mixture to moisten the mixture and mixed thoroughly. The moisture was maintained at 60-70% level and the compost was ready for field application at 70^{th} day. Method for preparation of activated EM solution is given in Appendix I.

3.1.5.2. Preparation of Growth Promoters

3.1.5.2.1. Preparation of Vermiwash

A cement tank of size $80cm^3$ was constructed for the collection of Vermiwash as is given in plate 5(A). A layer of gravels was placed at the bottom of the tank. Above it a layer of coconut fibre of 3-4 cm thickness was placed. A definite quantity of biowaste *(i.e.* banana pseudo stem and leaves-4 kg) was

Plate 1 Vermicomposting yard

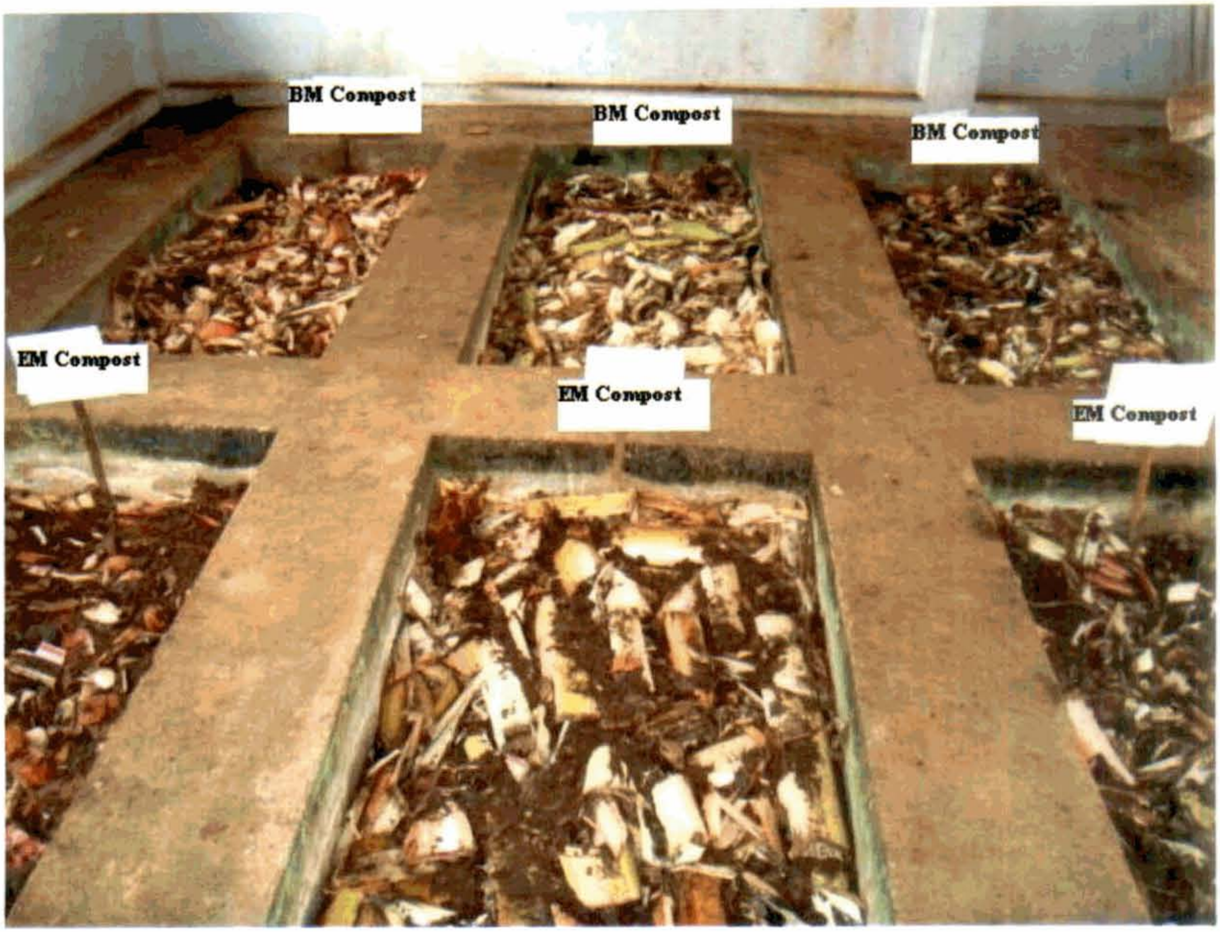

Plate 2 Production of BM compost and EM compost

Plate 3 EM compost

Plate 4 BM compost

added to the system along with 2 kg of earthworms. After 2 weeks the entire mass of the biowaste turned into brownish black compost. Then 2L of water was added to the tank containing freshly formed compost and earthworms. Vermiwash was collected through the side tap after 24 hours. Again the biowaste was added to the system and the process was repeated till the entire quantity of Vermiwash required for the experiment was collected. (KAU,2009).

3.1.5.2.2. Preparation of Panchagavya

Cowdung (7 kg) and cowghee (1 kg) were mixed in a clean plastic container thoroughly both in morning and evening hours and kept aside for 3 days. After 3 days cow's urine (10L) and water (10L) were added. The mixture was kept for 15 days with regular mixing both in morning and evening hours. After 15 days, cow milk (3L), cow curd (2L), tender coconut water (3L), jaggery (3 kg) and well ripened poovan banana (12 numbers) were added to the mixture. It was stored in shade covered with plastic mosquito net. Panchagavya stock solution will be ready after 30 days (KAU,2009).

3.1.6. Fertilizers

Urea analysing 46% N, Rajphos with 20% P_2O_5 and MOP analysing 60% K_2O were applied as per the Package of Practices Recommendations of Kerala Agricultural University (KAU, 2007).

3.2. METHODS

The different methods used for the analysis of soil, manures and plant samples and details of field experiment are presented below.

3.2.1. Design and Layout of The Experiment (Fig.2)

Design: Randomised Block Design

Replication:2

Treatments:16

Plot size:6 m^2

Spacing:45×45 cm

Treatments:

(A) Vermiwash Collection Tank

(B) Tank Overview

Plate 5 Vermiwash Collection Tank

Plate 6 Vermiwash

Plate 7 Panchagavya

The experiment was conducted by adopting the following treatments.

T_1: Absolute control

T_2: POP (FYM @ 20-25 t ha^{-1}, NPK @ 75:40:25 kg ha^{-1})

T_3: 100% N as EM compost

T_4: 100% N as BM compost

T_5: 75% N as EM compost

T_6: 75% N as BM compost

T_7: 75% N as EM compost + Panchagavya

T_8: 75% N as BM compost + Panchagavya

T_9: 75% N as EM compost + Vermiwash

T_{10}: 75% N as BM compost + Vermiwash

T_{11}: 50% N as EM compost

T_{12}: 50% N as BM compost

T_{13}: 50% N as EM compost + Panchagavya

T_{14}: 50% N as BM compost + Panchagavya

T_{15}: 50% N as EM compost + Vermiwash

T_{16}: 50% N as BM compost + Vermiwash

Layout plan of the experiment is presented in Fig.2.

N

R_1T_2	R_1T_{13}	R_1T_1	R_1T_7	R_1T_6	R_1T_4	R_1T_{15}	R_1T_{12}
R_1T_3	R_1T_{16}	R_1T_{14}	R_1T_{11}	R_1T_{10}	R_1T_8	R_1T_5	R_1T_9
R_2T_4	R_2T_{14}	R_2T_7	R_2T_{13}	R_2T_{15}	R_2T_{16}	R_2T_2	R_2T_{11}
R_2T_1	R_2T_{12}	R_2T_3	R_2T_{10}	R_2T_8	R_2T_5	R_2T_9	R_2T_6

3.2.2. Nursery

Raised bed of 1×1 m size was prepared for raising seedlings. Seeds of chilli variety 'Vellayani Athulya' were soaked in *Pseudomonas* solution (2%) for 30 minutes before sowing. The seeds were sown and irrigated twice in a day.

3.2.3. Land Preparation

The main field was worked to a fine tilth and plots of size 3×2 m were taken with bunds of width 20 cm all around. Small ridges were taken 45 cm apart. One month old seedlings were transplanted in the furrows at 45 cm spacing. The seedlings were given uniform irrigation and shade was also provided till they were established.

3.2.4. Application of Manures and Fertilizers

3.2.4.1. Application of Fertilizers

Fertilizers were applied as per the schedule of treatments. The entire dose of P, half the quantity of N and K were applied as basal dressing. 1/4th N and ½ of K were applied 1 MAT and the remaining quantity of N was applied 2 MAT.

3.2.4.2. Application of Composts

½ the quantity of N was given as basal dressing according to the treatments. 1/4th N was applied 1 MAT and the remaining quantity of N was applied 2 MAT.

3.2.4.3. Application of Growth Promoters

Panchagavya @ 3% and Vermiwash @ 10% were sprayed 2 WAT and continued at fortnightly intervals. Foliar spray was done in the early morning using Knapsac sprayer.

3.2.5. Maintenance of Crop

During the initial stages irrigation was given twice daily. Gap filling was done on the 5th day after transplanting. Weeds were removed as and when necessary.

3.2.6. Incidence of Pests and Diseases

Occurrence of mosaic disease was found even in the early stages which could be effectively controlled by spraying 2% nimbicidin to control the vector transmitting the disease. *Colletotrichum* fruit rot appeared during the fruit maturity stage. Disease incidence was calculated as average of the disease occurrence throughout the crop period. A few fruits showed blossom end rot in the maturity stage.

3.2.7. Harvest

The crop was ready for first harvest 2 MAT and subsequent harvests were made at 10 days interval. The fruits were picked when a slight yellowish green colour appeared.

3.2.8. Biometric Observations

3.2.8.1. Days to 50% Flowering

Number of days taken for 50% of the plant population to flower in each plot was recorded by visual observation.

3.2.8.2. Plant Height (cm)

Height of the plant from the base to the growing tip at 3 stages *viz.* 30, 60 and 90 DAT were taken from four observational plants. The mean plant heights were worked out and expressed in cm.

3.2.8.3. Number of Primary Branches

Number of primary branches at 3 stages *viz.* 30, 60 and 90 DAT were taken and the mean worked out.

3.2.9. Yield and Yield Attributes

3.2.9.1. Number of Fruits Plant^{-1}

Numbers of fruits on four observational plants were recorded and the mean worked out.

3.2.9.2. Length and Girth of Fruit (cm)

Lengths of randomly selected fruits from the four observational plants were measured and mean worked out and expressed in cm. Fruits used for measuring length were used for recording the girth also. It was measured at the broadest part of fruit and expressed in cm.

3.2.9.3. Fruit Weight (g)

Weights of randomly selected fruits from four observational plants were taken and mean weight of single fruit was calculated by dividing the total weight by the total number of fruits and expressed in g.

3.2.9.4. Green Fruit Yield Plant^{-1} (g plant^{-1})

Summing up the weights of fruits on the four observational plants and the mean worked out and expressed in g plant^{-1}.

3.2.9.5. Total Fruit Yield (t ha^{-1})

Summing up the total weights of fruits and mean worked out and expressed in t ha^{-1}.

3.2.9.6. Total Drymatter Yield (t ha^{-1})

Observational plants were carefully removed and the aerial part was taken and oven dried to constant weight at 70^{0}C. The weight was averaged and expressed in t ha^{-1}.

3.3. Incidence of Pests and Diseases

Occurrence of *Collectotrichum* sp. was noticed during 75-80 DAT. Average of the percentage disease incidence was calculated at various stages throughout the crop period. 2% Nimbicidin was sprayed at fortnightly intervals to control white flies transmitting mosaic disease. No other serious pests or diseases were reported.

3.3.1. Quality Parameters of Fruit

3.3.1.1. Capsaicin (%)

Estimated by colourimetric method (Balasubramanian et al., 1982).

3.3.1.2. Oleoresin(%)

Oleoresin was estimated by Soxhlet distillation method (AOAC, 1997) and expressed as percentage on dry weight basis.

3.3.1.3. Ascorbic Acid (mg 100g^{-1})

Estimated by titrimetric method (Sadasivam and Manickam, 1992).

3.3.1.4. Shelf Life

Sample fruits were taken treatment wise separately and the number of days taken from the harvest of fruits to the stage at which fruits become shrunken and lost firmness was recorded.

3.3.2. Uptake of NPK by the Crop (kg ha^{-1})

Plant parts were analysed for NPK content using standard procedures and total uptake was calculated based on their contents in the parts and their corresponding drymatter weight.

3.3.3. ANALYTICAL PROCEDURES

3.3.3.1. Soil Analysis

Soil samples were taken from the experimental area before the start of the experiment and after the experiment. The air-dried samples passed through 2 mm sieve were used for the analysis of physico-chemical properties and fresh soil samples were collected for biological analysis using standard procedures given in Table 2.

