EVALUATION OF MINERAL ENRICHED COMPOSTS FOR SOIL REMINERALISATION AND CROP NUTRITION

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DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of mineral enriched composts for soil remineralisation and crop nutrition**.**"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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<u>CERTIFICATE</u>

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EXTERNAL EXAMINER

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Sreeja S.V

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LIST OF ABBREVIATIONS AND SYMBOLS USED

%	Per cent
@	At the rate of
µg	microgram
µm	micrometer
B:C	Benefit:Cost
BEC	Bio enriched compost
BMEC	Biomineral enriched compost
cmol kg^{-1}	Centi mol per kilogram
Ca	calcium
CD	Critical difference
Cd	cadmium
CEC	Cation exchange capacity
cfu	Colony forming units
cm	centimeter
Cr	chromium
CRD	Completely randomized design
Cu	copper
DAS	Days after sowing
et al.	and other co workers
Fe	iron
Fig.	Figure
FYM	Farmyard Manure
g	Gram
i.e.	that is
IAA	Indole acetic acid
K	potassium
KAU	Kerala Agricultural University
kg ha^{-1}	Kilogram per hectare
MEC	Mineral enriched compost
meq	Milli equivalent
MEVC	Mineral enriched vermicompost
Mg	magnesium
mg kg^{-1}	Milligram per hectare
Mg m^{-3}	Mega gram per cubic metre
mm	millimeter
Mn	Manganese

MOP	Muriate of potash
mS cm^{-1}	milli Simens per centimeter
MSL	Mean Sea Level
N	nitrogen
Ni	Nickel
OC	Ordinary compost
P	phosphorus
Pb	lead
PGPR	Plant Growth Promoting Rhizobacteria
pH	Negative logaritham of hydrogen ions
POP	Package of practice
ppm	Parts per million
PSM	Phosphorus solubilising microorganism
RBD	Randomized Block Design
RDF	Recommended dose of fertilizer
SE	Standard error
SSP	Single super phosphate
TPF	Tetraphenyl formazon
viz.	Namely
Zn	Zinc
µS m^{-1}	micro Simens per metre

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Introduction

1. INTRODUCTION

Agriculture is the backbone of Indian economy.Indian agricultural sector is driven by the subsistencestrategies of small holder farmers and their families. Becauseof lack of interests, land degradation, water scarcity and erraticnature of monsoon, agricultural practices in India areundergoing a structural change leading to a crisis situation.The rate of growth of agricultural output is steadily fading in the recent years and it is an alarming situation that India ismoving towards food scarcity.

Declination in agriculturalpractices has adverseaffects on food supply, prices of foodgrains, cost of living,health and nutrition, poverty, employment, labour market andland loss. Root cause of these crisis are mismanagement ofnatural resources, degradation of soil or land due to continuoususe of chemical fertilizers, water scarcity, dependence onrainfall and climate, landuse changes and urbanization. Organic farming is today's answer for sustained productivity and also for safe nutritious food.One of the major constraints in popularizing organic farming is the non availability of good quality organic manures. This is achieved partially by the adoption of technologies for enrichment of nutrients. Use of natural additives and bio-inoculants are the development in composting technologies to enrich manures. Such enriched products are required for intensive crop production.

The part of organic farming is agrogeological concept of sustained farming. Agrogeology is one of the research sectors of applied geology useful for the benefit of society. It addresses all geological characteristics of the superficial soil deposits and the related geological processes taking place therein which are of crucial importance for agricultural production (Straaten, 2006). Geological investigations help us for accessing groundwater potential (qualitative and quantitative), land reclamation, slope management and other factors responsible for degradation of soil, which are of vital importance for sustainable agriculture (Straaten, 2007). Risk assessment and risk management as far as soil pollution, water pollution and air pollution and natural disasters like drought, desertification, salinisation and others responsible for troubling agricultural activities can be best predicted and managed by performing geoscientific investigations.

Agro-minerals like niter, phosphate minerals, zeolites, tourmaline and gypsum and rock dust of basalt, granite and limestone are useful for improving soil fertilityand for conserving nutrients and water in the agriculture land. Soil nutrient deficiencies and crop diseases can be cured or prevent by mixing suitable rock dust in soil for its regeneration.

Rock dusts, as the term is used in organic agriculture, refers to those granite meals and quarry dusts and rock flours that are derived from very finely ground rock minerals. Rock dust contains many of the nutrients essential to plant growth, with the exception of nitrogen. Ground rock also improves soil structure and increases water holding capacity and cation exchange capacity (Fragstein, 1987). Rock dusts are valued for the fineness of grind and trace element content. Soil remineralization is a common term used in association with rock dusts. Remineralization can be used as a generic term for any addition of rock minerals to soils as a means to replenish mineral nutrients and provide agronomic benefits. It recognizes the fact that continuous harvesting of crops removes a certain amount of minerals from the soil, and that remineralization can provide essential mineral elements or help balance mineral nutrients, especially trace elements and secondary nutrients like calcium and magnesium.

One of the uses of rock dusts, as an amendment to composts, is of particular interest with respect to enhancement of microbial activity and bioavailability of mineral elements contained in rock minerals. "**Mineralized compost**" is a term used in association with composts amended with rock dusts to take advantage of this microbial action (solubilization and mineralization).Rock dust when added as amendment to compost, trace element contained in rock minerals function as biocatalysts in microbially- driven enzyme reactions critical to breakdown and buildup process. Hence rock dust feeds microbes with necessary trace elements and by products of microbial activity, organic acids, helpto solubilise the slow-to-release mineral elements tied up in rock minerals. All these reactions and activities occur simultaneously.

In Kerala, among various crops grown, cowpea occupies a prime position due to its protein and fibre content. Though being a leguminous crop, it can fix atmospheric nitrogen thus reduces the N requirement but requires high P content.Considering the above aspects, present study was undertaken with the following objectives

- To evaluate mineral enriched composts by monitoring nutrient release pattern under laboratory conditions and
- To study the effects of enriched composts on soil remineralization and crop nutrition.

Review of literature

2. REVIEW OF LITERATURE

Soil remineralisation creates fertile soil by mixing dust of rocks and minerals to the soil and regenerate minerals in the soil much the same way earth does. Remineralisation of soil with finely ground rock dust is the economical and ecological alternative to chemical fertilizers and pesticides (Sherwood and Uphoff 2000). It returns all of the deficient mineral nutrients which creates fertile soils and healthy crop.

Soil re-mineralisation is one of the best solutions for improving soil fertility because:

1. Remineralization is essential to restore ecological balance and stabilize the climate and to recycle and return mineral nutrients creating fertile soils and healthy crops.
2. It provides slow, natural release of elements and trace minerals and improves soil productivity and increase crop yields.
3. It increases nutrient intake of plants and produce more nutritious crops. Increase resistance to insects, diseases and drought. The research results relating to the use, nutrient supplying ability and its influence on crop growth and yield are being reviewed in this chapter.

2.1 ROCK DUST USED AS A SOURCE OF NUTRIENTS

In Brazil, there were reports showing that use of potassium rich (zeolitized) phonolite (Frayha, 1950), basalt (Leonardos *et al.,* 1982) and other rock types as alternative for laterite soils.

And rock spectrum such as dunites and serpentines (Chittenden *et al*., 1969), granite and gneisses (Geering, 1952) had also been successfully employed as source of potassium and magnesium.

The use of rock to improve crop yields dates back from ancient times. In the 18th century, James Huton, the father of modern geology not only recommended but also used rocks like marl to increase the soil fertility of his farm in Scotland (Bailey, 1967).

The rocks were reported to have fast solubility rates both in water and weak organic acids promptly releasing nutrients in a matter of minutes (Singer and Narrot, 1976) .

Hamaker and Weaver (1982) reported that the ideal rocks for remineralization are basalt and rhyolite and also reported the advantages of heterogenous combination of various rocks and minerals .

Walter (1991) reported that glacial moraine is an ideal rock for remineralization because these rocks are formed very deep within the earth and also from a large variety of rock types and particle size.

Leonardos *et al.* (2000) suggested that the ultimate way to restore the leached tropical soils is by the use of native rocks (stone meal) which is a balanced composition where plant growth and biodiversity can thrive.

Hildebrand and Kirchner (2000) conducted research on plant uptake of nutrients from ground silicate rocks and also several researchers concluded that ground silicate rocks had potential as slow release fertilizers.

Coventry *et al*. (2001) reported that minplus, which is a geo source , improved plant growth in acidic, highly weathered soils of low fertility in humid tropics, and reduced fertilizer use in acidic, iron-rich soils with strong phosphorus fixation properties. It also ensured more sustainable uses of soil resources and fertiliser, replaced high cost imported fertilizers, reduced environmental hazards from decreased use of agricultural lime, erosional losses of nutrients from farmlands and their deposition in sensitive natural wetlands and near-shore marine systems.

Ground silicate rocks which act as soil amendments may increase soil pH and cation exchange capacity. Gillman *et al*. (2001) found that after 9 months, granite applied to a highly weathered soil @ 300 t ha^{-1} increased the soil cation exchange capacity from 9-14 cmol kg^{-1}.

Ground rocks such as amphibolite, basalt, diabase, dunite, gneiss, granite, phenolite, serpentine, syenite and a volcanic ash had been investigated as sources of calcium, magnesium and some micronutrients for plants (Gillman *et al*., 2002).

Szmidt and Ferguson (2004) reviewed some replicated trials of various types of rockdust at varying rates of application and resulted in increased soil moisture infiltration, increased soil nutrients and improved plant nutrient uptake.

Straaten (2006) reviewed the advantages and disadvantages of using rock fertilizers in agriculture. The advantages were discussed as the possibility of multi elemental release, high pH, possible improvement to the acid neutralization capacity of some soils, or changes to the cation exchange capacity of some soils. The disadvantages were identified as the low solubility and slow nutrient release, large application rates required and that a large portion of the rock contained minerals with no nutrient value.

In a field experiment conducted at FSRS, Kottarakara during 2001- 2003, khondalite (rock powder) was used as nutrient source for cassava either alone or in combination with chemical fertilizers and farmyard manure (Shehana *et al*., 2006).

Finely powdered khondalite-charnockite type rocks were used either alone or in combination with FYM and chemical fertilizer for coleus. (Rose, 2008)

2.2 PARTICLE SIZE OF ROCK DUST FOR BETTER RELEASE OF NUTRIENTS:

Gillman (1980) reported a high correlation between cation exchange capacity and the amount of applied rockdust material passing the 125 µm sieve.

Hamaker and Weaver (1982) reported that in rock dust 90 percent of it must pass through 200 mesh screen and he also stated that the ideal particle size of rock dust is that 20 percent of which must pass through a 200 mesh screen and 50 per cent must pass through 100 mesh screen.

The effect of grinding basalt rock dust was investigated by Blum *et al*. (1989) who showed that reducing particle size from 100 percent passing a 2 mm sieve to 100 percent passing a 200 µm sieve doubled the amount of easily soluble elements.

Wang *et al.* (2000) showed a significant increase in plant growth when using fine particle size (1-2 mm) gneiss compared to coarse size (2-5 mm). This was attributed to some physical or chemical effect other than K since no difference in response to the supply of K was found between the two size fractions.

It is expected that smaller grain size would lead to greater reactivity of rock dust due to greater exposure of the reactive surface of minerals. Harley and Gilkes (2000) reviewed that grains larger than 2 mm can be suggested as a nutrient reservoir and smaller grains may not have greatest dissolution rates.

Nutrient release from ground silicate rocks depends on their dissolution in soil which is influenced by rock properties, soil properties and climatic conditions. Dissolution of silicate rocks was improved by small grain size (Gillman *et al*., 2002).

2.3 ROLE OF ROCK DUST IN CARBON SEQUETRATION

Hamaker and Weaver (1982) reported that if rock dust were used on a global scale soil, would lock up the carbon dioxide and prevent catastrophic consequences of climate change.

Berner and Robert (1991) mathematically reported that under natural conditions, the atmospheric CO_2 content is controlled primarily by the rate of weathering of silicate rocks. As the silicate rocks weather, the calcium and magnesium combine with atmospheric CO_2 to ultimately form calcium carbonate and magnesium carbonate which is deposited primarily in the oceans in the form of limestone and dolomite deposits. The CO_2 is ultimately returned to the atmosphere by volcanic eruptions.

2.4 NUTRIENT RELEASE FROM ROCK DUST

Gillman (1980) found that only a small fraction of the cations applied as crushed basalt scoria was mobilized in incubation experiments. However, crushed basalt addition resulted in an increased level of exchangeable cations.

Five rock powder with different chemical and mineralogical characteristics were investigated for their suitability as soil conditioners by Blum *et al.* (1989). The highest cation exchange capacity was determined for the powder of smectite rich volcanic ash. Carbonate rock powder showed highest values for the acid neutralization capacity (ANC). Silicate rock powder (granite, basalt) recorded the lowest values for both parameters.

A positive pH effect was also shown by Mersi *et al*. (1992) who showed that addition of a basalt/diabase/bentonite powdered rock mixture to acid forest soils could lead to higher soil pH.

Weerasuriya *et al*. (1993) stated that one of the potential benefits of rockdust was the possibility of multi-elemental release of K, Mg, Fe, Zn, Mn and Cu.

Brien *et al.* (1999) investigated changes in a range of extractable nutrients from a plant growth medium treated with either basaltic or glacial rock fines. Most nutrients were significantly affected by fines addition although the increases were most marked in macro-nutrients such as Ca and Mn.

The factors influencing mineral dissolution were investigated by Harley and Gilkes (2000) who stated that it would be dependent on the soil environment including pH, redox reaction, soil solution, composition and temperature. Decreased soil pH increases silicate dissolution, localised reducing conditions could increase Fe in solution, diffusion gradients in the soil solution could accelerate rock weathering and mineral dissolution occured faster at higher temperatures.

Wang *et al*. (2000) also postulated that root induced acidification might have influenced the release of mineral K from gneiss rock dust.

Hinsinger *et al*. (2001) showed that the incongruent dissolution of basalt weathered plagioclase minerals (releasing calcium and sodium) faster than ferromagnesian silicates.

Wilpert and Lukes (2003) suggested that the slower reaction of phonolite compared to dolomite (lime) could mean that it was an alternative where the risk of nitrate mobilization is high. Nitrate mobilization was noticed as a result of the increase in soil pH brought out by dolomite application.

Despite the range of elements present in quarry fines, Vetterlein (2004) stated that most of the nutrients are not readily available.

Bakker *et al.* (2004) showed that weathering of powdered plagioclase could be stimulated by plants although mineral dissolution was primarily due to geochemical (pH) effects.

He *et al*. (2005) stated that the easily weathered constituents of basaltic rocks contained Cu, Zn, Co and Mn.

Silva *et al*. (2005) showed that the most soluble elements from granite powder were calcium and magnesium.

Release of Si, Al, Ca, Mg, Fe and Mn in the presence of plant roots from andesite was investigated by Meheruna and Akagi (2006) and from basalt by Akter and Akagi (2005).

Supanjani *et al*. (2006) found that the combined application of phosphate and potassium rock powder with P and K solubilising bacteria increased plant yields similarly to those gained using soluble fertilizers. This treatment also increased P and K availability in treated plots to the same level as soluble fertilizer.

2.5 COMPOST MATERIALS ENRICHED WITH ROCK DUST

Lertola (1991) stated that compost and rock dust had a symbiotic combination. The compost provides an excellent medium for the micro organism population explosion and incorporation of rock dust increased the microbial activity of soil.

Experiment 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.

Gracia *et al*. (2002) stated an increase in microbial respiration, which was shown by a loss in biomass and increased carbon dioxide production, when using a blend of glacial silt and quartz dolerite in the composting of spent mushroom substrate (SMS). They also postulated that rockdust could have improved the physical properties of SMS allowing 'faster surface reactions, gas exchange and spatial effects'.

Sikora (2004) aimed to show that addition of basaltic mineral fines to an animal manure composting mixture could stimulate biological activity and improve compost quality by reaching higher temperatures during the process.

Mitchell *et al*. (2004) found that growth media manufactured from compost and quarry fines would need to be supplemented with fertilizer to establish plants and produce good growth in the medium-term.

Guillou and Davies (2004) combined various composts with four types of rock dust reported that the best soil substitutes were formed using green waste compost with any type of rock dust had detrimental effects on acceptability to the consumer of tomato fruit.

2.6 ASSESSMENT OF QUALITY OF COMPOST

Saha and Panwar (2009) conducted a study to investigate physico-chemical properties, fertilizing potential and heavy metal polluting potentials of municipal solid waste composts produced in 29 cities of the country. Under the scheme, 'Fertilizing index' was calculated from the values of total organic C, N, P, K, C/N ratio and stability parameter, and 'clean index' was calculated from the contents of heavy metals, taking the relative importance of each of the parameters into consideration. As per the scheme, majority of the compost samples did not belong to any classes and hence, have been found unsuitable for any kind of use. As per the regulatory limits of different countries, very few compost samples (prepared from source separated biogenos wastes) were found in marketable classes (A, B, C and D) and some samples were found suitable only for some restricted use.

2.7 EFFECT OF MINERAL ENRICHED COMPOST ON SOIL PROPERTIES

Water holding capacity of soil was increased when treated with ground silicate rocks and minerals (Khant *et al.*, 1986).

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

Mersi *et al*. (1992) showed a significant effect on protease activity. They suggested that applications of rock dust could increase C and N mineralization which could affect mineral nutrient turnover in forest ecosystems in the long-term.

The United State Department of Agriculture (USDA, 1998) conducted experiments on by product utilization such as quarry waste fines, gypsum and coal dust. Combined composting of these with municipal by product, reduced pathogens, toxins and other odours and created high quality natural fertilizers for the soil.

The role of microorganisms in dissolution of minerals had been well established. The solubilization of P from phosphate rock by microorganisms like *Bacillus* had been reported. Organic acids or chelating agents such as alfa-2-keto gluconic acid produced during the decomposition of organic matter helped in the release of nutrients from applied rock or insoluble minerals in soil (Russel, 1998).

Hartmann *et al.* (1999) applied N-enriched rock powder (containing apatite, biotite, kolemanite and dolomite) to poor sandy soils and showed that it stimulated microbial activity and soil organic matter formation.

Harley and Gilkes (2000) reviewed some evidence of the ability of rhizosphere microorganisms to release soil minerals or increase trace element mobility.

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

Richardson (2001) reported that microorganisms increased the dissolution of ground rock fertilisers by release of organic ligands, H^+ ions and organic acids into the soil.

Dahia *et al*. (2003) observed that application of sugarcane trash enriched with Mussoorie 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 favoured soil conditioning, aggregate stability and nutrient recycling.

Shehana (2003) reported that application of khondalite resulted in an increase in soil porosity and water holding capacity.

Monedero *et al*. (2004) suggested that mixing compost with peat resulted in lower bulk density and higher porosity and water holding capacities along with lower salinities and electrical conductivities.

BBC (2004) reported a success story of two Scottish teachers, Moriya Thomson and Cameron, who had spent 20 years experimenting with remineralization. In 1997, a charitable trust named SEER centre was set up in Perth Shire, Scotland for experimental research in organic gardens and small holdings.

Szmidt (2004) commented that rock dust, as with other inert mineral materials such as sand, could have effects on physical properties of plant growth media. Effects could occur on density, moisture holding capacity and air porosity.

Ground rock fertilizer might directly affect soil micro organism through their nutrient composition. Studies had shown that micro organism colonising mineral surfaces in other environment were influenced by mineral chemistry (Gleeson *et al*., 2006).

Rose (2008) reported that soil treated with rock dust along with farmyard manure had shown better release of nutrients required for coleus.

Rock dust helped to stabilise soil organic matter, and its paramagnetic characteristics might aid plants in taking up water and nutrients. (Egli *et al.,* 2010).

Seventy five percent of nitrogen as biomineral compost (compost enriched with rock dust and *Trichoderma*) along with panchagavya application was superior to all other organic sources in promoting soil health, yield and quality of chilli (Lekshmi, 2011).

Moreover, the ground rock is naturally alkaline which might constitute an effective alternative to traditional liming materials for correcting the pH (Silva *et al.*, 2013).

2.8 EFFECT OF MINERAL ENRICHED COMPOST ON PEST AND DISEASE CONTROL

Rock dust is perhaps the ideal soil amendment for promoting improved immunity to pests and disease. In the short term, rock dust sprayed on plants deters insects and in the long term silica in rock dust strengthens plant tissue (which contain silica granules called phytoliths) and makes them less susceptible to drought, insects, and diseases (Fragstein, 1995).

Bob (2001) explained that finely crushed rock contains about 25 percent silicates when applied directly to the plant, these small particles disable and discourage insects by causing various forms of mechanical discomfort.

Lekshmi (2011) registered lowest disease incidence percentage (*Colletotrichum* fruit rot) in plant treated with 75 percent N as biomineral compost + panchagavya whereas highest incidence was observed in absolute control.

Campe (2012) reported that in the short term, very fine dust sprayed directly on plants and trees has been shown to deter insect infestations very effectively and in the long term remineralized plants will not be plagued by insects as they become healthier and more insect resistant.

Nutrients are important for growth and development of plants and microbes, and they are also important factors in plant disease control. The raised soil pH and Ca content were the key factors for the rock dust amendment controlling bacterial wilt under greenhouse condition (Gang and Dong, 2013). He also suggested that copper, supports the synthesis of vitamin A and vitamin C which help the plant (and person eating the plant) to resist disease.

2.9 EFFECT OF MINERAL ENRICHED COMPOST ON CROP GROWTH AND YEILD

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.

Plant growth effects were also shown by Weerasuriya *et al*. (1993) who found that acidulated mica chips gave significant increases in panicle number and seed weight of rice compared to muriate of potash control.

Gowda *et al*. (1995) reported that rice yield increased with the application of SSP with green manure and P solubilising fungi when comparable to MRP along with green leaf manure .

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

Savithri *et al.* (1995) reported that rock phosphate along with coir pith were incubated and resulted in twenty eight per cent increased grain yield in rice over the sole application of rock phosphate.

Compost enriched with rock phosphate had increased the yield of rice when compared with that of SSP (Singh and Amberger, 1995).

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

Yarrow (1997) studied the effect of rock dust (rhyolitic tuff brecia) in potatoes, sugar beet and various trees and found an increase in beet and potato yield and increase in tree growth and wood volume.

Sudhirkumar *et al.* (1997) reported that rock phosphate applied along with organic amendments had increased the grain and straw yield in chickpea.

From the experiment in various trees in Australia using granite and diorite @ 12-20 t ha^{-1}, Oldfield (1998) found that application of rock dust increased plant growth and nitrogen fixation capacity.

Barker (1998) conducted an experiment to restore soil fertility through basalt dust from a rock quarry or glacial moraine fines from a gravel quarry were evaluated for their effects on nutrient availability in soils and on yields and composition of tomato, apple and sweet corn. Yield of produce from crops produced with additions of mineral fines and composts generally were equivalent to those of crops grown with commercial fertilizers.

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

Oldfield (1999) reported that there was increase in plant growth, particularly at higher rock dust rate and increased N fixation in trees treated with grainte or diorite.

Wang *et al.* (2000) reported that plant selection played vital role in dissolution of nutrients because plants released organic ligands which attack mineral surfaces and form complexes and lower soil pH by releasing H^+ ions and organic acids into the soil. He also reported that plant species and varieties varied in their ability to increase rock dissolution and careful plant selection might enhance mineral dissolution.

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

Sreenivas and Narayanasamy (2003) observed that compost enriched with 2 per cent RP, 1 per cent pyrite and *Trichoderma viridae* (500 g t^{-1}) resulted in higher yield in crops.

Bugbee (2002) reported increased plant growth of flowering annuals and herbaceous perennials when biosolids compost was added @ 50 – 100 per cent in a mix of biosolids compost, bark, peat and sand.

Soumare *et al*. (2003) showed that mineral fertilizer in combination with compost significantly increased dry matter yield of rye grass.

Namdeo *et al.* (2003) reported that application of P_2O_5@ 60 kg ha^{-1} or jhabua rock phosphate charged phosphocompost @ 25 t ha^{-1} or 25 percent jhabua rock phosphate charged phosphocompost @ 15 t ha^{-1} showed statistically identical performance for growth and yield parameters of soyabean and it was found to be superior than control (without P).

Dahia *et al*. (2003) reported that MRP enriched sugarcane trash compost had increased the ratoon yield of sugarcane.

Szmidt (2004) reported that plant that received basalt or glacial silt has shown better plant establishment and growth of Brassicas.

Nicholas *et al*. (2006) conducted an experiment and objective was to improve the availability of phosphorus (P) from rock phosphate (RP) through feeding, mixing and composting manure. The results show that P-enriched composting in the presence of wheat straw significantly increased P availability and increased plant growth.

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 @ 1t ha^{-1} along with seventy five percent of recommended dose of chemical fertilizer registered the highest yield of 21.3 t 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)

Silva (2007) reported that combination of minplus rockdust and rainforest inoculum had enhanced the growth of the nursery plants and also suppressed the development of pathogenic bacterial populations particularly gram negative bacteria and also improved bacterial properties of soil thereby enhanced the growth and yield of tea.

Phosphate rock was shown by Msolla *et al*. (2007) to give positive responses on maize growth when applied to acid soil. There was also a better residual effect than triple superphosphate due to solubilization of the rock over time in acid soil and lower plant uptakes of phosphate during the first harvest period.

Rose (2008) suggested that hundred percent chemical fertilizer can be substituted with rock dust 10 t ha^{-1} and FYM 10 t ha^{-1} for coleus wherever rock dust is locally available.

Seventy five percent of nitrogen as biomineral compost (compost enriched with rock dust and *Trichoderma*) along with panchagavya application recorded highest value for yield characters like fruit weight, total fruit yield, green fruit yield per plant, fruit girth, total dry matter yield and quality in chilli (Lekshmi, 2011) .

Ayanlowo and Awodun (2014) reported that maize treated with 3 t ha^{-1} poultry manure + 0.5 t ha^{-1} granite dust promoted the growth and yield parameter of maize to a level of the standard recommended fertilizer rate of 200 kg ha^{-1} of NPK fertilizer in the ecological zone of the south western Nigeria.

2.10 EFFECT OF VERMICOMPOST AND ENRICHED VERMICOMPOST ON CROP GROWTH, YIELD AND QUALITY

Lee (1985) observed that the application of vermicompost has increased the pH of the soil. Worm casts have a pH near to neutral range than the surrounding soil and the possible factors that act on soil pH may be excretion of $NH4^{+}$ ions from calciferous glands of the earthworms.

Shuxin *et al*. (1991) reported that by manure application, the organic C in the red arid soil increased from 0.5 - 0.6 per cent.

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

Studies on the effect of compost addition by Martin and Marinissen (1993) revealed that the activity of dehydrogenase increased to the range of 210 µg TPF hydrolysed 24 $hr^{-1}$with the application of vermicompost.

Vijayalekshmi (1993) reported that soil properties such as porosity, soil aggregation, soil water transmission and conductivity of soil were improved for soil treated with worm cast when compared with no worm cast amended soil.

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

Application of vermicompost had significantly increased the P uptake in green gram when compared to FYM (Reddy and Mahesh, 1995)

Sagaya and Gunthilagaraj (1996) obtained more P content in amaranthus plant grown with introduction of earthworms.

Organic C content and pH has increased significantly by vermicompost application (Pushpa, 1996).

According to Vasanthi and Kumaraswamy (1996) vermicompost + NPK treated plants had given higher P content .

Rajalekshmi (1996) in her experiment found that application of organic manure in the form of vermicompost recorded the highest value for all available nutrients.

Vermicompost and phosphobacteria in combination with two inorganic P sources namely superphosphate and Tumis rock phosphate were verified in a calcareous black soil for their effect on yield parameter of black gram (CO5) and cotton (LRA 5155). The application of TRP (100 %) 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 (Thiyageswari and Perumal, 1998)

According to Meera (1998) use of vermicompost coated seeds had produced the maximum uptake of all nutrients. Soil analysis of available nutrients revealed that the treatments receiving vermicompost had significant influence on the Ca, Mg, Zn, Cu and Mn content in soil compared to inorganic fertilizers.

According to Sailajakumari (1999), application of enriched vermicompost with rock phosphate had increased the plant height, number of branches, nodules number and yield in cowpea and also increased the available N, P_2O_5, and K_2O status of the soil

Arunkumar (2000) reported that vermicompost when applied to amaranthus had recorded highest ascorbic acid content and lowest fibre content.

