# ECO-FRIENDLY RECYCLING OF ORGANIC WASTES FOR SUSTAINABLE SOIL HEALTH AND ENHANCED CROP PRODUCTIVITY

By

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A THESIS SUBMITTED TO THE AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND HIGHER EDUCATION FOR WOMEN (DEEMED UNIVERSITY), COIMBATORE-641 043 IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

**DOCTOR OF PHILOSOPHY**

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# CERTIFICATE

This is to certify that the thesis entitled "**ECO-FRIENDLY RECYCLING OF ORGANIC WASTES FOR SUSTAINABLE SOIL HEALTH AND ENHANCED CROP PRODUCTIVITY**" submitted to the Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, for the award of the degree of Doctor of Philosophy in Life Sciences, is a record of original research work done by **Ms.T.YASODHA** during the period of her study in Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or similar title to any candidate of any University.

A. Vijayalakshmi 30/6/99

Signature of the Guide

# DECLARATION

I hereby declare that the matter embodied in this thesis is the result of investigations carried out by me in the Department of Life Sciences, Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore, under the supervision of **Dr.A.VIJAYALAKSHMI, M.Sc., M.Phil., Ph.D.**, Lecturer in Botany, Avinashilingam Institute for Home Science and Higher Education for Women (Deemed University), Coimbatore and it has not been submitted for the award of any Degree / Diploma / Associateship / Fellowship etc. of any other University or Institute.

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## ABBREVIATIONS

| | | |
|---|---|---|
| C / N ratio | - | Carbon, Nitrogen ratio |
| pH | - | Percentage of hydrogen ion concentration |
| EC | - | Electrical conducticity |
| N | - | Nitrogen |
| P | - | Phosphorus |
| K | - | Potassium |
| Fe | - | Iron |
| Mn | - | Manganese |
| Cu | - | Copper |
| Zn | - | Zinc |
| CO2 | - | Carbon-di-oxide |
| DMP | - | Dry matter production |
| VAM | - | Vesicular Arbus cular Mycorrhiza |
| V.S. | - | Vegetative stage |
| F.S. | - | Flowering stage |
| H.S. | - | Harvest stage |
| N.P.P. | - | Number of pods per plant |
| P.L., | - | Pod length |
| Pod FW | - | Pod fresh weight |
| Pod DW | - | Pod dry weight |
| No.G/P | - | Number of grains per pod |
| H.Wt. | - | Haulm weight |
| Gy | - | Grain yield |
| NFP | - | Number of fruits per plant |
| F.L. | - | Fruit length |
| F.C. | - | Fruit circumference |
| F.Y. | - | Fruit yield |
| O.C. | - | Organic carbon |
| O.M. | - | Organic matter |
| C.D | - | Critical Difference |

# INTRODUCTION

# CHAPTER-1

# INTRODUCTION

Enhancement of environmental quality is an accepted national goal. Under the present conditions of energy crisis, environment degradation and rise in population, it has become essential to develop appropriate technologies for the recovery and use of non-conventional sources. The waste biomass from domestic, agricultural, urban and industrial sources is the main cause of organic pollution in developing countries like India.

There has been much concern in recent years about the collection and disposal problems arising from the ever increasing quantities of solid, urban, domestic and industrial wastes. Piling up of wastes in and around human settlements leads to lot of health and environmental hazards. Hence management of solid wastes has assumed paramount importance in recent years. Recycling of these wastes/residues is necessary to prevent pollution and to conserve our scarce natural resources.

The need for conservation of resources and the realization for ideal solution to these problems would result in maximum reduction in the generation of wastes. Hence, by treating, "wastes" as resources, recycling could be considered as an essential policy of all waste management systems.

The decrease in organic matter in the soils used for cultivation and the continuous use of synthetic fertilizers will eventually lead to problems in agriculture. Hence the need for enriching the soils with organic matter is unavoidable. One source for the production of organic matter is solid agro-industrial wastes. Recycling the agro-industrial wastes could be promoted to produce soil conditioning materials and at the same time provide a solution to the problem of waste disposal.

Composting is a waste management strategy that must be considered among the existing possibilities of biomass valorization. Many people in the field of environmental protection are aware of the Nation's solid waste disposal problems and the increased interest in composting. The wide range of multiple environmental benefits recognized by the environmentalists are as follows: increased aeration, retention of moisture and nutrients, decreased soil erosion, reduced soil surface crusting, plant disease suppression, protection of surface and ground water quality, organic soil conditioners for polluted lands and soil fertility through humus balance (Kashmanian *et al.*, 1990). In the present investigation, the impact of composting sugarcane bagasse and coffee waste on soil-plant ecosystem has been carried out.

The fibrous residue remaining after juice extraction from the sugarcane stalk is commonly referred as 'Bagasse'. Bagasse is one of the most important by-product of sugar industry (Plate A). In India, 5.3 million tonnes of bagasse is

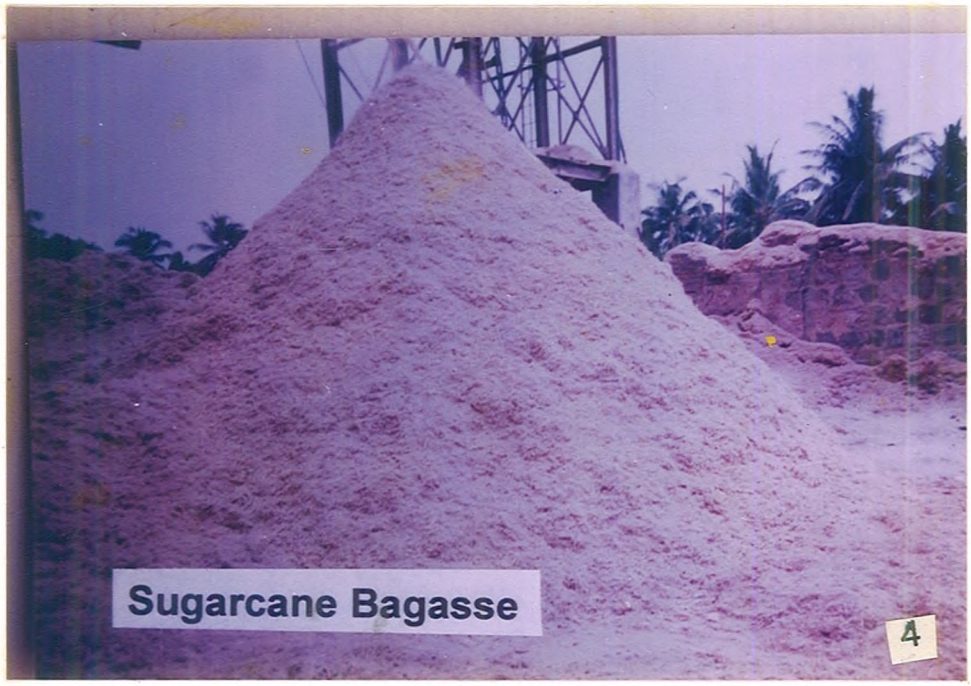
Plate A

## WASTE GENERATION FROM SUGAR FACTORY


Sugarcane carried to crusher


Crushed cane passed to water boiler

Plate A

produced per annum (Pathak *et al.*, 1990). In most of the sugar factories, bagasse constitutes the greatest volume of solid residue to be handled. Recycling of these residue by composting leads to volume reduction (Branch and Hendrick, 1992).