Table 2 Analytical procedures followed in soil analysis

Sl No	Properties	Method	Reference
	A. Physical Properties		
1	Texture	International pipette method	Piper(1966)
2	Bulk Density	Core method	Gupta and Dakshinamurthy (1980)
3	Particle Density	Core method	Gupta and Dakshinamurthy (1980)
4	Porosity	Core method	Gupta and Dakshinamurthy (1980)
5	Water Holding Capacity	Core method	Gupta and Dakshinamurthy (1980)
6	Moisture	Core method	Gupta and Dakshinamurthy (1980)
7	pH	pH meter	Jackson (1973)
8	EC	Conductivity meter	Jackson (1973)
	B. Chemical Properties		
9	Organic carbon	Walkley and Black rapid titration method (1934)	Jackson (1973)
10	Available N	Alkaline permanganate method	Subbiah and Asija (1956)
11	Available P	Extraction with Bray and estimation by colorimetry	Jackson (1973)
12	Available K	Flame photometry	Jackson (1973)
13	Exchangeable Ca	Neutral normal ammonium acetate extraction and titration	Hesse (1971)
14	Exchangeable Mg	Neutral normal ammonium acetate extraction and titration	Hesse (1971)
15	Available Fe, Mn, Zn, Cu	DTPA extraction and AAS	Lindsay and Norvell (1978)

Table 2 Analytical procedures followed in soil analysis (continued)

Sl No	Properties	Method	Reference
	C. Microbial Properties		
16	Dehydrogenase	TPF method	Page et al. (1982)
17	Microbial count Fungi, Bacteria Actinomycetes	Serial dilution plate technique	Timonin (1940)

3.3.3.2. Analysis of Manures

Enriched manures and growth promoters were analysed for pH, EC, organic carbon, total nitrogen, total phosphorus, total potassium, C:N, calcium, magnesium, zinc, iron, copper, manganese and microbial count using standard analytical procedures (Table 3) and data are presented in Table 4.

Table 3 Analytical procedures followed in the analysis of manures

Sl No	Parameters	Methods	Reference
1	Organic carbon	Walkley and Black rapid titration method (1934)	Jackson (1973)
2	Nitrogen	Digestion in H_2SO_4 and microkjedahl distillation	Jackson (1973)
3	Phosphorus	Nitric-perchloric(9:4) digestion and colorimetry	Jackson (1973)
4	Potassium	Nitric-perchloric(9:4) digestion and flamephotometry	Jackson (1973)
5	Calcium	Nitric-perchloric(9:4) digestion and estimation by Versanate method	Jackson (1973)
6	Magnesium	Nitric-perchloric(9:4) digestion and estimation by Versanate method	Jackson (1973)
7	Fe, Mn, Zn, Cu	Nitric-perchloric(9:4) digestion and AAS	Jackson (1973)
8	pH	pH meter method	Jackson (1973)
9	EC	Conductivity meter method	Jackson (1973)
10	Microbial count	Serial dilution plate technique	Timonin (1940)

Table 4 Property of manures

Sl No	Properties	BM compost	EM compost	Panchagavya	Vermiwash
1	Organic carbon (%)	17.23	16.45	0.80	0.22
2	Nitrogen	0.83%	0.76%	229 ppm	200 ppm
3	Phosphorus	0.62%	0.56%	209 ppm	60 ppm
4	Potassium	1..38%	1.24%	232 ppm	810 ppm
5	Calcium (ppm)	394.50	386.50	27.00	112.00
6	Magnesium (ppm)	237.50	212.50	25.00	32.00
7	Iron (ppm)	417.50	477.50	0.83	8.29
8	Manganese (ppm)	14.25	9.15	0.23	0.12
9	Copper (ppm)	0.98	0.82	0.20	0.22
10	Zinc (ppm)	7.00	5.25	0.26	0.52
11	pH	7.39	6.27	5.90	8.70
12	EC (dS m^{-1})	3.30	3.27	10.20	4.40
13	Microbial count (CFU g^{-1}) a. Fungi b. Bacteria c. Actinomycetes	19.4×10^4 25×10^6 3.7×10^8	13×10^4 15.7×10^6 1.7×10^8	22.7×10^4 50.3×10^6 5.3×10^8	12.3×10^4 30×10^6 1.3×10^8

3.3.3.3. Plant Analysis

One plant out of the observational plants was uprooted after harvest and the root was removed. The plant was chopped, air dried and then dried at 70^0C in a hot air oven. The dried samples were powdered and used for analysis. The standard procedures adopted are given in Table 5.

Table 5 Analytical methods followed in plant analysis

Sl No	Parameters	Methods	Reference
1	Nitrogen	Microkjedahl distillation after digestion in H_2SO_4	Jackson (1973)
2	Phosphorus	Nitric-perchloric (9:4) digestion and colorimetry using Vanadomolybdo-phosphoric yellow colour method	Jackson (1973)
3	Potassium	Nitric-perchloric (9:4) digestion and flame photometry	Jackson (1973)

3.3.3.4. Statistical Analysis

Data generated from the experiment were subjected to statistical analysis applying ANOVA technique and significance tested by 'F' test (Snedecor and Cochran, 1975). In the cases where the effects were found to be significant, CD was calculated using standard techniques.

3.3.3.5. Economic Analysis

Economics of cultivation was worked out for the field experiment after taking into account the cost of cultivation and prevailing market price of chilli. The net income and BC ratio were calculated as follows.

Net income (Rs/ha) = Gross income- Total expenditure

Benefit: Cost ratio = Gross income/Total expenditure

RESULTS

4. RESULTS

The present study was undertaken to schedule organic nutrition strategies to enhance the health of the soil and organic production of the test crop, chilli. The study comprised of a field experiment to test the efficiency of various organic nutrient sources.

Results based on statistically analysed data pertaining to the experiment conducted during the course of investigation are presented in this chapter.

4.1. FIELD EXPERIMENT

Field experiment was conducted to evaluate relative efficiency of different organic sources to release nutrients and their influence on physico-chemical and biological properties of soil and also their influence on the growth and productivity of the test crop, chilli.

4.1.1. Biometric Observations

The data of various biometric observations are presented in the tables 6 to 7. Various growth characters of crop *viz.* plant height, number of primary branches at different stages of plant growth (30, 60 and 90 DAT) and days to 50% flowering were recorded and presented.

4.1.1.1. Plant Height

Plant height was significantly influenced by the application of organic sources (Table 6).

At 30 DAT highest mean value for plant height (26.15 cm) was recorded by the treatment T_8(75% N as BM compost + Panchagavya) and was significantly superior to all other treatments. Second best treatment was T_7 (75% N as EM compost + Panchagavya)(23.97cm) and was found to be on par with the treatment T_4(100% N as BM compost)(23.78cm). The treatment T_1 (Absolute control) registered the lowest mean value (17.78 cm).

For the observation at 60 DAT, treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value for the plant height (44.27 cm). Second best treatment was T_7 (75% N as EM compost + Panchagavya)(39.62cm)

Plate 8 General view of field experiment

Plate 10 Vellayani Athulya

(A) Seedling stage

(B) Flowering stage

(B) Bearing stage

Plate 9 Stages of chilli in the field

Table 6 Plant height(cm) and number of primary branches affected by different organic manures on chilli

Treatments	Plant height(cm)			Number of primary branches		
	30 days	60 days	90 days	30 days	60 days	90 days
T_1	17.78	27.69	32.88	2.00	3.88	5.50
T_2	22.43	32.68	43.76	2.00	3.88	6.00
T_3	23.33	33.13	41.49	2.00	4.63	7.50
T_4	23.78	34.26	43.13	2.50	4.38	8.50
T_5	21.12	32.02	41.14	3.00	5.25	6.50
T_6	21.70	32.54	40.71	2.50	4.25	5.50
T_7	23.97	39.62	51.65	3.00	4.00	8.50
T_8	26.15	44.27	57.52	2.50	4.63	9.50
T_9	22.80	37.62	46.40	2.50	4.88	6.50
T_{10}	22.49	38.36	47.29	2.00	4.88	6.00
T_{11}	19.08	30.70	39.85	2.00	4.38	5.50
T_{12}	19.47	31.52	39.83	2.00	4.38	6.00
T_{13}	21.81	34.11	44.57	2.00	4.25	7.00
T_{14}	22.84	35.89	44.92	2.50	3.63	7.50
T_{15}	21.29	34.12	42.59	2.00	5.00	6.00
T_{16}	22.14	33.84	42.79	2.50	4.75	6.50
CD(0.05)	0.54	0.55	0.47	NS	NS	1.26

NS- Non significant

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

followed by the treatment T_{10} (75% N as BM compost + Vermiwash) with a mean value of 38.36cm. The lowest mean value of 27.69 cm was registered by the treatment T_1 (Absolute control). Treatments T_4, T_{15}, T_{13} and T_{16} were on par.

The treatment T_8 (75% N as BM compost + Panchagavya) represented the highest mean value (57.52 cm) for the observation at 90DAT also and second best treatment was T_7 (75% N as EM compost + Panchagavya)(51.65cm) followed by the treatment T_{10} (75% N as BM compost + Vermiwash)(47.29cm). The treatment T_1 (Absolute control) registered the lowest value (32.88 cm). In general, the plant height showed an increasing trend during the three observations.

4.1.1.2. Primary Branches per Plant

Table 6 represents the mean number of primary branches per plant during the three observations, *i.e.,* (30, 60 and 90 DAT). It was observed that there was no significant difference in the number of primary branches due to different treatments during 30 and 60 DAT. At 90 DAT, highest mean value of 9.50 was registered by the treatment T_8 (75% N as BM compost + Panchagavya) and was on par with T_7 (75% N as EM compost + Panchagavya) and T_4(100% N as BM compost). The treatment T_1 recorded the lowest value (5.50). The treatments T_1, T_9, T_{10}, T_{12}, T_{15}, T_2, T_6 and T_{11}were found to be on par.

4.1.1.3. Days to 50% Flowering

Table 7 shows the number of days taken for 50% of the plant to flower in a plot after transplanting. Result indicated that different treatments did not significantly influence days to 50% flowering.

4.1.2. Yield and Yield attributes

4.1.2.1. Number of Fruits Plant^{-1}

The results revealed that number of fruits plant^{-1} was significantly influenced by different treatments (Table 7). Highest mean value of 27.00 was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) and it was found to be on par with T_7 (75% N as EM compost + Panchagavya) with a value of 25.50. The treatment T_1 (Absolute control) recorded the lowest value of 14.50. Treatments T_7, T_{10}, T_{14}, T_4 and T_9 were on par.

Table 7 Days to 50% flowering and number of fruits plant $^{-1}$ affected by different organic manures on chilli

Treatments	Days to 50% flowering	Number of fruits plant^{-1}
T_1	31.50	14.50
T_2	31.00	21.50
T_3	31.50	22.00
T_4	31.50	24.00
T_5	30.50	21.50
T_6	31.00	21.50
T_7	30.00	25.50
T_8	30.50	27.00
T_9	31.00	23.50
T_{10}	31.50	24.00
T_{11}	31.50	17.00
T_{12}	31.50	19.50
T_{13}	30.50	22.50
T_{14}	31.00	24.00
T_{15}	31.50	22.00
T_{16}	31.50	22.50
CD(0.05)	NS	2.43

NS- Non significant

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

4.1.2.2. Fruit Length

Table 8 reveals that fruit length was significantly influenced by different treatments. Highest value of 16.10 cm was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) and it was found to be on par with T_7 (75% N as EM compost + Panchagavya) which registered a mean value of 15.94 cm. Lowest value of 13.24 cm was recorded by the treatment T_1 (Absolute control).

4.1.2.3. Fruit Girth

Fruit girth was significantly influenced by different treatments (Table 8). The treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value of 9.49 cm which was statistically superior to all other treatments. Second best treatment was T_7 (75% N as EM compost + Panchagavya)(8.79cm) and was found to be on par with treatments T_{13}, T_{14} and T_{16} .Lowest value was recorded by T_1(Absolute control) with a mean value of 7.61 cm. Treatments T_1 and T_{11} (50% N as EM compost) were found be on par.

4.1.2.4 Fruit Weight

Table 8 presents the mean fruit weight of the plant. It was observed that there was significant difference in fruit weight due to different treatments. Highest mean value of 19.59g was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). The lowest mean value of 11.00g was recorded by the treatment T_1 (Absolute control). Treatments T_1, T_{11} (50% N as EM compost) and T_{12} (50% N as BM compost) were on par.

4.1.2.5. Total Fruit Yield

Total fruit yield was significantly influenced by different treatments (Table 9). The highest mean value of 36.52 t ha^{-1} was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) and was significantly different from all other treatments. Second best treatment was T_7 (75% N as EM compost + Panchagavya) (33 t ha^{-1}) .Lowest mean value of 6.90 t ha^{-1} was recorded by the treatment T_1 (Absolute control). Treatments T_2 and T_9 and T_{10} were found to be on par.

Table 8 Fruit length(cm) , weight (g) and girth (cm) affected by different organic manures on chilli

Treatments	Fruit length (cm)	Fruit weight (g)	Fruit girth (cm)
T_1	13.24	11.00	7.61
T_2	14.75	15.69	8.40
T_3	15.04	16.00	8.45
T_4	15.01	16.16	8.46
T_5	14.47	13.46	8.31
T_6	14.51	13.65	8.29
T_7	15.94	18.20	8.79
T_8	16.10	19.59	9.49
T_9	14.81	15.40	8.49
T_{10}	14.89	15.45	8.42
T_{11}	13.69	11.25	7.79
T_{12}	14.22	12.00	8.15
T_{13}	15.10	14.80	8.61
T_{14}	15.15	14.86	8.71
T_{15}	14.74	14.63	8.46
T_{16}	14.76	14.59	8.56
CD(0.05)	0.21	1.28	0.30

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

4.1.2.6. Green Fruit Yield Plant^{-1}

Table 9 shows the mean value of green fruit yield per plant. It was observed that there was significant difference in the fruit yield per plant due to various treatments. Highest mean value of 438.25 g plant^{-1} was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). Second best treatment was T_7 (75% N as EM compost + Panchagavya) with a mean value of 326.63g plant^{-1}. Treatment T_1(Absolute control) recorded the lowest mean value of 135.00gplant^{-1} Treatments T_2 and T_4 (100% N as BM compost) were found to be on par.