Sailajakumari and Ushakumari (2001) reported highest protein content in plants treated with vermicompost than with FYM.

According to Senthilkumar and Surendran (2002), vermicompost application has influenced the physical, chemical and biological properties of soil. They also opined that vermicompost had improved the water holding capacity of soil and acted as a mine for various plant essential nutrients such as N, P, K, S and trace elements.

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

Devi Krishna (2005) reported that plants which received vermicompost with PSM had found highest pod yield as well as highest nutrient uptake of bhusa and pod of cowpea.

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

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

2.11 EFFECT OF BIO ENRICHED COMPOST ON SOIL AND CROP YEILD

Kapoor *et al.* (1990) studied the effects of addition of *Paecilomyces fusisporus* , *Azotobacter chroococcum,* Mussoorie rock phosphate (MRP), MRP + *Aspergillus awamori,* MRP + *A. awamori* +*A. chroococcum* or *P. fusisporus,* or MRP + *A. awamori* + *A. chroococcum* + *P. fusisporus* to a leaf/grass/legume straw compost on total percentage N, C:N ratio, available N and citric acid soluble P and on grain yield of wheat in 1983-84 and 1985-86 when applied with or without 60kg N + 30kg P/ha were studied. After 90 days, total N percentage and available N in the compost were highest and C:N ratio was lowest with multiple inoculations of compost. Addition of MRP increased soluble P content. Wheat grain yield was higher with enriched compost than ordinary compost.

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

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 C:N ratio. Rock phosphate enrichment accelerated the decomposition and improved the nitrogen mineralization. Phosphorus from rock phosphate was solubilised during composting and transformed into available form.

Ichida *et al*. (2001) reported that feathers soaked in an inoculum of *B. licheniformis* and *Streptomyces sp.* degraded more quickly and more completely than feathers that were not presoaked. Inoculation of feather waste could improve composting of the large volume of feather waste generated every year by poultry farms and processing plants.

Bolta *et al. (*2003) reported that inoculation of a mixture of household organics and shredded wood with inoculate from the active phase of composting enhanced mineralization of organic matter and yielded a biologically stabilized product with a more favourable C/N ratio than in a no inoculated treatment.

Singh and Sharma (2003) reported that the combination of *P. sajor-caju*, *T. harzianum* and *A. chrocooccum* produced the highest quality compost. The percentage of mycorrhizal infection in mung bean was influenced by the three inoculants and crop growth was enhanced significantly with the combination of *P. sajor-caju*, *T. harzianum* and *A. chrocooccum* over other treatments.

Composts were produced from rice straw enriched with rock phosphate and inoculated with *Aspergillus niger, Trichoderma viride* and or farmyard manure (FYM). The resulting composts were evaluated as organic phosphate fertilizers for cowpea plants in pot experiments. The results showed that the maximum amount of soluble phosphorous (1000 ppm) was produced in composts inoculated with *A. niger* + *T. viride* with or without FYM.(Zayed and Motaal, 2005).

Wei *et al.* (2006) reported that inoculation with microbes in composting would improve the degree of humification and maturation processes and mixed inoculation of MSW with complex microorganisms and lingo-cellulolytic during composting gave a greater degree of HA aromatization than inoculation with complex microorganisms or lingo-cellulolytic alone.

Nishanth and Biswas (2007) reported that enriched composts prepared with RP and waste mica along with *A. awamori* resulted in significantly higher biomass yield, uptake and recoveries of P and K as well as available P and K in soils than composts prepared without inoculum.

Thenmozhi and Paulraj (2009) studied the effect of using inoculants during composting and found highest rhizome yield for plants received poultry manure enriched with microbial inoculants followed by *Trichoderma viride*-banana pseudostem compost @ 750 kg ha^{-1} along with 75% of the recommended dose of fertilizer .

2.12 EFFECT OF BIO FERTILIZER IN CROP YEILD

Bacteria like *Pseudomonas* and *Bacillus* are widely used in organic production system and also important phosphorus solubilizing microorganisms, resulting in improved growth and yield of crops. (Dobereiner, 1997).

Raupach and Klopper (1998) reported that the three-way mixture of PGPR strains (INR7 plus ME1 plus GB03) as a seed treatment showed intensive plant growth promotion and disease reduction to a level statistically equivalent to the synthetic elicitor Actigard applied as a spray.

Esitken *et al*. (2003) studied the effect of bio fertilizer in apricot and found that PGPR could stimulate growth and increase yield in crop.

Patidar and Mali (2004) studied the effect of farmyard manure 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 bio fertilizer addition.

Han and Lee (2005) reported that un-inoculated plants, compared to the inoculated plants, under soil salinity conditions had an increased antioxidant activity and concentration of proline, MDA, GR and APX. The results suggested that inoculation of salt-stressed plants with PGPR strains could alleviate salinity stress.

Orhan *et al*. (2006) conducted an experiment on plant growth promoting effects of two *Bacillus* strains OSU-142 (N_2-fixing) and M3 (N_2-fixing and phosphate solubilizing) which were tested alone or in combinations on organically grown primocane fruiting raspberry. The result showed that *Bacillus* M3 alone or in combination with *Bacillus* OSU-142 have the potential to increase the yield, growth and nutrition of raspberry plant under organic growing conditions.

Adesemoye *et al.* (2008) conducted 3 year field trial on corn and found that microbial inoculants that increase plant growth and yield can enhance nutrient uptake, and thereby remove more nutrients, especially N, P, and K from the field as part of an integrated nutrient management system.

Rifat *et al*. (2010) reported that the direct promotion on plant growth by symbiotic and non- symbiotic PGPR (plant growth promoting rhizobacteria) was mainly, due to production of plant hormones such as auxins, cytokinins, gibberellins, ethylene, abscisic acid and production of indole 3- ethanol or indole - 3- acetic acid (IAA) which had been reported for several bacterial genera.

Turan *et al.* (2010) suggested that mixed PGPR inoculations with the strain of OSU-142 + M-13 + *Azospirillum* sp.245 has significantly increased grain yield of wheat as good as full doses of nitrogen. All bacterial inoculations especially mixed inoculation, significantly increased uptake of macro-nutrients (N, P, K, Ca, Mg and S) and micro-nutrients (Fe, Mn, Zn, and Cu) of grain, leaf, and straw part of the plant. The data suggested that seed inoculation with OSU-142 + M-13 + *Azospirillum* sp.245 may substitute N and P fertilizers in wheat production.

Greenhouse studies were conducted to evaluate the potential of the use of bacilli plant growth-promoting rhizobacteria (PGPR) for control of *Phytophthora blight* on squash (Zhang *et al*., 2010).

Khaled *et al.* (2012) reported that bio-fertilizer and organic materials like compost, humic acid and compost tea could be used as an integrated plant nutrition with 20, 30 or 40 kg $fed^{-1}$of mineral N fertilizer producing higher sesame yield quantity and quality than those produced by the conventional recommended mineral N dose alone, meanwhile improve the soil characters under newly reclaimed saline soil conditions.

Sheeja *et al*. (2013) reported that the stimulatory effect on plant growth by the inoculation of NPK biofertiizer (PGPR Mix-I) was found to be more pronounced when it was applied with half recommended dose of NPK (45-22.5-7.5 kg ha^{-1}) and lime top dressing (250 kg ha^{-1}) and recorded the highest benefit cost ratio (3.25 and 1.67) a net returns (71316 and 21146 Rs ha^{-1}) with grain yield of 7355 kg ha^{-1} and 3520 kg ha^{-1} respectively during both the seasons.

Materials and Methods

3.MATERIALS AND METHODS

The present study entitled 'Evaluation of mineral enriched composts for soil remineralization and crop nutrition' has been carried out at College of Agriculture, Vellayani during 2014- 2015. The main objective of the study was the evaluation of mineral enriched composts by monitoring nutrient release pattern under laboratory conditions and to study the effects of enriched composts on soil remineralization and crop nutrition. The investigation consisted of three parts 1) preparation of mineral enriched compost 2) laboratory incubation study and 3) field experiment. The materials used and the methods adopted for the studies are briefly described in this chapter.

3.1 MATERIALS

3.1.1 Locations

The experiment was carried out at College of Agriculture, Vellayani. Geographically, the area is situated at 8^0 30' N latitude and 76^0 54' E longitude and at an altitude of 29 m above MSL.

3.1.2 Collection and analysis of rockdust:

Rock dust, which is finely powdered and 90 per cent of which passes through 200 mesh screen, was collected from the nearby quarry, Mookunnimala. The rock dust used was a mixture of khondalite- charnockite rock type. The elemental analysis of rock dust (Table.1) was carried out at NCESS, Aakkulam, Thiruvananthapuram.

Table 1. Composition of rock dust:

Constituent / Chemical property	Units	Content
SiO_2	per cent	57.26
Al_2O_3	per cent	13.92
Fe_2O_3	per cent	5.07
CaO	per cent	6.42
MgO	per cent	8.23
Na_2O	per cent	2.72
MnO	per cent	0.23
P_2O_5	per cent	0.85
K_20	per cent	3.27
ZnO	per cent	0.03
Ni	ppm	4
Cu	ppm	12

3.2 PREPARATION OF DIFFERENT COMPOSTS

Enriched composts were prepared using finely powdered rock dust, composting inoculum and their combination as additive along with the biowaste-cow dung mixture during composting.

3.2.1 Preparation of mineral enriched compost

Rock dust, the geo nutrient source was used for the preparation of mineral enriched compost. Cemented tanks of size 2.5 x 1 x 0.5 m were used for compost preparation and biowaste used were banana leaves and pseudostem. These wastes were collected, chopped and mixed with cowdung in the ratio 10:1 (volume basis) along with rock dust @ 25% on volume basis during composting. Frequent raking was done and 60% moisture level was maintained throughout the period and final product was termed mineral enriched compost, which was ready by 80 days.

3.2.2 Preparation of bio enriched compost

Composting inoculum developed at Department of Microbiology, College of Agriculture, Vellayani was added at the rate of 5g kg^{-1} of biowaste cowdung mixture (10:1) during composting. Composting inoculum was applied 2 weeks after the initiation of composting process. Moisture level was kept at 60% during composting. Frequent raking were done for aeration. Final compost was ready within 90 days.

3.2.3 Preparation of biomineral enriched compost

Additives used for preparing enriched compost were a combination of rock dust (25%) and composting inoculum (5g kg^{-1}) along with the biowaste cowdung mixture. Moisture level was maintained at 60 per cent level and biomineral enriched compost was ready by 80 days.

Plate 1. Production of different enriched composts:

Table 2. Analytical methods followed in the analysis of enriched composts

SI. No.	Properties	Methods	Reference
1	Organic carbon	Loss on ignition method	Jackson (1973)
2	Nitrogen	Digestion in H_2SO_4 and Micro Kjeldahl distillation	Jackson (1973)
3	Phosphorus	Nitric-Perchloric (9:4) digestion and colorimetry	Jackson (1973)
4	Potassium	Nitric-Perchloric (9:4) digestion and flame photometry	Jackson (1973)
5	Ca, Mg	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
6	Micronutrients : Fe, Mn, Zn, Cu	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
7	Cadmium	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
8	Nickel	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
9	Lead	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
10	Chromium	Nitric-Perchloric (9:4) digestion and AAS	Jackson (1973)
11	Microbial count ($cfug^{-1}$)	Serial dilution plate technique	Timonin (1940)
12	Respiratory activity	CO_2 evolution method	Jenkinson and Powlson (1976)
13	pH	1:2.5 soil:water, pH meter	Jackson (1973)
14	EC	Conductivity meter	Jackson (1973)
15.	C:N	C- loss on ignition method N- Digestion in H_2SO_4 and Micro Kjedahl distillation	Jackson (1973)

3.2.4 Preparation of mineral enriched vermicompost:

The raw material used and the methods adopted were the same as that in preparation of enriched compost. Two weeks after filling the tank, 1 kg of earthworm (*Eudrillus euginae*) was introduced into the biowaste cowdung mixture. Rock dust at the rate of 25 per cent was added as additive for enriching the vermicompost in the beginning of composting and final compost was ready by 60 days. The moisture level was maintained to 60 per cent level and frequent raking were done for aeration and final compost was termed as mineral enriched vermicompost

3.2.5 Preparation of ordinary compost:

The biowaste used were banana leaves and pseudostem which was laid into tank of size 2.5 x 1 x 0.5 m and was well mixed with cowdung in the ratio of 10:1 on volume basis. The moisture level was maintained at 60 per cent by adding water as and when required. Frequent raking was done for aeration. Final compost was ready by 120 days.

The prepared composts were analysed and methods were mentioned in Table 2.

3.2.6 Method of assigning grade for the quality of composts

Assigning grade to the composts is done on the basis of their potential for improving soil productivity, content of plant nutrient and level of maturity (collectively indicated by ‘fertilizing index’) as well as on the basis of their potential of contaminating land with heavy metals (indicated by ‘clean index’) as proposed by Saha and Panwar (2009).

Hence based on potential to improve soil productivity and to contaminate land with heavy metals, fertilizing index and clean index were computed.

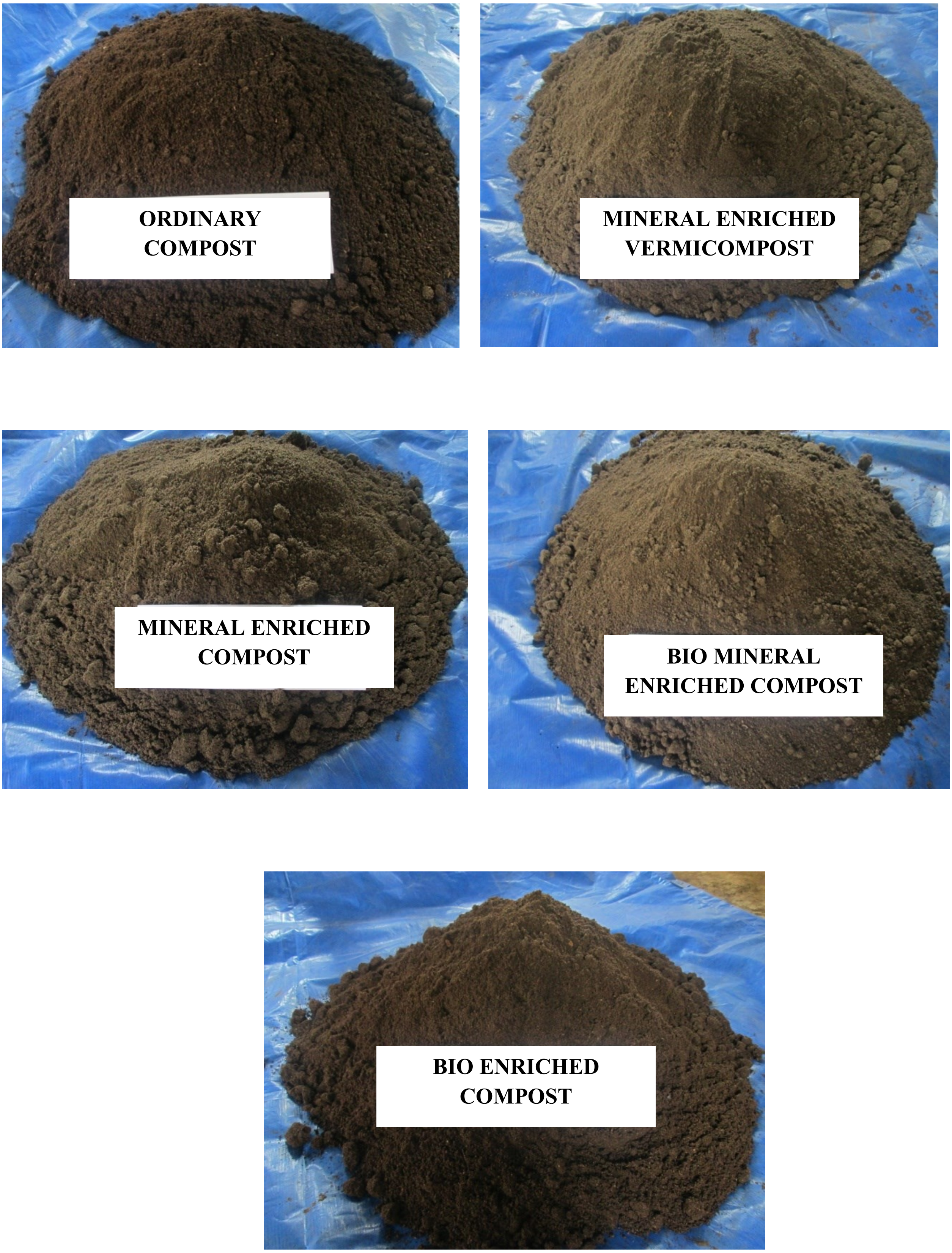

Plate 2. Different types of composts used for the study.

3.1.6.1 Fertilizing index

It is the measure of nutrient supplying potential of compost. Table.3 shows the methodology used for calculation of fertilizing index.

Table 3. Criteria for assigning weighing factor to fertility parameters and score value to analytical data

Fertility parameters	Score value (Si)					Weighing factor (Wi)
	5	4	3	2	1	
Total OC %	>20	15.1-20	12.1-15	9.1-12	<9.1	5
Total N %	>1.25	1.01-1.25	0.81-1.00	0.51-0.80	<0.51	3
Total P %	>0.60	0.41-0.60	0.21-0.40	0.11-0.20	<0.11	3
Total K %	>1.00	0.76-1.00	0.51-0.75	0.26-0.50	<0.26	1
C:N	<10.1	10.1-15	15.1-20	20.1-25	>25	3
Respiration Activity (mg g^{-1})	<2.1	2.1-6	6.1-10	10.1-15	>15	4

The fertilizing index of the composts is computed using the formula,

$$\text{Fertilizing index} = \frac{\sum S_i W_i}{\sum W_i}$$

3.1.6.2 Clean index:

It is used by regulatory authority for restricting the entry of heavy metals into sensitive components of environment (Table 4).

Table 4.Criteria for assigning weighing factor to heavy metal parameters and score value to analytical data

Heavy metals (mg kg^{-1})	Score value (Sj)						Weighing factor (Wj)
	5	4	3	2	1	0	
Zn	< 151	151-300	301-500	501-700	701-900	> 900	1
Cu	< 51	51-100	101-00	201-400	401-600	> 600	2
Cd	< 0.3	0.3-0.6	0.7-1.0	1.1-2.0	2.0-4.0	> 4.0	5
Pb	< 51	51-100	101-150	151-250	251-400	> 400	3
Ni	< 21	21-40	41-80	81-120	121-160	> 160	1
Cr	< 51	51-100	101-150	151-250	251-350	> 350	3

The clean index of the composts is computed using the formula,

$$\text{Clean index} = \frac{\sum S_j W_j}{\sum W_j}$$

Table5 Classification of compost for their marketability and use in different area:

Class		Fertilizing index	Clean index	Quality control compliance	Overall quality and area of application
Marketable classes	A	> 3.5	> 4.0	Complying for all heavy metal parameters	Best quality. High manurial value and low heavy metal content. Can be used for high value crops and in organic farming
Marketable classes	B	3.1 to 3.5	> 4.0	Complying for all heavy metal parameters	Very good quality. Medium fertilizing potential and low heavy metal content.
Marketable classes	C	> 3.5	3.1-4.0	Complying for all heavy metal parameters	Good quality. High fertilizing potential and medium heavy metal content.
Marketable classes	D	3.1 - 3.5	3.1-4.0	Complying for all heavy metal parameters	Medium quality. Medium fertilizing potential and medium heavy metal content.
Restricted use classes	RU-1	< 3.1	-----	Complying for all heavy metal parameters	Low fertilizing potential but safe for environment. Can be used as soil conditioner.
Restricted use classes	RU-2	≥ 3.1	> 4.0	Not complying for all heavy metal parameters	Can be used for growing non- food crops. Requires periodic monitoring of soil quality if used repeatedly.
Restricted use classes	RU-3	≥ 3.1	≤ 4.0	Not complying for all heavy metal parameters	Can be used for developing lawns/ gardens, tree plantation in forestry (with one time application.)
The samples not falling under above marketable and restricted use classes are not suitable for agricultural land application and can be used for rehabilitation of degraded land.					

3.3 LABORATORY INCUBATION STUDY

The incubation study was conducted under the laboratory condition for a period of four months from29-10-2014 to 28-2-2015. The main objective of the study was to assess the nutrient release pattern from different enriched composts.

3.3.1 Collection and preparation of soil sample for incubation study

The soil for the incubation study was collected from the model organic farm. Five kilogram of soil was filled in plastic buckets into which enriched composts and biofertilizers were added as per treatment. Sixty percent moisture was maintained throughout the study period. The details of experiment are presented below:

3.3.2 Design and layout of experiment:

Design : CRD

Treatments : 10

Replication : 3

3.3.3 Treatments

T1 : soil alone, 5 kg

T2 : soil, 5kg + ordinary compost @ 20 t ha^{-1}

T3 : soil, 5 kg + mineral enriched compost (rock dust 25%) @ 20 t ha^{-1}

T4 : soil, 5 kg +bioenriched compost (composting inoculum 5g/kg) @ 20 t ha^{-1}

T5 : soil, 5 kg + bio mineral enriched compost (rock dust 25% + composting Inoculum 5g/kg) @ 20 t ha^{-1}

T6 : soil, 5 kg + mineral enriched vermicompost (rock dust 25%) @ 20 t ha^{-1}

T7 : soil, 5 kg + mineral enriched compost (rock dust 25%) @20 t ha^{-1} + PGPR Mix -1(2%)

T8: soil, 5 kg + bioenriched compost (composting inoculum 5g kg^{-1}) @ 20 t ha^{-1} + PGPR Mix -1(2%)

T9 : soil, 5 kg + bio mineral enriched compost (rock dust 25% + composting

inoculum 5g kg^{-1}) @ 20 t ha^{-1}+ PGPR Mix -1(2%)

T10 : soil, 5 kg + mineral enriched vermicompost(rock dust 25%) @ 20 t ha^{-1}

+PGPR Mix -1(2%)

The layout of laboratory incubation study was presented in Fig. 1

3.3.4Soil sampling

Sampling were done at 15^{th}, 30^{th}, 60^{th}, 90^{th} and 120^{th} day of incubation and analysis was done for the following parameters.

3.3.5 Analysis of soil sample

i) Soil reaction (pH)
ii) Electrical conductivity (EC)
iii) Available nitrogen
iv) Available phosphorus
v) Available potassium
vi) Exchangeable calcium
vii) Exchangeable magnesium
viii) Available micronutrients viz. Fe, Mn, Zn, and Cu.

The analytical methods followed are presented in Table.6

Plate 3. Overall view of laboratory incubation study

R1	R2	R3
T1	T6	T9
T10	T3	T8
T8	T7	T10
T5	T2	T1
T6	T9	T5
T3	T1	T7
T2	T5	T4
T7	T4	T2
T4	T10	T6
T9	T8	T3

Fig 1. Layout of incubation study

Plate. 4 Overall view of field experiment

Table 6. Analytical methods followed in soil analysis

SI No	Properties	Methods	Reference
A. Physical properties			
1	Texture	International pipette method	Piper (1966)
2	Bulk density	Core method	Gupta and Dakshinamurthy (1980)
3	Water holding capacity	Core method	Gupta and Dakshinamurthy (1980)
4	Moisture	Core method	Gupta and Dakshinamurthy (1980)
B. Chemical properties			
5	pH	1:2.5 soil:water, pH meter	Jackson (1973)
6	EC	Conductivity meter	Jackson (1973)
7	CEC	Ammonium saturation using neutral normal ammonium acetate	Jackson (1973)
8	Organic carbon	Walkley and Black rapid titration method	Jackson (1973)
9	Available nitrogen	Alkaline permanganate method	Subbiah and Asija (1956)
10	Available phosphorus	Extraction with Bray and estimation by colorimetry	Jackson (1973)
11	Available potassium	Flame photometry	Jackson (1973)
12	Exchangeable Ca	Versanate titration method	Hesse (1971)
13	Exchangeable Mg	Versanate titration method	Hesse (1971)
14	Available Fe, Mn, Cu, Zn	Atomic Absorption Spectrophotometer	O'Connor (1988)
C. Microbial properties			
15	Dehydrogenase	TPF method	Page *et al*. (1982)
16	Microbial count Bacteria, fungi, actinomycetes	Serial dilution plate technique	Timonin (1940)

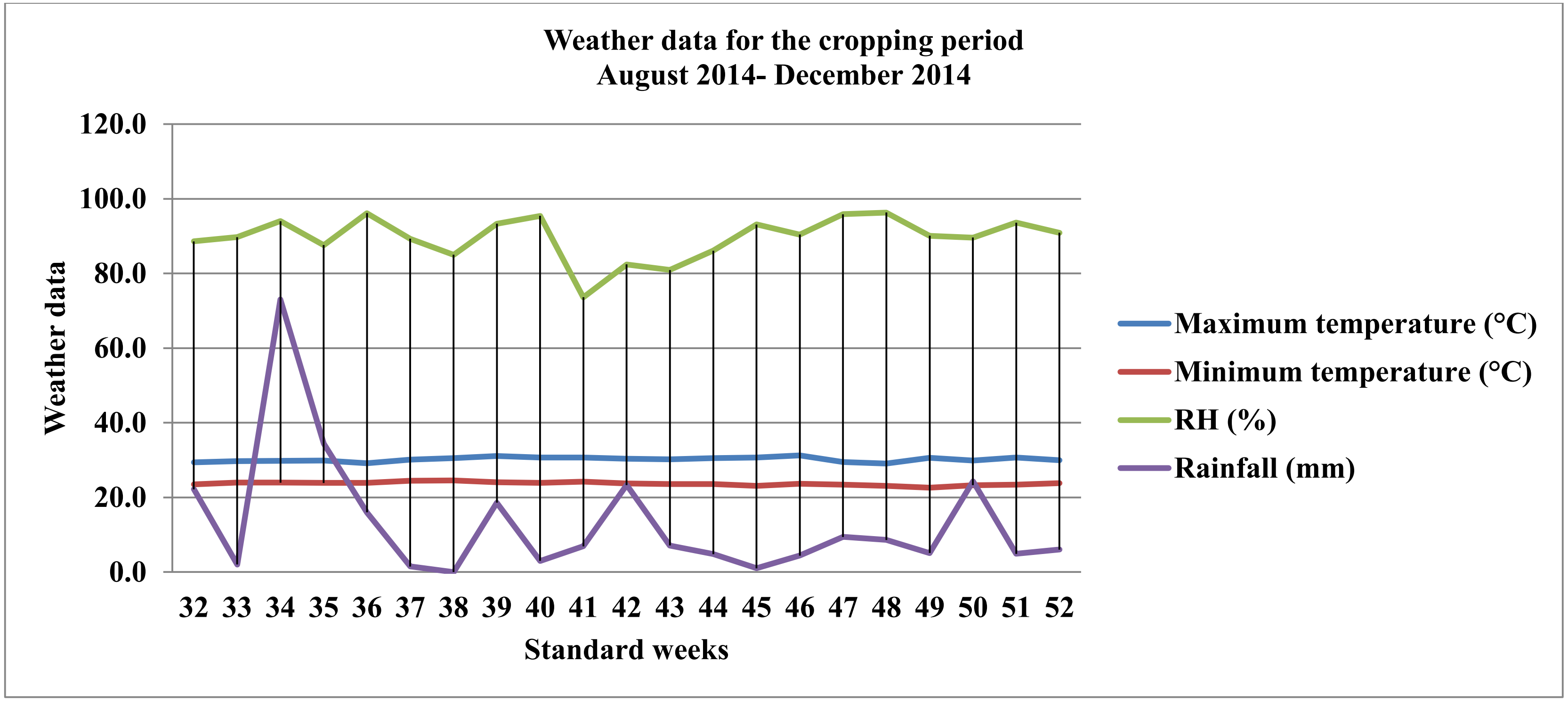

Fig.2 Weather data for cropping period August -December 2014.

3.4FIELD EXPERIMENT

3.4.1 Materials

3.4.1.1 Manures

Five type of composts *viz*. ordinary compost, mineral enriched compost, bio enriched compost, biomineral enriched compost and mineral enriched vermicompost were applied at 50 per cent N basis. Biofertilizer (PGPR Mix I) was applied as per treatments.

3.4.1.2 Seasons:

The period of crop growth was from August 2014 to December 2014. Average rainfall, temperature, evaporation and relative humidity at monthly intervals were collected from meteorological observatory attached to the College of Agriculture, Vellayani during the cropping period and are given in Fig. 2.