Sugarcane bagasse is difficult to decompose because of its high content of lignin, cellulose and hemicellulose. Its C:N ratio is always greater than 150:1. Under natural conditions, it takes 18 months to obtain mature bagasse compost (Huang *et al.*, 1996).

Agro-industrial wastes of major environmental concern are the coffee processing by-products. Several wastes are generated during processing coffee fruits and coffee bean. The pulp, mucilage and hulls totally represent 53.4 per cent of the weight of the whole fresh fruit. Approximately 3 tonnes of by-products are generated during the production of 1 tonne of dried dehulled coffee (Rolz *et al.*, 1985). Cherry and parchment husk generated from the pulping and curing units cause pollution problems in and around estates (Jayarama *et al.*, 1996) (Plate B).

In recent years, a new concept of agriculture has been attracting attention in Europe and America called "Low Input Sustainable Agriculture" (LISA). This concept aims to prevent further environmental pollution caused by agriculture and industries and to achieve sustainable farming by curtailing the use of chemical fertilizers and pesticides.

Plate B

**WASTE GENERATION FROM COFFEE INDUSTRY**


Coffee fruits


Coffee fruits passed to pulper

Plate B


Pulping and demucilaging process


Coffee wastes dumped in pit

Careful and systematic management of organic wastes and animal manures should be aimed at achieving maximum recycling of nutrients with minimum losses. These biodegradable nutrient rich and eco-friendly organic wastes must be supplied in adequate quantities so as to increase or at least to maintain the humus content of the soil. Hence in the present study, an eco-friendly management of agro-industrial wastes and scope of sustainable agriculture through organic farming are enlighted with following objectives :

1. To evaluate the efficiency of microbial consortia in biodegradation of agro-industrial wastes and to evolve a low input technology for its utilisation.
2. To monitor changes in physico-chemical characteristics of agro-industrial wastes during composting.
3. To evaluate the maturity of composts in obtaining an eco-friendly organic manures.
4. To assess the effect of organic manures and bioinoculants in promoting the productivity of crops.
5. To investigate the efficiency of integrated nutrient management and to evolve eco-friendly technologies for sustaining the soil fertility and crop productivity.

# REVIEW OF LITERATURE

# CHAPTER 2

# REVIEW OF LITERATURE

The available literature pertaining to the influence of ligno-cellulolytic fungi in degrading agro-industrial wastes; enrichment technique in minimizing the period of composting and maximizing the fertilizer value of composts; preparing nutrient rich composts from various wastes; its effect on crop productivity and soil fertility as relevant to the present investigation are reviewed and presented in this Chapter.

## 2.1. Bio-degradation of agro-industrial wastes (Bagasse and Coffee Wastes)

Edwards *et al.*, (1979) reported that the bio-conversion of coffee waste by fungi helped to control pollution of water ecosystems in Guatemala and Salvador regions. Increased nutrient contents of coffee waste after inoculation with *Trichoderma viride* and *Penicillium crustosum* has been reported by Sood *et al.*, (1979).

Rao and Reddy, (1980) revealed that the nutrient rich coffee seed waste after composting could be utilized as animal feed. Rao *et al.*, (1983) utilized coffee waste and sugarcane pressmud as alternative carrier material for the production of *Rhizobium* cultures.

Calzada *et al.*, (1989) analysed the integrated utilization of coffee industrial wastes and carried out cost effective studies on it. Dimalanta and Latiza in 1990 reported that biodegradation process of sugarcane bagasse was shortened within 6-8 weeks by *Trichoderma harzianum*.

Jadhav and Babar, (1990) revealed that microbial starters such as Bactin and Fabearth at optimum levels biodegraded the mixtures of sugarcane bagasse and pressmud. Cane bagasse constitutes the greatest volume of solid residue to be handled in sugar factories. Composting of bagasse as a volume reduction technology was proposed by Branch and Hendrick, (1992).

Fernandes *et al.*, (1993) recorded that the more humus content with less C:N ratio was obtained when cane bagasse composted with sewage sludge.

Baca *et al.*, (1993) evaluated the changes during composting of sugarcane bagasse by the method of microbial respiration, physical and chemical variations.

Hutasoit and Toharisman, (1994a) reported the bio-conversion of sugarcane bagasse into compost in the presence of ligno-cellulolytic microorganisms. Mixtures of bagasse and pressmud cake were composted with urea, triple superphosphate and microbial inoculant. This experiment of Hutasoit and Toharisman, (1994b) revealed that the C:N ratio, lignin and cellulose were decreased to a greater extent within five weeks.

Composting of bagasse with olive press cake and poultry manure was reported by Baca *et al.*, (1995). Altuna *et al.*, (1995) reported the potential advantages of composting cane bagasse by microbial inoculants and urea.

Kostenberg *et al.*, (1995) revealed that the coffee waste dumps pose a threat of environmental pollution. After treatment with anaerobic bacteria, the digested slurry was used as growth medium for mungbean and *Gravillea rondaeu* plantlets. Roussos *et al.*, (1995) isolated *Aspergillus, Trichoderma, Fusarium, Humicola* and *Penicillium* and studied their efficiency in degrading caffeine, lignin and cellulose contents of coffee pulp and husk.

Coffee wastes from coffee industries could be recycled and used as manure for its fertilizer value (Jayarama *et al.*, 1996). Moorthy *et al.*, (1996) reported a brief study on pollution problems in coffee estates of Karnataka and recommended composting of coffee pulp and husk as solid waste management.

Dinsdale *et al.*, (1996) revealed that the anaerobic digestion of coffee waste along with effluent could moderately reduce the higher lignin, cellulose and hemicellulose during batch studies. Huang *et al.*, (1996) found a rapid method to compost sugarcane bagasse within one month since under natural conditions it took 18 months to decompose because of its high lignin, cellulose contents and wide range of C:N ratio. Muralidhara and Raghuramulu, (1997) evaluated the nutrient contents of coffee wastes based on various experiments.