4.1.2.7. Total Drymatter Yield

Total drymatter yield was significantly influenced by different treatments (Table 9). Treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value (2.55 t ha^{-1}) followed by the treatment T_{10} (75% N as BM compost +Vermiwash) and T_{10} was found to be on par with treatments T_9, T_7, T_{14}, T_2, T_{13} and T_{16}. The lowest value (1.07 t ha^{-1}) was registered by the treatment T_1 (Absolute control).

4.1.3. Incidence of Pests and Diseases

Application of Nimbicidin reduced the vectors transmitting the mosaic disease and no other serious pests were reported. There was significant difference among treatments with respect to disease incidence percentage (*Colletotrichum* fruit rot) (Table 10). Highest value (62.50%) was recorded by the treatment T_1 (Absolute control). Treatment T_8 (75% N as BM compost + Panchagavya) registered the lowest mean value of 19.65% and it was found to be on par with T_4 (100% N as BM compost).

4.1.4. Quality Parameters of Fruit

4.1.4.1. Capsaicin

Data on capsaicin content are presented in Table 11. Different treatments significantly influenced capsaicin content of the fruit. Treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value of 0.79% and it was found to be on par with treatments T_7 (75% N as EM compost +

Table 9 Green fruit yield plant^{-1} (g plant^{-1}), total fruit yield (t ha^{-1}) and total drymatter yield (t ha^{-1}) affected by different organic manures on chilli

Treatments	Green fruit yield plant^{-1} (g plant^{-1})	Total fruit yield (t ha^{-1})	Total drymatter yield (t ha^{-1})
T_1	135.00	6.90	1.07
T_2	225.63	12.13	1.73
T_3	202.63	11.48	1.48
T_4	223.75	11.63	1.50
T_5	185.88	9.25	1.37
T_6	188.25	11.21	1.39
T_7	326.63	33.00	1.85
T_8	438.25	36.52	2.55
T_9	231.25	12.83	1.84
T_{10}	256.88	12.67	1.89
T_{11}	143.75	8.37	1.31
T_{12}	146.90	8.05	1.31
T_{13}	200.63	11.25	1.66
T_{14}	213.13	11.53	1.74
T_{15}	160.13	10.23	1.60
T_{16}	164.37	10.49	1.66
CD(0.05)	4.11	0.98	0.21

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

Table 10 Disease incidence percentage and B: C affected by different organic manures on chilli

Treatments	Disease incidence percentage (*Colletotrichum* fruit rot)	BC ratio
T_1	62.50	0.79
T_2	46.52	3.40
T_3	42.72	2.45
T_4	20.50	2.51
T_5	51.31	2.00
T_6	23.40	2.24
T_7	26.80	4.08
T_8	19.65	4.20
T_9	32.80	3.73
T_{10}	26.10	3.46
T_{11}	56.92	1.13
T_{12}	25.65	1.13
T_{13}	28.45	2.30
T_{14}	24.70	2.61
T_{15}	39.86	2.14
T_{16}	27.55	2.20
CD(0.05)	1.90	

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

Panchagavya) and T_{10} (75% N as BM compost + Vermiwash). Lowest mean value (0.65%) was registered by treatment T_1 (Absolute control).

4.1.4.2. Oleoresin

Table 11 shows the oleoresin content of the fruit recorded by different treatments. It was found that there was no significant difference among the different treatments on the oleoresin content of the fruit.

4.1.4.3. Shelf Life

Different treatments significantly influenced shelf life of fruits (Table 11). Highest mean value of 11.50 days was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). Treatments T_8, T_7, T_{13}, T_{14} and T_{15} were found to be on par. Lowest mean value of 8.00 days was registered by the treatment T_1 (Absolute control). Treatments T_{11} (50% N as EM compost),T_{12} (50% N as BM compost) and T_1 (Absolute control) were on par.

4.1.4.4. Ascorbic Acid

Table 11 presents the data regarding the influence of different treatments on the ascorbic acid content of the fruit. Treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value (118.30 $mg100g^{-1}$) and was found to be on par with T_{14} (50% N as BM compost + Panchagavya) and T_7 (75% N as EM compost + Panchagavya). Lowest mean value (81.90 $mg100g^{-1}$) was recorded by the treatment T_1 (Absolute control).

4.1.5. Uptake of NPK by the Crop

Perusal of data on plant nutrient uptake revealed that different treatments significantly influenced the uptake of nutrients (Table 12).

4.1.5.1. Nitrogen uptake (Table 12)

In the case of Nitrogen T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value of 79.92 kg ha^{-1}. Second best treatment was T_7 (75% N as EM compost + Panchagavya) with a mean value of 65.32 kg ha^{-1} and was on par with the treatments $T_9$and T_{10}. Lowest value of 13.93 kg ha^{-1} was registered by treatment T_1 (Absolute control). Treatments T_{15}, T_{12}, T_{11} and T_1 (Absolute control) were on par.

Table 11 Quality parameters of fruit affected by different organic manures on chilli

Treatments	Ascorbic acid content (mg 100g $^{-1}$)	Oleoresin (%)	Capsaicin (%)	Shelf life (days)
T_1	81.90	11.49	0.65	8.00
T_2	92.82	12.14	0.72	9.50
T_3	96.46	12.15	0.72	10.00
T_4	92.82	12.17	0.74	10.00
T_5	94.64	12.16	0.70	10.00
T_6	96.46	12.13	0.71	9.50
T_7	112.84	12.18	0.78	11.00
T_8	118.30	12.20	0.79	11.50
T_9	101.92	12.15	0.76	9.50
T_{10}	103.74	12.14	0.77	10.00
T_{11}	92.82	12.17	0.70	8.00
T_{12}	94.64	12.17	0.71	8.50
T_{13}	109.20	12.20	0.74	11.00
T_{14}	114.66	12.21	0.72	11.00
T_{15}	100.10	12.17	0.72	10.50
T_{16}	103.74	12.18	0.75	10.00
CD(0.05)	8.49	NS	0.02	1.23

NS- Non significant

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

4.1.5.2. Phosphorus Uptake (Table 12)

There was significant difference due to various treatments on P uptake. For P highest mean value was recorded by treatment T_8 (75% N as BM compost + Panchagavya)(13.38kg ha^{-1}). Second best treatment was T_7 (75% N as EM compost + Panchagavya) with a mean value of 9.94kg ha^{-1} and was on par with the treatments T_9, T_{10}, T_2, T_{13}, T_4 and T_6. The lowest mean value of 4.14 kg ha^{-1} was recorded by the treatment T_{11} (50% N as EM compost) and was found to be on par with T_3, T_5, T_1, T_{15} and T_{12}.

4.1.5.3. Potassium Uptake (Table 12)

Various treatments influenced the K uptake significantly the treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value of 89.58 kg ha^{-1} and was found to be on par with T_9 (75% N as EM compost + Vermiwash). The lowest mean value of 4.14 kg ha^{-1} was recorded by the treatment T_{11} (50% N as EM compost) and was found to be on par with T_1, T_{15} and T_{12}.

4.1.6. Economics of Cultivation

Table 10 presents the data regarding economics of cultivation of chilli. Data showed that the treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest BC ratio(4.20). Next highest value for BC ratio was recorded by the treatment T_7 (75% N as EM compost and Panchagavya) (4.08) followed by T_9 (75% N as EM compost + Vermiwash) (3.73). The lowest BC ratio of 0.79 was recorded by the treatment T_1 (Absolute control).

Table 12 Plant uptake of major nutrients (kg ha^{-1}) affected by different organic manures on chilli

Treatments	N	P	K
T_1	13.93	5.07	33.65
T_2	44.62	8.11	49.62
T_3	32.68	6.47	45.42
T_4	35.03	7.79	54.16
T_5	31.15	6.36	43.31
T_6	34.33	7.53	44.99
T_7	65.32	9.94	71.33
T_8	79.92	13.38	89.58
T_9	64.09	9.02	76.35
T_{10}	59.52	8.71	73.60
T_{11}	14.77	4.14	28.04
T_{12}	17.32	4.45	35.14
T_{13}	37.48	8.69	52.50
T_{14}	30.35	6.99	46.26
T_{15}	21.79	4.69	39.99
T_{16}	31.16	7.06	57.79
CD(0.05)	10.13	2.48	13.79

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

4.1.7. Post Harvest Analysis of Soil

4.1.7.1. pH

There were significant differences among treatments for pH values of soil (Table 13). Highest mean value was recorded by treatment T_8 (75% N as BM compost + Panchagavya) and was found to be on par with T_{10}, T_{14} and T_7. The lowest mean value was recorded by the treatment T_2 (POP) (5.40) and was on par with T_1 (Absolute control).

4.1.7.2. Electrical Conductivity

Different treatments influenced the Electrical conductivity(EC)of soil (Table 13). The treatments T_3 (100% N as EM compost) and T_4 (100% N as BM compost) registered the maximum value for Electrical Conductivity (EC) of soil. Lowest mean value was recorded by the treatment T_1 (Absolute control). Generally by the addition of organic manures EC of the soil was found to be increased.

4.1.7.3. Bulk Density

From the results (Table 13) it can be inferred that the bulk density of soil was influenced by different treatments. Lowest mean value of 1.12 Mg m^{-3} was recorded by treatment T_7 (75% N as EM compost + Panchagavya) and was found to be on par with T_8 (75% N as BM compost + Panchagavya). The treatments T_{12} (50% N as BM compost), T_{11} (50% N as EM compost) and T_1 (Absolute control) were found to be on par.

4.1.7.4. Organic Carbon

Table 15 shows that the organic carbon content of soil after the harvest of crop. The result indicated that the treatment T_8 recorded the highest mean value of 1.20% and was found to be on par with T_7 (75% N as EM compost + Panchagavya). Lowest value of 0.63% was recorded by the treatment T_1 (Absolute control).

4.1.7.5. Available Nitrogen

Available nitrogen in the soil after the harvest of the crop was significantly influenced by different treatments (Table 14). The treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value of 299.49 kg ha^{-1}

Table 13 Post harvest analysis for pH, EC and BD

Treatments	pH	EC(dS m^{-1})	Bulk density(Mg m^{-3})
T_1	5.50	0.16	1.36
T_2	5.40	0.34	1.30
T_3	5.80	0.49	1.29
T_4	5.85	0.49	1.31
T_5	5.90	0.32	1.22
T_6	6.00	0.38	1.20
T_7	6.05	0.38	1.12
T_8	6.20	0.37	1.15
T_9	6.00	0.35	1.28
T_{10}	6.10	0.33	1.28
T_{11}	5.90	0.30	1.37
T_{12}	6.00	0.30	1.39
T_{13}	5.95	0.28	1.23
T_{14}	6.10	0.29	1.22
T_{15}	5.90	0.30	1.35
T_{16}	5.95	0.30	1.31
CD(0.05)	0.16	0.01	0.04

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

followed by T_{10} representing 75% N as BM compost + Vermiwash. The treatment T_9 was found to be on par with T_7. T_1 (Absolute control) registered the lowest value of 213.25 kg ha^{-1}. Treatments T_1 and T_{11} (50% N as EM compost) were found to be on par.

4.1.7.6. Available Phosphorus

There was significant difference among treatments for available phosphorus content of soil (Table 14). The treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value of 84.5 kg ha^{-1} and is superior to all other treatments. Second best treatment was T_7 (75% N as EM compost + Panchagavya) with a mean value of 74.55 kg ha^{-1}. The treatments T_{16}, T_4 and T_{15} were found to be on par. As expected lowest value of 25.4 kg ha^{-1} was recorded by the treatment T_1 (Absolute control).

4.1.7.7. Available Potassium

Available Potassium content of the soil after the harvest of the crop was influenced by different treatments and is presented in Table 14. The treatment T_{10} (75% N as BM compost + Vermiwash) showed the highest mean value of 175.28 kg ha^{-1} followed by T_9 (75% N as EM compost + Vermiwash) (171.92 kg ha^{-1}) Lowest value was recorded by the treatment T_1 (Absolute control)(116.25 kg ha^{-1}).

4.1.7.8. Exchangeable Calcium

Significantly different treatments were recorded for the exchangeable calcium content of soil (Table 15). The highest value of 1.58 c mol (+) kg^{-1} was recorded by T_8 (75% N as BM compost + Panchagavya) and was found to be on par with T_7 (75% N as EM compost + Panchagavya). The treatment T_1 (Absolute control) recorded the lowest value (1.10 c mol (+) kg^{-1}). Treatments T_1 and T_{11} were on par.

4.1.7.9. Exchangeable Magnesium

Table 15 shows the exchangeable magnesium content of soil after the harvest of the crop. Result indicated that treatment T_8 recorded the highest mean value of 2.30 c mol (+) kg^{-1}. The treatment T_7 (75% N as EM compost +

Table 14 Effect of treatments on post harvest soil properties

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	213.25	25.40	116.25
T_2	283.81	50.77	136.64
T_3	239.91	38.46	146.16
T_4	241.47	64.35	149.28
T_5	219.52	36.96	134.96
T_6	222.66	39.67	138.32
T_7	285.38	74.55	160.26
T_8	299.49	84.50	171.45
T_9	285.38	51.56	171.92
T_{10}	291.65	52.76	175.28
T_{11}	216.38	37.23	126.60
T_{12}	217.95	37.67	137.40
T_{13}	244.61	53.17	140.56
T_{14}	249.31	54.44	144.18
T_{15}	254.02	63.71	148.90
T_{16}	255.59	64.65	148.90
CD(0.05)	4.51	6.78	1.79

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

Table 15 Effect of treatments on soil properties after harvest

Treatments	Organic carbon (%)	Ca (c mol(+)kg^{-1})	Mg (c mol(+)kg^{-1})
T_1	0.63	1.10	1.30
T_2	1.03	1.26	1.58
T_3	0.93	1.22	1.61
T_4	0.93	1.29	1.70
T_5	0.90	1.21	1.51
T_6	0.92	1.26	1.54
T_7	1.16	1.53	2.11
T_8	1.20	1.58	2.30
T_9	1.10	1.30	1.69
T_{10}	1.12	1.34	1.74
T_{11}	0.78	1.14	1.35
T_{12}	0.80	1.18	1.36
T_{13}	0.95	1.36	1.93
T_{14}	0.97	1.35	1.98
T_{15}	0.86	1.25	1.57
T_{16}	0.93	1.27	1.58
CD(0.05)	0.08	0.05	0.04

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

Panchagavya) showed a value closer to T_8 (2.11). Treatment T_1 (Absolute control) recorded the lowest value (1.30 c mol (+) kg^{-1}).