3.4.1.3 Soils:

The soil of the experimental site was sandy clay loam belonging to the family 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 12.

3.4.1.4 Crop:

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

3.4.1.5 Biofertilizer :

PGPR Mix I, biofertilizer used for the study was purchased from the Department of Agricultural Microbiology, College of Agriculture, Vellayani.

3.4.1.6 Fertilizer

Urea analysing 46% N, Rock phosphate with 20% P_2O_5 and MOP analysing 60% K_2Owere applied as per the Package of Practice Recommendations of Kerala Agriculture University (KAU, 2011)

3.4.2 Methods

3.4.2.1 Design and layout of experiment

Design	:	Randomised block design
Crop	:	Yardlong bean as test crop
Variety	:	Vellayani Jyothika
Spacing	:	2 x 2m
Plot size	:	4 x 4m
Replication	:	3
Treatments	:	11

The layout of the field experiment is given in Fig.3

3.4.2.2 Treatments

T1 : KAU POP

T2 : 75% N as ordinary compost

T3 : 75 % N as mineral enriched compost (rock dust 25%)

T4 : 75 % N as bio enriched compost (composting inoculum 5g kg^{-1})

T5 : 75 % N as bio mineral enriched compost (rock dust 25% +composting

T6: 75% N as mineral enriched vermicompost (rock dust 25%)

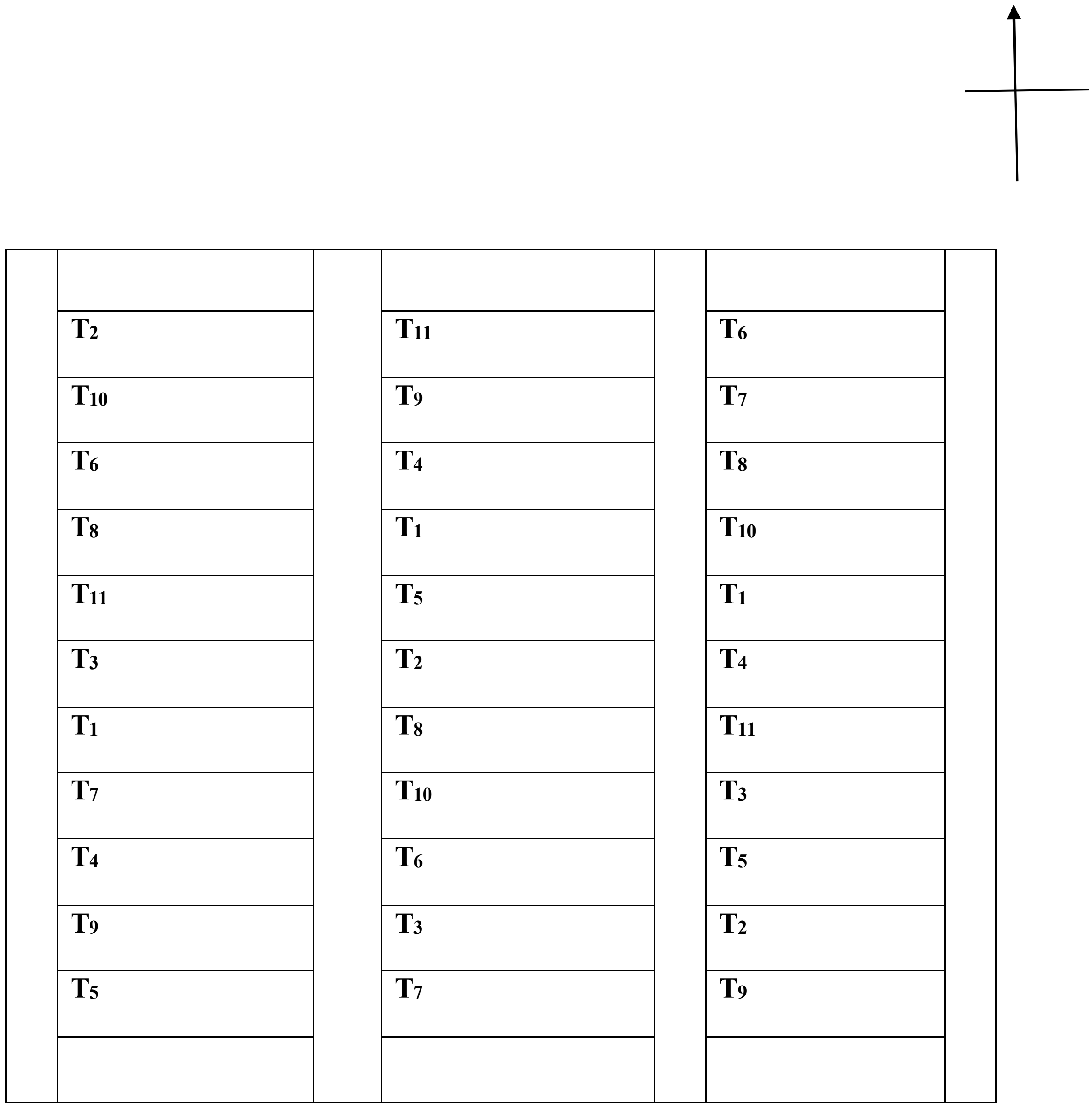

Fig.3 Layout of field experiment

T7 : 50%N as ordinary compost + PGPR Mix I (2%)

T8 : 50 % N as mineral enriched compost (rock dust 25%) + PGPR Mix I (2%)

T9 : 50 % N as bio enriched compost + PGPR Mix I (2%)

T10: 50% N as bio mineral enriched compost (rock dust 25% + composting inoculum 5g kg^{-1})+ PGPR Mix I (2%)

T11 : 50 % N as mineral enriched vermicompost (rock dust 25%) + PGPR Mix I (2%)

3.4.2.3 Land preparation

The main field was made into fine tilth and plots of size 4m x 4m were taken with bunds of width 20 cm all around. As per treatments allotted, 33 plots were made and pits were taken at 2 x 2m spacing (Fig. 3). Uniform irrigation was given in all plots as and when required.

3.4.2.4Application of manures and fertilizer

Farmyard manure was applied uniformly in all plots @ 20 t ha^{-1}. Lime was applied @ 250 kg ha^{-1}. The five types of composts were applied as per treatment based on N equivalent basis. PGPR Mix I @ 2 % was applied in T_7, T_8, T_9, T_{10} and T_{11}.

3.4.2.5 Crop maintenance:

During initial stage, irrigation was given daily. Gap filling was done five days after sowing. Weeds were removed as and when necessary.

3.4.2.6 Incidence of pest and disease:

Occurrence of yellow mosaic virus disease and aphid attack was found during initial stages of crop which was controlled by spraying 2 per cent nimbicidin and during later stages of crop, *Fusarium wilt* was observed and was controlled by 3 per cent fish amino acid spray.

3.4.2.7 Harvest

The crop was ready for the first harvest 49 days after sowing and subsequent harvests were made at 3 days interval. The pods were picked at correct maturity stage**.**

3.4.3 Biometric observation

3.4.3.1 Days to 50 per cent flowering

Number of days to reach 50 per cent flowering as counted from the date of dibbling to the date in which flowering was noticed in nearly 50 per cent of the population in a plot

3.4.3.2 Leaf area index

LAI (Leaf Area Index) was measured using leaf area meter at 50 per cent flowering stage.

LAI was worked out using the formula,

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}}$$

3.4.3.3 Crop duration

Duration is the number of days from sowing to final harvest of the plant.

3.4.3.4 Number of harvest

Number of times pods were harvested from each plot was noted.

3.4.3.5 Appearance of the product

Scoring test was used for evaluating the appearance of the product as suggested by Swaminathan (1974). A four point rating scale was applied for appearance.

3.4.4 Yield characters

3.4.4.1 Pod length

Five pods were selected at random from the observation plants. Length of the pod was measured as the distance from pedicel attachment of the pod to the apex using twine and scale. Average was worked out and expressed in centimeters.

3.4.4.2 Pod weight

Pods used for recording pod length were weighed and the average weight was found out and expressed in grams.

3.4.4.3 Pod yield

Total weight of pods from the observation plants from each plots at each harvest was taken and the average was expressed as pod yield/ plot. It is expressed in kg ha^{-1}.

3.4.4.4 Number of pods/ plant

Total number of pods harvested from the observation plant from each plot at each harvest was taken.

3.4.4.5 Bhusa yield

After the pods were picked from observation plants from each plot, the plants were uprooted and weighed and average weight was expressed in kg ha^{-1}

3.4.4.6 Total dry matter production

The two observation plants were uprooted without damaging the roots and separated into leaves, stem, and roots. They were dried under shade and then oven dried at 65^0C for 10 hours till two consecutive weights coincided. The total dry weight of pods and Bhusa were added to get the total dry matter production (kg ha^{-1}.)

3.4.4.7 Harvest index

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}}$$

Plate. 4 Overall

3.4.5Quality parameters

3.4.5.1 Protein content

The pod N values were multiplied by the factor 6.25 to obtain the protein content of pods and the values were expressed as per cent (Simpson *et al* .,1965).

3.4.5.2 Fibre content

The crude fibre content in the pods were estimated using gravimetric method and expressed in per cent (Kanwar and Chopra, 1976).

3.4.5.3 Shelf life

The harvested pods kept under ordinary room condition to study its shelf life and number of days, up to which the pods remained fresh for consumption without loss of colour and glossiness, were recorded.

3.4.6 Incidence of pest and disease

Aphid incidence was calculated using the formula,

$$\text{Aphid incidence (\%)} = \frac{\text{Number of affected branches} \times 100}{\text{Total number of branches}}$$

Fusariumwilt incidence was calculated using the formula,

$$\textit{Fusariumwilt}\text{ incidence (\%)} = \frac{\text{Number of affected plants} \times 100}{\text{Total number of plants}}$$

3.4.7 Soil analysis

Soil samples were taken at the time of final harvest of pods. The samples were air dried under shade, sieved through 2 mm sieve and used for the analysis of pH, EC, organic carbon and available N, P, K, Ca, Mg, Fe, Mn, Zn and Cu using standard analytical procedures as presented in Table 6.

3.4.8 Plant analysis

Plant and pods samples were collected at final harvest. The samples were oven dried at 70^{0}C, powdered and used for estimation of N, P, K, Ca, Mg, Fe, Mn, Zn, and Cu . Whole plant analysis of these nutrients were also done after final harvest. Analytical procedures were presented in Table 7 .

3.4.9 Plant uptake

$$\text{Nutrient uptake} = \frac{\text{Concentration of nutrients x Total dry matter production}}{100}$$

3.4.10 Statistical analysis

The experimental data generated from the study were subjected to statistical analysis as described by Cochran and Cox (1965). Contrast analysis weredone to study the effect of biofertilizer as described by Rengaswamy (1995)

Table 7. Standard analytical methods followed for plant analysis

Sl No.	Parameters	Methods	References
1	Nitrogen	Micro Kjeldhal distillation after digestion in sulfuric acid	Jackson (1973)
2	Phosphorus	Nitric – perchloric acid (9:4) digestion and colorimetry making use of vanadomolybdo phosphoric yellow colour method	Jackson (1973)
3	Potassium	Nitric- perchloric acid (9:4) digestion and flame photometry.	Jackson (1973)
4	Calcium and magnesium	Atomic absorption spectroscopy	Jackson (1973)
5.	Fe, Mn, Zn, Cu	Nitric-perchloric acid (9:4) digestion and atomic absorption spectroscopy	Jackson (1973)

Results

4. RESULTS

The present study was undertaken to investigate the effect of various composts and vermicompostenriched with additives *viz.* rock dust and composting inoculumseparately and in combination on nutrient release pattern from soil and to evaluate their impact on soil remineralization, crop growth, yield and quality using yardlong bean as test crop. The study comprised of three parts: 1) preparation and analysis of different composts 2) laboratory incubation study and 3) field study.

4.1 PREPARATION AND ANALYSIS OF DIFFERENT COMPOSTS

Enriched composts were prepared using additives *viz*., rock dust and composting inoculum with biowaste (banana leaves and pseudostem) and cowdung mixture (10:1). The prepared enriched composts include mineral enriched compost, bio enriched compost, biomineral enriched compost, mineral enriched vermicompost and ordinary compost. These composts were analysed for physico-chemical and biological properties and data are presented in Table 8. From the data on fertility parameters and heavy metal contents, fertilising index and clean index were calculated for each compost and assigned quality grade for composts.

4.1.1 Fertilizing index of different composts:

For calculating fertilising index, certain fertility parameters *viz.* total organic carbon, N, P, K, C:N and respiratory activity were estimated. The data on fertility parameters and fertilising index of different enriched composts and an ordinary compost are presented in Table 9. It revealed that the nutrient status of the mineral enriched composts and mineral enriched vermicompost were increased when compared with that of ordinarycompost and bio enriched compost. The C:N ratio of mineral enriched composts were found to be narrow and the value ranged from 11.76-14.40, when compared with that of bio enriched

Table 8 Properties of different composts :

SI. No.	Properties	units	Mineral enriched compost	Bio enriched compost	Biomineral enriched compost	Ordinary compost	Mineral enriched vermicompost
1	Organic carbon	%	9.68	20.06	10.11	21.71	9.88
2	Nitrogen	%	0.67	0.78	0.78	0.62	0.84
3	Phosphorus	%	0.34	0.44	0.52	0.27	0.37
4	Potassium	%	0.75	0.63	0.77	0.43	0.77
5	Calcium	%	0.24	0.18	0.21	0.10	0.28
6	Magnesium	ppm	776.4	787.2	762.0	721.0	794.4
7	Iron	%	0.62	0.28	0.55	0.26	0.67
8	Manganese	ppm	142.0	157.0	132.0	159.2	169.2
9	Copper	ppm	28.4	25.6	42.4	26.4	34.0
10	Zinc	ppm	91.20	83.60	85.20	89.20	105.20
11	Cadmium	ppm	0.44	0.40	0.40	0.40	0.40
12	Nickel	ppm	20.0	19.80	18.60	20.0	18.80
13	Lead	ppm	53.20	53.60	52.00	52.40	49.20
14	Chromium	ppm	13.60	21.60	24.80	18.40	21.60
15	C:N		14.40	25.58	12.89	35.24	11.76
16	Respiratory activity	mg of CO_2 g^{-1} of sample	1.13	1.11	1.11	1.12	1.01
17	Microbial count	cfu g^{-1} of sample					
	a. Bacteria		128×10^7	172×10^7	116×10^7	85×10^7	156×10^7
	b. Fungi		6.5×10^4	20.7×10^4	17.8×10^4	8.4×10^4	11.3×10^4
	c. Actinomycetes		3.7×10^5	4.2×10^5	4.5×10^5	1.5×10^5	3.9×10^5
18	pH		6.29	6.25	6.39	6.24	6.60
19	EC	mS cm^{-1}	5.39	5.42	5.58	4.63	6.10

compost (25.58) and ordinary compost (35.24). Fertilising index of mineral enriched compost, bio enriched compost, bio mineral enriched compost, mineral enriched vermicompost and an ordinary compost were 3.4, 3.4, 3.4, 3.5 and 3.2 respectively.

4.1.2 Clean index of different composts

The data on heavy metal contents and clean index of different enriched composts and ordinary compost were presented in Table 10. From the table it was clear that the heavy metal contents of the different composts used for the study were low with aclean index of 4.5.

4.1.3 Assigning grade for quality of compost

The grade for quality of compost were assigned based on fertilising index and clean index. Here fertilizing indices of different enriched composts ranged from 3.1-3.5 whereas all the composts recorded the same clean index value (4.5). Accordingly all the composts were classified under marketable B class which indicated that all composts were of very good quality (medium fertilizing potential and low heavy metal content).

4.1.4 Other physico-chemical and biological properties of different composts

Other physico-chemical and biological properties of different composts used in thestudy were presented in Table 11. It is clear from the table that chemical properties *viz.*Ca, Mg, Fe and Mn were found high for mineral enriched vermicompost (0.28 %, 798.4 ppm, 0.67 %, 169.2 ppm respectively) when compared to other enriched composts and ordinary compost. In case of biological properties, bacterial and fungal population were found high for bio enriched compost (172 x 10^7 and 20.7 x 10^4 cfu g^{-1}) and highest actinomycetes population was recorded by bio mineral enriched compost (4.5 x 10^5 cfu g^{-1}).

Table 9: Fertility parameter and fertilising index of different composts

compost	Total organic carbon %	N %	P %	K %	C:N	Respiratory Activity (mg of CO_2/g of sample)	Fertilizing index
Mineral enriched compost	9.68 (2)	0.67 (2)	0.34 (3)	0.75 (3)	14.40 (4)	1.13 (5)	3.4
Bio enriched compost	20.06 (5)	0.78 (2)	0.44 (4)	0.63 (4)	25.58 (1)	1.11 (5)	3.4
Bio mineral enriched compost	10.11 (2)	0.78 (2)	0.52 (4)	0.77 (4)	12.89 (4)	1.11 (5)	3.4
Mineral enriched vermicompost	9.88 (2)	0.84 (3)	0.37(3)	0.77 (4)	11.76 (4)	1.01 (5)	3.5
Ordinary compost	21.71 (5)	0.62 (2)	0.27 (3)	0.43 (2)	35.24 (1)	1.12 (5)	3.2

Table 10: Heavy metal contents and clean index of different composts

compost	Zn mg kg^{-1}	Cu mg kg^{-1}	Cd mg kg^{-1}	Pb mg kg^{-1}	Ni mg kg^{-1}	Cr mg kg^{-1}	Clean index
Mineral enriched compost	91.20 (5)	28.4 (5)	0.44 (4)	53.2 (4)	20.0 (5)	13.6 (5)	4.5
Bio enriched compost	83.60 (5)	25.6 (5)	0.40 (4)	53.6 (4)	19.8 (5)	21.6 (5)	4.5
Bio mineral enriched compost	85.20 (5)	42.4 (5)	0.40 (4)	52.0 (4)	18.6 (5)	24.8 (5)	4.5
Mineral enriched vermicompost	105.20(5)	34.0 (5)	0.40 (4)	49.2 (4)	18.8 (5)	21.6 (5)	4.5
Ordinary compost	89.20 (5)	26.4 (5)	0.40 (4)	52.4 (4)	20.0 (5)	18.4 (5)	4.5

Table 11. Physico- chemical and biological properties of different composts

Compost	pH	EC mS cm^{-1}	Ca %	Mg ppm	Fe %	Mn ppm	Bacteria x 10^7	Fungi x 10^4	Actinomycetes x 10^5
							cfu g^{-1} of sample		
Mineral enriched compost	6.29	5.39	0.24	776.4	0.62	142.0	128	6 .5	3.7
Bio enriched compost	6.25	5.42	0.18	787.2	0.28	156.8	172	20.7	4.2
Bio mineral enriched compost	6.39	5.58	0.21	762.0	0.55	131.6	116	17 .8	4.5
Mineral enriched vermicompost	6.60	6.10	0.28	798.4	0.67	169.2	156	11.3	3.9
Ordinary compost	6.24	4.63	0.10	721.0	0.26	159.2	85	8.4	1.5

4.2 LABORATORY INCUBATION STUDY

The incubation experiment was conducted to study the nutrient release pattern of enriched composts under laboratory conditions. Properties *viz.*, pH, EC, available nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients were estimated on 0^{th} , 15^{th} , 30^{th} , 60^{th} , 90^{th} and 120^{th} days of incubation period and presented in Table 12- 22.

4.2.1 pH

Mean value of pH of incubated soil for 4 months are shown in the Table 12. It was found that there was significant difference in pH at varying intervals *viz.,* 0^{th} 15^{th} , 30^{th} , 60^{th}, 90^{th} and 120^{th} days after the application of treatments. On 0^{th} day T_{10}, T_5, T_6, T_7 and T_8 recorded highest value of 6.2. On the 15^{th} day, highest mean value of 6.3 was observed in T_{10} which was on par with T_9 and T6. On 30^{th} day highest value was recorded by T_{10} (6.3) which was found on par with T_3, T_5, T_6, T_7 and T_9. On 60^{th} day T_{10} recorded the highest mean value (6.5) significantly different from T_1, T_2, T_3, T_4, T_5, T_6, T_7, T_8 and T_9. On 90^{th} and 120^{th} day highest value of 6.6, 6.8 respectively was recorded by T_{10} which was significantly different from rest of other treatments. The lowest value was recorded by T_1 during all the period. pH values were found enhanced by increasing the duration of incubation. T1(soil without treatments) recorded a gradual increase in pH from 60^{th} day of incubation.

4.2.2 EC

Different treatments significantly influenced electrical conductivity of the soil on 30^{th}, 90^{th}, 120^{th} day of incubation. The mean values are presented in the Table 13. During 30^{th} days of incubation T_{10} recorded the highest value of 114.76 μSm^{-1} which was significantly superior than T_7, T_6, T_5, T_3, T_4, T_2, T_1 and was on par with T_9 and T_8.On 90^{th} day of incubation T_9 recorded highest mean value of 94.89 μSm^{-1} which was superior than T_5, T_6,T_3, T_4, T_2, T_1 and was on par with T_{10}, T_7 and T_8. On 120^{th} day of incubation highest mean value was recorded by T_{10} (98.57 μSm^{-1}) which was superior than T_7, T_3, T_5, T_2, T_8, T_6, T_4, $T_1$and was on par with T_9. T_1 (soil without treatments) recorded lowest value throughout incubation period.

Table 12 Change in pH of soil during incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	6.0	6.0	5.9	6.1	6.2	6.2
T_2	6.1	6.2	6.2	6.3	6.4	6.5
T_3	6.1	6.2	6.3	6.4	6.4	6.5
T_4	6.1	6.2	6.2	6.3	6.4	6.5
T_5	6.2	6.2	6.3	6.4	6.4	6.5
T_6	6.2	6.3	6.3	6.4	6.5	6.6
T_7	6.2	6.2	6.3	6.4	6.5	6.6
T_8	6.2	6.2	6.2	6.3	6.5	6.6
T_9	6.1	6.3	6.3	6.4	6.5	6.6
T_{10}	6.2	6.3	6.3	6.5	6.6	6.8
CD (0.05)	0.040	0.022	0.039	0.02	0.028	0.02

Table 13 Change in available EC (μSm^{-1}) of soil during the incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	45.72	47.28	42.84	54.72	45.7	52.95
T_2	54.85	62.81	74.34	82.95	80.24	84.72
T_3	61.64	76.24	79.94	84.21	81.44	86.84
T_4	58.84	68.18	76.81	83.46	80.84	83.92
T_5	65.42	77.43	84.65	88.42	84.74	85.24
T_6	64.56	79.88	86.94	90.24	82.84	83.95
T_7	63.74	82.35	88.48	94.75	92.58	90.65
T_8	62.43	84.76	94.57	99.86	91.58	84.47
T_9	69.22	92.75	106.36	112.56	94.89	96.57
T_{10}	71.16	96.37	114.76	121.57	93.57	98.57
CD(0.05)	NS	NS	18.85	NS	7.08	5.98

4.2.3 Available nitrogen

Available nitrogen content of incubation study are presented in Table.14. There was significant difference in available nitrogen content between treatments during all periods of incubation.

On 0th day, highest value was recorded by T_{10} (388.86 kg ha^{-1}). On 15th day T_{10} recorded highest mean value of 405.59 kg ha^{-1} and it was significantly superior than all other treatments followed by T_6 with 393.05 kg ha^{-1}. On 30th day, T_{10} recorded highest mean value of 430.68 kg ha^{-1} and followed by T_9 with 405.59 kg ha^{-1} which was significantly superior than T_8, T_4, T_7, T_5, T_3, T_2, T_1 and was on par with T_6. On 60th day, highest mean value was recorded for T_{10} (439.04 kg ha^{-1}) followed by T_9 (426.50 kg ha^{-1}). On 90th day, highest mean value was recorded for T_{10} (451.58 kg ha^{-1}) followed by T_6 (430.68 kg ha^{-1}) which was found on par with T_8 (430.86 kg ha^{-1}) and T_9 (429.04 kg ha^{-1}). On 120th day, highest value was recorded by T_{10} (473.40 kg ha^{-1}) followed by T_8 (456.21 kg ha^{-1}) which was found on par with T_6 (455.77 kg ha^{-1}). The treatment T_{10} recorded highest mean value throughout the incubation period. T_1 (soil without treatments) recorded lowest value throughout incubation period.

4.2.4 Available phosphorus

Different treatments significantly influenced the P content in soil throughout the incubation period after the application of treatments (Table 15).

On 0th day of incubation, highest value was recorded by T_9 with 28.75 kg ha^{-1} . On 15th day of incubation, T_9 recorded highest mean value of 30.99 kg ha^{-1} followed by T_{10} with 29.87 kg ha^{-1}which was significantly superior than T_1, T_2, T_4, T_6 and was on par with T_3, T_5, T_7, and T_8. On 30th day, T_9 was recorded highest value of 33.23 kg ha^{-1} followed by T_{10} (32.11 kg ha^{-1}) which was significantly superior than T_1,T_2, T_3, T_4, T_6 and T_7 and on par with T_5 and T_8. On 60th day, T_9 recorded highest value of 34.35 kg ha^{-1} which was followed by T_{10} with 33.23 kg ha^{-1} which was significantly superior than T_7, T_5, T_6, T_1, T_3 and T_2 and was on par with T_8. On 90th day, T_{10} recorded the highest value of 37.33 kg ha^{-1}which was significantly superior than all other treatments followed by T_8 with 36.21 kg ha^{-1} . On 120th day, T_{10} recorded highest value of 43.31 kg ha^{-1} which was significantly superior than other treatments followed by T_9 (37.41 kg ha^{-1}). The treatment T_1 (soil without treatments) recorded lowest value throughout incubation period.

Table 14 Change in available N (kg ha^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0th	15th	30th	60th	90th	120th
T_1	317.78	330.33	326.14	313.60	326.14	330.33
T_2	326.14	338.69	347.05	326.14	330.32	342.87
T_3	342.86	355.41	367.96	347.05	342.99	347.05
T_4	351.23	367.96	380.47	372.14	342.87	422.31
T_5	355.41	351.23	367.96	372.14	355.41	418.13
T_6	376.32	393.05	401.41	413.95	430.68	455.77
T_7	338.68	351.23	376.32	367.23	413.95	434.86
T_8	351.23	359.59	392.99	389.77	430.86	456.21
T_9	355.41	380.50	405.59	416.50	429.04	448.31
T_{10}	388.86	405.59	430.68	439.04	451.58	473.40
CD(0.05)	6.45	8.53	9.12	13.29	13.67	14.78

Table 15 Change in available P (kg ha^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0th	15th	30th	60th	90th	120th
T_1	20.53	22.40	23.52	20.53	22.03	27.25
T_2	21.28	24.27	28.37	22.77	23.11	25.76
T_3	22.40	29.49	30.61	27.25	29.12	27.18
T_4	22.40	26.51	29.87	23.89	26.13	25.01
T_5	26.51	29.49	31.33	30.61	30.24	29.87
T_6	24.27	27.63	33.23	30.99	29.12	31.36
T_7	25.76	29.49	32.82	30.61	35.09	31.44
T_8	27.25	29.12	31.36	32.48	36.21	32.19
T_9	28.75	30.99	33.23	34.35	33.31	37.41
T_{10}	27.63	29.87	32.11	33.23	37.33	43.31
CD(0.05)	0.705	0.955	1.05	1.115	0.906	1.44

Available K content were given in Table.16 Significant difference were observed at different intervals.

On 0^{th} day, T_{10} recorded highest mean value of 231.60 kg ha^{-1} and was found on par with T_9 (231.60). On 15^{th} day, highest mean value was recorded by T_{10} with 280 kg ha^{-1} which was significantly superior than all other treatments. On 30^{th} day of incubation, the highest mean value of 298.73 kg ha^{-1} recorded by T_{10} which is significantly superior than all other treatment followed by T_9 of 287.47 kg ha^{-1}. On 60^{th} day, same trend was followed with highest value of 339.73 kg ha^{-1}. On 90^{th} day, T_6 recorded the highest value of 339.73 kg ha^{-1} followed by T_{10} and T_7 (332.47 kg ha^{-1}). On 120^{th} day, T_6 recorded highest mean value of 343.47 kg ha^{-1} which was significantly higher than T_1, T_3, T4, T_2, T_5, T_7, T_9, T_8 and on par with T_{10}. The treatment T_1 (soil without treatments) recorded lowest value throughout incubation period.