## 2.2. Microbial degradation by enrichment technique

Organic material decomposition under supplemental nitrogen enrichment showed an improvement in the rate of $CO_2$ evolution (Couture and Fortin, 1983). Mathur and Debnath, (1983) reported that the incorporation of Mussoorie rock phosphate on farm waste improved the quality of compost, macro and micronutrients.

Composting of pear-millet residues with nitrogen, molasses and low grade rock phosphate significantly increased the nitrogen and phosphorus contents within short period (Singh *et al.*, 1983).

Kapur *et al.*, (1983) reported that the enrichment of compost by *Azotobacter, Aspergillus awamori* and Mussoorie rock phosphate enhanced the nitrogen and phosphorus contents. Bangar *et al.*, (1985) revealed that the Mussoorie rock phosphate enriched composts resulted in more quantity humus content. Hastening the process of composting by microbial inoculam and enrichment of city wastes and crop residues by Mussoorie rock phosphate was reported by Bhardwaj and Gaur, (1985).

Martinez *et al.*, (1985) reported that the high amount of lignin, tannin and caffeine in coffee pulp were degraded by *Pleurotus ostreatus*. Genterova and Lazorova (1987) inferred that increase in decomposition velocity in terms of $CO_2$ evolution attributed to lignin and cellulose degrading capacity by white-rot fungus

*Pleurotus sajor-caju*. Singh, (1987) studied the decomposition dynamics of farm waste inoculated with soil, dung and low grade rock phosphate.

Tiwari *et al.*, (1988) revealed that the composting of rice straw with Mussoorie rock phosphate and microbial inoculants enriched its manurial value. Biodegradation of wool waste by cattle dung and rock phosphate resulted in better quality compost was obtained by Tiwari *et al.*, (1989). Kanotra and Mathur, (1994) reported that the microbial respiration in terms of $CO_2$ evolution revealed the rate of bio-degradation of paddy straw.

## 2.3. Composting of wastes/residues and its maturity

Gomez and Park, (1983) revealed a stack method of composting cane bagasse with poultry manure whose maturity was evaluated by cellulose, lignin, nitrogen and ash contents. Compost maturity of mixture of farm waste, rock phosphate with and without pyrite was assessed by different fractions of phosphorus, nitrogen, calcium, magnesium and micronutrients (Mathur and Dębnath, 1983). Singh *et al.*, (1983) assessed the maturity based on pH, nitrogen, phosphorus and organic matter contents of pear-millet boobla (threshing residue) composted with low grade rock phosphate. Composting of sugarcane bagasse by *Cyathus* sp. And its maturity evaluation based on weight loss, lignin content and reducing sugars were analysed by Kuhad and Johari, (1987).

De Bertoldi *et al.*, (1990) had given brief guide lines to evaluate maturity of composts prepared from solid municipal, industrial and agricultural wastes.

Baca *et al.*, (1990) reported the maturation of composts prepared from mixture of sugarcane bagasse, tobacco dust and hen manure. The composts were assessed by germination experiments, bioassay of *Helianthus annus* seedlings, pH, EC, N, P, K and C:N ratio.

Biodegradation of organic material based on $CO_2$ evolution experiments was conducted by Pagga *et al.*, (1995). Singh and Amberger, (1995) reported that enrichment of wheat straw with Mussoorie rock phosphate contained high amount of phosphorus, organic and formic acid. The agro-industrial wastes enriched by rock phosphate and *Aspergillus niger* resulted in high content of minerals (Vassilev *et al.*, 1996).

Increased $CO_2$ evolution attributed to ligno-cellulose degradation during decomposition of cane bagasse with *Pleurotus sajor-caju* was found out by Puniya *et al.*, (1996). The experiments on enrichment of rice straw and city garbage compost by nitrogen-fixers and phosphorus solubilizers enhanced its mineral content and decreased the C:N ratio (Manna *et al.*, 1996).

Dimalanta and Latiza, (1990) successfully composted the cane bagasse and pressmud using *Trichoderma harzianum* as compost activator and assessed its maturity based on temperature and C:N ratio. Ott, (1991) reported that the addition

of rock phosphate to farm yard manure increased the quality of compost and its maturity was assessed by organic matter and temperature.

The changes in organic carbon, total nitrogen and microbial biomass during composting of paddy straw and redgram residue with Mussoorie rock phosphate and with and without nitrogen supplementation were studied by Singh *et al.*, (1992).

Experiments of Adhikary *et al.*, (1992) revealed that maturity of composts prepared from cane bagasse, paddy straw and water hyacinth was evaluated by microbial biomass, ligno-cellulose and nitrogen contents. The mixture of sugarcane bagasse and filter cake was composted by Araxa phosphate and its maturity was assessed by volume and mineral contents (Manhaes, 1993).

The efficiency of microbes in composting coirpith was assessed based on organic carbon and nitrogen contents (Theradimani and Marimuthu, 1993). A good quality compost within one month was obtained from bagasse mixed with vinasse or solid pig waste based on lignin, cellulose and C:N ratio estimation (Huang *et al.*, 1996).

Maturity of composts prepared from mixture of solid swine manure and plant residue was evaluated by temperature in the pile, C:N ratio, pH, EC, macro and micro-nutrients (Georgacakis *et al.*, 1996). Composts prepared from mixtures of eight different organic wastes were examined for their maturity and stability

parameters such as temperature, organic matter, organic carbon, cation exchange capacity, pH, lignin and C:N ratio (Bernal *et al.*, 1998).

## 2.4. Influence of composts on productivity of crops

Grishkova and Beigelman, (1977) reported that the organic compost prepared from bark enhanced the cucumber yield upto 10 per cent greater than farm yard manure. Kumar *et al.*, (1977) reported that the tuber yield of Cassava was increased by the application of farm yard manure and NPK. Koregave *et al.*, (1978) revealed that the farm yard manure application at the rate of 75 kg $ha^{-1}$ and 25 kg $ha^{-1}$ to the bajra and wheat crops respectively increased the productivity.

Yield of paddy and wheat crops was enhanced to 6.62 and 6.74 t $ha^{-1}$ respectively and the result was equivalent to 30 kg N $ha^{-1}$ and 30 kg P/ha (Meelu *et al.*, 1981). Mishra *et al.*, (1982) revealed that the phosphate enriched compost prepared from cattle dung and farm waste increased the grain yield of *Vigna radiata* and wheat which was comparable to single super phosphate.