4.1.7.10. Iron (Table 16)

In the case of Iron T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value of 33.00 ppm and was found to be on par with T_7 (75% N as EM compost + Panchagavya). Lowest value of 11.95 ppm was recorded by the treatment T_1 (Absolute control). Treatments T_9, T_{15} and T_{16} were on par.

4.1.7.11. Copper (Table 16)

There was significant difference due to various treatments on copper content of soil. For copper highest value was recorded by T_7 (75% N as EM compost + Panchagavya) (0.85 ppm). Second best treatment was T_8 (0.75 ppm) and it was found to be on par with T_{10} and T_9. Lowest value of 0.15 ppm was recorded by the treatment T_1 (Absolute control).

4.1.7.12. Zinc (Table 16)

Various treatments influenced zinc content of soil significantly. The treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value (2.88 ppm) and the lowest value (0.83 ppm) was recorded by treatment T_1 (Absolute control). After T_8, T_7 was found to be the better treatment with a mean value of 2.60 ppm and it was on par with the treatment T_{10}. T_1 was found to be on par with T_2 (POP).

4.1.7.13. Manganese (Table 16)

There was significant difference due to various treatments on manganese content. The treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value of 20.65 ppm. The treatment T_7 followed by T_8 with a mean value of 10.53 ppm was on par with the treatments T_9, T_{10}, T_{14} and T_{13}. Lowest value of 2.80 ppm was registered by the treatment T_1 (Absolute control). Treatments T_{12}, T_{11}, T_2 and T_1 were on par.

4.1.7.14. Dehydrogenase

Table 17 shows the dehydrogenase content of soil after the harvest of crop. The results indicated that the treatment T_7 (75% N as EM compost + Panchagavya) registered the highest mean value (311.88μgTPFg^{-1} h^{-1} soil) for the

Table 16 Effect of treatments on post harvest soil properties

Treatments	Fe	Cu	Zn	Mn
T_1	12.03	0.15	0.83	2.80
T_2	11.95	0.60	0.85	3.43
T_3	14.70	0.53	1.50	7.25
T_4	15.13	0.50	1.93	7.50
T_5	14.43	0.48	1.28	4.20
T_6	13.65	0.50	1.05	4.28
T_7	32.00	0.85	2.60	10.53
T_8	33.00	0.75	2.88	20.65
T_9	23.88	0.68	2.25	10.35
T_{10}	25.75	0.70	2.55	10.30
T_{11}	13.45	0.45	1.00	3.70
T_{12}	13.55	0.45	1.00	3.80
T_{13}	17.75	0.65	1.90	9.35
T_{14}	18.43	0.58	2.05	9.90
T_{15}	23.38	0.60	1.63	7.43
T_{16}	23.00	0.55	1.75	7.60
CD(0.05)	1.31	0.08	0.09	1.19

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

Table 17. Effect of treatments on post harvest soil properties

Treatments	Fungi (CFU g^{-1} soil) (Dilution 10^4)	Bacteria (CFU g^{-1} soil) (Dilution 10^6)	Actinomycetes (CFU g^{-1} soil) (Dilution 10^8)	Dehydrogenase (µgTPF $g^{-1}h^{-1}$)
T_1	10.00	10.00	1.00	200.63
T_2	12.85	10.00	2.50	201.88
T_3	14.85	22.00	4.00	236.88
T_4	17.30	22.00	5.00	235.00
T_5	13.20	12.00	2.00	238.75
T_6	13.65	13.00	2.00	238.75
T_7	18.85	28.00	2.50	311.88
T_8	22.35	14.00	3.00	301.88
T_9	15.15	25.00	6.00	241.25
T_{10}	17.15	25.50	6.50	243.75
T_{11}	12.50	12.00	1.50	204.38
T_{12}	13.65	13.00	2.00	223.75
T_{13}	17.65	22.50	2.50	226.25
T_{14}	18.50	24.00	3.50	229.38
T_{15}	14.20	24.00	5.00	234.38
T_{16}	15.65	24.50	6.00	231.88
CD(0.05)	1.37	8.99	2.13	1.93

T_1 Absolute control
T_2 POP
T_3 100% N as EM compost
T_4 100% N as BM compost
T_5 75% N as EM compost
T_6 75% N as BM compost
T_7 75% N as EM compost + Panchagavya
T_8 75% N as BM compost + Panchagavya
T_9 75% N as EM compost + Vermiwash
T_{10} 75% N as BM compost + Vermiwash
T_{11} 50% N as EM compost
T_{12} 50% N as BM compost
T_{13} 50% N as EM compost + Panchagavya
T_{14} 50% N as BM compost + Panchagavya
T_{15} 50% N as EM compost + Vermiwash
T_{16} 50% N as BM compost + Vermiwash

amount of dehydrogenase in soil .Second best treatment was T_8 (75% N as BM compost + Panchagavya) which registered a mean value of 301.88 $\mu gTPFg^{-1}$ h^{-1} soil. Lowest mean value of 200.63 $\mu gTPFg^{-1}$ h^{-1} soil was recorded by the treatment T_1 (Absolute Control) and was found to be on par with T_2 (POP).

4.1.6.15. Microbial Count

Table 17 shows the changes in microbial population due to various treatments. Among microbes fungal population was significantly influenced by different treatments.

Regarding the fungal count treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value of 22.35 followed by the treatment T_7 (75% N as EM compost + Panchagavya) with a mean value 18.85. It was found to be on par with treatments T_{14} and T_{13} . Lowest mean value was recorded by the treatment T_1 (Absolute Control) (10.00).

For bacteria highest mean value was recorded by the treatment T_7 (75% N as EM compost + Panchagavya) (28.00) and it was found to be on par with treatments T_{10}, T_9, T_{16}, T_{14} T_{15}, T_{13}, T_4 and T_3. Lowest values are shown by T_1 (Absolute Control) and T_2 (POP) (10.00).The treatments T_1, T_2, T_8, T_{12}, T_6, T_{11} and T_{15} were also on par.

For actinomycetes the treatment T_{10} (75% N as BM compost +Vermiwash) registered the highest mean value of 6.50 followed by T_9 (75% N as EM compost +Vermiwash). The treatments T_{10}, T_9, T_{16}, T_{15} and T_4 were on par. Lowest mean value of 'one' was registered by T_1 (Absolute Control). The treatments T_1, T_{13}, T_7, T_2, T_5, T_6, T_{11} and T_{12} were found to be on par.

DISCUSSION

5. DISCUSSION

The experimental findings detailed in the previous chapter have been briefly discussed here in the light of published information and fundamental theoretical knowledge.

5.1.1 BIOMETRIC OBSERVATIONS

Important biometric observations recorded are days to 50% flowering, plant height and primary branches per plant. Except days to 50% flowering, plant height at 30 DAT, 60 DAT and 90 DAT and primary branches per plant at 90 DAT showed significant difference among treatments.

The critical evaluation of the data (Table 6) revealed that T_8 received 75% N as BM compost along with Panchagavya was significantly superior to all other treatments with respect to plant height at all stages. The increased plant height might be due to increased uptake of nutrients supplied through soil application by BM compost and foliar spray in the form of Panchagavya. Combined effect of *Trichoderma*, rockdust and Panchagavya helped in improving the growth characters of the plant. According to Kishor and Ghosh (2010) *Trichoderma* strains solubilise phosphates and micronutrients and increases the root growth and development, crop productivity and uptake and use of nutrients. Similar results were also reported by several workers. (Inbar *et al.*, 1994; Requena *et al.*, 1996; El-Din *et al.*, 2006; and Kumar *et al.*, 2007). Madeley (1999) reported that the shoot height, root length and plant weight were significantly higher in the rockdust applied plants (lettuce and brassicas). Enhanced vegetative growth of the plant might be due to the favorable effects of IAA, GA_3, major and micronutrients and also microorganisms (Somasundaram, 2003; Somasundaram and Sankaran ,2004) present in Panchagavya resulted in stimuli in the plant system and in turn increased the production of growth

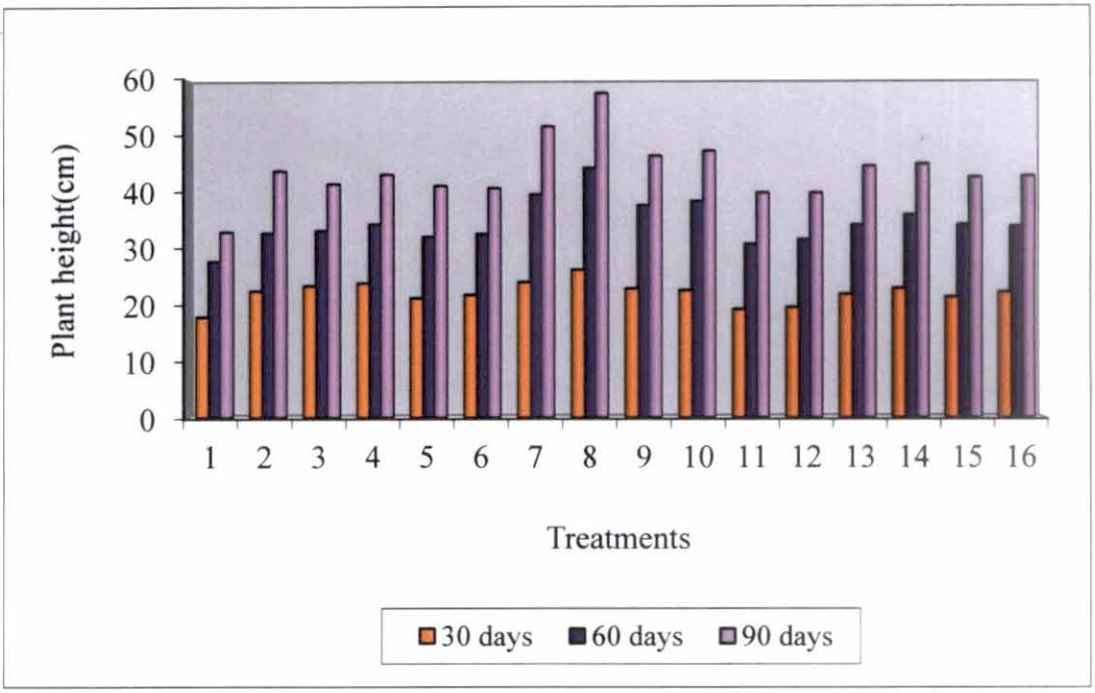

Fig.3. Effect of different types of organics on plant height (cm)

regulator in the cell system. Role of Panchagavya as growth promoter was also reported by Manjunatha *et al.* (2004); Sundararaman (2004); Mathivanan *et al.* (2006); Satish *et al.* (2006);Chandrakala (2008) and Venkataramana *et al.* (2009). Increased plant height by the addition of 75% N as BM compost along with Panchagavya is in conformity with these findings.

Primary branches per plant at 90 DAT were significantly influenced by various treatments (Table 6). Maximum number of primary branches was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) and was found to be on par with T_7 (75% N as EM compost + Panchagavya) and T_4 (100% N as BM compost). This indicates that application of BM compost alone or in combination with Panchagavya can give more number of primary branches per plant. Application of BM compost and Panchagavya produced more vegetative growth, thereby enhanced more number of primary branches. Rose (2008) reported that application of rock dust @ 10t ha^{-1} mixed with equal quantity of FYM increased the number of branches per plant in coleus. Sailajakumari (1999) reported that in cowpea maximum number of branches per plant was produced by the treatment, which received enriched vermicompost. Beneficial effects of organic amendments in increasing the number of branches per plant were reported by Pushpa (1996); Anitha (1997); Sharu (2000); Sheeba (2004) ; Deepa (2005) and Chandrakala(2008).

5.1.2 YIELD AND YIELD ATTRIBUTES

Yield and yield characters showed significant variation due to the treatments. In general the treatment that received 75% N as BM compost along with Panchagavya showed better performance in terms of yield and yield attributes.

Regarding the number of fruits per plant (Table 7), the highest value was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). But this was on par with the treatment T_7 (75% N as EM compost + Panchagavya). It is evident that plants supplied with Panchagavya is efficient in producing more number of fruits, provided it is applied along with sufficient quantity of compost (either BM compost or EM compost). Number of fruits is closely associated with growth parameters like plant height, number of primary branches and dry matter production. It was also attributed to the maximum uptake of N, P and K (Chandrakala, 2008; Gangamrutha, 2008). Since 75% N as BM compost along with Panchagavya was significantly superior to all other treatments with respect to all these parameters, similar effect was produced in number of fruits per plant also.

With respect to fruit length (Table 8) different treatments showed significant difference and maximum fruit length was recorded by the treatment of T_8 (75% N as BM compost + Panchagavya) and it was on par with T_7 (75% N as EM compost + Panchagavya). The result showed that BM compost can be substituted for EM compost for combined application with Panchagavya for getting lengthier fruits.