4.2.6 Exchangeable calcium

Calcium content of the soil during incubation study was presented in Table.17. The different treatments significantly influenced the calcium content of soil.

There was significant difference in calcium content between treatments throughout the period. On 0^{th} and 15^{th} days, highest mean value was recorded by T_{10} with value of 1.53 and 1.77cmol kg^{-1} respectively, which was found significantly superior than other treatments followed by T_9 and T_6. On 30^{th}, 60^{th}, 90^{th}, 120^{th} days of incubation highest value was recorded by T_{10} with 2.55, 2.68, 2.72 and 2.56 c mol kg^{-1} respectively and followed by T_9 which was found to be on par with T_6 on 90^{th} day and T_7 on 120^{th} day of incubation. The treatment T_1 (soil without treatments) recorded lowest value throughout incubation period.

Table 16 Change in available K (kg ha^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	171.73	197.87	186.73	197.87	205.33	197.87
T_2	194.13	216.53	205.33	216.53	224.00	212.80
T_3	209.07	242.67	238.93	227.87	238.93	227.87
T_4	201.60	235.20	246.40	224.13	257.60	242.67
T_5	216.53	253.87	265.07	242.80	276.27	257.60
T_6	224.00	265.07	276.27	302.40	339.73	343.47
T_7	220.27	257.60	276.27	257.80	332.27	309.87
T_8	205.33	246.40	272.53	272.53	328.53	283.73
T_9	231.60	272.53	287.47	324.80	306.13	313.60
T_{10}	231.60	280.00	298.73	339.73	332.27	343.47
CD(0.05)	8.181	7.053	6.29	8.69	11.68	16.05

Table 17 Change in available Ca (cmol kg^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	1.08	1.15	1.32	1.18	1.32	1.24
T_2	1.13	1.22	1.47	1.35	1.40	1.32
T_3	1.25	1.37	1.60	1.53	1.47	1.37
T_4	1.22	1.27	1.55	1.49	1.33	1.22
T_5	1.33	1.42	2.10	2.15	1.82	1.35
T_6	1.47	1.57	2.15	2.07	2.20	1.68
T_7	1.35	1.48	1.90	1.72	1.95	2.07
T_8	1.20	1.37	1.68	1.72	1.60	1.53
T_9	1.35	1.57	2.35	2.33	2.24	2.12
T_{10}	1.53	1.77	2.55	2.68	2.72	2.56
CD(0.05)	0.06	0.05	0.07	0.07	0.04	0.05

4.2.7 Exchangeable magnesium

Exchangeable magnesium content due to treatments effects during the incubation period are presented in Table.18. There was significant difference in Mg content between treatments at different intervals. On 0th, 15th and 30th days of incubation, highest mean value was recorded by T_{10} (MEVC+ PGPR Mix I) with 0.569, 0.628 and 0.750 cmol kg^{-1} respectively which was significantly superior than other treatments followed by T_9 (MBEC + PGPR Mix I). On 60th day of incubation, soil treated with mineral enriched vermicompost with PGPR Mix I (T_{10}) recorded the highest mean value of 0.781 c mol kg^{-1} which was found to be on par with T_9 (MBEC+ PGPR Mix I). On 90th and 120th days of incubation, highest values were registered by T_{10} (MEVC+ PGPR Mix I) with 0.869 c mol kg^{-1} and 1.22 cmol kg^{-1} respectively followed by T_9. The treatment T_1 (soil without any treatment) recorded lowest value throughout the incubation period.

4.2.8 Available Fe

The available Fe content showed significant difference at different intervals during incubation period (Table 19). On 0th and 15th days of incubation, highest value was recorded by soil treated with mineral enriched vermicompost with PGPR Mix I (T_{10}) with values of 27.89 and 30.45 mg kg^{-1} respectively which was found to be on par with T_5, T_6 and T_9. On 30th day of incubation, T_{10} recorded the highest value of 39.89 mg kg^{-1} followed by T_9 which was found to be on par with T_6. On 60th day of incubation, T_{10} registered the highest value which was significantly superior than other treatments which were followed by T_9 found to be on par with T_5, T_6 and T_7. On 90th and 120th days of incubation, T_{10} recorded the highest values of 38.57 and 34.48 mg kg^{-1} respectively and which was on par with T_9, T_7, T_6 and T_5 . In addition to that, T_3 was found on par on 90th of incubation. The treatment T_1 (soil without any treatment) recorded lowest value throughout theincubationperiod.

Table 18. Change in available Mg (cmol kg^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	0.444	0.472	0.508	0.453	0.519	0.544
T_2	0.506	0.536	0.567	0.508	0.550	0.561
T_3	0.519	0.578	0.650	0.600	0.650	0.661
T_4	0.514	0.556	0.608	0.619	0.567	0.608
T_5	0.544	0.603	0.686	0.703	0.719	0.742
T_6	0.556	0.597	0.700	0.711	0.747	0.764
T_7	0.531	0.586	0.686	0.703	0.681	0.703
T_8	0.519	0.578	0.703	0.711	0.714	0.758
T_9	0.556	0.614	0.725	0.758	0.729	0.972
T_{10}	0.569	0.628	0.750	0.781	0.869	1.222
CD(0.05)	0.006	0.007	0.016	0.016	0.016	0.049

Table 19. Change in available Fe (mg kg^{-1}) content of soil during the incubation period

Treatment	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	16.76	16.98	17.23	15.27	17.57	16.89
T_2	18.80	19.58	22.89	21.89	24.79	21.87
T_3	22.35	25.68	29.96	28.57	32.24	25.67
T_4	19.87	20.46	25.45	23.46	26.56	22.35
T_5	24.89	27.65	32.54	31.69	36.32	31.98
T_6	25.89	28.38	34.89	31.98	38.45	33.56
T_7	24.67	27.45	32.45	30.45	34.56	31.24
T_8	22.76	25.35	27.67	25.67	28.47	28.79
T_9	25.74	28.78	36.76	32.46	35.78	32.98
T_{10}	27.89	30.45	39.89	36.85	38.57	34.48
CD(0.05)	1.19	2.45	2.24	3.01	5.49	2.91

4.2.9 Available Mn

Manganese content of the incubation study was presented in the Table.20 and it was clear that different treatment significantly influenced the Mn content of soil. On 0th and 15th days of incubation, T_{10} (MVEC+PGPR Mix I) recorded highest mean value of 12.04 and 16.69 mg kg^{-1} respectively which was found to be on par with T_9, T_8, T_7 and T_6. On 30th and 60th days of incubation, T_{10} registered highest mean value with 22.63 mg kg^{-1} and 24.67 mg kg^{-1} which was on par with T_9. On 90th and 120th days of incubation, soil treated with mineral enriched vermicompost and PGPR Mix I was found highest value of 21.85 mg kg^{-1} and 21.37 mg kg^{-1} respectively which was found on par with T_9 and T_6. The treatment T_1 (soil without treatments) recorded lowest value throughout incubation period.

4.2.10 Available Zn

Mean value of Zn content of soil incubated for different period was presented in the Table 21. A significant difference was found among treatments. On 0th, 15th, 30th, 60th days of incubation, same release pattern was observed. During these period soil treated with mineral enriched vermicompost and PGPR Mix I (T_{10}) was found best with 5.64, 5.41, 5.73 mg kg^{-1} that was found on par with T_9 (BMEC + PGPR Mix I). On 90th day and 120th day of incubation, highest mean value was recorded by T_{10} with 6.20 and 6.18 mg kg^{-1} which was found on par with T_9, T_5 and T_6. During all the period soil without any treatment was found lowest (T_1).

4.2.11 Available Cu

Different treatments significantly influenced the copper content of incubated soil. On 0th day of incubation the treatments were found non significant. On 15th and 30th days of incubation T_{10} recorded the highest mean value of 0.91 and 1.29 mg kg^{-1} which was found on par with T_9, T_7, T_6 and T_5 in addition to that T_3 and T_8 found equal on 15th day. On 60th and 90th days of incubation, soil treated with mineral enriched vermicompost in conjunction with PGPR Mix I (T_{10}) found best with 1.03 and 1.18 mg kg^{-1} and on par with T_9. On 120th day of incubation, T_6 was found best with 0.97 mg kg^{-1} and on par with T_5, T_9 and T_{10}. Soil without any treatment (T_1) was found lowest during all the period.

Table 20 Change in available Mn (mg kg^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0th	15th	30th	60th	90th	120th
T_1	6.09	6.78	7.89	11.98	9.56	6.79
T_2	7.98	8.04	12.86	13.87	11.56	11.73
T_3	9.56	10.68	15.58	17.64	14.74	15.76
T_4	8.64	9.64	13.79	14.89	13.87	13.92
T_5	10.57	12.86	17.83	19.39	16.46	17.43
T_6	10.86	14.79	19.78	21.45	19.92	20.32
T_7	10.89	14.68	16.43	18.42	16.45	17.56
T_8	9.65	13.97	15.98	18.04	14.97	14.05
T_9	11.45	15.74	20.89	23.67	20.23	19.89
T_{10}	12.04	16.69	22.63	24.67	21.85	21.37
CD(0.05)	2.16	2.28	2.21	1.89	2.88	2.26

Table 21. Change in available Zn (mg kg^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0th	15th	30th	60th	90th	120th
T_1	2.86	2.78	2.63	2.87	3.04	2.92
T_2	3.33	3.37	3.24	3.32	3.98	3.85
T_3	3.74	3.82	3.62	3.86	4.15	4.01
T_4	3.47	3.45	3.21	3.34	3.95	3.81
T_5	4.12	4.24	4.11	4.34	4.92	4.81
T_6	4.30	4.35	4.21	4.46	5.03	4.92
T_7	3.98	4.13	4.05	4.25	4.82	4.76
T_8	3.53	3.57	3.32	3.58	4.12	4.15
T_9	5.27	5.34	5.25	5.48	5.92	5.83
T_{10}	5.53	5.64	5.41	5.73	6.20	6.18
CD(0.05)	0.51	0.62	0.65	0.67	1.07	1.21

Table 22. Change in available Cu (mg kg^{-1}) content of soil during the incubation period

Treatments	Days after incubation					
	0^{th}	15^{th}	30^{th}	60^{th}	90^{th}	120^{th}
T_1	0.58	0.61	0.72	0.54	0.62	0.43
T_2	0.61	0.73	0.96	0.72	0.83	0.64
T_3	0.64	0.79	1.06	0.87	0.94	0.72
T_4	0.61	0.75	0.91	0.76	0.86	0.67
T_5	0.69	0.83	1.15	0.86	0.98	0.91
T_6	0.71	0.88	1.18	0.94	1.06	0.97
T_7	0.66	0.82	1.10	0.92	1.05	0.74
T_8	0.63	0.79	1.06	0.83	0.97	0.69
T_9	0.72	0.84	1.24	0.95	1.10	0.87
T_{10}	0.74	0.91	1.29	1.03	1.18	0.92
CD (0.05)	NS	0.11	0.16	0.039	0.082	0.98

4.3 FIELD EXPERIMENTS

A field experiment was conducted using yardlong bean as test crop to study the effect of enriched compost on soil remineralization, growth, yield and quality of the crop. Physico-chemical and biological properties of soil before the experiment were analysed and mentioned in Table. 23.

The data of various biometric observations are presented in Table 24. Days to 50 per cent flowering, leaf area index, crop duration, number of harvest, appearance of the product are the biometric observations recorded.

4.3.1.1 Days to 50 per cent flowering

Table.24 shows that lowest mean value was recorded by T_6 with 42.67 days which was found on par with T_1, T_5 and T_{11}. Highest mean value was recorded by T_2 (44.3 days) and was found to be on par with rest of the treatments.

4.3.1.2 Leaf area index

Data on leaf area index showed significant difference among treatments. The treatment T_{11} got the highest value of 0.49 which was significantly superior followed by T_6 (0.42) which was found on par with T_{10}. The lowest mean value was recorded by T_1 (0.33) and was found on par with T_2 (0.34).

4.3.1.3 Crop duration

From the data presented in the Table 24, it was found that different treatments did not significantly influence the crop duration.

4.3.1.4 Number of harvest

The result presented in Table 24 revealed that there was no significant difference among treatments on number of harvest.

Table 23. Physico-chemical and biological properties of soil

SI.No.	Parameters	Units	Content
A. Physical properties			
1.	Mechanical composition: Sand Silt Clay	 % % %	 61.09 9.35 24.56
2.	Texture		Sandy clay loam
3.	Bulk Density	Mgm^{-3}	1.50
4.	Water Holding Capacity	%	25.68
5.	pH		6.18
6.	EC	μSm^{-1}	92.48
7.	CEC	cmol kg^{-1}	5.75
B. Chemical properties			
8.	Organic carbon	%	0.75
9.	Available Nitrogen	kg ha^{-1}	213.24
10.	Available Phosphorus	kg ha^{-1}	30.24
11.	Available Potassium	kg ha^{-1}	229.09
12.	Exchangeable Ca	cmol kg^{-1}	2.13
13.	Exchangeable Mg	cmol kg^{-1}	0.82
14.	Micronutrients Fe Mn Cu Zn	 ppm ppm ppm ppm	 18.09 5.69 1.08 2.36
C. Microbial properties			
15.	Dehydrogenase	µg TPF g^{-1} soil 24 hr^{-1}	187
16.	Microbial count Bacteria Fungi Actinomycetes	cfu g^{-1} soil	 21.2 x 10^6 11 x 10^4 2.6 x 10^3

Table: 24 Effect of different treatments on biometric observation of yard long bean:

Treatments	Days to 50% flowering	Leaf area index(m^2)	Crop duration (days)	Number of harvest	Appearance of the product
T_1	43.00	0.33	125	13.33	3.0
T_2	44.33	0.34	125	13.67	3.0
T_3	44.00	0.35	125	13.67	3.0
T_4	44.00	0.37	125	13.67	3.0
T_5	43.00	0.40	126	14.00	3.3
T_6	42.67	0.42	126	14.00	3.7
T_7	44.00	0.34	125	13.33	3.0
T_8	44.00	0.38	125	14.00	3.0
T_9	44.00	0.38	125	14.00	3.3
T_{10}	44.00	0.41	127	14.00	3.3
T_{11}	43.00	0.49	127	14.00	3.7
CD (0.05)	0.438	0.015	NS	NS	NS

4.3.1.5Appearance of the product

Appearance of the product was not significantly influenced by different treatments.

4.3.2Effect of enriched manures on yield characters

4.3.2.1Pod length

Data (Table 25) pertaining to the pod length showed that there was significant difference among treatments. The treatment T_{11} recorded highest mean value of 53.93 cm, which was significantly superior than all other treatments, followed by T_{10} (52.31cm) which was on par with T_1,T_6, T_5 and T_8 and significantly superior than T_4, T_3, T_9, T_7, T_2. The lowest value was recorded by T_2 (49.04 cm).

4.3.2.2 Pod weight

From the data presented in Table 25, it was found that T_{11} recorded highest mean value of 28.62 g which was superior than rest of the treatments. It was followed by T_{10} (27.60 g) which was significantly superior than T_4, T_3, T_9, T_7, T_2 and was found on par with T_6, T_5, T_1 and T_8. The lowest value was recorded by T_2 with 24.24 g and was found on par with T_7 (24.42 g).

4.3.2.3 Number of pods per plant

Observations presented in Table 25 regarding number of pods per plant revealed significant difference among treatments. Highest mean value was recorded by T_{11} (43.52)and was significantly superior than all other treatments which was followed by T_{10} with 42.17. Treatment with 50 per cent N as ordinary compost (T_2) recorded lowest value of 30.11.

Table: 25 Effect of different composts on yield and yield attributing characters of yard long bean

Treatments	Pod length cm	Pod weight g	Number of pods/plant	Pod yield kg ha^{-1}	Bhusa yield kg ha^{-1}	Total dry matter production kg ha^{-1}	Harvest index
T_1	51.81	26.47	38.87	9500	6250	3426	0.53
T_2	49.04	24.24	30.11	7357.5	6308	3505	0.54
T_3	50.76	26.01	36.17	9000	6750	3721	0.57
T_4	50.85	26.52	33.53	8175	6533	3607	0.56
T_5	51.16	26.93	38.22	9170	7267	4210	0.56
T_6	51.27	27.53	39.45	9825	7300	4330	0.57
T_7	50.16	24.42	32.95	7642.5	6392	3534	0.54
T_8	51.02	26.80	36.14	9375	6825	3919	0.58
T_9	50.73	25.29	32.72	8625	6558	3750	0.57
T_{10}	52.31	27.60	42.17	10200	7563	4694	0.57
T_{11}	53.93	28.62	43.52	10825	7642	5207	0.59
CD (0.05)	1.15	0.70	0.69	687.40	168	286	0.017

4.3.2.4 Pod yield:

On scrutinizing the result (Table 25), it was noted that pod yield showed significant variation with the treatments. Treatment with mineral enriched vermicompost and PGPR Mix I (T_{11}) was found superior (10,825 kg ha^{-1}) which was significantly superior than all other treatments except T_{10} which was found on par with it. The treatment T_2 got lowest yield of 7357.5 kg ha^{-1}which was found on par with T_7.

4.3.2.5 Bhusa yield

It could be inferred from the Table 25 that bhusa yield varied significantly among the treatments. The treatment T_{11} obtained highest bhusa yield of 7642 kg ha^{-1} which was superior than rest of treatments except T_{10} which was found on par with it. This was followed by T_6 with value of 7300 kg $ha^{-1}$and was found to be on par with T_5 (7267kg ha^{-1}). The least value was recorded by T_1 (6250kg ha^{-1}) .

4.3.2.6 Total dry matter production

Significant difference was found among treatments on total dry matter production (Table 25). From the data, T_{11} recorded highest mean value of 5207 kg ha^{-1} which was found to be superior than all other treatments. This was followed by T_{10} with mean value of 4694kg ha^{-1}. The lowest value was noted for KAU POP recommendation (T1) with 3426kg ha^{-1} of dry matter.

4.3.2.7 Harvest index

It was noticed that there exists significant influence on harvest index of plants by various treatments (Table 25). The treatment T_{11} has registered highest value of 0.59 which was found to be superior than T_2, T_1, T_4, $T_5$and T_7 and on par with T_3, T_6, T_8, T_9, T_{10}.

4.3.3 Effect of enriched manure on quality of pods

4.3.3.1 Crude protein content

The level of crude protein content of different treatments are given in Table. 26. Among various treatments, T_{11} registered highest value of 27.69 per cent which was found to be on par with T_{10}. T_7 have got lowest value of 21.31 per cent on par with T_2 and T_4.

4.3.3.2 Crude fibre content

Crude fibre content of pods is presented in Table 26. The lowest value was noticed in T_6 (8.13 per cent) which was found to be on par with T_{11} (8.20 per cent) and highest value was found in T_1 (KAU POP recommendation) with 11.18per cent. The high value indicates low quality of the produce.

4.3.3.3Shelf life

Shelf life of pods were studied and the data in Table 26, showed that T_{10}, T_{11}, T_8, T_6 have got highest mean value of 5 days which were found to be on par with T_3, T_9, T_5.The lowest mean value of 3 days was noticed in T_1 (KAU POP) with 3 days.

4.3.4 Effect of enriched compost on control of pest and disease:

The pest, aphids was observed and was controlled by application of nimbicidin (2%). The disease, *Fusarium wilt* was observed and controlled by spraying fish amino acid (3%) (Table 27). No significant variation was observed among treatments

4.3.5Effect of enriched manure on soil properties

4.3.5.1 Physical properties

The physical properties of the soil after harvest of the crop are presented in the Table 28 and was significantly influenced by enriched manure addition. The

Table 26 Effect of different composts on quality of yard long bean:

Treatments	Protein content %	Fibre content %	Shelf life days
T_1	23.40	11.18	3.0
T_2	21.67	10.72	3.7
T_3	22.25	10.07	4.7
T_4	21.71	10.22	3.7
T_5	22.73	9.70	4.7
T_6	23.81	8.13	5.0
T_7	21.31	10.64	4.0
T_8	22.06	10.33	5.0
T_9	22.75	10.47	4.7
T_{10}	25.38	8.63	5.0
T_{11}	27.69	8.20	5.0
CD (0.05)	2.64	0.19	0.6

.

Table :27 Effect of different composts on pest and disease control of yard long bean:

Treatments	Pest incidence (aphid) %	Disease incidence (*Fusarium wilt*) %
T_1	18.34	12.5
T_2	15.24	12.5
T_3	7.89	4.1
T_4	11.32	8.3
T_5	10.78	0.0
T_6	9.89	0.0
T_7	11.47	4.1
T_8	4.21	0.0
T_9	9.46	4.1
T_{10}	3.24	0.0
T_{11}	3.12	0.0

physical properties like bulk density and water holding capacity are the properties studied.

4.3.5.1.1 Bulk density

Bulk density was found to be significantly influenced by enriched compost application (Table 28). It recorded a lowest value of 1.33 Mg $m^{-3}$for the soil treated with 75% N as mineral enriched compost (T_3) which was found significantly superior than all other treatments followed by T_6 which was on par with T_{10} and T_{11}. The highest value (1.52 Mg m^{-3}) was observed in T_1 (KAU POP).

4.3.5.1.2 Water holding capacity:

From the experiment, it was observed that the different treatments had a significant influence on water holding capacity of soil (Table 28). The treatment T_8 recorded higher values of 34 per cent and was found on par with T_7 (32.93 per cent) and significantly higher than the other treatments. The lowest value was obtained in T_1 (25.17 per cent) and was found to be on par with T_4.

4.3.5.2 Chemical properties

4.3.5.2.1 pH

The different treatments significantly influenced by pH of soil (Table 29). The highest mean value was recorded by T_6 with a value of 6.5 which was significantly superior than all other treatments followed by T_5 which was found to be on par with T_3, T_{10}, T_2 and T_9. The lowest value was recorded by T_1 (6.2)which is on par with T_4, T_7 andT_8.

4.3.5.2.2 EC

From the Table.29 it is clear that electrical conductivity of soil varies significantly among treatments. The best was found to be T_{10} (124.3µS m^{-1}) which was significantly superior than all other treatments except T_6 which was

Table 28 Effect of different composts on physical properties of soil:

Treatments	Bulk density Mg m^{-3}	Water Holding Capacity (%)
T_1	1.51	25.17
T_2	1.47	28.17
T_3	1.33	30.17
T_4	1.47	25.40
T_5	1.46	27.73
T_6	1.41	26.73
T_7	1.45	32.93
T_8	1.47	34.00
T_9	1.47	27.93
T_{10}	1.42	28.43
T_{11}	1.45	30.20
CD (0.05)	0.22	0.07

Table :29 Effect of different composts on physico-chemical properties of soil:

Treatments	pH	EC µS m^{-1}	CEC cmol kg^{-1}	Organic carbon (%)
T_1	6.17	66.02	5.25	0.98
T_2	6.27	112.50	5.67	1.03
T_3	6.33	100.82	5.82	1.10
T_4	6.22	104.08	5.62	1.12
T_5	6.34	111.71	5.82	1.16
T_6	6.53	118.63	5.88	1.18
T_7	6.22	102.97	5.55	1.22
T_8	6.21	102.24	5.70	1.25
T_9	6.27	113.93	5.62	1.35
T_{10}	6.29	124.30	6.08	1.43
T_{11}	6.25	116.03	6.35	1.54
CD (0.05)	0.07	4.88	0.07	0.04

found to be on par with it. The treatment, T_1 was found inferior among all other treatments.

4.3.5.2.3 CEC

The cation exchange capacity (CEC) of soil significantly varied among treatments (Table 29). The highest mean value was found to be 6.35 cmol kg^{-1} which was recorded by T_{11} which was found superior among all the treatments followed by T_{10} with value of6.08cmol kg^{-1}. The lowest value was registered by T_1 (5.25cmol kg^{-1}).

4.3.5.2.4 Organic carbon

Organic carbon in soils treated with different enriched composts with and without PGPR Mix I were found significantly different among each other (Table 29). The highest per cent of organic carbon was recorded by T_{11} with 1.54 per cent which was found superior among all other treatments and was followed by $T_{10}$with 1.43 per cent. The lowest value was recorded by T_1(0.98 per cent)and it was found on par with T_2.

4.3.5.2.5 Available nitrogen

Available nitrogen in the soil after harvest of the crop was significantly influenced by different treatments (Table 30). The treatment T_{11} (50% N as MEVC+ PGPR Mix I) registered the highest mean value of 485.03 kg ha^{-1}followed by T_{10} (50% N as BMEC+ PGPR Mix I) which is found to be on par with T_6. The T_1 (KAU POP) registered the lowest value of 246.69 kg ha^{-1} .

4.3.5.2.6 Available phosphorus

There was significant difference among treatments for available phosphorus content of soil (Table 30) . The treatment T_{11} registered the highest value of 48.16 kg ha^{-1} and is superior among treatments except T_{10} which was on par with it. Second best treatment was T_6 with a mean value of 42.93 kg ha^{-1}

Table 30 Effect of different composts on major nutrients of soil:

Treatments	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}	Ca cmol kg^{-1}	Mg cmol kg^{-1}
T_1	246.70	26.88	238.93	2.83	0.80
T_2	263.42	30.99	238.93	3.13	1.25
T_3	321.96	39.95	250.13	3.72	1.43
T_4	334.50	41.81	257.60	3.62	1.38
T_5	409.77	42.56	265.07	3.83	1.57
T_6	417.76	42.93	265.07	4.20	1.68
T_7	301.05	39.57	242.67	3.23	1.34
T_8	397.23	42.19	261.33	4.27	1.76
T_9	309.42	39.95	242.67	3.58	1.36
T_{10}	426.49	47.41	268.80	4.52	1.90
T_{11}	485.03	48.16	276.27	4.47	1.87
CD (0.05)	10.580	2.008	9.930	0.830	0.223

which is on par with T_5, T_8 and T_4. As expected, the lowest value of 26.88 kg ha ^{1}was recorded by the T_1 (KAU POP).

4.3.5.2.7Available potassium

Available potassium content of the soil after the harvest of the crop was influenced by different treatments and is presented in Table. 30. The treatment T_{11} showed the highest mean value of 276.26 kg ha^{-1} which was on par with T_{10}, T_5, T_6. The lowest value recorded by T_1 with 238.93kg ha^{-1}was found to be on par with T_2, T_9, T_7, T_3.

4.3.5.2.8Exchangeable calcium

Significantly different values were recorded for the exchangeable calcium content of soil (Table. 30).The highest value of 4.52 cmol kg^{-1}was recorded by T_{10} and found to be on par with T_{11}, T_8, T_6, T_5, T_3, T_4, T_9. The treatment T_1 recorded the lowest value (2.88 cmol kg^{-1}) which was on par with T_2 and T_7.

4.3.5.2.9 Exchangeable magnesium

Table.30 shows the exchangeable magnesium content of soil after the harvest of the crop. Results indicated that treatment T_{10} recorded the highest mean value of 1.90 cmol kg^{-1} which was found to be on par with T_{11}, T_8 and T_6. The treatment T_1recorded the lowest value (0.80 cmol kg^{-1}).

4.3.5.2.10 Iron

In case of iron T_1 (KAU POP) recorded highest value of 35.80 mg kg^{-1} followed by T_2 (75%N as OC) (Table 31) . The lowest mean value of 25.22 mg kg^{-1} was recorded by T_{11} (50% N as MEVC + PGPR Mix I).

4.3.5.2.11 Manganese

There was significant difference due to various treatments on manganese content (Table 31). The treatment T_{11} recorded the highest mean value of 7.59 mg

Table 31 Effect of different composts on micro nutrients of soil, mg kg^{-1}

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
T_1	35.80	5.91	1.94	0.90
T_2	34.39	6.00	2.44	0.98
T_3	30.91	6.68	2.84	1.08
T_4	33.80	6.25	2.63	1.03
T_5	28.49	7.15	3.13	1.13
T_6	27.51	7.20	3.19	1.16
T_7	33.72	6.17	2.52	1.03
T_8	29.48	6.73	2.95	1.11
T_9	31.85	6.50	2.73	1.05
T_{10}	26.91	7.41	3.39	1.20
T_{11}	25.22	7.60	3.62	1.21
CD (0.05)	0.38	0.05	0.03	0.02

kg^{-1}followed by $T_{10}$with 7.40mg kg^{-1}. The lowest value was registered by T_1 (KAU POP) with 5.91mg kg^{-1}.

4.3.5.2.12 Zinc

Various treatments influenced zinc content of soil significantly (Table 31). The treatment T_{11} registered highest mean value of 3.62 mg kg^{-1} which was followed by T_{10} with 3.39 mg kg^{-1}. The lowest value was recorded by T_1 (KAU POP) with 1.94 mg kg^{-1}.