Ahmad and Jha in 1982 surmised that dry matter yield of soybean crop was increased markedly due to the inoculation of biofertilizers along with rock phosphate. Deshpande *et al.*, (1983) revealed that the addition of farm yard manure along with rock phosphate increased the early stages of growth and grain yield of rice.

Sharma and Kaushal, (1984) reported that the pot trials of maize and spinach supplied with farm yard manure and town refuse resulted in better dry matter and yield than the chemical fertilizers. Singh (1985) reported that the farm waste compost enriched with low grade rock phosphate improved the growth and yield of mungbean and wheat in micro-plot field experiment. Bangar *et al.*, (1985) revealed that the growth and yield of cluster bean and redgram were efficiently increased by phosphocomposts. Debnath and Basak in 1986 conducted field and pot culture experiments with rice, wheat and greengram and reported an increase in crop yields due to addition of rock phosphate compost as soil amendments.

Ishac *et al.*, (1987) reported that the growth and yield parameters of maize and wheat were increased significantly due to addition of pulverized maize stalk and bioinoculants in pot experiments. Kulkarni and Kulkarni, (1987) reported that the application of farm yard manure and NPK showed better crop yield than NPK alone. Tiwari *et al.*, (1988) reported that the incorporation of paddy straw compost along with Azotobacter inoculation enhanced the nodulation and yield of green gram.

Application of rice straw compost and farm yard manure on wheat and rice in pot trials increased grain yields which was comparable with chemical fertilizer (Basak *et al.*, 1989). Nagarajan *et al.*, (1990) indicated that the application of composted coir pith with and without NPK significantly increased the growth and yield of groundnut.

Bhosekar and Raikhelkar, (1990) evidenced that the grain yield of sorghum was increased to 5.32 to 6.78 t $ha^{-1}$ due to the incorporation of farm yard manure with and without inorganic nitrogen.

Veerabadran, (1992) stated that the composted coirpith incorporation significantly increased the grain yield of rainfed millets by 32-37 per cent. Rajasekhar *et al.*, (1995) inferred that there was an appreciable increase in growth and yield of bhendi in 25 t $ha^{-1}$ farm yard manure along with the 2 kg $ha^{-1}$ *Azospirillium* incorporated treatment than inorganic fertilizer applied treatment. Ravikumar *et al.*, (1995) reported that the combined inoculation of *Glomus mosseae* and *Rhizobium* recorded maximum plant height, number of nodules, fresh and dry weight of plant and yield of cluster bean.

Raut *et al.*, (1995) reported that coinoculation of *Pseudomonas striata* with *Bradyrhizobium japonicum* on soybean in pot trials greatly influenced the yield parameters. Prabhakaran *et al.*, (1995) reported that the coir compost along with bioinoculants prominently increased the growth and yield of greengram than other organic amendments. Vermicompost and VAM application recorded significant increase in plant height, leaf diameter, flower and seed yield of sunflower (Venkatakrishnan and Balasubramanian, 1995).

Glory Swarupa and Reddy, (1996) reported that utilization of composted coirpith in cultivating plantation crops would increase the quantity and quality of corps and this could serve as substitute for farm yard manure.

Rita Joseph *et al.*, (1996) concluded that composted coirpith at 12.5 t $ha^{-1}$ along with 50 per cent NPK markedly increased the yield parameters of cowpea in pot culture experiments. Moorthy *et al.*, (1996) evidenced that the fruit yield of coffee plants enhanced significantly due to the addition of composted coffee waste.

## 2.5. Fertility status of soil

Durai and Rajagopal, (1983) found out that the addition of organic manures improved the soil physical environment. According to Ramaswamy and Sree Ramulu, (1983) the incorporation of composted coir pith improved the water holding capacity of soils. The application of organic manure with and without inorganic fertilizers provided proper nutrition to crops and maintaining the soil fertility (Gupta *et al.*, 1988).

Ganal and Singh, (1988) inferred that the bulk density, infiltration rate, pH, organic carbon and available N, P and K of experimental soils were improved by FYM application. Raza *et al.*, (1989) confirmed that the increase in crop yield was due to the increased soil moisture by farm yard manure. According to Anabayan and Palaniappan, (1991) the soil moisture retention and higher yield of sorghum

recorded due to the combined effect of coir compost and *Azospirillium* inoculation.

Manhaes, (1993) confirmed that the soil fertility improvement was due to the mineral contents of bagasse compost and it also enhanced the crop yield. Sarkar *et al.*, (1995) reported that the application of organic materials improved the soil physical environment and recorded 10-17 per cent higher grain yield of rice over 50 per cent recommended fertilizer.

Vinasse from distillery industry could be profitably recycled to improve soil properties and increase crop yield while alleviating environmental pollution (Pande *et al.*, 1995).

Application of 5 t $ha^{-1}$ farm yard manure and 5 t $ha^{-1}$ press mud for soybean crop as soil treatment improved the soil moisture at 0-60 cm depth and increased the seed yield (Tiwari *et al.*, 1995). Verma and Thampan, (1995) revealed that soil organic matter and organic carbon were improved due to different kinds of composted organic materials.

According to Naidu and Reddy, (1996) soil amendment with farm yard manure provided resistance of groundnut to dry root rot disease and gave highest pod yield.

Toor and Bishnoi, (1996) opined that the application of farm yard manure with and without poultry manure improved the available nutrient status of soil and enhanced the yield of maize and wheat. Karthikeyan, (1996) revealed that mixture

of neem cake and farm yard manure gave good disease control (seed and collar rot) and increased yield of groundnut.

Cheng, (1996) surmised that composting of bagasse prevent land pollution through soil amendment, saving fertilizer to crops and giving resistance to disease by saving pesticide at Huwei. Jagdev *et al.*, (1997) confirmed that the nutrient status of experimental soil was improved by the addition of enriched compost at the rate of 5 t $ha^{-1}$ on wheat crop.

Dadarwal, (1997) highlighted the importance of organic wastes for environmental protection, nutrient supply through soil microorganisms and their role in crop productivity. Composts prepared from pine needles, oak leaves, straw grass, neem cake and farm yard manure (organic amendments) resulted in highest number of VAM spores and highest degree of controlling yellow disease of ginger (Dohroo *et al.*, 1997).

# MATERIALS AND METHODS

# CHAPTER-3

# MATERIALS AND METHODS

The details regarding microbial degradation and enrichment of agro-industrial wastes, composting technology, evaluation of compost maturity, pot culture experiments, the biometrics and yield parameters recorded, analytical procedures followed for soil physical and chemical characteristics and the statistical analysis of the data are presented in this Chapter.