Regarding the girth of the fruit (Table 8), various treatments significantly influenced the fruit girth. Maximum girth was recorded by the treatment T_8 and was statistically superior to all other treatments. The result revealed that 75 percent N as BM compost is efficient in producing fruits with maximum girth when applied along with Panchagavya.

Fruit weight (Table 8) was significantly influenced by different treatments. Highest value was recorded by the treatment of T_8 and was significantly superior to all other treatments. Second highest value for fruit weight was recorded by T_7. This shows the beneficial influence of Panchagavya in increasing the fruit weight. Somasundaram *et al.* (2003) observed increased number of seeds pod^{-1}, higher grain weight and grain yield by the application of Panchagavya in green gram.

Green fruit yield per plant and total fruit yield were significantly influenced by different treatments (Table 9). The treatment T_8 recorded the maximum value and this indicates that application of organics along with Panchagavya is essential to get higher crop yield. Among the composts, BM compost is found to be superior and the superiority is due to the complementary effect of *Trichoderma* and rock dust. The organic manures increases the availability of native nutrients to the crops and also improves the soil environment, which encouraged proliferous root system resulting in better absorption of water and nutrients from lower layers resulting in higher uptake and yield(Thenmozhi and Paulraj, 2009). The fruit yield is the manifestation of various growth and yield attributing characters and the higher yield could be traced back to significant differences in dry matter production and its accumulation. The higher accumulation of assimilates reflected in higher number of fruits per plant, fruit length, fruit weight and ultimately the yield. Rose (2008) reported that application of rock dust @ 10t ha^{-1} along with an equal quantity of FYM increased the number of fruits per plant and yield in Coleus. Similar results were reported by several workers (Edward ,1993 and Yarrow ,1997) Effect of *Trichoderma* in enhancing the yield of crops was reported by El-Din *et al.* (2000); Misra *et al.* (2002); Zayed and Abdel-Motaal (2005); Rajamoni *et al.* (2006) and Gaind *et al.* (2009). Reddy (2004) reported that promoting the use of Panchagavya as a nutrient and a hormone can help to get better yield at very cheap cost. Similar findings were reported by Somasundaram *et al.* (2003), Manjunatha *et al.* (2004), Somasundaram and Sankaran (2004), Satish *et al.* (2006), Venkataramana *et al.* (2009) and Sangeetha and Thevanathan (2010).

Dry matter production and its accumulation accomplished only with the development of sound vegetative growth *viz*., plant height and number of primary branches. The growth parameters recorded at different stages of crop were significantly higher with the treatment T_8 (75% N as BM compost +

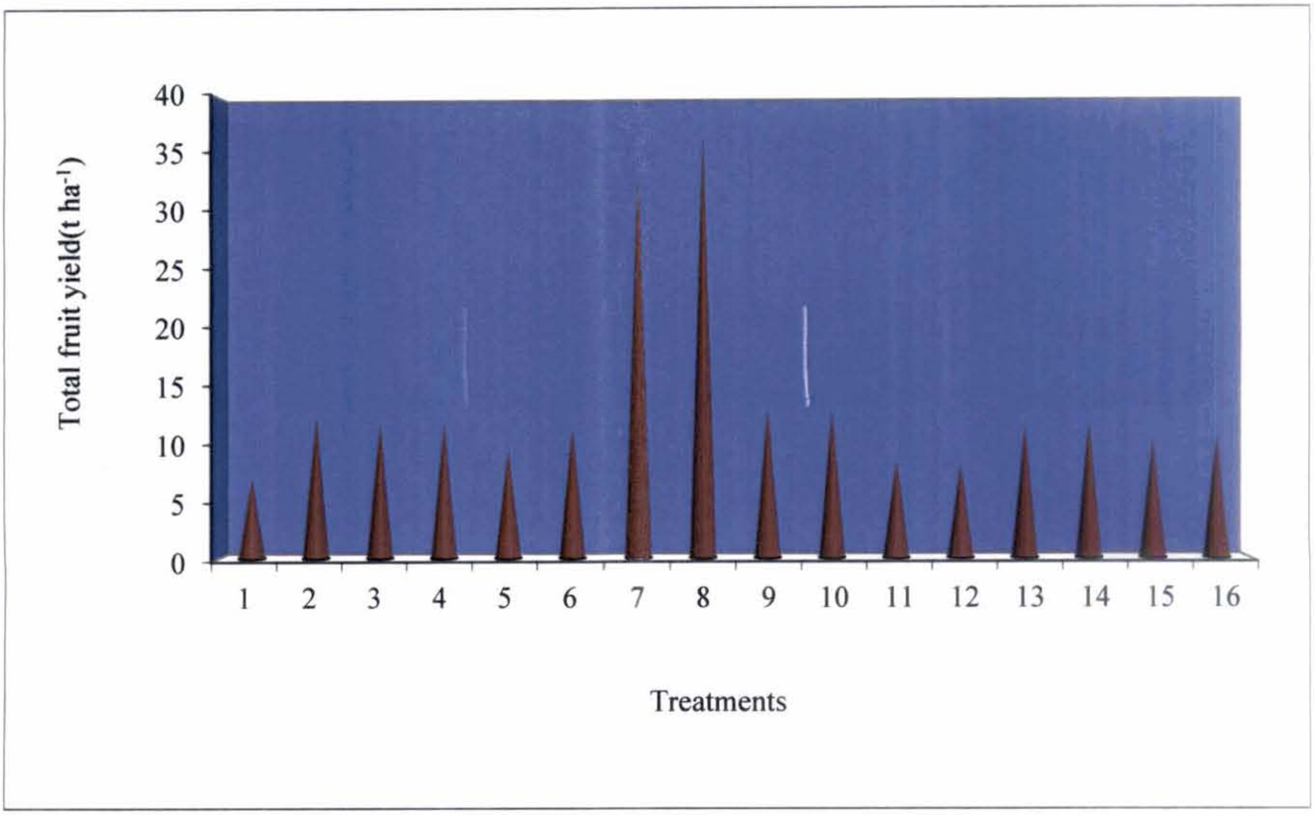

Fig.4. Effect of different types of organics on total fruit yield (t ha^{-1})

Panchagavya) and hence dry matter yield (Table 9) was also highest for T_8. Combined effect of *Trichoderma*, rock dust and Panchagavya helped in improving the growth characters of the plant. This was supported by findings of Coroneos (1996); Somasundaram and Sankaran (2004); Satish *et al.* (2006) and Rose (2008).

5.1.3 INCIDENCE OF PESTS AND DISEASES

Application of Nimbicidin reduced the population of white flies transmitting mosaic disease and no other serious pests were reported. There were significant differences among treatments with respect to the disease incidence percentage (*Colletotrichum* fruit rot) (Table 10). Highest value for disease incidence percentage was recorded by the treatment T_1 (Absolute control). Treatment T_8 (75% N as BM compost + Panchagavya) registered the lowest mean value and it was found to be on par with T_4 (100 % N as BM compost). The result showed that application of Panchagavya along with 75 percent of BM compost can reduce the disease incidence percentage. This is in conformity with the findings of Sundararaman (2004) who observed that Panchagavya acts 75% as manure and 25% as pest controller. It stimulates plant growth, rectifies micro nutrient deficiencies and helps plants to develop resistance against diseases. Similar findings were reported by Somasundaram and Sankaran (2004) and Mathivanan *et al.* (2006). From the result it was inferred that 75% N as BM compost + Panchagavya can be substituted with 100 % BM compost. BM compost containing *Trichoderma* spp. can help the plant to develop resistance against diseases. This was supported by Viswanathan and Samiyooran (1999) who reported that *Pseudomonas* sp. and *Trichoderma* sp. has antagonistic activity against soil pathogens make them complement to enhance the crop growth and systematic resistance. Similar observations were reported by Hoitink *et al.*(1991); Inbar *et al.*(1994); Cotxarrera *et al.*(2002) ; Howell(2003); Kumar *et al.*(2007); Kerkeni *et al.*(2007) and Kishor and Ghosh (2010).

5.1.4 QUALITY PARAMETERS OF FRUIT

5.1.4.1. Capsaicin

Different treatments significantly influenced capsaicin content of the fruit (Table 11). The treatment T_8 recorded the highest value and it was on par with treatments T_7 and T_{10}. Singh *et al.* (2003) and Garg (2009) reported that variation in capsaicin content was due to cultivars, environmental factors, size of fruits, thickness of pericarp height of plant, weight of fruit plant^{-1}, ratio of seed to pericarp and yield. Since the combination of 75% N as BM compost and Panchagavya reported the highest value for the growth and yield characters. Capsaicin content also observed to be the highest for the above mentioned treatment. The result showed that BM compost can be substituted for EM compost (T_7- 75% N as EM compost + Panchagavya) and vermiwash can be substituted for Panchagavya (T_{10} - 75% N as BM compost + Vermiwash) when the BM compost and Panchagavya are not available.

5.1.4.2 Oleoresin

From the result it was found that there was no significant difference among the various treatments on the oleoresin content of the fruit (Table 11).

5.1.4.3 Shelf life

Different treatments significantly influenced shelf life of fruits(Table 11). Highest mean value was recorded by the treatment T_8 and was found to be on par with treatments T_7, T_{13}, T_{14} and T_{15} .The result indicated that the application of Panchagavya along with reduced doses (75 % and 50%) of either BM compost or EM compost can increase the shelf life. This is in conformity with the findings of Sangeetha and Thevanathan (2010) who reported that application of Panchagavya amended with seaweed extract increased the shelf life of fruits.

5.1.4.4 Ascorbic acid

Ascorbic acid content of fruit was greatly influenced by different treatments(Table 11). Treatment T_8 (75% N as BM compost and Panchagavya) registered the highest value and was on par with T_{14} (50% N as BM compost and

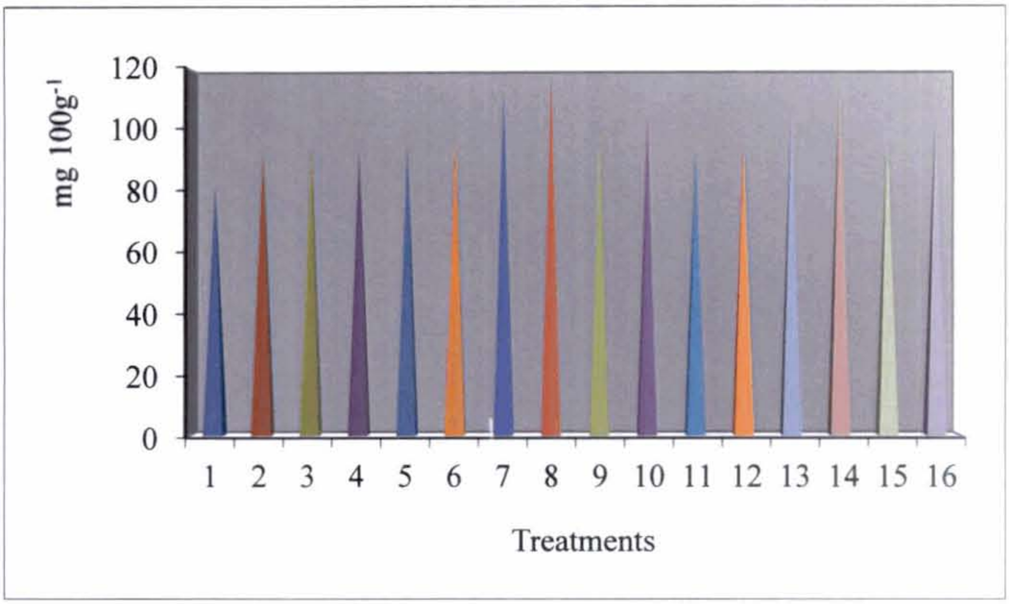

Fig.5. Effect of different types of organics on ascorbic acid content(mg $100g^{-1}$)

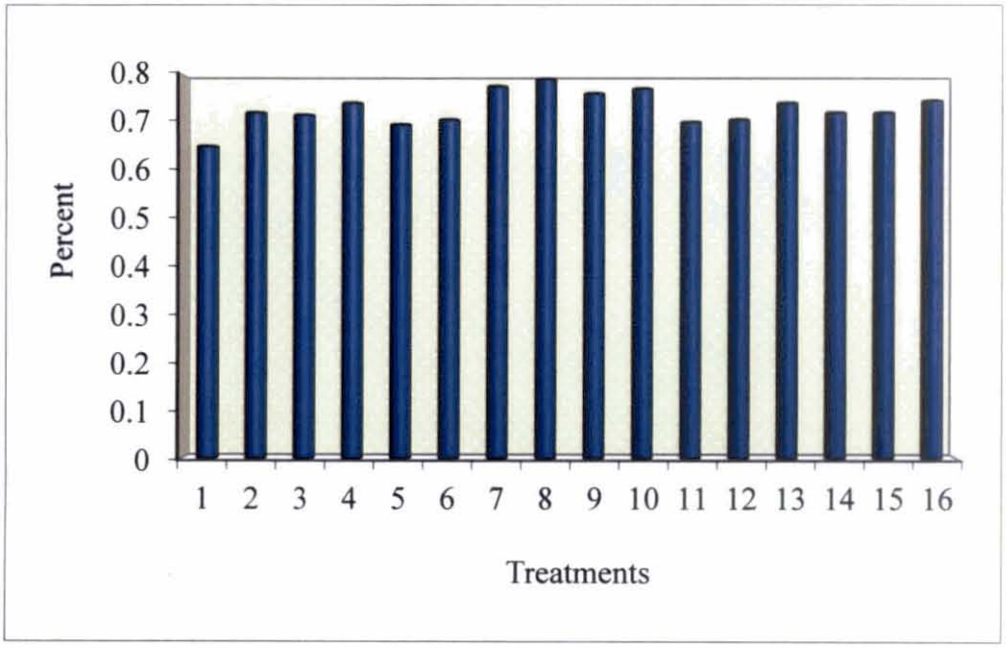

Fig.6. Effect of different types of organics on capsaicin content (%)

Panchagavya) and T_7 (75% N as BM compost and Panchagavya). The result revealed that Panchagavya play a vital role in enhancing the ascorbic acid content of the fruit. The increase in ascorbic acid content might be due to better availability and uptake of plant required nutrients and also favourable conditions resulted by the applied Panchagavya which help in the synthesis of chlorophyll and increased ascorbic acid content (Kaminwar and Rajagopal, 1993). Ascorbic acid content of the fruit depends on species, genotypes and agro-climate.(Rani ,1996 ;Singh *et al.*,2003 and Naveen *et al.*,2009).