4.3.5.2.13 Copper

There was significant difference due to various treatments on copper content of soil (Table 31). For copper, the highest value was recorded by T_{11} (50 % N as MEVC +PGPR Mix I) with value of 1.21mg kg^{-1} which was found on par with T_{10}. The lowest value was recorded by T_1(KAU POP) with 0.90mg kg^{-1}.

4.3.5.3 Biological properties

4.3.5.3.1 Microbial count

Microbes *viz.* bacteria, fungi and actinomycetes population in soil were estimated to study the effect of different composts in microbial population and it was found to vary with different treatments (Table 32).

The treatmentT_4 recorded the maximum bacterial population of 37.3 x 10^6 cfu g^{-1} which was superior to all other treatments except T_{11} which was statistically on par. This was followed by T_7which was found on par withT_{10}, T_9, T_8 and T_5. Lowest population of 10.33 x 10^6 cfu g^{-1} was recorded inT_1 (KAU POP).

Maximum fungal population of 25.67 x 10^4 cfu g^{-1} was recorded in T_9 which was par with T_{10}, T_{11} and T_7.The lowest population of 6.33 x 10^4 cfu g^{-1} was recorded in T_1 (KAU POP).

Table 32 Effect of different composts on biological properties of soil:

Treatments	Bacteria x 10^6 (cfu g^{-1} soil)	Fungus x 10^4 (cfu g^{-1} soil)	Actinomycetes x 10^3 (cfu g^{-1} soil)	Dehydrogenase activity (µg TPFg $^{-1}$24 hr^{-1} soil)
T_1	10.33	6.33	1.00	209
T_2	21.33	16.67	2.67	216
T_3	15.67	11.33	2.67	229
T_4	37.33	19.00	3.33	240
T_5	24.33	15.00	4.00	248
T_6	23.33	14.67	5.00	256
T_7	30.00	23.00	4.33	224
T_8	26.33	18.33	4.33	232
T_9	28.00	25.67	3.67	242
T_{10}	28.33	25.00	6.67	278
T_{11}	28.33	20.33	5.67	284
CD (0.05)	4.83	3.46	2.36	11.78

The highest population of actinomycetes of 6.67 x 10^3 cfu g^{-1} was registered in soil treated with 50 % N as BMEC with PGPR Mix-I (T_{10}) which was found to be statistically on par with T_{11},T_6, T_8,T_7 and T_5. Lowest number of colonies were recorded inT_1 (1.00 x 10^3 cfu g^{-1}).

4.3.5.3.2 Dehydrogenase activity:

Value presented in Table.32 showed that the treatment varied significantly. The treatment T_{11} (50 % N-MEVC+PGPR Mix I) was found superior with value of 284 µg TPF g $soil^{-1}$24 hr^{-1} and it was found on par with T_{10} (50%N-BMEC+PGPR Mix I). The lowest mean value was observed in T_1 (209 µg TPF g $soil^{-1}$24 hr^{-1}) which was found on par with T_2, T_7, T_3 and T_8.

4.3.6Effect of enriched manure on plant nutrient uptake

4.3.6.1 Nitrogen uptake

Significant difference was observed among treatments in plant N uptake (Table 33). The treatment T_{11} was found superior among other treatments with a value of 161.62 kg ha^{-1} and T_{10} was found to be the second best treatment in case of plant N uptake. The lowest value was recorded by T_1 (KAU POP) with a value of 63.33 kg ha^{-1}.

4.3.6.2 Phosphorus uptake

The details of plant P showed that there was significant difference among treatments (Table 33). Among the treatments, the highest mean value was recorded by T_{11} (35.78 kg ha^{-1}) which was superior than all other treatments. The second best treatment was T_{10} with a value of 29.90 kg ha^{-1}. The lowest value was recorded by T_1 (KAU POP) with 12.37 kg ha^{-1} which was on par with T_2 and T_7.

4.3.6.3 Potassium uptake

Significant differences in K content between the treatments were recorded in Table 33. The highest mean value was recorded by T_{11} (92.60 kg ha^{-1}) which

Table33 Effect of different composts on uptake of major nutrients by plant, kg ha[1]

Treatments	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	63.33	12.37	17.39
T_2	67.20	13.27	19.62
T_3	86.77	19.23	34.92
T_4	77.35	16.95	25.64
T_5	113.71	24.42	51.38
T_6	120.74	26.64	63.26
T_7	70.87	13.94	20.28
T_8	100.27	21.68	41.36
T_9	91.90	19.81	31.63
T_{10}	137.23	29.90	75.69
T_{11}	161.62	35.78	92.60
CD (0.05)	9.660	2.400	3.200

Table 34 Effect of enriched composts on uptake of secondary nutrients by plants, kg ha^{-1}

Treatments	Ca(kg ha^{-1})	Mg(kg ha^{-1})
T_1	20.63	17.97
T_2	22.04	18.04
T_3	25.87	21.80
T_4	23.98	20.07
T_5	32.75	27.28
T_6	35.31	27.99
T_7	24.59	19.51
T_8	28.90	24.00
T_9	25.14	21.54
T_{10}	42.83	32.36
T_{11}	52.56	37.98
CD (0.05)	3.460	4.410

was followed by T_{10} with 75.69 kg ha^{-1}. The lowest value was recorded by T_1 with a value of 17.39 kg ha^{-1} which was found on par with T_2 and T_7.

4.3.6.4 Calcium uptake

Plant Ca showed significant variation between the treatments (Table 34). T_{11} (50 % N as MEVC+PGPR Mix I) recorded highest mean value of 52.56 kg ha^{-1}which was significantly superior than all other treatments and was followed by T_{10} with 42.83kgha^{-1}.The lowest mean value was recorded by T_1 (20.63kgha^{-1})which was found to be on par with T_2, T_4 and T_7.

4.3.6.5 Magnesium uptake

Significant difference was noticed in Mg content of the plants with different treatments (Table 34). The highest value of 37.98 kg ha^{-1} was registered by treatment with 50 % N as MEVC+ PGPR Mix I (T_{11}). The second best was registered by T_{10} which was on par with T_6 and T_5. The lowest value (17.97 kg ha^{-1}) was registered by KAU POP (T_1) on par with T_2, T_7, T_4, T_9 and T_3.

4.3.6.6 Iron uptake

The values from the data (Table 35) make it clear that Fe content in plants showed significant difference among treatments. As usual, T_{11} registered highest value of 2.171 kg ha^{-1} followed by T_{10}. The lowest value (1.176) was registered by T_1 on par with T_2 and T_7.

4.3.6.7 Manganese uptake

The values from the Table.35 clearly showed significant variation among treatments. Here same trend was followed as T_{11} recorded highest value of 1.076 kg $ha^{-1}$and T_1 with lowest value of 0.559 kg ha^{-1}.

Table 35 Effect of enriched composts on uptake of micro nutrients by plants, kg ha^{-1}

Treatments	Fe (kg ha^{-1})	Mn (kg ha^{-1})	Zn (kg ha^{-1})	Cu (kg ha^{-1})
T_1	1.176	0.559	0.156	0.038
T_2	1.220	0.581	0.170	0.040
T_3	1.355	0.650	0.201	0.049
T_4	1.293	0.618	0.188	0.045
T_5	1.615	0.790	0.254	0.064
T_6	1.699	0.839	0.270	0.068
T_7	1.247	0.597	0.177	0.041
T_8	1.463	0.704	0.225	0.054
T_9	1.364	0.651	0.201	0.046
T_{10}	1.896	0.919	0.309	0.081
T_{11}	2.171	1.076	0.367	0.093
CD (0.05)	0.093	0.060	0.036	0.016

4.3.6.8 Zinc uptake

Plant zinc content was studied and there was significant difference between treatments (Table 35). As in the case of uptake of other nutrients, here also T_{11} registered highest value of 0.367kg ha^{-1} followed by T_{10}. The treatment T_1 (KAU POP) was found inferior with other treatments except T_2, T_7 and T_4 which is on par with it.

4.3.6.9 Copper uptake

The plant copper uptake was presented in Table 35. It showed significantly different among treatments. The treatment T_{11} has registered highest value of 0.093kg ha^{-1} which was found on par with T_{10}. The lowest value (0.038 kg ha^{-1}) was recorded by T_1 (KAU POP) which was on par with T_9, T_4, T_7 and T_2.

4.3.7 Economic analysis:

It was observed that cost benefit ratio was found highest for treatment T_{11}(2.32) (50 % N as mineral enriched vermicompost and bio fertilizer) followed by T_{10}. The lowest B:C (1.83) was recorded by T_1. And all other treatments are significantly superior than control.

4.3.8 Contrast analysis:

Contrast analysis was done to study the effect of PGPR Mix I in quality and yield and yield attributes of yard long bean. Here treatments were grouped into two. Group 1 (G1) consisted of treatments with 75 % N as different composts and Group 2 (G2) consisted of treatments with 50 % N as different composts. (Tables. 36-37).

It was observed that in quality and yield and yield attributes Group 2 (G2) has recorded highest mean value when compared with that of Group 1 (G1).

Table 36 Effect of enriched composts on economics

Treatments	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1	286800	130078.69	1.83
T_2	294300	153486.61	2.09
T_3	360000	195616.44	2.19
T_4	327000	171285.72	2.10
T_5	380000	209596.50	2.23
T_6	393000	219106.20	2.26
T_7	305700	163513.96	2.15
T_8	375000	205317.75	2.21
T_9	345000	175316.75	2.18
T_{10}	408000	229834.07	2.29
T_{11}	433000	246362.07	2.32
CD(0.05)			0.021

Table 37 Effect of PGPR Mix I on quality of yard long bean:

Treatments	Protein content (%)	Fibre content (%)
G1	324.5	146.54
G2	357.6	144.81
G1 Vs G2	S	S

S- Significant.

Table 38 Effect of PGPR Mix I on yield characters of yard long bean:

Treatments	Pod length(cm)	Pod weight(g)	Pod yield (kg ha^{-1})	Bhusa yield (kg ha^{-1})	Total dry matter production (kg ha^{-1})
G1	759.23	393.7	131572	102475	43117
G2	774.44	398.2	140002	104937	48310
G1 Vs G2	S	S	S	S	S

S- Significant.

Discussion

5. DISCUSSION

The main constraint faced by present agriculture is soil degradation especially soil demineralisation. Agriculture effectively mines the soil of plant nutrients and minerals by intensive harvesting of crops, altering the natural cycling of nutrients in soil (Parikh and James, 2012). This problem can be mitigated by the application of rock dust to mineral deficient soil as rock dust contains many of the nutrients essential for plant growth. This concept is known as soil remineralization. One of the uses of rock dusts as an amendment to composts is of particular interest with respect to enhancement of microbial activity and bioavailability of mineral elements contained in rock minerals. 'Mineralized compost' is a term used in association with composts amended with rock dusts to take advantage of the microbial action (solubilization and mineralization). With this concept, present research was undertaken and the results of the research are discussed below.

5.1 PREPARATION AND ANALYSIS OF DIFFERENT COMPOST

Five types of compost *viz.,* mineral enriched compost, bio enriched compost, biomineral enriched compost, mineral enriched vermicompost and an ordinary compost were prepared for the present study. These different composts were characterized for different quality parameters and developed a method of assigning quality indices for the purpose of grading composts in accordance to their fertilizing value and magnitude of environmental threats due to heavy metal contents. Thus fertilizing index and clean index of different composts were calculated.

5.1.1 Fertilizing index:

Fertilizing index is a measure of nutrient supplying potential of compost. Fertility parameters like organic carbon, total N, total P, total K, C:N, respiration activity were estimated for different composts. For each parameter score value was given and based on the score value fertilizing index was calculated for each compost. From the Table.10, it was noted that total N, P, K contents of the mineral enriched vermicompost recorded high nutrient content when compared to other composts. This might be due to combined effect of rock dust and vermicompost. The high P content of mineral enriched vermicompost may be due to solubilization of P from rock dust during composting and transformed into available form due to the presence of P solubilising micro organism associated with vermicompost and earthworm. Similar findings were reported by Mba (1997). The C:N of different compost was narrowed down by enrichment and it is an indication for maturity of compost and enhanced mineralization consequent to high microbial activity. Respiratory activity was found highest for enriched composts compared to ordinary compost. This might be due to the fact that rock dust acts as feed for microorganism in compost and thereby enhanced their activity. Gracia (2002) reported that application of rock dust increased microbial activity in the initial period of composting. Based on the fertility parameters, fertilizing index were calculated and it was found that mineral enriched vermicompost recorded a value of 3.5 whereas mineral enriched compost, bio enriched compost and bio mineral enriched compost recorded a value of 3.4 and the least value of 3.2 was found for ordinary compost.

5.1.2. Clean index:

Clean index is used by regulatory authority for restricting the entry of heavy metals into sensitive components of environment. Hence heavy metal parameters *viz.,* Zn, Cu, Cd, Pb, Ni and Cr concentration were estimated. Based on their concentrations, score values were calculated. Based on score values and weighing factor, clean index was calculated for each compost. From table 11 it was noted that all the composts used for study were low in heavy metal concentration which means that rock dust and other materials used for composting are practically devoid of heavy metal content. All the composts recorded a clean index of 4.5.

5.1.3 Classification of composts for their marketability:

Based on fertilizing and clean indices, composts were categorised into any one of the classes ranged from A to D and RU-1 and 2 (Table.6) . Accordingly, all the composts used for the study were under marketable class B which means that they have very good quality. The composts under this class have medium fertilizing potential and low heavy metal content.

5.1.4 Other physico-chemical and biological properties of different composts

Considering other parameters like pH, EC and microbial count, all rock dust enriched composts were found superior than non rock dust enriched compost. This shows that rock dust was rich in nutrients to enrich the compost and also helped to enhance the microbial activity. The compost and rock dust had a symbiotic combination, then compost provide an excellent medium for the “microorganism population explosion”. Incorporation of rockdust increased the microbial population in soil. (Lertola, 1991).

5.2 LABORATORY INCUBATION STUDY

The effect of enriched composts with and without biofertilizer (PGPR Mix-I) on soil was assessed by periodical monitoring of changes in pH, EC and available nutrients *viz*. N, P, K Ca, Mg, Fe, Mn, Zn and Cu and the results are discussed below.

From Fig. 4 it was clear that there was an increasing trend in the pH of incubated soil in all the treatments except control. This was due to the addition of enriched composts which helps to increase the pH near to neutral point. The maximum pH of 6.8 was recorded by T_{10} (mineral enriched vermicompost in conjunction with PGPR Mix I)at 120th day of incubation which indicated an initial pH of 6.2 on 0th day. The treatments with enriched composts with biofertilizer (PGPR Mix I) recorded high pH when compared to treatments without biofertilizer. Campe *et al*. (1996) reported that rock dust can neutralize the soil to a great degree. This is evident from the treatment that rock dust enriched compost and rock dust enriched vermicompost had a positive effect on soil reaction. Increase in pH may be due to increase in bases by active degradation of organic matter and suppression of Fe and Al oxides and hydroxides activity which play vital role in protonation and deprotonation mechanisms controlling H^+ ion concentration in soil solution and the beneficial influence of bio fertilizer that provide favourable environment for nutrient availability. The soil pH significantly affects the availability of most of the nutrients required for plants, and optimum availability of all nutrients are at near neutral pH (Brady, 1990).

Electrical conductivity (EC) of incubated soil (Fig. 5) wasincreased by the addition of enriched compost. This may be due to faster release of bases and soluble organic fractions to the soil system by mineralization. This is similar to the findings of Thompson *et al.*(1989) who reported that organic amendments with ionic concentration increases to higher ionic mobility gives high EC value.

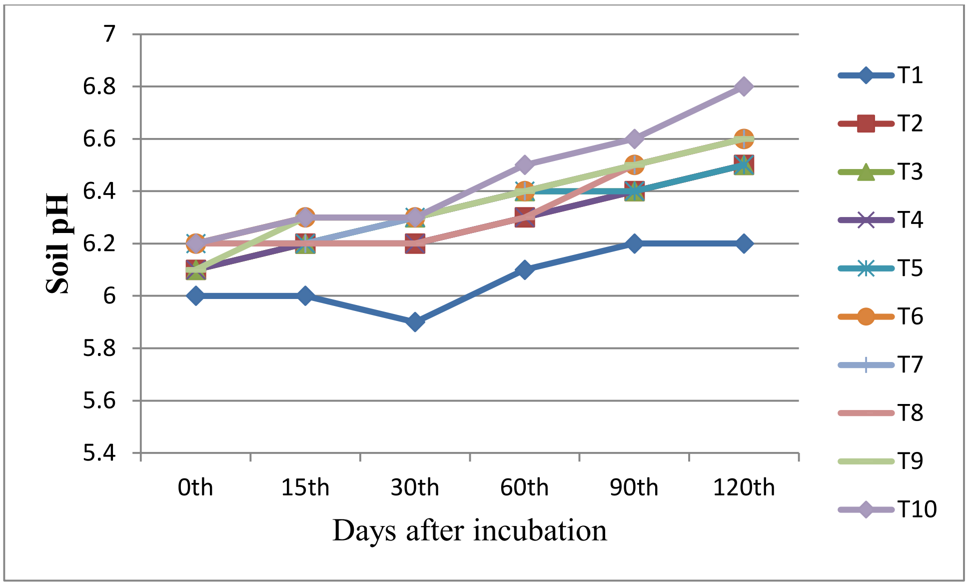

Fig. 4 Effect of different composts on pH of soil during incubation period.

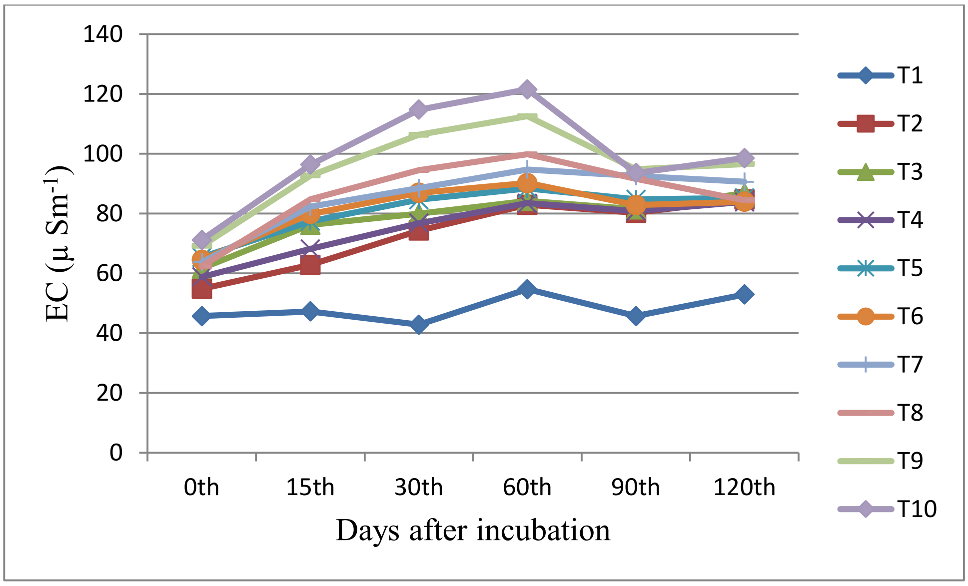

Fig.5 Effect of different composts on EC of soil during incubation period.

The available N during incubation period (Fig. 6) increased due to mineralisation of organic matter through high microbial activity. The soil treated with enriched compost shows active aminisation, ammonification, and oxidative deamination due to high microbially mediated system. Thus nitrogen is more available in the soil. The soil treated with mineral enriched vermicompost with PGPR Mix I showed an increase in nitrogen content which may be due to the PGPR Mix-I which is a consortium of microorganism which actively solubilize and fixes the nitrogen content in soil. The rock dust is devoid of nitrogen but vermicompost is a rich source of nitrogen and also PGPR Mix I which enhances its availability. Sheeba (2004) reported an increase in available N upto 45 days of incubation for soil treated with vermicompost enriched with bone meal (2%).

In case of available P (Fig. 7), during first two monthsof incubation soil treated with biomineral enriched compost and PGPR Mix Ishowed higher release of P. This may be due to the release of phosphorus from rock dust which was made available during composting period through the use of composting inoculum and also by theuse of PGPR Mix I. Vyas and Mothiramani(1971) reported a positive effect of organic matter and soil humus on P availability. But later soil treated with mineral enriched vermicompost in conjunction with PGPR Mix I showed higher release of P. This may be due to the greater mineralisation of organic matter with the help of microorganisms associated with earthworm and increased phosphatase activity. Mackey *et al.* (1983) reported that incorporation of earthworm to soil incubated with rock phosphate resulted in a 32 per cent increase in bray extractable P after 70 days.

The available K content (Fig. 8)in the soil ranged from 171.73 - 343.47 kg ha^{-1}. During first two months, soil treated with rock dust enriched vermicompost with PGPR Mix I as well as biomineral enriched compost with PGPR Mix I recorded the highest release of K content. This shows that rock dust played a vital role as well as vermicompost which is rich in all major nutrients also helped to maintain the K content throughout the incubation period. But during third and fourth months of incubation mineral enriched vermicompost alone showed higher

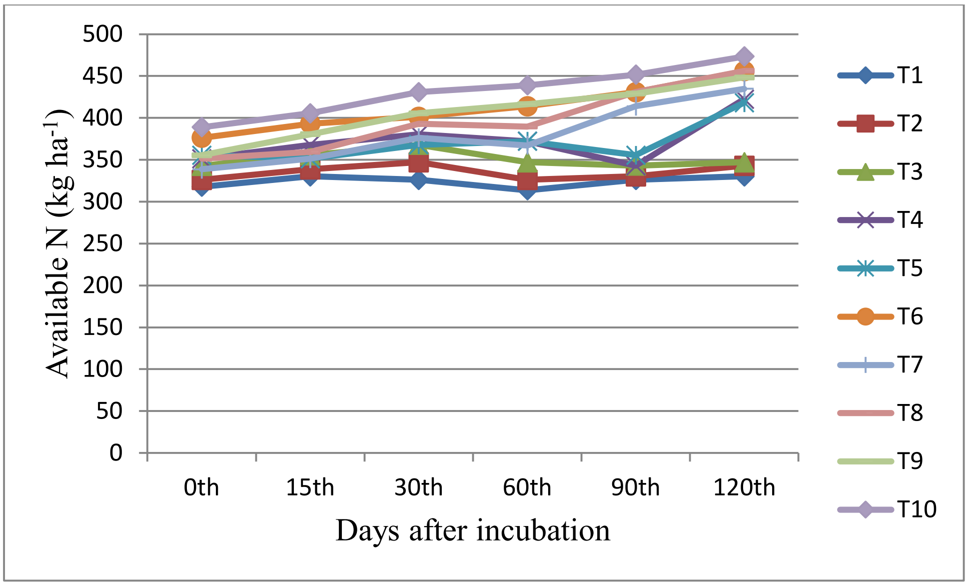

Fig.6 Effect of different composts on N of soil during incubation period.

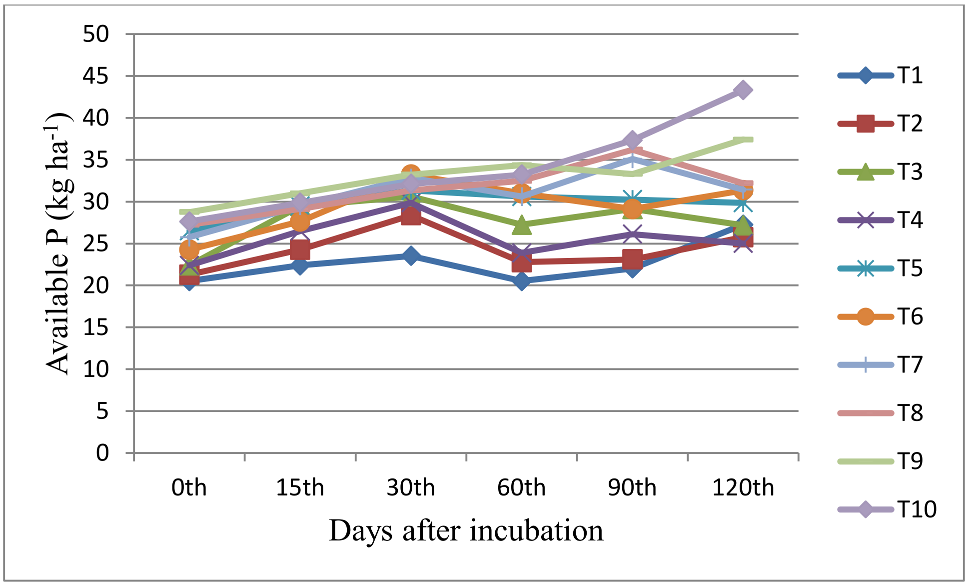

Fig. 7 Effect of different composts on P of soil during incubation period.

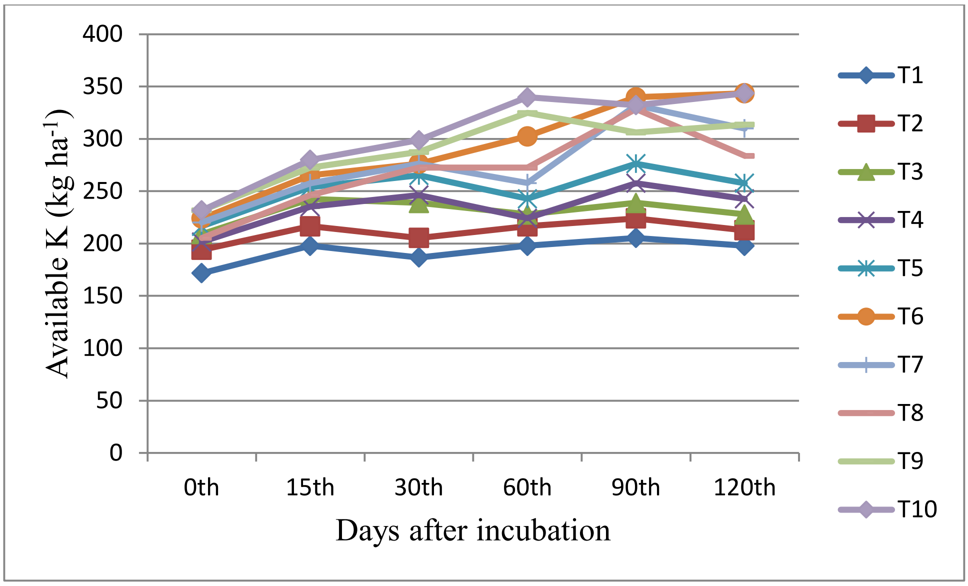

Fig.8 . Effect of different composts on K of soil during incubation period..

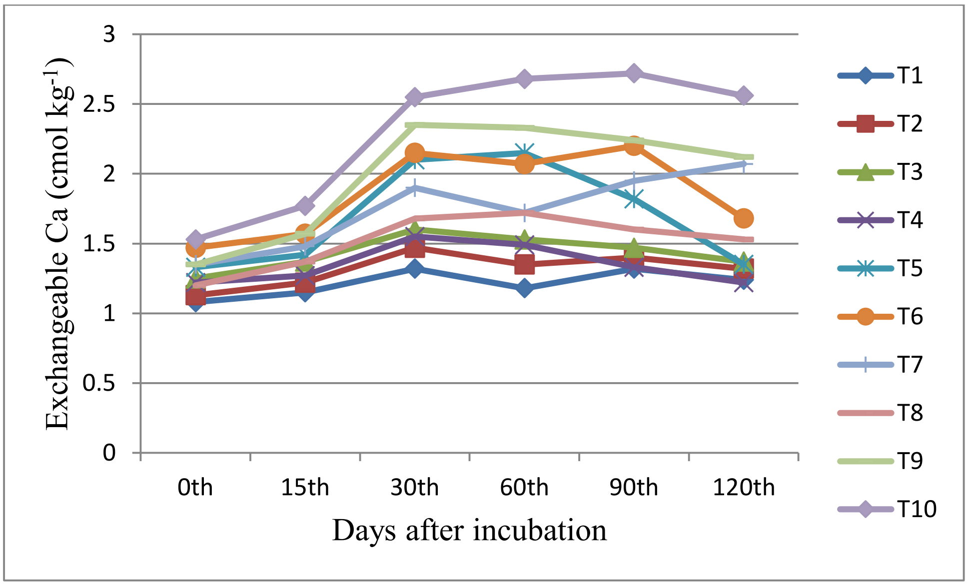

Fig. 9. Effect of different composts on Ca of soil during incubation period.

release of K in incubated soil. The highest release of K was observed due to accelerated mineralisation by the interaction of organic matter with clay (Tan, 1982). It was also reported that availability of K was increased by earthworm activity (Rao *et al*., 1996).