## 3.1. Collection of agro-industrial wastes

The agro-industrial wastes *viz.*, sugarcane bagasse from sugar factories, coffee wastes from coffee curing and pulping units of Pollachi, Udumalpet and Anamalais of Coimbatore District were collected.

## 3.2. Microbial degradation of agro-industrial wastes

A laboratory experiment was conducted to assess the biodegradation of bagasse and coffee waste inoculated with three ligno-cellulolytic fungi such as *Pleurotus sajor-caju, Trichoderma harzianum* and *Phanerochaete chrysosporium.* The details of treatments were :

$T_1$ - Uninoculated agro-waste alone (control)

$T_2$ - *Pleurotus sajor-caju*

$T_3$ - *Trichoderma harzianum*

$T_4$ - *Phanerochaete chrysosporium*

$T_5$ - *Pleurotus sajor-caju* + *Trichoderma harzianum*

$T_6$ - *Pleurotus sajor-caju* + *Phanerochaete chrysosporium*

$T_7$ - *Trichoderma harzianum* + *Phanerochaete chrysosporium*

Sugarcane bagasse and coffee waste were inoculated with the respective inocula at 10 per cent w/w. Sampling was done at regular intervals. The rate of decomposition of wastes was assessed by estimating the amount of carbon-di-oxide evolved by the method of Pramer and Schmidt, (1964). The details of the procedure are given in Appendix-I. Organic carbon by the method of Walkey and Black, (1934) and total nitrogen by method of Humphries, (1956) which are described in Appendix-II and III respectively. From the data the rate of $CO_2$ evolution and the cumulative $CO_2$ evolution were worked out.

### 3.3. Enrichment of agro-industrial wastes

An incubation study was conducted in the laboratory to find out a suitable composting technology for the selected agro-wastes by enriching them with urea and rock phosphate (Mussoorie). Sieved soil was taken in conical flasks and nine combinations were involved in the following treatments :-

$T_1$ - Soil + Agro waste (10:1)

$T_2$ - $T_1$ + Urea

$T_3$ - $T_1$ + Rock phosphate

$T_4$ - $T_1$ + Urea + Rock phosphate

$T_5$ - $T_1$ + *Pleurotus sajor-caju*

$T_6$ - $T_5$ + Urea

$T_7$ - $T_5$ + Rock phosphate

$T_8$ - $T_5$ + Urea + Rock phosphate

$T_9$ - $T_8$ + *Trichoderma harzianum*

The quantity of microbial inocula, urea and rock phosphate varied for the selected agro-wastes and required amounts were added to the treatments. Minimum period required for composting was arrived based on the rate of microbial respiration during enrichment of organic wastes.

### 3.4. Composting of agro-industrial wastes

The selected agro-industrial wastes were composted individually following open heap method. A study area with 5 m length and 3 m width was selected and the agro-industrial wastes (including coir waste since it has been selected as one of the treatment in phase-I of the pot culture experiment). Experiments were composted using required amount of adjunctants as given in the Table below :-

| Raw materials | Spawn *P. sajor-caju* (kg) | Urea (kg) | Rock phosphate (kg) | *T. harzianum* (kg) | Composting period |
|---|---|---|---|---|---|
| 1 ton coir waste | 1.50 | 5 | - | - | 7 weeks |
| 1 ton bagasse | 1.75 | 5 | 10 | 1 | 7 weeks |
| 1 ton coffee waste | 2.00 | 10 | 25 | 2 | 8 weeks |

### 3.5. Evaluation of compost maturity

Physical, chemical and biological assays of composted agro-wastes were carried out based on the standard methods of Zucconi and De Bertoldi, (1987) and Harada, (1991). From these assays the degree of maturity of composts was evaluated.

#### 3.5.1. Physical parameters

The temperature inside the heaps, pH and elctrical conductivity of composted materials were noted down.

#### 3.5.2. Chemical parameters

Many methods have been proposed for estimating the degree of maturity. Among them few are simple and reliable.

a. Organic carbon and total nitrogen by methods of Walkey and Black, (1934) and Humphries, (1956) respectively given in Appendix-II and III.

b. The diphenyl amine test is the method in which qualitative analyses are conducted on nitrate nitrogen, the substance generated by nitrification in the composting process. A sample compost is taken in a small beaker and stirred with a glass rod after distilled water is added. Filter paper is used to filter the compost and the filtrate is taken on a white board with wells. Several drops of diphenyl amine solution are added to the filtrate. The change in colour of the filtrate is noted down (Harada, 1991).

c. Lignin, cellulose and caffeine by methods of A.O.A.C., (1980) (Appendices-IV,V and VI).

d. Available nitrogen by method of Subbiah and Asija, (1956) (Appendix-VII)

e. Available phosphorus by method of Jackson, (1973) Appendix-VIII)

f. Available potassium by method of Standford and English, (1949) (Appendix-IX)

g. Micronutrients by method of Lindsay and Norwell, (1978) Appendix-X)

### 3.5.3. Bioassay estimation

A number of organic and inorganic substances that may accumulate in the liquid phase of composts early during composting process have the potential for inducing a phytotoxic response, particularly in seedlings. Hence in the present study, a bioassay using cowpea as test plant to assess the impact of bagasse and coffee waste composts maturity on seedling growth was carried out. The composts were soaked in distilled water (1:2 w/v) overnight. Extracted solutions were prepared by filtration. The seeds were germinated in germination towels. After one week hypocotyl length, epicotyl length, root length and number of lateral roots were recorded.

## 3.6. Pot culture experiments

Pot culture experiments were conducted in two phases with cowpea and cluster bean as test crops in the first phase.

In the first phase of pot culture experiment, cowpea and cluster bean were used as test crops to evaluate the effect of undecomposed and decomposed agro wastes in combination with and without chemical fertilizers.

In the second phase of pot culture experiment, cowpea, cluster bean and bhendi were used as test crops to evaluate the efficacy of composted agro wastes along with biofertilizers.

### 3.6.1. Selection of experiment soil and test crops

Red sandy loam soil from Coimbatore area was collected for the pot culture experiment.

The plants selected for the present investigation were:- *Vigna unguiculata*, L.WALP. Var.CO.2 (Cowpea); *Cyamopsis tetragonaloba*, T. Var. Pusa naubahar (Cluster beans); *Abelmoschus esculentus*, L. Moench. Var. Arka anamica (Bhendi).

### 3.6.2. Design and layout of the experiment

The design followed for the experiment was a completely randomized block design consisting of a control and fifteen treatments in the first experiment and nine treatments in the second experiment each replicated three times.