5.1.5 UPTAKE OF NPK BY THE CROP.

Uptake of major nutrients was affected by different treatments(Table 12). In the case of N and P highest mean value was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). For K also the highest mean value was recorded by T_8 and was found to be par with T_9 (75% N as EM compost + Vermiwash). From the result it can be inferred that application of Panchagavya along with BM compost enhanced the uptake of NPK by the crop. The increase in N uptake may be due to the fact that vast portion of non-oxidisable N present in organic matter could be made available to plants through microbial activity. Also it can be attributed to small increase in N input from biological N fixation. The increased mineralization of soil P and added P as a result of production of organic acid during decomposition is one reason for high P uptake. Chattopadhyay *et al.* (1993) and Rasal *et al.* (1996) found that plant P uptake was significantly enhanced by the application of compost amended with *T. Viride* compared with non-amended compost. El-Din *et al.* (2000) reported that compost produced by highly effective cellulose decomposing micro-organisms like *T. Viride* or *Streptomyces auerofaciens* induced a significance increase in plant drymatter, N and P uptake and fruit yield in Tomato. Similar result was reported by Requena *et al.* (1996). Rose (2008) observed that application of rockdust @ 10t ha^{-1} along with 50 percent of NPK and FYM produced highest N uptake of coleus when compared to 100 percent recommendation. As uptake of K is mostly through root

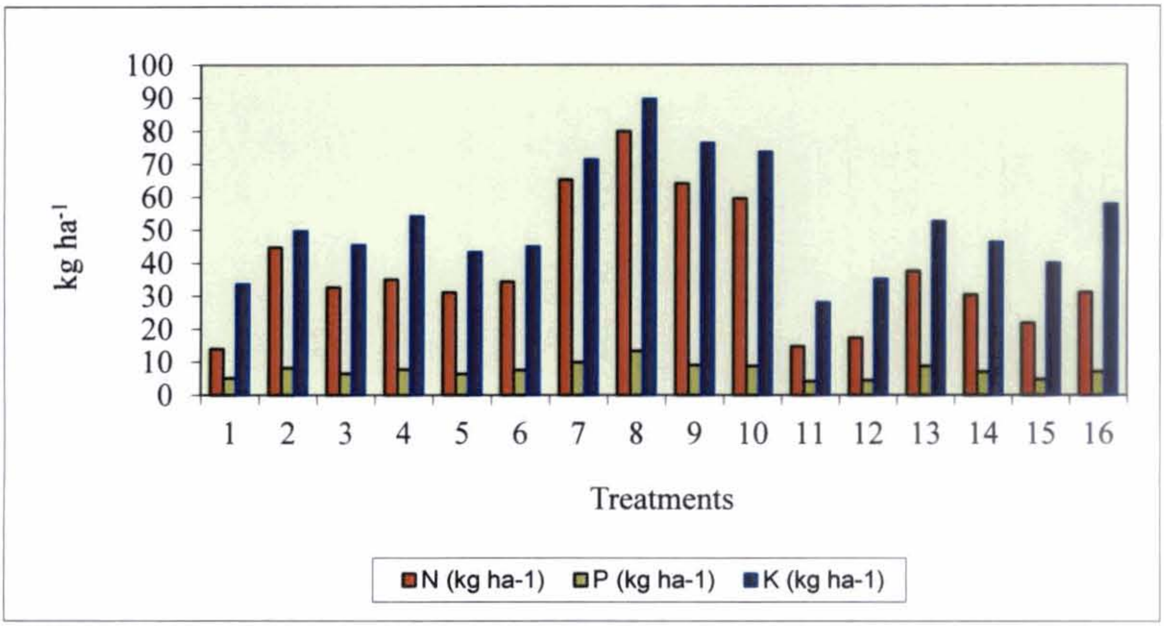

Fig.7.Effect of different organic sources on plant uptake of major nutrients (kg ha^{-1})

interception, better the root system the more is K uptake. (Niranjana, 1998). However, the increase in uptake of nutrients with foliar spray of Panchagavya was due to increased availability of nutrients due to build up of soil microflora resulting in increased enzymatic activity and biological efficiency of crop plants creating greater source and sink in the plant system (Boomathi *et al.*, 2005) that might have helped in absorption of the nutrients. It might also be due to increased leaf area index in Panchagavya treatments indicating increased photosynthetic efficiency of plants leading to increased uptake of nutrients. (Chandrakala, 2008)

5.1.6 ECONOMICS OF CULTIVATION

Highest BC ratio was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) (Table 10) and this could be attributed to greater availability and uptake of nutrients leading to enhanced yield of crop. Next highest value for BC ratio was recorded by the treatment T_7 (75% N as EM compost + Panchagavya) followed by T_9 (75% N as EM compost + Vermiwash). Higher BC ratio for T_8 and T_7 could be attributed to higher gross income since the organic produce fetch premium price(Rs.20/kg) in the market compared to non-organics (Rs.15/kg) and the lower cost of cultivation provided the farmers produced these manures on their own farm. The results are in accordance with those of Madhuri *et al.* (2006). Shwetha (2008) reported that the net return in soybean was significantly higher with combined application of organic and fermented liquid manures over no fermented liquid manures. Similarly Yadav and Christopher (2006) reported significantly higher net returns with Panchagavya spray over no Panchagavya spray. However BC ratio was also higher with combined application of RDF and Panchagavya (2.28) over RDN through organics + Panchagavya spray in rice.

5.1.7 POST HARVEST ANALYSIS OF SOIL

The available nutrient status of soil is greatly enhanced by the application of BM compost as an organic source. Korcak (1996) stated that out of the 16 elements considered to be essential for the growth of the plants, most of them are provided by rockdust and from the environmental healthy soil systems. Fragsein and Vogtmann (1987) also reported that rockdust contained most of the nutrients essential for plant growth.

Highest value for available N (Table 14) was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) followed by T_{10} (75% N as BM compost + Vermiwash). The significant increase in available N content of soil was due to the increased multiplication of microbes which mineralize the nitrogen contained in the applied organic manures and the presence of rockdust also enhanced the availability of N. This is in conformity with the findings of Rose (2008) who reported that rockdust along with FYM was able to supply the N required for the growth of Coleus. Similar to Panchagavya, Vermiwash also contains macro and micro nutrients and growth promoting substances essential for plant growth. (Thangavel *et al.*, 2003) Several reports supporting this observation had been made by Sheild and Earl (1982), Tomati and Galli (1995) Pramoth (1995); Kale (1998), Giraddi (2001), Giraddi *et al.* (2003) and Ismail (2005). For P (Table 14), treatment T_8 (75% N as BM compost + Panchagavya) recorded highest mean value and this treatment is found to be superior to all other treatments. Increase in available P content of soil might be due to greater decomposition of native soil P by organic acids released during the decomposition of organic matter by vigorous root proliferation and contribution through biomass. The significant increase in available P content could also be attributed to the organic manure mediated complexation of cations like Cu, Mg and Al responsible for fixation of P in soil (Sushma *et al.*, 2007). Similar results were reported by Fragstein and Vogtmann (1987); Chattopadhyay *et al.*(1993), Rasal *et al.* (1996) Korcak (1996) Somasundaram and Sankaran (2004), Zayed and Abdel-Motaal (2005) and Rose (2008).

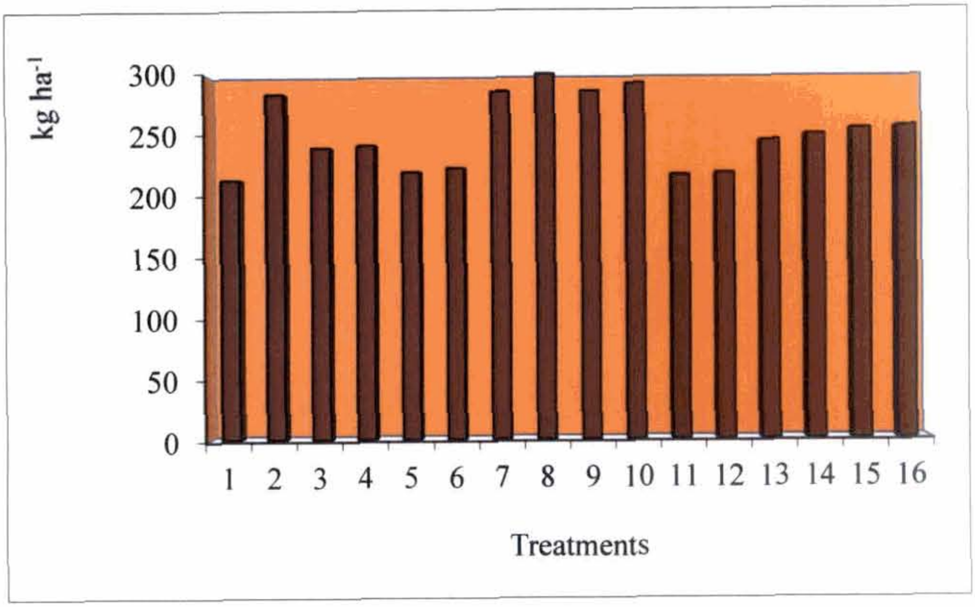

Fig.12.Influence of different organic sources on available nitrogen content(kg ha^{-1}) of soil

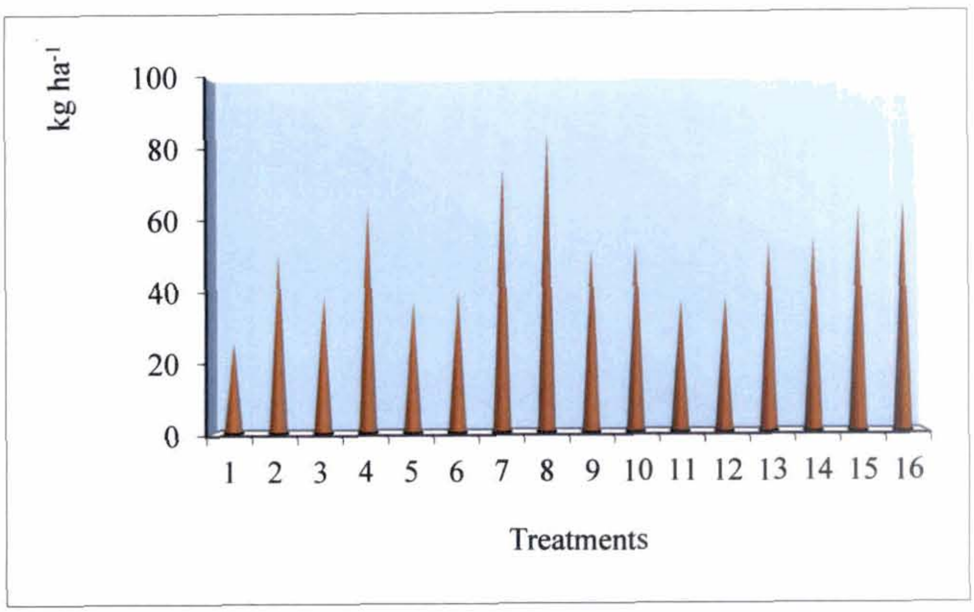

Fig.13.Influence of different organic sources on available phosphorus content (kg ha^{-1}) of soil

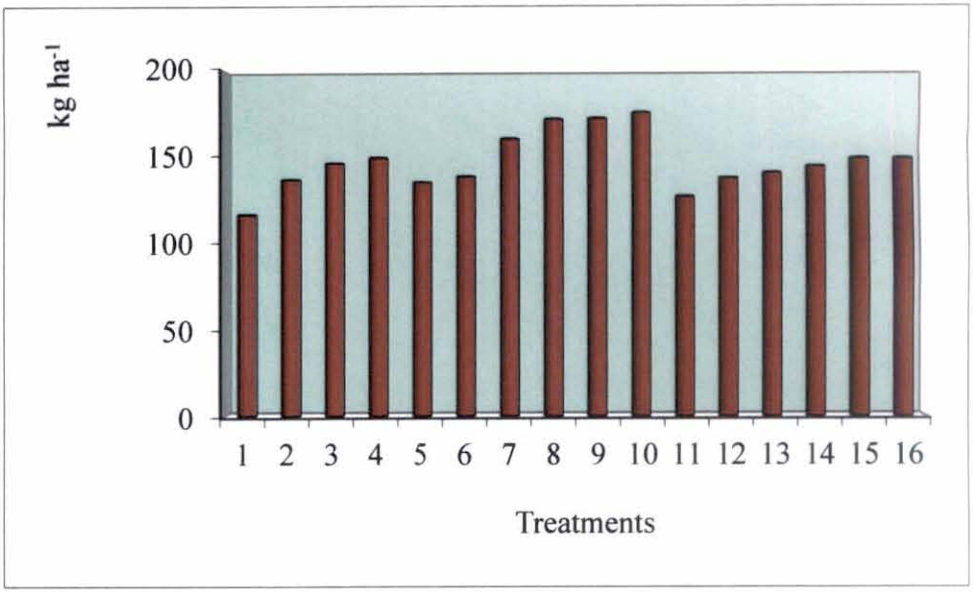

Fig.14.Influence of different organic sources on available potassium content(kg ha^{-1}) of soil

For K (Table 14), the treatment T_{10} (75% N as BM compost + Vermiwash) showed the highest mean value for available K content in soil.. The increase in available K in soil is due to the decomposition products of organic matter which contain various organic acids, might have aided in release of non-exchangeable K to the water soluble forms (Chitra and Janaki, 1999). The increase in available K content of soil is due to the application of Vermiwash along with BM compost containing rockdust and *Trichoderma* spp. These findings are in conformity with those of Hangarge *et al.* (2002) reported that the application of RDF or organic sources alone were not beneficial, but the combined effects of different sources of nutrients proved to be better compared to either organic alone or combination of organic and inorganic fertilizer.