Exchangeable calcium during laboratory incubation period was studied and significant difference among treatments was observed (Fig. 9). It was observed that soil treated with mineral enriched vermicompost with PGPR Mix I showed better release of calcium throughout the period because rock dust is a source of many kind of nutrients. Korcak (1996) reported that rock dust contain major nutrients (H, O, N, C, K, Mg, P, S, and Ca) in larger amount where as micronutrients (Mn, Zn, Cu, Fe, B, and Mo) in smaller amount. Russel (1998) opined that microorganisms were involved in the weathering of amino silicates through the removal of divalent cations and the solubilization of silica, which was observed on newly exposed rock. This can be attributed to the increased availability of Ca, Mg, Fe, Mn in soils supplied with rock dust. Rose (2008) reported that application of rock dust in equal quantity with FYM increased the calcium as well as magnesium contents in soil.

In case of magnesium (Fig. 10)same trend like calcium was observed, throughout the period. Incubated soil with mineral enriched vermicompost in conjunction with PGPR Mix I showed a better release of magnesium. The reason may be that the rock dust which is rich in nutrientbecome readily available during composting period and supplied along with PGPR Mix I tend to increases Mg availability. Extractable soil K and Ca were increased generally and some increases in extractable P, Fe, Mn, and Mg were detected in soils treated with basalt rock dusts. (Barker, 1998)

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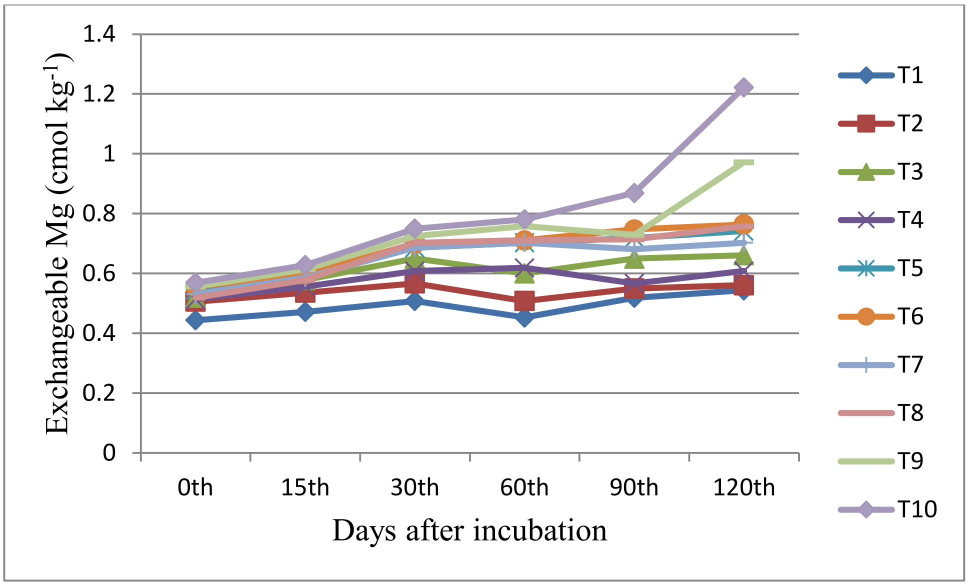

Fig.10 Effect of different composts on Mg of soil during incubation period.

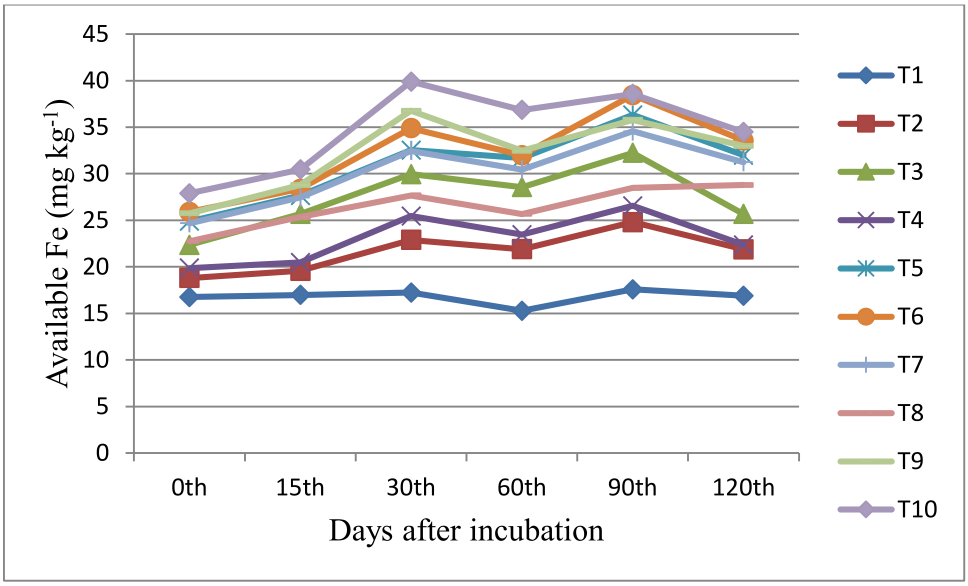

Fig.11 Effect of different composts on Fe of soil during incubation period.

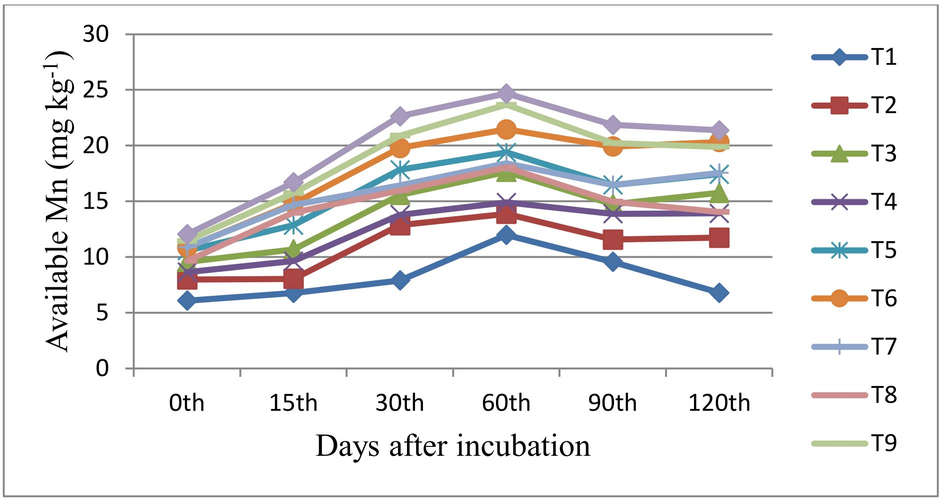

Fig.12 Effect of different composts on Mn of soil during incubation period

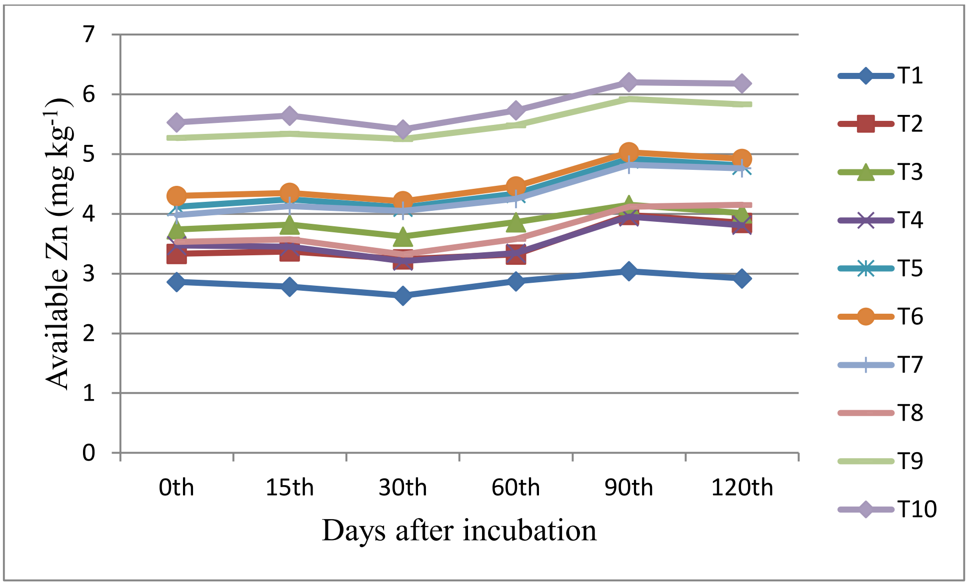

Fig.13 Effect of different composts on Zn of soil during incubation period.

There was increase in micro nutrients viz., Fe, Mn, Zn and Cu content of soil throughout the incubation period (Figs.11 - 14). Here also, mineral enriched vermicompost along with PGPR Mix I was found best among all treatments. It was noted that maximum solubility of Fe and Cu was observedon 30th day, for Mn it was on 60th day and for Zn it was on 90th day. These may be because of interaction among nutrients. Rose (2008) reported the pattern of solubilization of micro nutrients viz. Fe, Mn and Zn for soil treated with different doses of rock dust and FYM through incubation study and revealed that there was a gradual increase in the concentration of these nutrients during the early period of incubation and reached the higher value during the later stage of incubation

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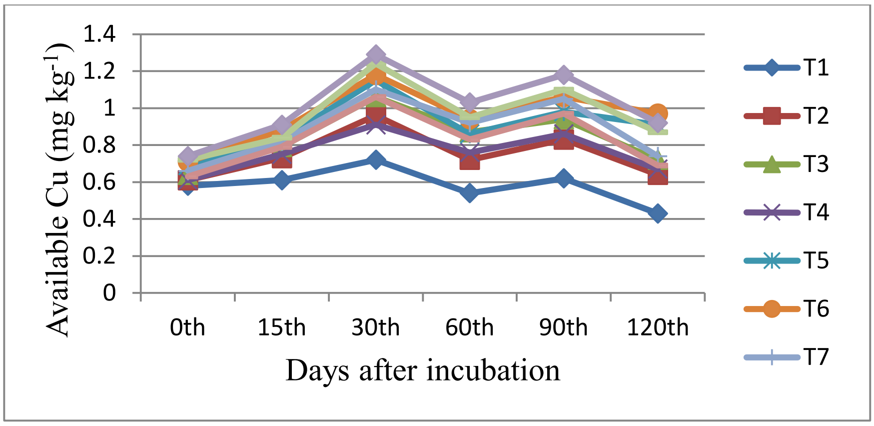

Fig. 14 Effect of different composts on Cu of soil during incubation period.

5.3 FIELD EXPERIMENT

5.3.1 Effect of mineral enriched composts on biometric characteristics of yard long bean

For evaluating the effect of mineral enriched composts on crop nutrition various biometric observation were noted *viz.*days to fifty per cent flowering, leaf area index, crop duration, number of harvest and appearance of the product. Among those observation,days to fifty per cent flowering and leaf area index were found significantly different whereas rest of the observations were found non significant.

From the Fig. 15 regarding days to fifty per cent flowering it was clearly understood that plants treated with rock dust enriched vermicompost flowered earlier. It was found on par with plants treated with mineral enriched vermicompost along with PGPR Mix I, biomineral enriched compost and integrated nutrient management (POP recommendation).Higher and sudden release of nutrients in these sources might have made the plant flower earlier. This was similar with the findings of Devi Krishna (2005) that least number of days for 50 percent bloom was registered by treatment received POP recommendation, and also for plants received vermicompost and phosphorus solubilising microorganism.

Leaf area index is a function of leaf size and number.Regarding leaf area index (Fig. 16) highest value was observed for the plants treated with mineral enriched vermicompost in conjunction with PGPR Mix I . It was also found that plants treated with mineral enriched compostsshowed better leaf area when compared with other non-mineral enriched compost. This might be because of higher level of N in soil. Russel (1973) reported that as the nitrogen supply increases, the protein content also increases that allows plant leaves to grow larger and hence more surface area for photosynthesis. Thus the increased leaf area might be due to enhanced production of leaves and it increases longevity. The higher level of N released from vermicompost had resulted in higher leaf area

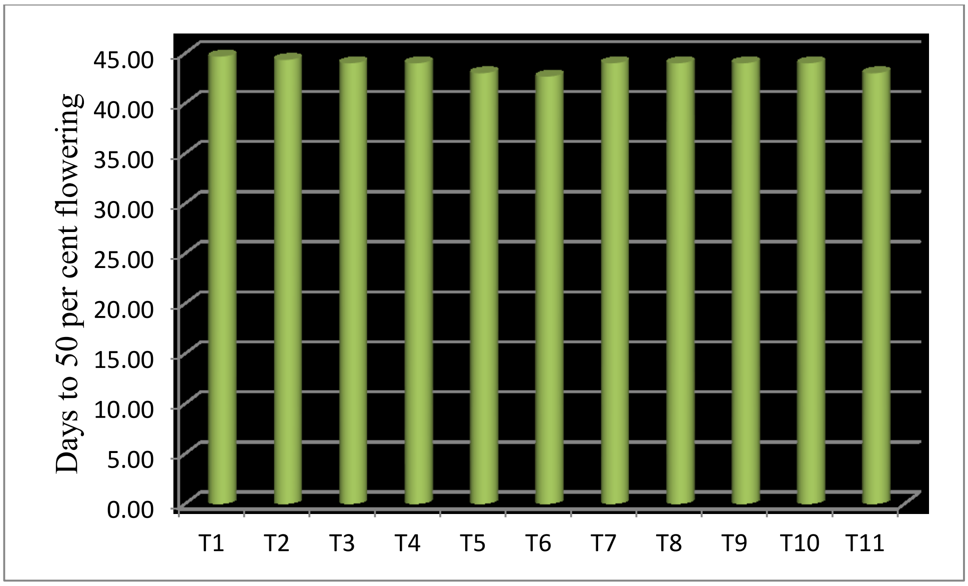

Fig.15. Days to 50% flowering as influenced by different composts.

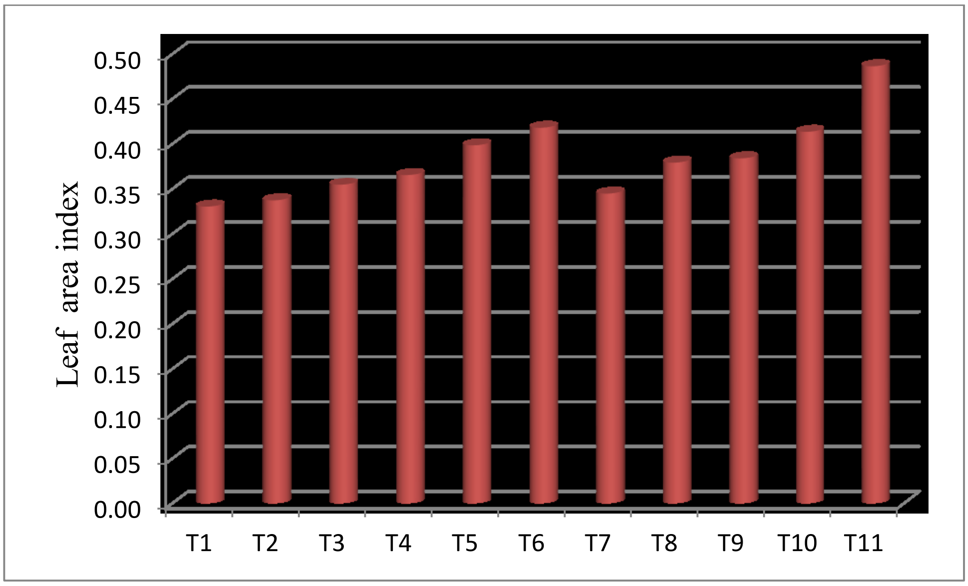

Fig. 16. Leaf area index as influenced by different composts.

index. Similar result were obtained in solaneaceous crops (Joshi and Nankar,1992).

5.3.2 Effect of mineral enriched composts on yield and yield attributes

Yield and yield characters of yard long bean showed significant variation among treatments. In general, 50% N as mineral enriched vermicompost with PGPR Mix-I showed best result in yield and yield attributing characters. (Fig.17-23).

Regarding pod length and pod weight highest values were recorded by plants treated with 50% N as rock dust enriched vermicompost along with PGPR Mix I, which was followed by bio mineral enriched compost with PGPR Mix I. The result so obtained may be because of combined use of enriched compost and bio fertilizer. It is well known with the fact that vermicompost is a potential source of readily available plant nutrients, growth enhancing substances and number of beneficial microorganisms and also PGPR Mix I is a excellent bio fertilizer with N fixers, P and K solubilizers. These microorganisms are known to induce many biochemical transformations like mineralization of organically bound form of nutrients, exchange reaction, fixation of atmospheric nitrogen and various other changes leading to better availability of nutrients already present in soil and provide additional nutrients to plants. This may result in higher pod length and pod weight. Lekshmi (2011) reported that highest fruit length, fruit weight and total fruit yield were observed for plants treated with seventy five per cent N as bio mineral compost with panchagavya.

With respect to number of pods per plant highest value was recorded by T_{11} (50% N as mineral vermicompost +PGPR Mix I). It is evident that plant supplied with bio fertilizer along with the rock dust enriched vermicompost might provide sufficient nutrients to plants and influenced plants to set more number of pods.Rose (2008) reported highest number of tubers per plant in coleus due to application of rock dust along with FYM .

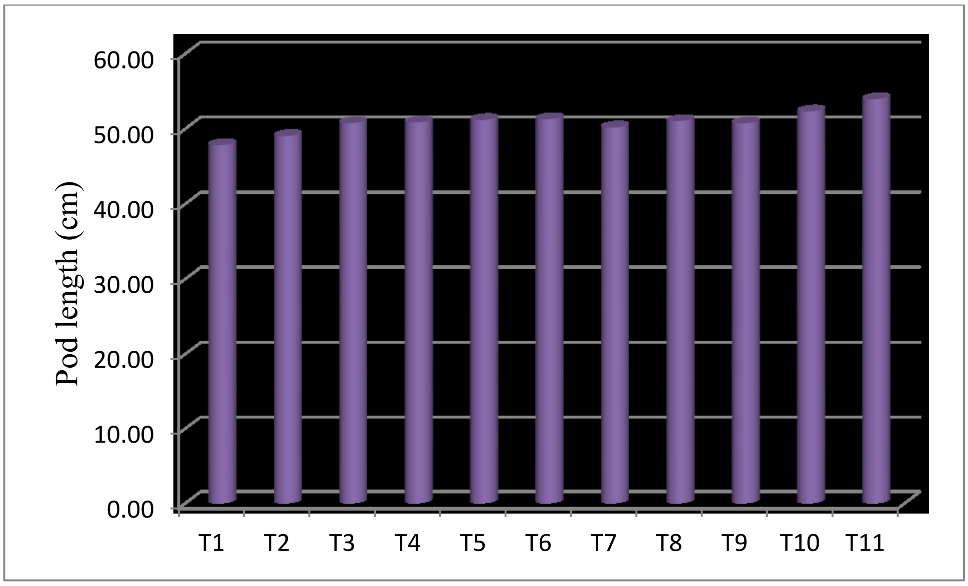

Fig. 17 Influence of different composts on pod length(cm) of yard long bean.

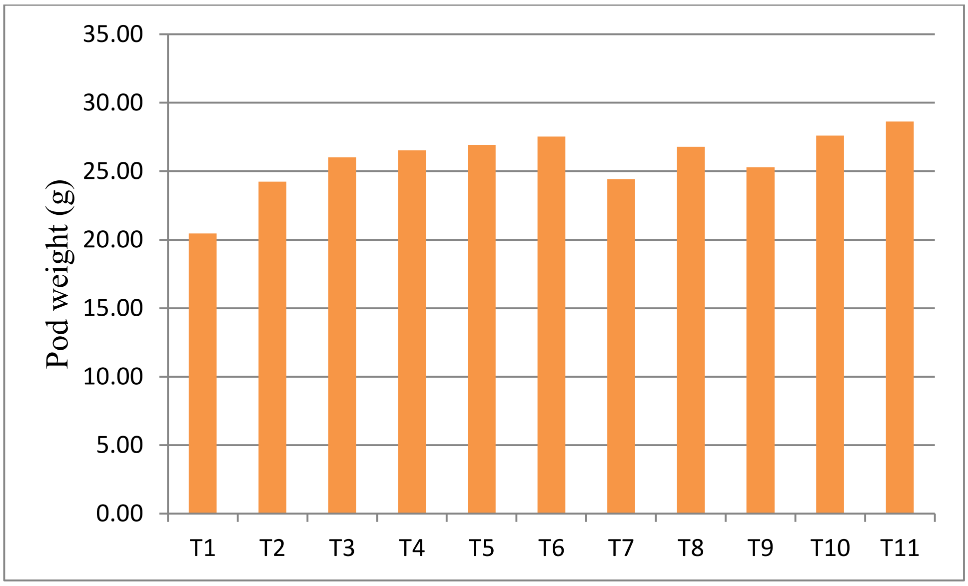

Fig.18 Influence of different composts on pod weight (g) of yard long bean.

Pod yield was found significantly different among treatments. T11(50% N as mineral enriched vermicompost + PGPR Mix I) was found superior and found on par with $T_{10}$and this indicated that compost enriched with rock dust applied along with bio fertilizer may become an excellent source for getting higher crop yield. Though yardlong bean is a legume crop,it fixes N symbiotically and thus fifty percent of recommended nutrient is sufficient for the crop to produce higher yield. If crop was supplied with full dose of manure, that enhances the vegetative growth and yield get reduced drastically. Devi Krishna (2005) reported highest pod yield in yardlong bean when treated with vermicompost and PSM. Rose (2008) reported that rock dust @ 10 t ha^{-1} applied along with equal quantity of FYM increased the number of tubers per plant and yield in coleus. Lekshmi (2011) reported highest yield in chilli for plants treated with seventy five per cent N as bio mineral enriched compost with panchagavya.

From the Fig. 21, it is clear that bhusa yield significantly varied among treatments. The best treatment was T_{11} and found on par with T_{10} because of the combined effect of rock dust enriched compost and bio fertilizer. Here also superiority of enriched vermicompost in accelerating the yield when compared to other organic sources were observed. Singh *et al.* (1998) reported the influence of vermicompost on vegetative growth of plant because of higher level of N and P in compost. Kale *et al*. (1992) reported that worm cast when used as organic source increases the vegetative characters due to the presence of growth promoting substances. It could also be viewed that plant height and leaf area index were found highest for treatment with enriched vermicompost with PGPR Mix I which in turn increases the bhusa yield. Devi Krishna (2005) also reported similar result.

The data pertaining to the dry matter production were presented in Fig. 22. As in the case of pod yield and bhusa yield, plant treated with mineral enriched vermicompost in conjunction with bio fertilizer was found best for total dry matter production also. Sakr (1985) reported the increase of dry weight of plants after organic manure application. This was due to the production of humus substances which improve the physical, chemical properties of soil and also increased the

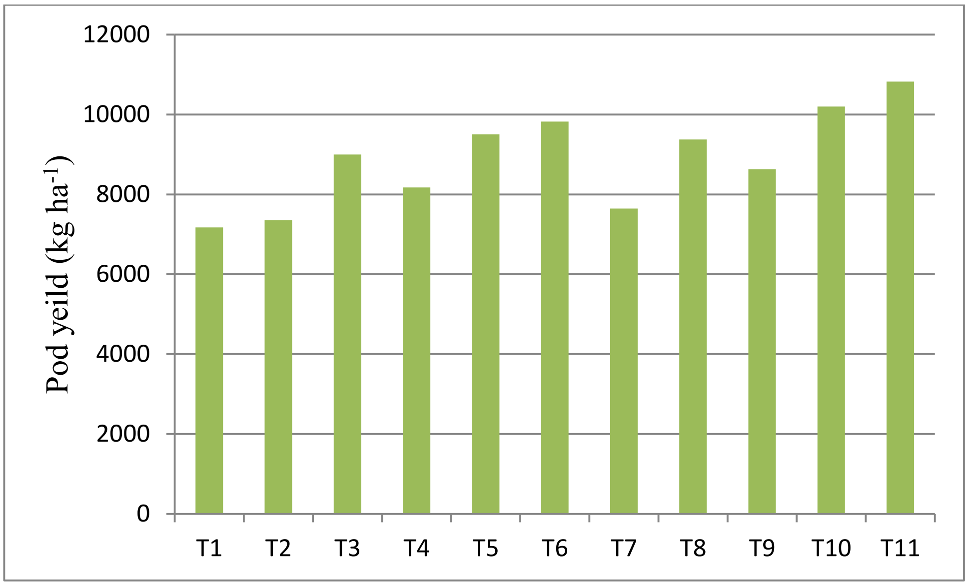

Fig. 19. Influence of different composts on pod yield (kg ha^{-1}) of yard long bean.

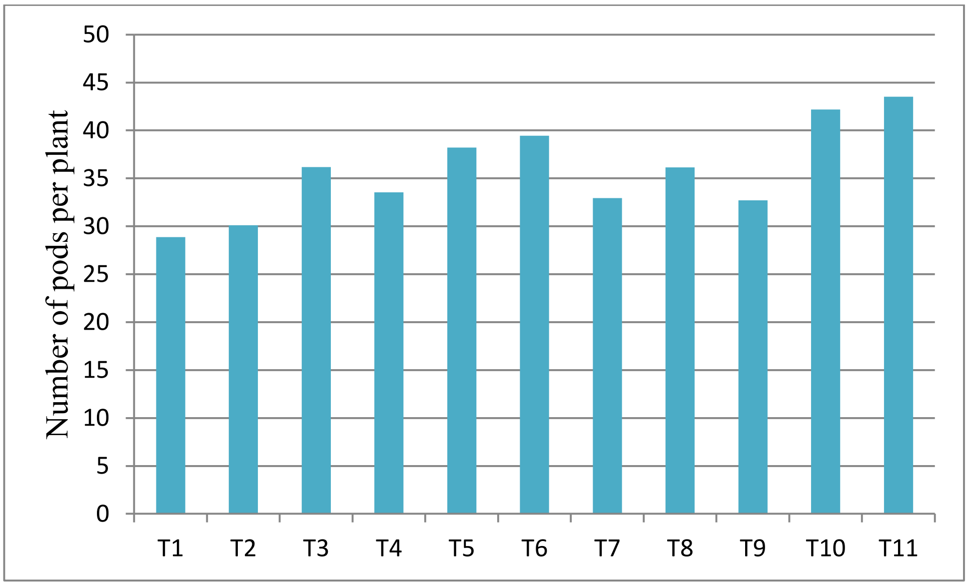

Fig. 20. Influence of different composts on pod number/plant of yard long bean.

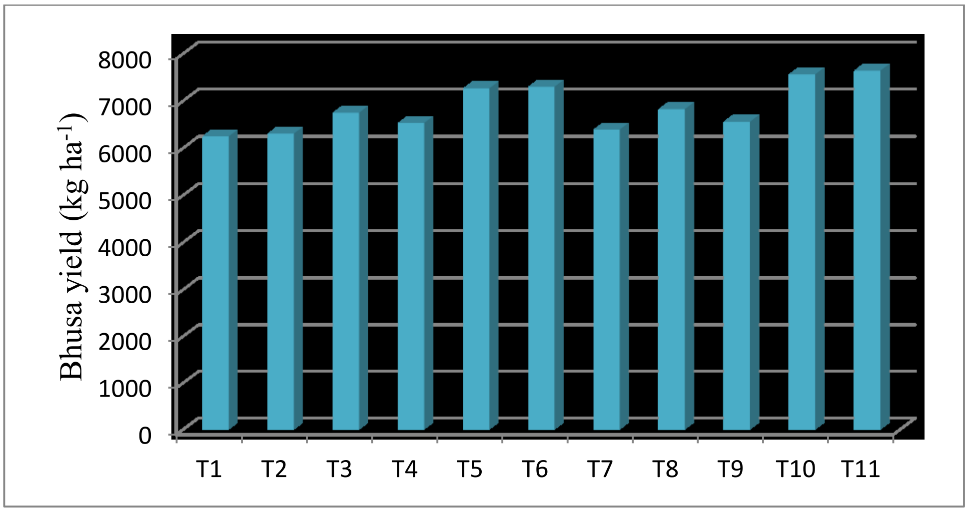

Fig.21. Bhusa yield as influenced by different composts.