### 3.6.3. Treatment details of first experiment

$T_1$ - Control – No manure

$T_2$ - Raw bagasse (12.5 t $ha^{-1}$)

$T_3$ - Raw coffee waste (12.5 t $ha^{-1}$)

$T_4$ - Composted coir waste (12.5 t $ha^{-1}$)

$T_5$ - Composted bagasse (12.5 t $ha^{-1}$)

$T_6$ - Composted coffee waste (12.5 t $ha^{-1}$)

$T_7$ - Farm yard manure (12.5 t $ha^{-1}$)

$T_8$ - N, P, K (100%)

$T_9$ - Composted bagasse (12.5 t $ha^{-1}$) + 50% NPK

$T_{10}$ - Composted coffee waste (12.5 t $ha^{-1}$) + 50% NPK

$T_{11}$ - Composted bagasse (12.5 t $ha^{-1}$) + 100% NPK

$T_{12}$ - Composted coffee waste (12.5 t $ha^{-1}$) + 100% NPK

$T_{13}$ - Raw bagasse (12.5 t $ha^{-1}$) + 50% NPK

$T_{14}$ - Raw coffee waste (12.5 t $ha^{-1}$) + 50% NPK

$T_{15}$ - Raw bagasse (12.5 t $ha^{-1}$) + 100% NPK

$T_{16}$ - Raw coffee waste (12.5 t $ha^{-1}$) + 100% NPK

### 3.6.4. Treatment details of second experiment

S $T_1$ - 100 % NPK

S $T_2$ - Composted bagasse (25 t $ha^{-1}$)

S $T_3$ - Composted coffee waste (25 t $ha^{-1}$)

S $T_4$ - Composted bagasse (25 t $ha^{-1}$) + Phosphobacteria (2 kg $ha^{-1}$)

S $T_5$ - Composted bagasse (25 t $ha^{-1}$) + *Rhizobium/Azospirillium* (2 kg $ha^{-1}$)

S $T_6$ - Composted bagasse (25 t $ha^{-1}$) + VAM (2 kg $ha^{-1}$)

$\S T_7$ - Composted coffee waste (25 t $ha^{-1}$) + Phosphobacteria (2 kg $ha^{-1}$)

$\S T_8$ - Composted coffee waste (25 t $ha^{-1}$) + *Rhizobium/Azospirillium* (2 kg $ha^{-1}$)

$\S T_9$ - Composted coffee waste (25 t $ha^{-1}$) + VAM (2 kg $ha^{-1}$)

$\S T_{10}$ - Composted bagasse(12.5 t $ha^{-1}$) + Composted coffee waste (12.5 t $ha^{-1}$)

The chemical fertilizers (NPK) were applied at the rate of 25, 50, 40 kg $ha^{-1}$ for legumes and 20, 50, 30 kg $ha^{-1}$ for bhendi. The organics were applied at the rate of 25 t $ha^{-1}$ and the biofertilizers were applied at the rate of 2 kg $ha^{-1}$. All these TNAU recommended doses were applied at required amounts for 7 kg red sandy loam soil.

### 3.6.5. Treatment application and cultivation

Stones and pebbles were removed from the soil and all the pots were filled with seven kilograms of soil in each. Nitrogen as urea, phosphorus as super phosphate and potash were applied to the respective pots and mixed thoroughly.

Viable seeds were selected and about five seeds were sown in each pot and after germination and establishment, four healthy plants were maintained per pot.

Plant protection measures and other cultural practices were followed as per recommendations by the Tamilnadu Agricultural University, Coimbatore.

### 3.6.6. Collection and analysis of plant samples

On the 30th day (vegetative), 60th day (flowering) and at harvest stages, plants were uprooted from the pots for recording various biometric observations.

The plant samples collected during vegetative, flowering and at harvest stages were air dried and then oven dried at 60°C and weight recorded for dry matter production (DMP).

For legumes various growth and yield parameters like plant height, plant fresh weight, plant dry weight, nodule index, root volume, pod length, pod weight per plant, haulm weight, number of pods per plant, grain yield per plant were recorded.

The data on nodule index was calculated as follows:

$$\text{Nodule index (NI)} = \frac{\text{Number of nodules}}{\text{Tap root length (cm)}}$$

For bhendi crop, biometrics such as number of leaves, root volume, plant height, plant fresh weight, plant dry weight and yield parameters such as number of fruits per plant, fruit length, fruit girth and fruit yield per plant were recorded.

### 3.7. Experimental soil analysis

#### 3.7.1. Soil reaction (pH) and Electrical Conductivity (EC)

Soil reaction in a soil : water suspension ratio of 1:2.5 was estimated using a glass electrode (Jackson, 1973). The electrical conductivity was measured using a conductivity bridge and expressed as $dSm^{-1}$.

#### 3.7.2. Physical constants

Apparent density (Bulk density), total porosity and maximum water holding capacity were determined by the method of Keen and Raczkowski, (1921). The details of the procedure are given in Appendix-XI.

#### 3.7.3. Organic carbon

Soil organic carbon was estimated by wet chromic acid oxidation method of Walkey and Black, (1934). The details of the methods are given in Appendix-II.

#### 3.7.4. Available nitrogen

Available nitrogen of the soil sample was estimated by the alkaline permanganate method of Subbiah and Asija, (1956) which is described in Appendix-VII.

#### 3.7.5. Available phosphorus

This was estimated by extracting the soil with 0.03 N ammonia in 0.025 N HCl extract (Bray No.1) as described by Jackson, (1973) which is described in Appendix-VIII.

### 3.7.6. Available potassium

The available potassium was estimated by extracting the soil with neutral normal ammonium acetate as per the procedure outlined by Standford and English, (1949). The details of the method are given in Appendix-IX.

### 3.7.7. Micronutrients

The micronutrients such as iron, manganese, copper and zinc were estimated using Diethylene Triamine Penta Acetic acid (DTPA) soil test method as proposed by Lindsay and Norwell, (1978). Appendix-X gives the details of the method.

## 3.8. Statistical Analysis

Analysis of variance was applied to find out the statistically significant variations caused by different treatments. Following the study of critical differences the groups that were similar and statistically significant in terms of growth and yield were identified.

# RESULTS

# CHAPTER 4

# RESULTS

The experimental results pertaining to the microbial degradation and enrichment of agro-wastes ; composting and maturity of composts; biometrical and yield parameters of test crops recorded during pot culture experiments; physico-chemical analysis of soil samples are presented in this chapter.