Greater concentration of secondary nutrients *viz.* Ca, Mg (Table 15) and available micronutrients (Table 16) *viz.* Fe, Mn and Zn was observed in soils treated with 75% N as BM compost along with Panchagavya. For Cu the treatment T_7 (75% N as BM compost + Panchagavya) recorded the highest value. The increase in available Fe, Cu, Mn and Zn upon addition of organic matter might be due to intensified microbial and chemical reduction, pH of soil and also formation of stable complexes with organic ligands. This might have decreased the susceptibility of micronutrients to adsorption, fixation or precipitation reaction in soil resulting in greater availability.

The role of micro-organisms in mineralization of organic matter has been well established. The micro-organisms present in Panchagavya, EM compost and BM compost enhanced the microbial activity of the soil thereby increased the availability of macro and micro nutrients in soil.

Different treatments showed significant variation with respect to organic carbon content of soil (Table 15). Treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest value for organic carbon content of soil.

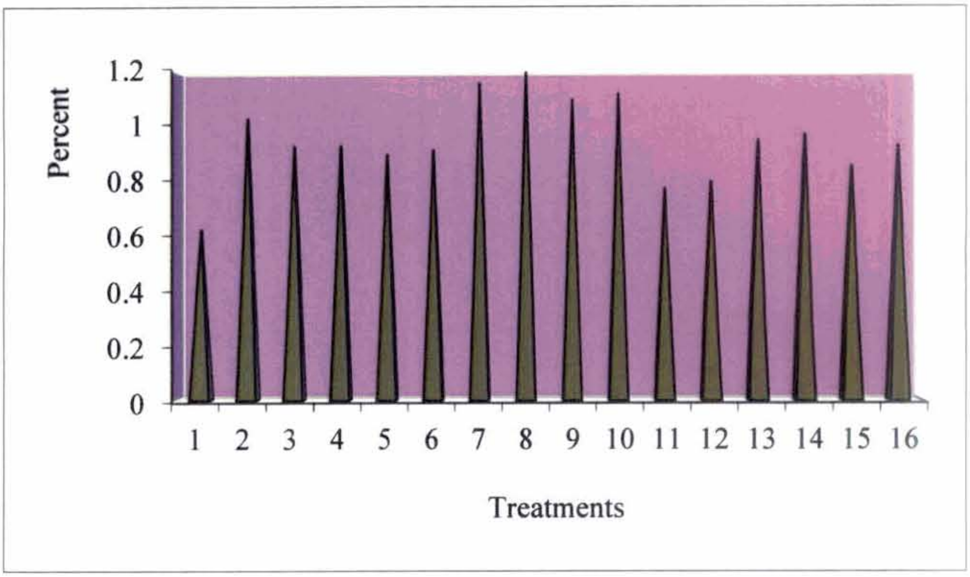

Fig.11.Influence of different types of organics on organic carbon(%) of soil

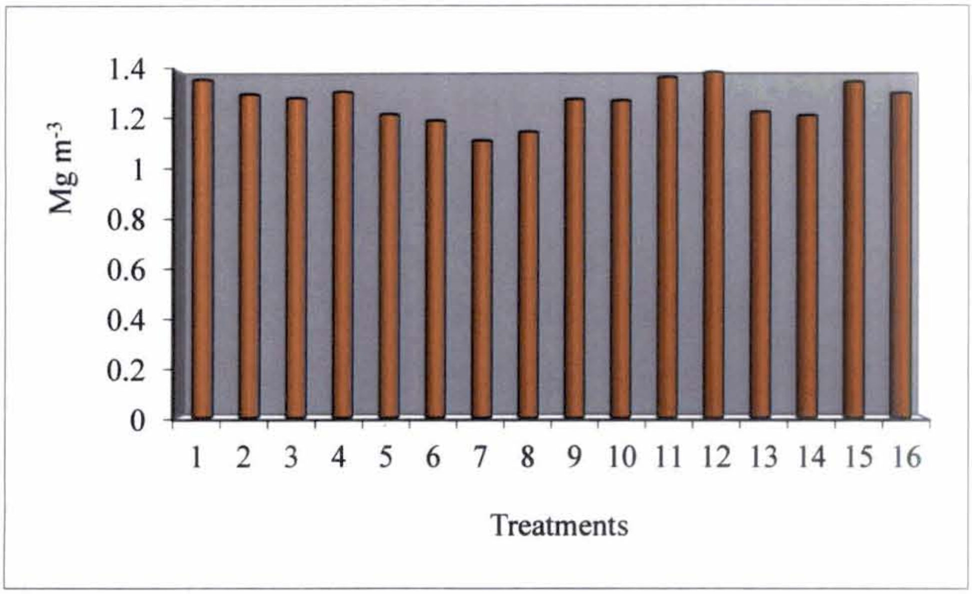

Fig.10. Influence of different types of organics on bulk density(Mg m^{-3})

More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon, available N, available P and available K of the soil.

There were significant differences among treatments for pH values of soil (Table 13). The highest value was recorded by the treatment T_8 (75% N as BM compost + Panchagavya) and was on par with T_{10} (75% N as BM compost + Vermiwash), T_{14} (50 % N as BM compost + Panchagavya) and T_7 (75% N as EM compost + Panchagavya). The results indicated that by the addition of organic manures, soil pH found to be increased near to neutral point. The increase in pH might be due to increase in bases of active degradation of organic matter and the suppression of activity of Fe and Al oxides and hydroxides which play vital role in protonation and deprotonation mechanisms controlling H^+ ion concentration in soil solution. This is in agreement with the observation by Datta (1996) and Dahia *et al.* (2003).

Different treatments influenced the Electrical Conductivity (EC) of soil (Table13). The treatments T_3 (100% N as EM compost) and T_4 (100% N as BM compost) registered the maximum value for Electrical Conductivity (EC) of soil. Generally by the addition of organic manures EC of the soil was found to be increased. This might be due to the faster release of bases and soluble organic fractions to the soil system by mineralization. This is in agreement with the findings of Thompson *et al.* (1989). They reported that total ionic concentration of system containing organic amendments is increased leading to higher ionic mobility expressing high EC values.

Various treatments influenced the bulk density of soil (Table 13). Lowest mean value was recorded by the treatment T_7 (75% N as EM compost + Panchagavya) and was on par with T_8 (75% N as EM compost + Panchagavya). Generally by the addition of organic manures bulk density of the soil was found

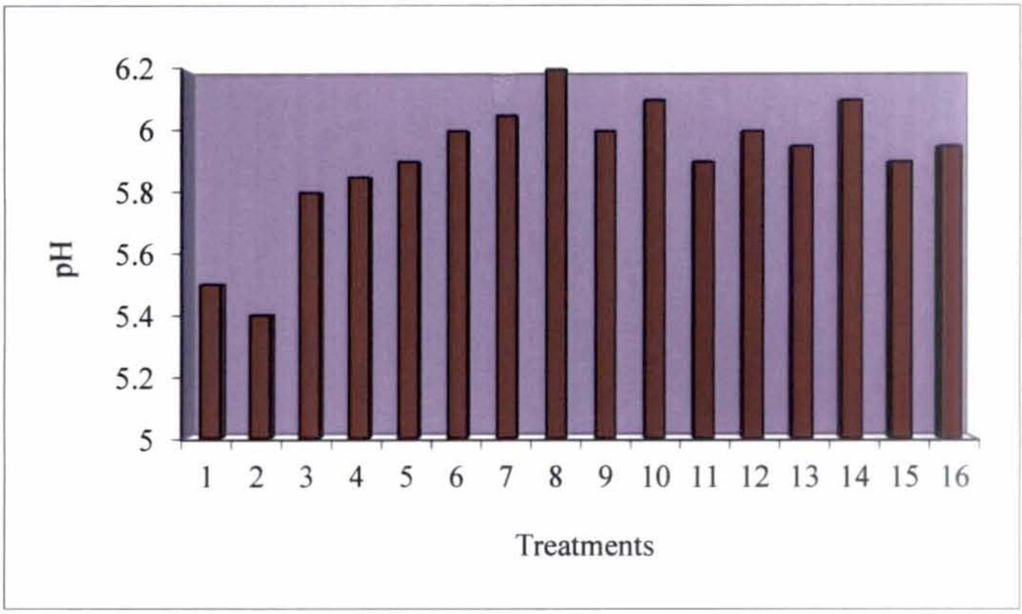

Fig.8. Influence of different organic sources on pH of soil.

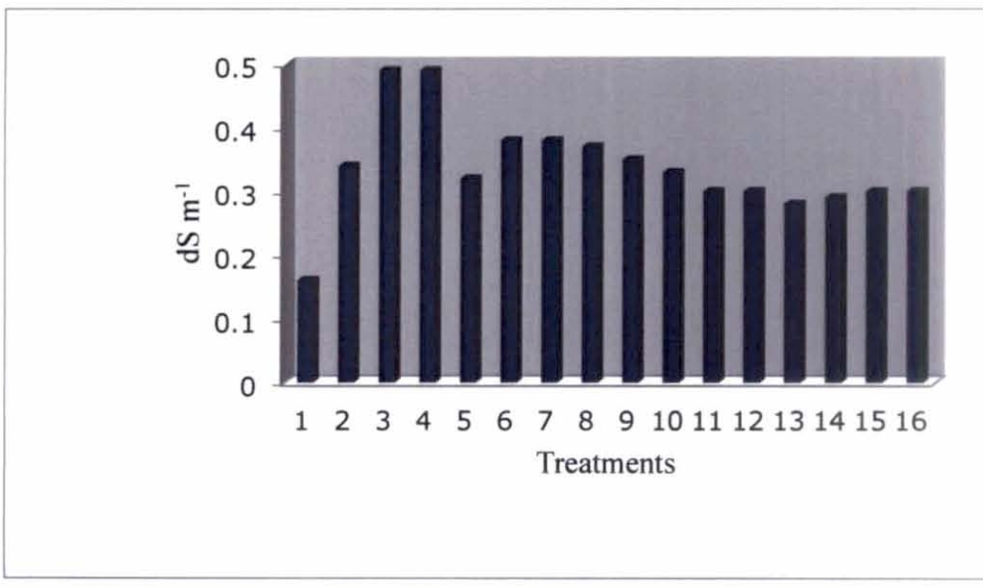

Fig.9. Influence of different organic sources on EC(dS m^{-1}) of soil.

to be decreased. Mbagwu (1989) also obtained the same result. Application of FYM has favorable effects on soil aggregation compared to chemical fertilizers (Rabindra *et al.*, 1985). In another experiment a decrease in bulk density by the addition of organic matter residues over long time was reported by Rasmussen *et al.* (1991). Dahia *et al.* (2003) observed that application of sugarcane trash enriched with mussorie rock phosphate and photosynthetic bacteria decreased bulk density favoured soil conditioning, aggregate stability and nutrient recycling. Reduction in bulk density may be due to better soil aggregation and aeration brought about by organic amendments. (Kadalli *et al.*,2000)

Dehydrogenase activity of soil was affected by the application of different types of organic manures (Table 17). Soil enzymes are the indicators of soil fertility as their activity depends on numerous factors such as climate, amendment, cultivation practices, crop type and edaphic properties. Naseby and Lynch (1997) considered enzymatic determinations were more useful than microbial measures. Since the dehydrogenase is involved in the respiratory chain of microorganisms and has often been used as a parameter to evaluate the overall microbial activity of soil (Serra-wittling *et al.*, 1995). The result indicated that the treatment T_7 (75% N as EM compost + Panchagavya) registered the highest mean value for the maximum dehydrogenase activity in soil. Increase in dehydrogenase activity showed that organic fertilizer added to soil in the form of compost or growth promoter had enormous load of microorganisms as this assay is a measure of viable microbial activity. Improved dehydrogenase activity in organically amended soils was in accordance with the findings of Beyer *et al.* (1992), Ramamurthy *et al.*(1995),Cooper and Warman (1997), Tatento (1998) , Monreal *et al.* (1998) ;Dahia *et al.* (2003) ,Manjunatha *et al.* (2004) , Shwetha (2008) and Tejada *et al.*(2009).