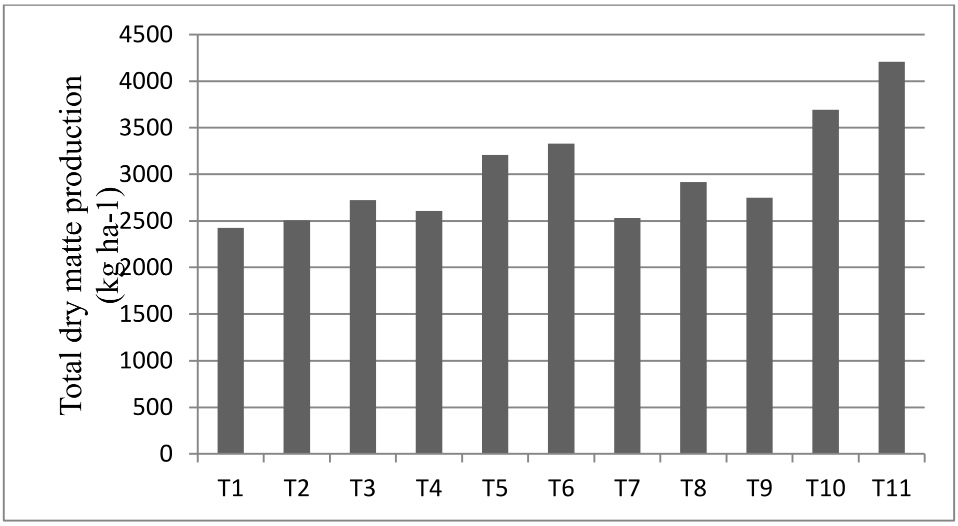

Fig. 22 Total dry matter production as influenced by different composts.

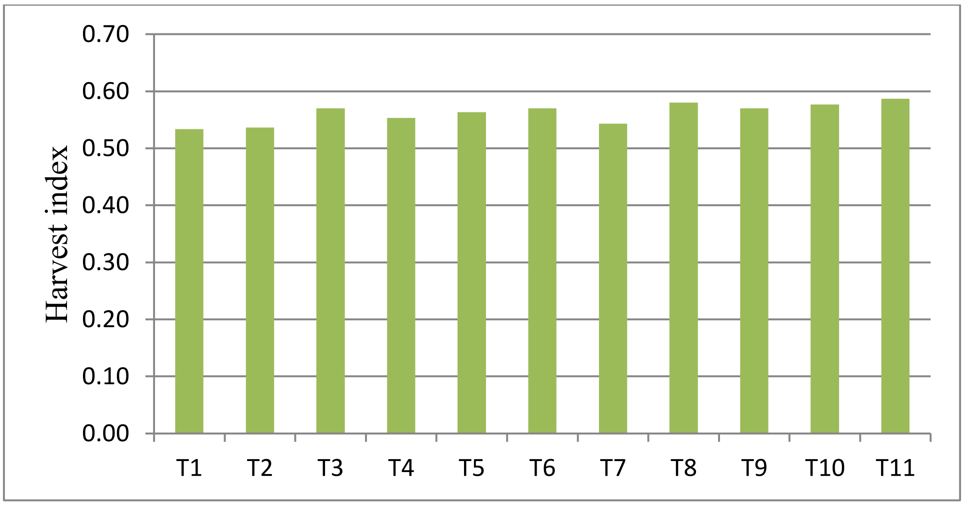

Fig. 23 Harvest index as influenced by different composts.

nutrient release which in turn enhanced the ability of growing parts. Devi Krishna (2005) reported highest dry matter production for the plants treated with vermicompost and phosphorus solubilising micro organism.

Harvest index was found significantly different among treatments. From the result of pod and bhusa yield, it was clear that organic source especially vermicompost enriched with rock dust applied along with bio fertilizer was superior. Hence harvest index was found highest for the same treatment followed by biomineral enriched compost with biofertilizer. Plants received POP treatment (T_1) also showed better performance but lower than plants treated with enriched compost with biofertilizer. Hence lowest harvest index was recorded by T_1. This was found similar with the findings of Devi Krishna (2005).

5.3.3 Effect of mineral enriched composts on quality of yard long bean

From the Fig. 24 highest protein content were observed by plants treated with mineral enriched vermicompost with PGPR Mix I. This might be due to better translocation of N to the pods. The lowest value was recorded by POP recommended plants. Mineral enriched vermicompost with PGPR Mix I treated pods showedhigher N content that directly contribute to build up of protein content in pod becausebio fertilizer which consisted of N fixers make N more available to plant. Nitrogen thus obtained was metabolized via ammonia into alpha-ketoglutamic acid. Carbon skeleton provided by photosynthesis was incorporated in the process of aminoacid synthesis which were converted as protein and found similar with the findings of Sheeba (2004).

From the Fig. 25 it was clear that crude fibre contents of yard long bean were significantly influenced by the different treatments. The lowest fibre content, was found as desirable quality for pods that was observed in treatment T_{11} (50 % N as mineral enriched vermicompost + PGPR Mix I) and all other treatments which received organic nutrition have lower fibre content when compared with POP recommendation. This might be due to the production of growth hormones which might have decreased the crude fibre content in organic plots, especially

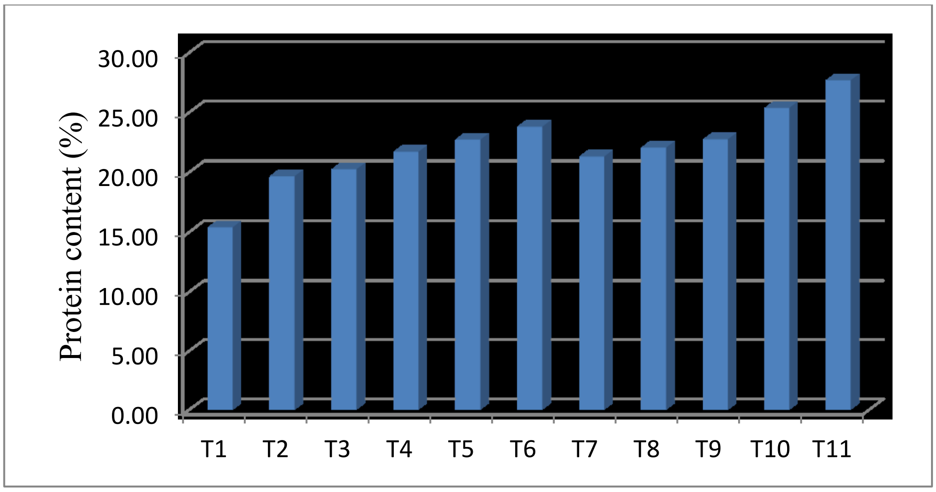

Fig. 24. Protein content of yardlong bean as influenced by different composts.

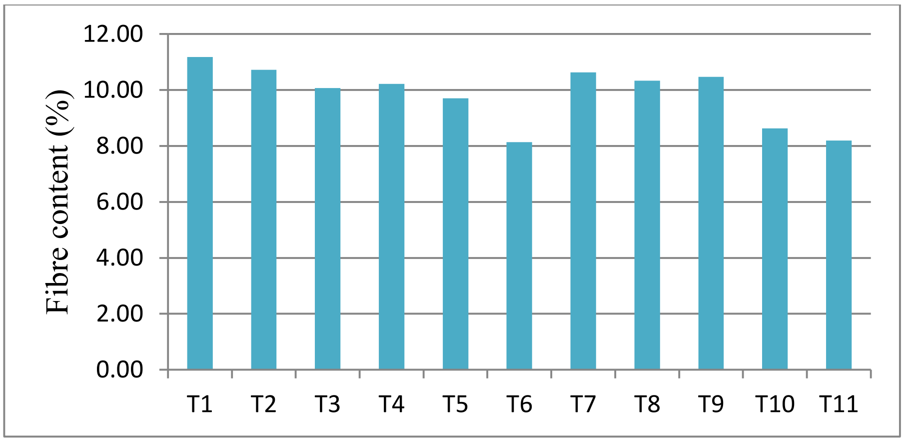

Fig.25 Fibre content of yardlong bean as influenced by different composts.

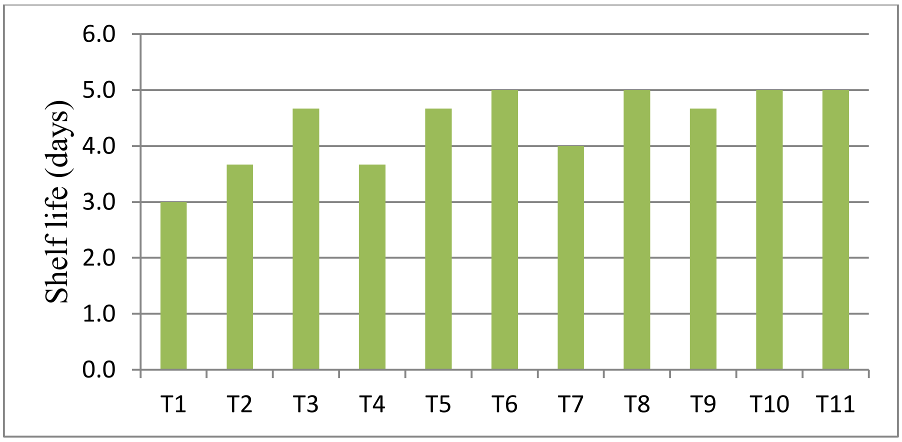

Fig. 26 Influence of different composts in shelf life of pod.

plants received with mineral enriched vermicompost with PGPR Mix I. Indole-3-acetic acid is a phytohormone which is known to be involved in root initiation, cell division,and cell enlargement (Salisbury, 1994). This hormone is very commonly produced by PGPR (Barazani and Friedman, 1999). Increased N uptake also have resulted in increasing the succulence and thereby decreasing crude fibre content. Similar results were obtained by Raj (1999). Tiwana *et al*. (1975) reported the decrease in crude fibre content in Napier bajra hybrid fodder due to N application

Shelf life of pod was significantly influenced by different sources of nutrition (Fig. 26). Highest keeping quality was observed in T_{11}, T_{10}, T_6, and T_8 where the plants were treated with 50% N as mineral enriched vermicompost with PGPR Mix I , 50% N as bio mineral enriched with PGPR Mix I, 75% N as mineral enriched vermicompost and 50% N as mineral enriched compost with PGPR Mix I. The PGPR Mix I which consisted of K solubilising bacteria solubilize the potassium in soil and makes available to plant. Thus maintain the quality of pod. Application of higher level of N through organic manure increase the ascorbic acid content and decreases crude fibre content (Raj, 1999) and the increased shelf life of pods was due to high K content. Hence from the observation it was clear that high K uptake by plants has resulted in the long shelf life of pods. Giovannoni (2001) reported that firmer fruits are obtained from PGPR-inoculated plants. Firmer fruits will be expected to be more resistant to spoilage by microorganisms' attack (Kramer *et al*., 1992) and consequently to have a longer shelf-life.

5.3.4 Effect of mineral enriched compost on pest and diseases incidence

Aphid attack noticed during the study was suppressed by nimbicidin spray. No other serious pest was recorded. *Fusarium wilt* was observed and fish amino acid (3%) was sprayed to control the disease. Treatments were found non significant. but no incidence of disease were observed for plants treated with mineral enriched composts. This is in conformity with the findings of Lekshmi

(2011) that seventy five percent N as biomineral compost with panchagavya had reduced the disease incidence percentage. Campe (2012) reported that in the short term , very fine dust sprayed directly on plants and trees has been shown to deter insect infestations very effectively and in the long term remineralized plants will not be plagued by insects as they become healthier and more insect resistant.

5.3.5 Effect of mineral enriched composts on properties of soil

5.3.5.1 Physical properties

Post harvest analysis of soil showed that bulk density (Fig. 27) was significantly influenced by the addition of enriched composts. It was found that soil treated with mineral enriched compost showed lowervalues when compared to other treatment. High bulk density indicates soil compactness and is unfavourable for crop growth. An increase in organic matter decreased the bulk density of soil which is optimum for plant growth (Das and Agarwal, 2002). Dahia *et al.* (2003) reported a reduction in bulk density when sugarcane trash enriched with mussorie rock phosphate and photosynthetic bacteria were applied to soil which has favoured soil conditioning, aggregate stability and nutrient recycling. The Bulk density may get reduced due to better soil aggregation and aeration brought about by organic amendments. (Kadalli *et al*., 2000). This was also found similar with findings of Lekshmi (2011)

Water holding capacity (Fig. 28) of soil was found significantly different among treatments. It was noted that water holding capacity of soil treated with mineral enriched compost along with PGPR Mix Iwas found highest. Khaleel *et al.* (1981) reported that more addition of organic matter increased the organic carbon content of the soil which resulted in an increase in water holding capacity of soil. Rock dust used in compost also might have contributed to increase the water holding capacity of soil. Shehana *et al*. (2006) reported that application of khondalite resulted in an increase in soil porosity and water holding capacity.

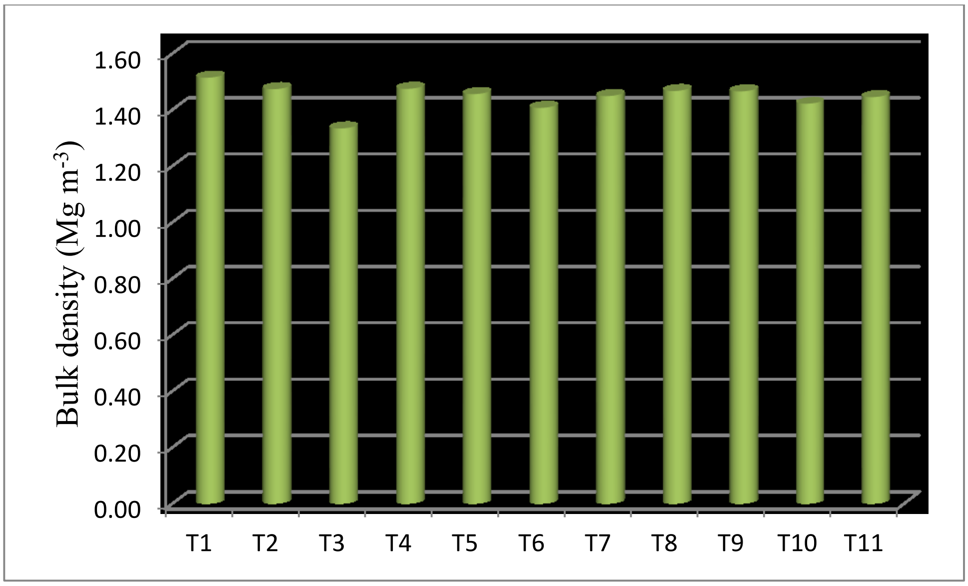

Fig.27 Effect of different composts on soil bulk density (Mg m^{-3}).

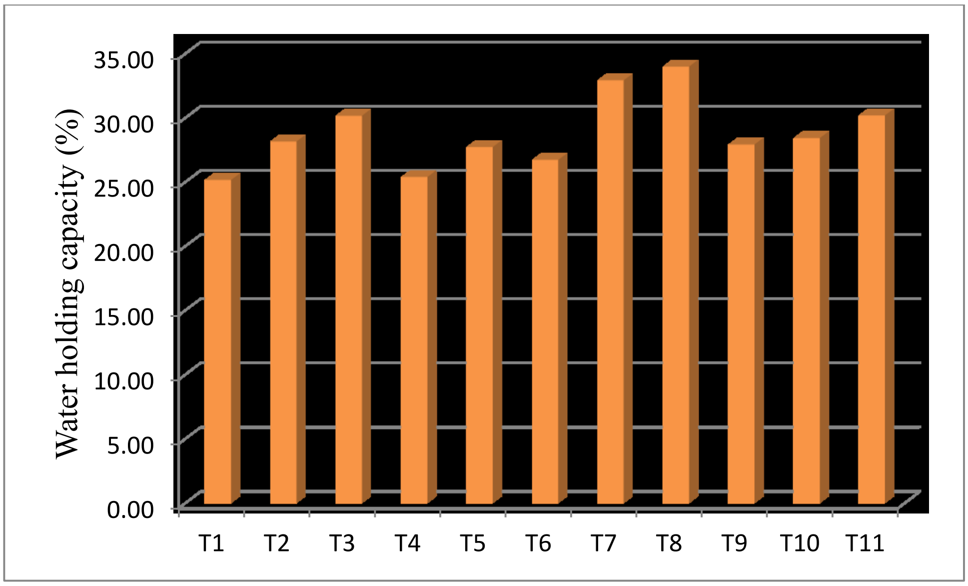

Fig. 28 Effect of different composts on water holding capacity of soil.

5.3.5.2 Chemical properties

There were significant differences among treatments for pH of soil. It was observed that soil treated with mineral enriched vermicompost alone was recorded higher mean value. This might be due to combined effect of rock dust and vermicompost. Devi Krishna (2005) reported increase in pH of soil that received vermicompost + phosphorus solubilising microorganismtreatment. Lekshmi (2011) reported an increase in pH of the soil treated with 75% N as BM compost with panchagavya. The increase in pH might be due to increase in bases by active degradation of organic matter and thus activity of iron and aluminium oxides and hydroxides been suppressed, which play vital role in protonation and deprotonation mechanism controlling H^+ ion concentration in soil solution. This is in agreement with the observation by Dahia *et al*. (2003).

Different treatments influenced the electrical conductivity (EC) of soil. The treatment T_{10} (50% N as biomineral compost+ PGPR Mix I) registered the maximum value for EC of soil. Addition of organic manure generally increases EC of soil whichmay be because of faster release of bases and soluble organic fractions to the soil system by mineralisation. This is in agreement with the findings of Thompson *et al*. (1989). Lekshmi (2011) reported highest EC value for the soil treated with `100 % bio mineral compost.

In case of organic carbon, highest value was recorded for the soil treated with 50% N as mineral enriched vermicompost+ PGPR Mix I. Halvorson *et al*. (1999) reported that the addition of organic matter to soil increased the root biomass production which in turn increases the carbon content in soil. Devi Krishna (2005) reported highest organic carbon content for soil treated with vermicompost and P solubilising micro organism. Similar findings were reported by Sheeba (2004).

The change in CEC as shown in Fig. 32 indicated the significant variation among enriched compost on ion exchange capacities of soil. It was clear that among treatments, T_{11} has got the highest value may be due to effect of

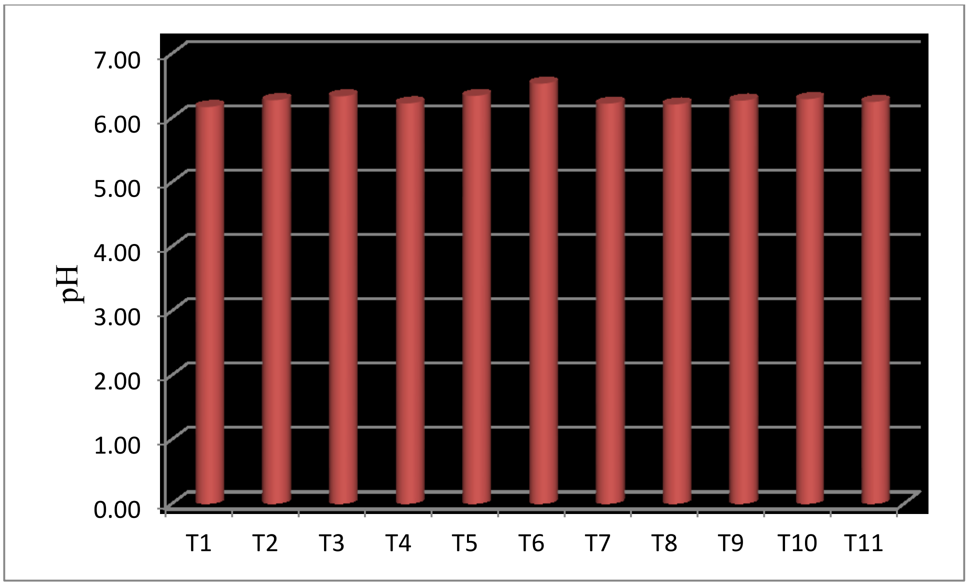

Fig.29 Influence of different composts on pH of soil .

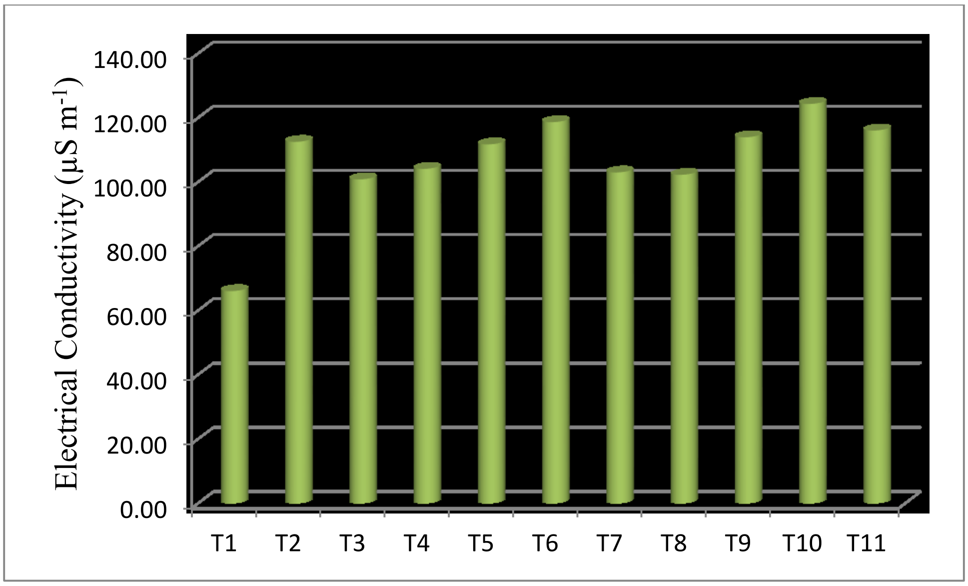

Fig. 30 Influence of different composts on EC ($\mu S\ m^{-1}$) of soil

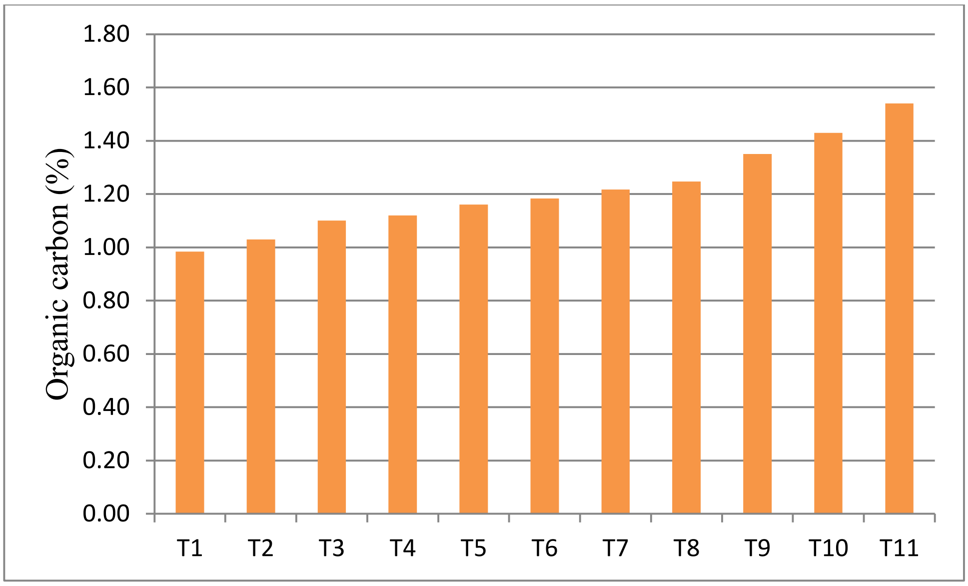

Fig. 31 Influence of different composts on soil organic carbon (%)

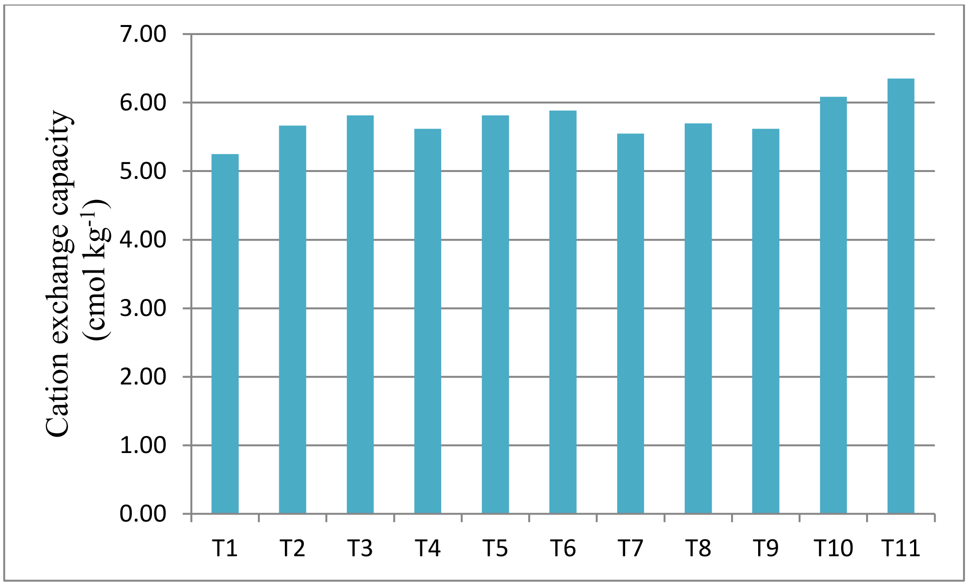

Fig.32 Influence of different composts on cation exchange capacity (cmol kg^{-1}) of soil.

vermicompost and rock dust. Vermicompost with higher amounts of active humic fraction having high CEChad thus resulted in maximum enhancement of this parameter. This findings was found similar with Devi Krishna (2005). Straaten(2006) reported that application of large quantities of ground basaltic rock raises pH, increases cation exchange capacity and enhance cation level in soil.

Highest value for available N was registered by T_{11} (50% N as mineral enriched vermicompost and PGPR Mix I) followed by T_{10} (50% N as Biomineral enriched compost and PGPR Mix I). The significant increase in N content in soil may be due to increase in microbial action which mineralize the nitrogen already present in the applied organic manures and presence of rock dust might have also enhanced the availability of N by enhancing the microbial activity. This is in conformity with the findings of Rose (2008) who reported that rock dust along with FYM was able to supply the N required for the growth of coleus. Lekshmi (2011) reported highest N content in soil when treated with panchagavya and bio mineral compost.

In case of P and K, highest values were recorded by T_{11} (50% N as mineral enriched vermicompost and PGPR Mix I) which was found on par with T_{10} (50% N as biomineral enriched compost and PGPR Mix I). The P and K contents of soil might have increased due to greater decomposition of native soil P and K by the usage of bio fertilizer and also by dissolution of P and K enriched compost. 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 Rose(2008) and Lekshmi (2011).

Greater concentration of secondary nutrients *viz*. Ca and Mg was observed in soils treated with T_{10} (50% N as biomineral enriched compost and PGPR Mix I). Same result was reported by Lekshmi (2011) that secondary nutrients were found higher for soil treated with 75% N as biomineral compost along with Panchagavya. The application of rockdust for corn crop resulted in an increase of

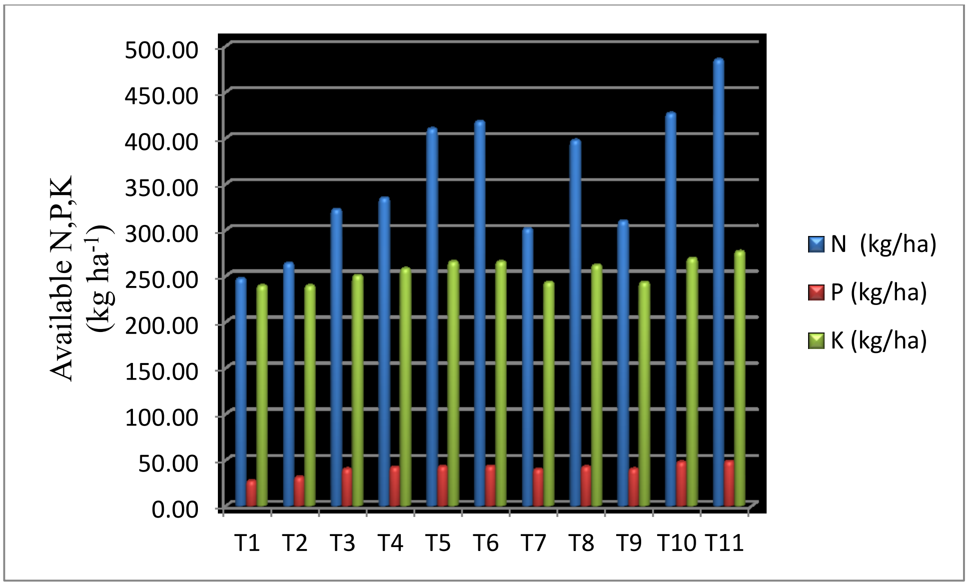

Fig.33 Influence of different composts on soil available primary nutrients (kg ha^{-1}).