## 4.1. MICROBIAL DEGRADATION OF AGRO-WASTES

### 4.1.1. C/N ratio as influenced by treatments during biodegradation of bagasse (Tables 1a, 1b & 1c)

During incubation experiment, the biodegradation of bagasse was assessed by C/N ratio. During initial stages in all the treatments, there were no significant changes. Consequently the microbial inoculated treatments decreased the C/N ratio with the advancement of incubation period. The combined inoculant (consortia) of *Pleurotus sajor-caju* and *Trichoderma harzianum* ($T_3$) showed higher potentialities in narrowing C/N ratio of the bagasse to 29:1 on 60$^{th}$ day than all other treatments and control (Figure 1).

### 4.1.2. Microbial respiration as influenced by treatments during biodegradation of bagasse (Tables 2a & 2b)

The cumulative and rate of $CO_2$ evolution were higher in $T_5$ where dual culture of *Pleurotus sajor-caju* and *Trichoderma harzianum* added to bagasse than

**Table 1a. Organic carbon as influenced by treatments during biodegradation of bagasse (percent)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 47.5 | 46.7 | 46.0 | 44.6 | 44.0 | 43.5 | 43.2 | 43.0 | 43.0 | 44.62 |
| $T_2$ | 46.3 | 44.9 | 40.1 | 36.2 | 33.0 | 29.3 | 26.6 | 23.8 | 21.9 | 33.57 |
| $T_3$ | 46.6 | 44.2 | 41.9 | 39.4 | 36.6 | 33.4 | 31.7 | 29.4 | 26.6 | 36.64 |
| $T_4$ | 46.6 | 44.7 | 42.4 | 40.0 | 36.3 | 34.3 | 30.6 | 27.7 | 25.3 | 36.43 |
| $T_5$ | 45.8 | 41.4 | 38.3 | 32.4 | 26.5 | 24.7 | 23.3 | 21.1 | 21.0 | 30.50 |
| $T_6$ | 46.9 | 44.8 | 44.8 | 40.0 | 33.0 | 30.0 | 26.2 | 23.8 | 23.3 | 34.75 |
| $T_7$ | 56.5 | 43.6 | 39.9 | 37.3 | 34.0 | 31.0 | 26.6 | 24.5 | 24.2 | 35.29 |
| Mean | 48.0 | 44.3 | 41.9 | 38.6 | 34.8 | 32.3 | 29.7 | 27.6 | 26.47 | 35.97 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.68 | 1.37 | 1.22 | 2.43 | 1.94 | 3.88 |

**Table 1b. Total nitrogen as influenced by treatments during biodegradation of bagasse (percent)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 0.25 | 0.25 | 0.25 | 0.26 | 0.27 | 0.27 | 0.29 | 0.29 | 0.29 | 0.26 |
| $T_2$ | 0.29 | 0.37 | 0.48 | 0.63 | 0.77 | 0.83 | 0.83 | 0.84 | 0.84 | 0.65 |
| $T_3$ | 0.27 | 0.34 | 0.38 | 0.46 | 0.59 | 0.65 | 0.66 | 0.67 | 0.68 | 0.52 |
| $T_4$ | 0.27 | 0.31 | 0.38 | 0.44 | 0.50 | 0.55 | 0.62 | 0.66 | 0.67 | 0.49 |
| $T_5$ | 0.31 | 0.42 | 0.52 | 0.67 | 0.77 | 0.85 | 0.87 | 0.87 | 0.87 | 0.68 |
| $T_6$ | 0.30 | 0.36 | 0.44 | 0.62 | 0.71 | 0.84 | 0.84 | 0.85 | 0.84 | 0.65 |
| $T_7$ | 0.29 | 0.38 | 0.51 | 0.64 | 0.71 | 0.80 | 0.84 | 0.85 | 0.85 | 0.65 |
| Mean | 0.28 | 0.35 | 0.42 | 0.53 | 0.62 | 0.68 | 0.70 | 0.72 | 0.72 | 0.56 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|
| 0.05 | 0.11 | 0.04 | 0.10 | 0.14 | 0.29 |

**Table 1c. C/N ratio as influenced by treatments during biodegradation of bagasse**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 190.0 | 186.8 | 184.2 | 171.5 | 163.1 | 161.1 | 148.9 | 148.3 | 148.3 | 166.9 |
| $T_2$ | 159.7 | 121.4 | 83.5 | 57.5 | 43.0 | 35.3 | 32.0 | 28.0 | 26.1 | 65.2 |
| $T_3$ | 172.6 | 130.0 | 110.3 | 85.6 | 62.0 | 51.4 | 48.0 | 43.9 | 39.1 | 82.5 |
| $T_4$ | 172.5 | 144.2 | 111.6 | 90.9 | 72.6 | 62.4 | 49.4 | 41.3 | 37.8 | 87.0 |
| $T_5$ | 147.7 | 98.6 | 73.7 | 48.4 | 34.4 | 29.1 | 26.8 | 24.4 | 24.1 | 56.4 |
| $T_6$ | 156.3 | 124.4 | 101.8 | 64.5 | 46.5 | 35.7 | 31.2 | 28.4 | 27.7 | 68.6 |
| $T_7$ | 194.8 | 114.7 | 95.0 | 58.3 | 47.9 | 36.9 | 31.2 | 28.8 | 28.5 | 70.7 |
| Mean | 170.5 | 131.4 | 108.6 | 82.4 | 67.1 | 58.8 | 52.5 | 49.0 | 47.7 | 85.3 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.75 | 1.56 | 0.92 | 1.85 | 1.63 | 3.28 |