Table 17 shows the microbial population of the soil after the harvest of crop. Among microbes fungal population was significantly influenced by

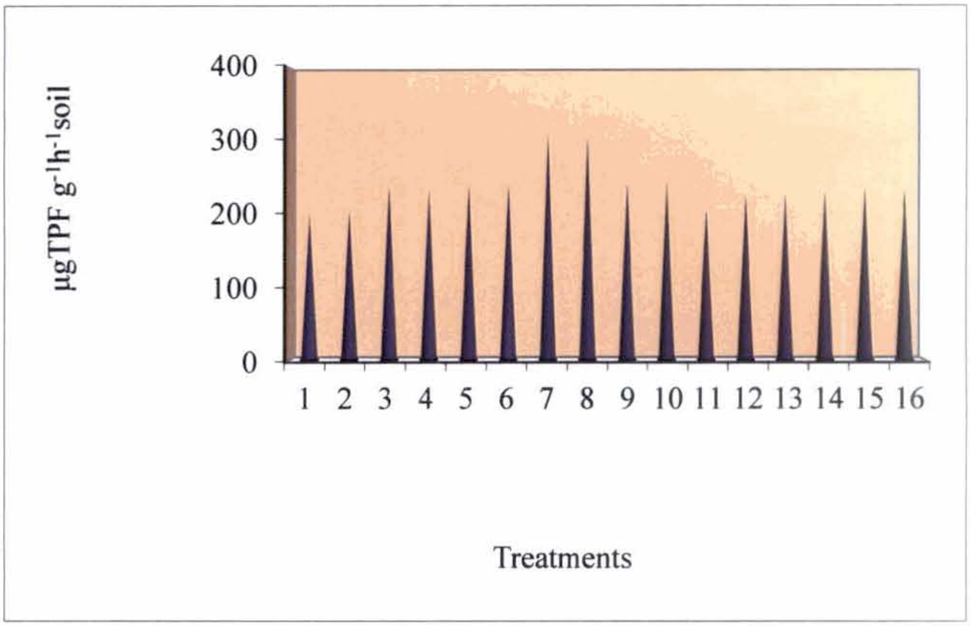

Fig.15.Effect of different types of organics on dehydrogenase(μgTPF g^{-1} h^{-1} soil)

different treatments. For fungus highest mean value was recorded by T_8 (75% N as BM compost + Panchagavya). In the case of bacteria, the treatment T_7(75% N as EM compost + Panchagavya) recorded the highest value and it was found to be on par with treatments T_{10} (75% N as BM compost + Vermiwash), T_9 (75% N as EM compost + Vermiwash), T_{16} (50% N as BM compost + Vermiwash), T_{14}(50 % N as BM compost + Panchagavya), T_{15} (50% N as EM compost + Vermiwash), T_{13} (50 % N as EM compost+ Panchagavya), T_3 (100 % N as EM compost and T_4 (100 % N as BM compost). Regarding the actinomycetes, the treatment T_{10} (75% N as BM compost + Vermiwash) registered the highest value and was on par with T_9 (75% N as EM compost + Vermiwash), T_{16} (50 % N as BM compost + Vermiwash), T_{15} (50 % N as EM compost + Vermiwash) and T_4 (100 % N as BM compost). The growth promoters *viz* Panchagavya and Vermiwash play a vital role in enhancing the microbial population of the soil. This was in conformity with the findings of Kale *et al.* (1992) and Somasundaram and Sankaran (2004). Presence of Effective Micro-organism in EM compost and *Trichoderma* in BM compost favoured the microbial activity of soil. Battikopad *et al.* (2009) reported that application of cattle dung enriched with rockphosphate along with Effective Microorganisms (0.5ml kg^{-1}) improved the microbial activities, enhanced the health and productivity of soil. Microbial biomass and enzyme activities are closely related to soil organic matter content. Organic amendments stimulated the biological activity preferably due to synergism of soil organic material and microorganisms. (Gaind and Nain,2010)

SUMMARY

6. SUMMARY

An investigation on "Organic nutrition for soil health and productivity of Chilli (*Capsicum annuum* L.) was carried out at Instructional Farm, College of Agriculture, and Vellayani during 2009-2010. The main objective of the study was to assess the effect of enriched composts along with growth promoters on physico-chemical and biological properties of soil and to study its impact on crop performance. The investigation consisted of preparation of enriched composts and growth promoters and also field experiment using chilli var. Vellayani Athulya as the test crop.

FIELD EXPERIMENT

The experiment was laid out in randomised block design with sixteen treatments and two replications. The treatment details are as follows. T_1- Absolute control, T_2- POP ,T_3- 100% N as EM compost,T_4 -100% N as BM compost,T_5 -75% N as EM compost ,T_6 -75% N as BM compost, T_7- 75% N as EM compost + Panchagavya,T_8- 75% N as BM compost + Panchagavya,T_9- 75% N as EM compost + Vermiwash,T_{10}- 75% N as BM compost + Vermiwash,T_{11} -50% N as EM compost ,T_{12} -50% N as BM compost,T_{13}- 50% N as EM compost + Panchagavya,T_{14}- 50% N as BM compost + Panchagavya,T_{15} -50% N as EM compost + Vermiwash,T_{16}- 50% N as BM compost + Vermiwash. The salient findings of the experiment are listed below.

- The tallest plant with the highest number of primary branches was found in the treatment T_8 (75% N as BM compost + Panchagavya) followed by T_7 (75% N as EM compost + Panchagavya) at 90DAT.
- During 30DAT and 60DAT also T_8 (75% N as BM compost + Panchagavya) recorded the highest value for plant height.
- Different treatments did not significantly affect 'days to 50% flowering'.

- Number of fruits per plant and fruit length were highest for the treatment T_8 (75% N as BM compost + Panchagavya) and was on par with T_7 (75% N as EM compost + Panchagavya).
- For yield characters like fruit girth , fruit weight , total fruit yield , green fruit yield per plant and total drymatter yield; T_8(75% N as BM compost + Panchagavya) recorded the highest value .
- With respect to disease incidence percentage (*Colletotrichum* fruit rot), treatment T_8 (75% N as BM compost + Panchagavya) registered the lowest mean value and it was found to be on par with T_4 (100% N as BM compost). Highest disease incidence percentage was recorded by the treatment T_1 (Absolute control).
- Treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value for capsaicin content and it was found to be on par with treatments T_7 (75% N as EM compost + Panchagavya) and T_{10} (75% N as BM compost + Vermiwash).
- For ascorbic acid content, treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value and was found to be on par with T_{14} (50% N as BM compost + Panchagavya) and T_7 (75% N as EM compost + Panchagavya).
- Different treatments did not significantly affect the oleoresin content of the fruit.
- For keeping quality (shelf life), highest mean value was recorded by the treatment T_8 (75% N as BM compost + Panchagavya). Treatments T_8, T_7, T_{13}, T_{14} and T_{15} were found to be on par.
- In the case of N and P uptake T_8 (75% N as BM compost + Panchagavya) recorded the highest value followed by T_7 (75% N as EM compost + Panchagavya).

- For K, T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value and was found to be on par with T_9 (75% N as EM compost + Vermiwash).
- The treatment T_8 (75% N as BM Compost + Panchagavya) recorded the highest BC ratio. Next highest value for BC ratio was recorded by the treatment T_7 (75% N as EM Compost and Panchagavya) followed by T_9 (75% N as EM compost + Vermiwash) .
- For pH values of soil, highest mean value was recorded by treatment T_8 (75% N as BM compost + Panchagavya) and was found to be on par with T_{10}, T_{14} and T_7.
- For bulk density of soil, lowest mean value was recorded by treatment T_7 (75% N as EM compost + Panchagavya) and was found to be on par with T_8 (75% N as BM compost + Panchagavya). The treatments T_{12} (50% N as BM compost), T_{11} (50% N as EM compost) and T_1 (Absolute control) registered high values and were found to be on par .
- T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value for organic carbon content of soil and was found to be on par with T_7 (75% N as EM compost + Panchagavya).
- For the available N and P in soil, T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value and the treatment T_{10} (75% N as BM compost + Vermiwash) showed the highest mean value for available K in soil followed by T_9 (75% N as EM compost + Vermiwash).
- T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value for exchangeable calcium and magnesium content of soil and was found to be on par with T_7 (75% N as EM compost + Panchagavya).
- For available Fe, Zn and Mn T_8 (75% N as BM compost + Panchagavya) recorded the highest mean value but for Cu T_7 (75% N as EM compost + Panchagavya) registered the maximum value.

- The treatment T_7 (75% N as EM compost + Panchagavya) registered the highest mean value for dehydrogenase activity in soil.
- Regarding the fungal count, treatment T_8 (75% N as BM compost + Panchagavya) registered the highest mean value followed by the treatment T_7 (75% N as EM compost + Panchagavya).
- For bacteria highest mean value was recorded by the treatment T_7 (75% N as EM compost + Panchagavya) and it was found to be on par with treatments T_{10}, T_9, T_{16}, T_{14} T_{15}, T_{13}, T_4 and T_3 .
- For Actinomycetes, the treatment T_{10} (75% N as BM compost + Vermiwash) registered the highest mean value followed by T_9 (75% N as EM compost + Vermiwash).

Considering the salient findings, different organic sources along with growth promoters favourably influenced the soil physico-chemical and biological properties. Among the various organic sources used, 75% N as BM compost + Panchagavya (T_8) and 75% N as EM compost + Panchagavya(T_7) are found to be on par with respect to biometric observations, crop yield and quality of chilli.

CONCLUSIONS

- A significant increase in yield of chilli was recorded with the combined application of enriched manures and growth promoters *viz.* 75% N as BM compost with Panchagavya and 75% N as EM compost with Panchagavya.
- Application of enriched manure along with growth promoter *viz.* 75% N as BM compost +Panchagavya and 75% N as EM compost +Panchagavya resulted in high quality chilli fruits.
- The soil available nutrient status was significantly high with the combined application of organic sources along with growth promoters.
- There was significant improvement in the soil biological properties (*i.e.* dehydrogenase activity and microbial load) with the combined application of organic manures and liquid manures (growth promoters).

FUTURE LINE OF WORK

- A long term field investigation needs to be conducted to ascertain the benefits of organic manures along with liquid manures on yield and quality of various crops.
- Response of different varieties to different organic sources should be studied.
- Exploration of other organic sources for use as alternative sources to chemical fertilizers should also be evaluated.

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ORGANIC NUTRITION FOR SOIL HEALTH AND PRODUCTIVITY OF CHILLI (*Capsicum annuum* L.)

by

LEKSHMI.V

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COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM - 695 522
KERALA, INDIA

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ABSTRACT

An investigation was carried out on the topic titled "Organic nutrition for soil health and productivity of Chilli (*Capsicum annuum* L.) at the Instructional farm, attached to the College of Agriculture, Vellayani to evaluate the effect of two enriched composts *viz.* BM compost and EM compost at different rates alone as well as in combination with two growth promoters *viz*, Panchagavya and vermiwash on physico-chemical and biological properties of soil and also their impact on crop performance using chilli variety Vellayani Athulya as test crop.

The results from the field experiment revealed that the plant growth characters *viz.* height of the plant at 30, 60 and 90 DAT and primary branches per plant at 90 DAT showed significant variation due to the application of 75% N as BM compost along with Panchagavya. The treatments did not significantly affect the biometric observation *viz.* 'days to 50% flowering'. Significant differences were observed among yield attributing characters *viz.* number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), green fruit yield per (g plant^{-1}), total fruit yield (t ha^{-1}) and total dry matter yield (t ha^{-1}). The treatment T_8 (75% N as BM compost + Panchagavya) recorded the highest values for all these characters but it was found to be on par with T_7 (75% N as EM compost + Panchagavya). This shows that BM compost can be substituted with EM compost when used along with Panchagavya.

As regards to quality characters, the treatment T_8 (75% N as BM compost + Panchagavya) registered the highest values for capsaicin, ascorbic acid and shelf life of fruits. However 'oleoresin content of the fruit' was not significantly influenced by different treatments.

Disease incidence percentage (*Colletotrichum* fruit rot) was found to be reduced by the treatments with organic sources. The treatment T_8 (75% N as BM compost + Panchagavya) reduced the incidence of pests and diseases to a considerable extent. Highest BC ratio also was recorded by the same treatment T_8 (75% N as BM compost + Panchagavya). Post harvest analysis of the soil

indicated that organic carbon, available macro and micro nutrients pH, EC and microbial load and dehydrogenase activity were increased by the combined application of enriched manures *viz.* 75% N as BM compost and Panchagavya or 75% N as EM compost and Panchagavya. Bulk density was found to be reduced favourably.

From the results it can be concluded that that 75% N as BM compost and Panchagavya or 75% N as EM compost and Panchagavya was superior to all other organic sources in promoting soil health and yield and quality of chilli.

APPENDICES

APPENDIX I

Method for preparation of activated EM solution

1. Ingredients for preparation of one litre activated solution
   a. EM stock solution – 50 ml
   b. Molasses or Jaggery – 50 g
   c. Well water – 900 ml

2. Methodology of preparation
   - Mix EM, Jaggery and water.
   - Pour the mixture into a clean one litre plastic container and close it air tight.
   - Keep in a cool, dark place at ambient temperature.
   - Open the lid for a few seconds to let out the accumulated gas everyday.
   - The solution is ready for use when the pH drops below 4, which takes approximately 7 to 10 days.

APPENDIX II

Weather parameters during the cropping period (2009)

Standard months	Maximum temperature (^0C)	Minimum temperature (^0C)	Maximum relative humidity (%)	Minimum relative humidity (%)	Rainfall (mm)	Evaporation (mm day^{-1})
June	31.0	24.0	90.3	81.1	174.0	2.9
July	30.1	24.0	90.5	83.7	190.6	2.8
August	30.2	24.1	87.5	81.7	74.9	3.3
September	29.6	24.2	91.0	85.0	114.2	3.3
October	30.4	24.2	90.2	84.3	100.9	3.5
November	29.5	23.8	90.6	83.4	485.7	2.9