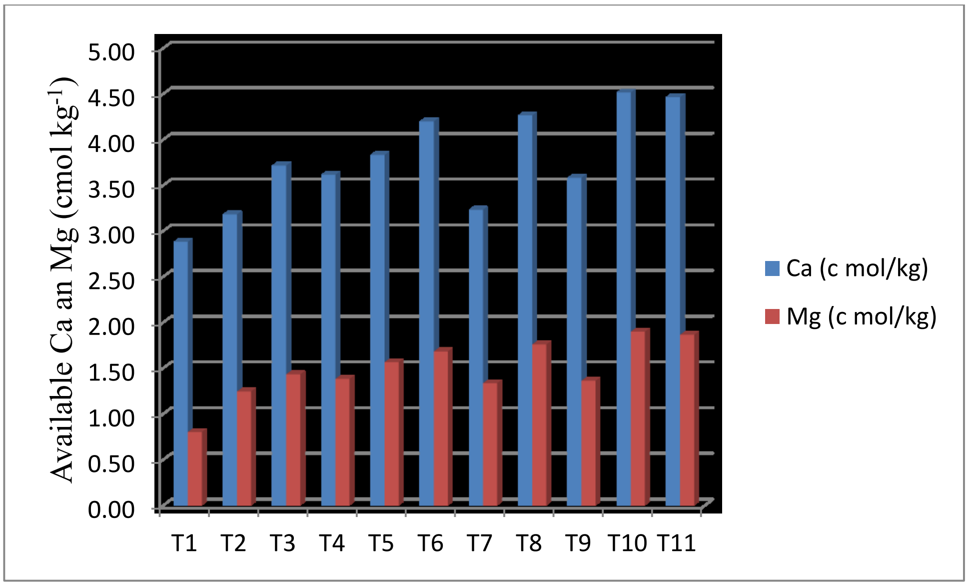

Fig. 34 Influence of different composts on soil available secondary nutrients (c mol kg^{-1}).

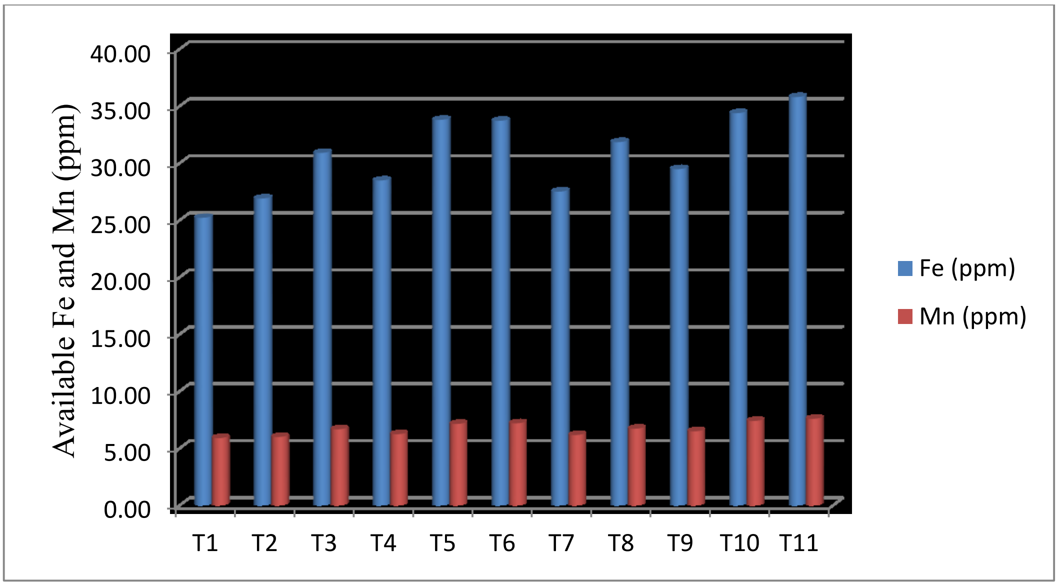

Fig. 35 Influence of different composts on soil available Fe and Mn content (ppm) .

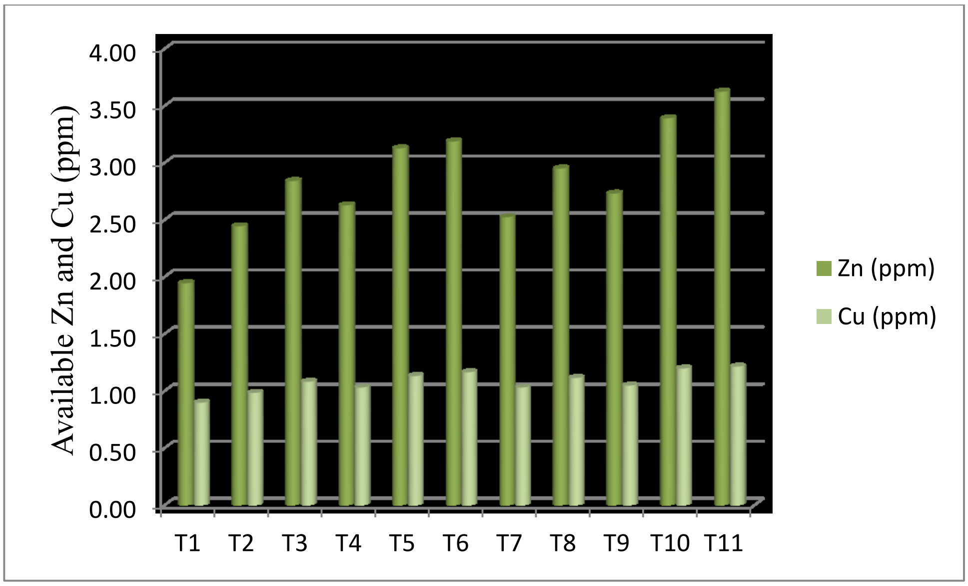

Fig. 36 Influence of different composts on soil available Zn and Cu (ppm).

57% P, 90% K, 47% Ca and 60% Mg than chemically grown crop from the same seed, (Hamaker and weaver, 1982).

Micronutrients viz. Fe, Mn, Zn and Cu of treated soils were studied and found a significant variation among treatments. Among enriched composts mineral enriched vermicompost along with PGPR Mix I reported to be the best followed by biomineral compost with PGPR Mix I for all micro nutrients.. The increase in Fe, Mn, Zn and Cu upon addition of organic matter might be due to intensified microbial action, pH of soil and also formation of stable complexes with organic ligands. This might have decreased the susceptibility of micro nutrient to adsorption, fixation or precipitation reaction in soil resulting in greater availability. This was found similar with findings of Rose (2008).

5.3.5.3 Biological properties

Dehydrogenase activity of soil was found affected by different enriched composts application. Dehydrogenase is a soil enzyme, which act as an indicator of soil fertility as the activity of the enzyme depends on numerous factors such as climate, amendment, cultivation practices, crop type and edaphic properties.The results indicated that soil treated with 50 % N as mineral enriched vermicompost with PGPR Mix I and 50% N as bio mineral enriched compost with PGPR Mix I registered maximum dehydrogenase activity in soil. This might be because of higher microbial activity in enriched compost. Increase in dehydrogenase activity showed that organic fertilizer added to soil in the form of compost or growth promoter had enormous load of micro organism as this assay is a measure of viable microbial activity. This was similar with the findings of Dahia *et al*. (2003), Manjunatha *et al*. (2004), Shwetha (2008) and Tejada *et al*. (2009). Devi Krishna (2005) reported highest dehydrogenase activity for soil treated with vermicompost with phosphorus solubilising microorganism.

Table. 32 shows the microbial population of the soil after the harvest of crop and was found varied among treatments. In case of bacterial population, soil treated with 75% N as bio enriched compost was foundto be the best. Whereas in

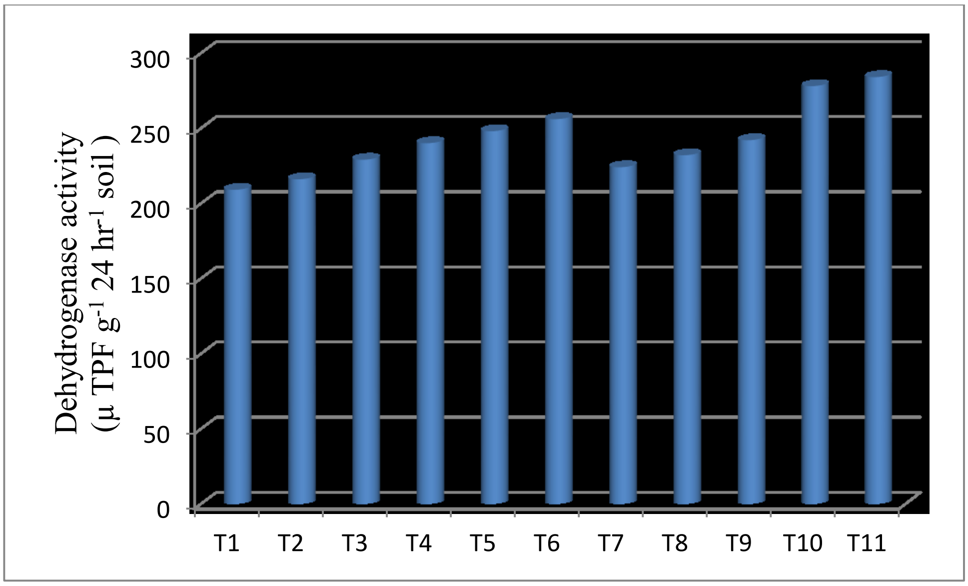

Fig.37 Effect of different composts on soil dehydrogenase activity (µg TPF g^{-1} hr^{-1} soil).

case of fungal population soil treated with 50% N as bio enriched compost along with PGPR Mix I and in actinomycetes population soil treated with bio mineral enriched compost along with PGPR Mix I was thebest. These results revealed that addition of composting inoculum during composting enhance the microbial population in compost. Lekshmi (2011) reported highest microbial population for the soil treated with 75% N as biomineral compost with panchagavya .Added organic amendments stimulated the biological activity preferably due to synergism of soil organic material and microorganisms. (Gaind and Nain, 2010).

5.3.6 Effect of mineral enriched composts on uptake of nutrients by plant

Uptake of major nutrients affected by different treatments were shown in Fig. 38. In case of N, P and K, highest mean values were recorded by T_{11} (50% N as mineral enriched vermicompost and PGPR Mix I)followed by T_{10}(50% N as biomineral enriched compost and PGPR Mix I). From the results, it can be inferred that application of enriched compost with bio fertilizer can increase the uptake of NPK by the crop. The increased N uptake may be due to the by fact that vast portion of non oxidisable N in organics could be available to plants through microbial activity and also through biological N fixation. The increased P uptake may be due to decomposition of P enriched compost. The uptake of K is mostly through root interception, better the root system the more is K uptake. Rose (2008) observed that application of rockdust @ 10 t ha^{-1} along with 50 percent of NPK and FYM produced highest N uptake by coleus when compared to 100 percent recommendation. El-Din *et al*. (2000) reported that compost produced by highly effective cellulose decomposing micro organism like *T. viride* or *Streptomyces auerofaciens* induced a significant increase in plant dry matter, N and P uptake and fruit yield in tomato.

The importance of enriched composts on secondary and micro nutrients was clear from the Figs. 39 and 40. For all the nutrients treatment T_{11} (50% N as mineral enriched vermicompost and PGPR Mix I) wasthe best. The combined effect of worm cast, rock dust and bio fertilizer may be the reason. The superiority

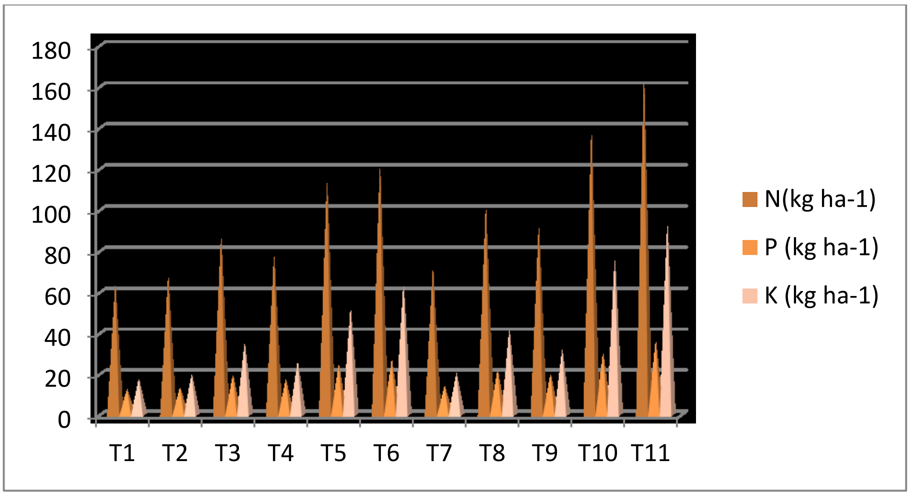

Fig.38 Effect of different composts on uptake of primary nutrients by plants.

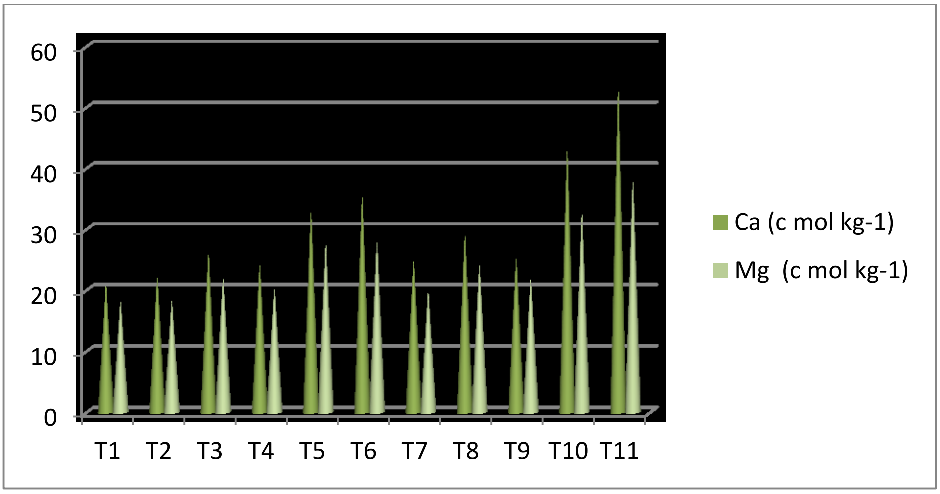

Fig. 39 Effect of different composts on uptake of secondary nutrients by plants.

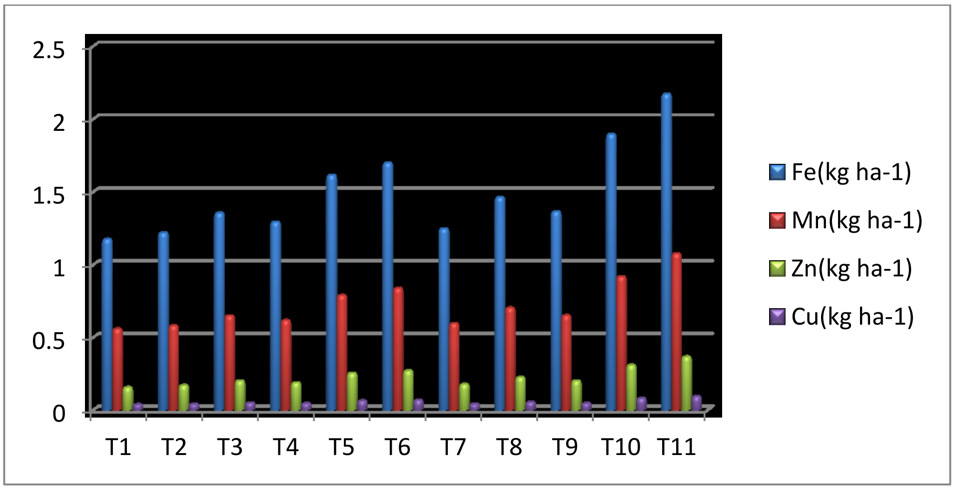

Fig. 40 Effect of different composts on uptake of micro nutrients by plants.

of vermicompost in supplying Ca, Mg, Cu, Zn, Mn to crop was revealed by Devi Krishna (2005). Soil organic matter have the ability to hold micro nutrients in stable combination. The organic ligands can keep the micro nutrients cations as soluble chelates and these are plant available. Micro organism assimilates these metal ions for many microbial transformation reactions and temporarily immobilize the micro nutrients in their body which however are released after the death of micro organism through mineralization process and are made available to plants (Deb and Sakal, 2002). The sixteen elements were considered to be essential for the growth of higher plants. These included those required in relatively large amount i.e. C, H, O, N, P, K, Ca, Mg and S and those required in relatively small amounts (ppm) i.e. Fe, Mn, Zn, Cu, B, and Mo and most of these were provided by rock dust (Korcak, 1996).

5.3.7 Economic analysis

The BC ratio was found highest for T_{11} when compared to control and other treatments. This might be because of greater nutrient availability and uptake and leading to yield enhancement of crop. This is similar with the findings of Lekshmi (2011) who reported highest BC ratio for seventy five percent N as biomineral enriched compost with panchagavya.

5.3.8 Contrast analysis

In contrast analysis, the group containing 50% N as different composts along with PGPR Mix I was found best in quality, yield and yield characters. This might be due to the effect of PGPR in nutrient release. Sheeja *et al.* (2011) reported that PGPR was effective in reducing the use of chemical fertilizers, improving the availability and uptake of nutrients and maintaining sustainability. Giovannoni (2001) reported that firmer fruits are obtained from PGPR inoculated plants, which desires the quality of fruit.

Summary

6. SUMMARY

An investigation entitled 'Evaluation of mineral enriched composts for soil remineralisation and crop nutrition' was carried out at the College of Agriculture, Vellayani during 2014-2015tomonitor the nutrient release pattern of enriched composts under laboratory conditions and also to study the effects of enriched composts along with bio fertilizer on soil remineralization and crop nutrition. 'Vellayani Jyothika' variety released from College of Agriculture, Vellayani was used as the test crop. The salient results of the study are summarized below

6.1 PREPARATION AND ANALYSIS OF DIFFERENT COMPOSTS

Different composts were prepared using different additives for investigation purpose. The mineral enriched composts were prepared by using rock dust as additive and bio enriched compost were prepared by using composting inoculum as additive and mineral enriched vermicompost were prepared by using rock dust and earthworm.Analysed data of different compostsrevealed that rock dust enriched composts were enriched with nutrients. C:N was narrowed down for mineral enriched composts when compared to ordinary and bioenriched compost. Among mineral enriched composts, mineral enriched vermicompost has recorded high nutrient status. On part of quality assessment of different composts, all the composts used in the study were under marketable B class which means that composts are of very good quality (medium fertilizing potential and low heavy metal content).

6.2 LABORATORY INCUBATION STUDY

Soil was collected from Model organic farm under the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani for conducting laboratory incubation study. Incubation was conducted for the period of 120 days at 60 per cent moisture content throughout the period. The study was conducted to monitor the nutrient release pattern from the enriched manures primed with and without PGPR Mix I.

The results of incubation study are summarised as follows.

- It revealed that pH of soil was found increasing throughout the period for treatments with enriched compost with and without PGPR Mix I except control. Among that mineral enriched vermicompost with PGPR Mix I recorded highest value throughout the period and during fourth month pH was found near neutral range.
- In the case of EC,during the first fifteen days there was no significant difference among treatments but later highest mean value was recorded by T_{10} at 30th day and later conductivity was found to be decreased.
- The available nitrogen, phosphorus and potassium content of soil was found to be increased during incubation period. The treatment T_{10} has recorded highest value for available N and K throughout the period but for available P, T_9 recorded highest value during first two months but later T_{10} recorded highest value. The maximum solubilization of N, P and K was observed during 120th day of incubation.
- The results of secondary nutrients revealed that there was a gradual increase in calcium and magnesium content in soils treated with enriched composts with and without PGPR Mix I. The T_{10} recorded highest value for secondary nutrients throughout the period. The solubilization of calcium and magnesium was found maximum during 90th and 120th day of incubation respectively.
- In case of micronutrients viz., Fe, Mn, Zn and Cu was found to be gradually increased during incubation period. For all the micronutrients T_{10} has recorded highest mean value. The pattern of solubilization of Fe, Mn, Zn and Cu content were observed during 30th, 60th, 90th and 30th days of incubation respectively.
- The mineral enriched vermicompost along with PGPR Mix I (T_{10}) resulted in maximum release of almost all the nutrients throughout the incubation period.

6.3 FIELD EXPERIMENT

The field experiment was conducted at Instructional farm, College of Agriculture, Vellayani using yardlong bean variety, 'Vellayani Jyothika'.

- Biometric observations like days to fifty percent flowering and leaf area index were found significantly different among treatments where as crop duration, number of harvests, appearance of the product were found non significant.
- In case of yield and yield attributing characters *viz.* pod length, pod weight, number of pods per plants and total dry matter production, T_{11} recorded highest value followed by T_{10}. In pod yield and bhusa yield T_{11} recorded the highest value and was found to be on par with T_{10}. T_{11} recorded highest value in harvest index and found on par with T_3, T_6, T_8, T_9 and T_{10}.
- Quality parameters *viz*. protein content, fibre content and shelf life were found significantly different among treatments. In protein content T_{11} recorded highest mean value which was found on par with T_{10}. The lowest fibre content was observed for pods treated with $T_6$and found on par with T_{11}. In case of shelf life longer duration were observed in T_6, T_8, T_{10} and T_{11} and found on par with T_3, T_5 and T_9.
- Soil properties like physical, chemical and biological properties of soil after experiment were found significantly different among treatments. The treatment T_3 recorded lowest mean value for bulk density and T_8 recorded highest mean value for WHC which were found on par with T_7 .In the case of chemical properties*viz*. pH, EC and CEC were found enhanced by mineral enriched composts application. The available N, P, K and micronutrients were found increased by enriched composts application among which50% N as mineral enriched vermicompost with PGPR Mix I recorded the highest value. In case of secondary nutrients, T_{10} recorded the highest mean value. Biological properties like dehydrogenase activity and

- microbial count found increased by addition of enriched composts application.
- The nutrient uptake by yardlong bean was found significant and T_{11}recorded maximum value for primary, secondary and micro nutrients uptake by plants.
- Pest and disease incidence were found non significant among treatments.
- Highest BC ratio was recorded by T_{11} and lowest was recorded by T_1 KAU POP (control).
- It was also found that if mineral enriched vermicompost is used as a nutrient source for yardlong bean, the nutrient requirement can be reduced to half of the recommended dose.

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EVALUATION OF MINERAL ENRICHED COMPOSTS FOR SOIL REMINERALISATION AND CROP NUTRITION

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Abstract of the thesis

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ABSTRACT

The research work entitled 'Evaluation of mineral enriched composts for soil remineralisation and crop nutrition' has been carried out at College of Agriculture, Vellayani during 2014-2015,to evaluate mineral enriched composts by monitoring nutrient release pattern under laboratory conditions and to study the effects of enriched composts on soil remineralization and crop nutrition using yardlong bean as test crop. The study consisted of three parts 1) Preparationand analysisof enriched composts 2) Laboratory incubation study and 3) Field experiment.

Rock dust, which was used as a nutrient source for enrichment consisted of 57.26 per cent Si, 5.07 per cent Fe_2O_3, 0.85 per cent P_2O_5, 3.27 percent K_2O, 6.42 per cent CaO, 8.23 per cent MgO etc. Five types of composts enriched with different additives *viz.* mineral enriched compost (Rock dust 25%), bio enriched compost (composting inoculum 5 g kg^{-1}), bio mineral enriched compost (rock dust 25%+ composting inoculum 5 g kg^{-1}), mineral enriched vermicompost (rock dust 25%) and ordinary compost were prepared and used for investigation. Among the various enriched composts prepared, mineral enriched vermicompost recorded high nutrient content. The C:N of rock dust enriched composts were found to be narrow compared to bio enriched and ordinary compost, which indicated that composting period was reduced by the addition of rock dust. As part of assessing the quality of composts as proposed by Saha and panwar (2009) all the composts were classified under same category of marketable B class ofmedium fertilizing potential and low heavy metal content.

The results of incubation study revealed that rock dust enriched composts and rock dust enriched vermicompost in conjunction with PGPR Mix-I resulted in an increase in the available nutrient content and enhanced pH and EC. The pattern of release of available N, Pand K was found maximum at 120th day of incubation. The pattern of solubilization of secondary and micronutrients recorded a gradual increase in the nutrient content. The mineral enriched vermicompost in conjunction with PGPR Mix I resulted in maximum release of almost all the nutrients throughout the incubation period.

The result of field experiment revealed that 50% N as mineral enriched vermicompost in conjunction withPGPR Mix I showed best result in all observations when compared to other enriched composts. Among the various biometric observations, days to 50 per cent flowering and LAI were found to be significant. Whereas crop duration, number of harvest and appearance of the product were found non significant. In case of quality parametersand yield and yield attributing characters *viz*. pod length, pod weight, number of pods per plant, pod yield, bhusa yield and total dry matter production,T_{11}(50% N as mineral enriched vermicompost + PGPR Mix I) was found to be the best.

Soil characters like physical, chemical and biological properties after the field experiment were improved by enriched composts application either alone or in conjunction with PGPR Mix I.The nutrient uptake by yardlong bean was significant and T_{11}showed the best performance. Pest and disease incidence were reduced for the plants treated with mineral enriched composts. Highest BC ratio was recorded by T_{11}. Contrast analysis of two groups (different composts with and without PGPR Mix I on 50 % and 75 % N basis) were done with respect to yield and yield attributing characters and qualities of yardlong bean andwere significantly different among groups.The group consisted of 50 % N as different composts with PGPR Mix I were found to be the best.

From the above points, it was concluded that rock dust when used as an additive to enrich compost might have reduced the composting period as well as enriched the compost with nutrients. The different composts used for the study were under the Marketable B Class (very good quality). Mineral enriched vermicompost in conjunction with PGPR Mix I has given the best result with respect tonutrient release, yield and yield attributes, nutrient uptake and soil remineralization.It was also found that if mineral enriched vermicompost is used as a nutrient source for yardlong bean, the nutrient requirement can be reduced to half of the recommended dose.

Appendix

APPENDIX I

Weather parameters during the cropping period August - December 2014

Standard weeks	Maximum temperature °C	Minimum temperature °C	Relative Humidity %	Rainfall mm
32	29.4	23.5	88.6	22.2
33	29.7	24.0	89.7	2.0
34	29.8	24.0	94.0	73.0
35	29.9	23.9	87.6	34.4
36	29.2	23.9	96.1	16
37	30.1	24.5	89.3	1.5
38	30.5	24.6	85	0
39	31.1	24.1	93.3	18.6
40	30.7	23.9	95.4	3
41	30.7	24.2	73.6	6.9
42	30.3	23.7	82.4	23.3
43	30.2	23.5	80.9	7.1
44	30.5	23.5	86.1	4.8
45	30.7	23.1	93.1	1
46	31.2	23.7	90.4	4.4
47	29.4	23.4	95.9	9.4
48	29.1	23.1	96.3	8.6
49	30.6	22.6	90.1	5.1
50	29.9	23.3	89.6	24.3
51	30.6	23.4	93.6	4.9
52	29.9	23.8	90.9	6

APPENDIX II

Score card for the assessment of appearance of vegetable cowpea pod

	1	2	3	4	5	6	7	8	9	10
Appearance										
Very good 4										
Good 3										
Fair 2										
Poor 1										