**Figure 1**
**C/N ratio of bagasse during biodegradation**

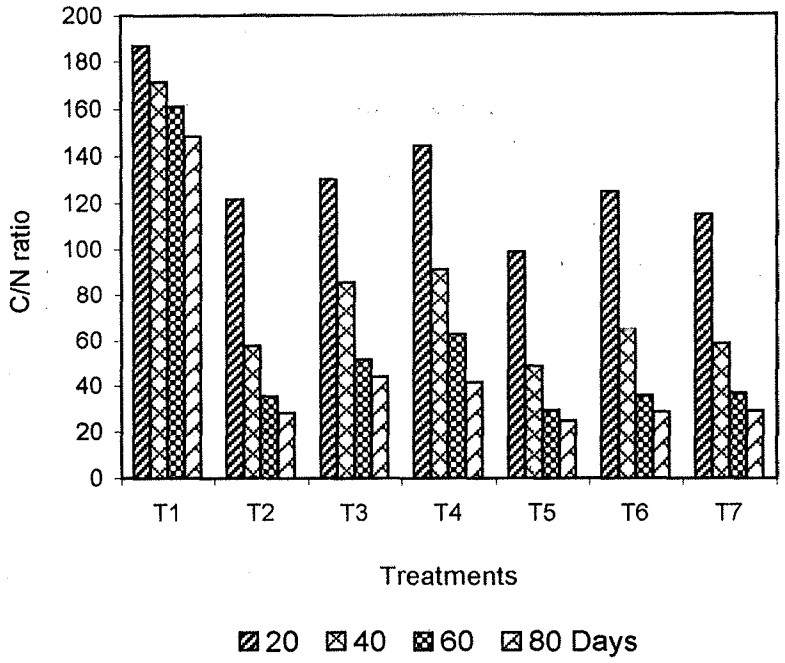



**Figure 2**
**Rate of $CO_2$ evolution during biodegradation of bagasse**

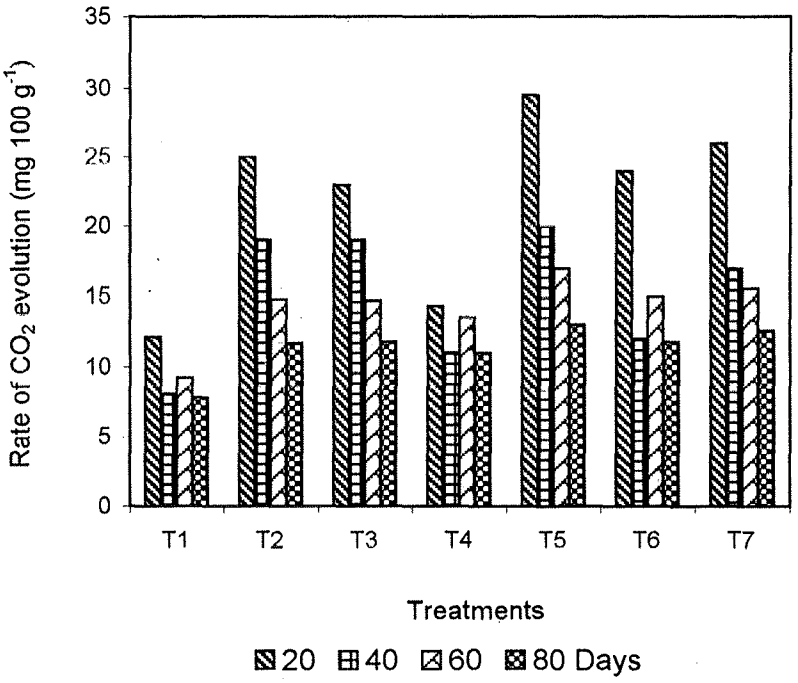


**Table 2a. Cumulative $CO_2$ evolution as influenced by treatments during biodegradation of bagasse (mg 100 $g^{-1}$)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 178 | 242 | 292 | 323 | 327 | 552 | 562 | 620 | 647 | 415.9 |
| $T_2$ | 372 | 495 | 660 | 748 | 803 | 885 | 903 | 933 | 963 | 751.3 |
| $T_3$ | 351 | 449 | 622 | 752 | 818 | 882 | 925 | 942 | 960 | 744.6 |
| $T_4$ | 245 | 285 | 405 | 449 | 650 | 809 | 840 | 880 | 920 | 609.3 |
| $T_5$ | 391 | 590 | 708 | 811 | 1002 | 1016 | 1040 | 1043 | 1065 | 851.8 |
| $T_6$ | 372 | 497 | 660 | 499 | 872 | 902 | 906 | 940 | 980 | 736.5 |
| $T_7$ | 370 | 520 | 647 | 698 | 850 | 938 | 975 | 1010 | 1027 | 781.7 |
| Mean | 325.6 | 439.7 | 570.6 | 611.4 | 760.3 | 854.9 | 878.7 | 909.7 | 800.3 | 698.7 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|
| 2.05 | 4.11 | 3.01 | 6.05 | 5.83 | 11.68 |

**Table 2b. Rate of $CO_2$ evolution as influenced by treatments during biodegradation of bagasse (mg 100 $g^{-1}$)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 17.8 | 12.1 | 9.7 | 8.1 | 6.5 | 9.2 | 8.0 | 7.8 | 7.2 | 9.6 |
| $T_2$ | 37.2 | 25.0 | 22.0 | 19.0 | 16.1 | 14.8 | 12.9 | 11.7 | 10.7 | 18.8 |
| $T_3$ | 35.1 | 23.0 | 21.0 | 19.0 | 16.4 | 14.7 | 13.2 | 11.8 | 10.7 | 18.3 |
| $T_4$ | 25.0 | 14.3 | 13.0 | 11.0 | 13.0 | 13.5 | 12.0 | 11.0 | 10.2 | 13.7 |
| $T_5$ | 39.0 | 29.5 | 24.0 | 20.0 | 20.0 | 17.0 | 15.0 | 13.0 | 11.8 | 21.0 |
| $T_6$ | 37.0 | 24.0 | 22.0 | 12.0 | 17.4 | 15.0 | 13.0 | 11.8 | 10.9 | 18.1 |
| $T_7$ | 37.0 | 26.0 | 22.0 | 17.0 | 17.0 | 15.6 | 14.0 | 12.6 | 11.4 | 19.2 |
| Mean | 32.6 | 22.0 | 19.1 | 15.2 | 15.2 | 14.3 | 12.6 | 11.4 | 10.4 | 17.0 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.06 | 0.13 | 0.05 | 0.11 | 0.17 | 0.35 |

the uninoculated control and all other treatments. Among the treatments, maximum response within 60 days was observed in $T_5$, $T_6$ and $T_7$ in which consortia of *Pleurotus sajor-caju* and *Trichoderma harzianum* (1016 mg $CO_2$ 100 $g^{-1}$ waste) *Pleurotus sajor-caju* + *Phanerochaete chrysosporium* (902 mg $CO_2$ 100 $g^{-1}$ waste) *Trichoderma harzianum* + *Phanerochaete chrysosporium* (938 mg $CO_2$ 100 $g^{-1}$ waste) were added respectively.

Microbial respiration was higher in $T_5$ and the respiratory rate (1002 to 1016 mg $CO_2$ 100 $g^{-1}$ waste) in this treatment was stabilised within 50-60 days (Figure 2).

### 4.1.3. C/N ratio as influenced by treatments during biodegradation of coffee waste (Tables 3a, 3b& 3c)

Among the single culture inoculum added treatments *Pleurotus sajor-caju* and *Phanerochaete chrysosporium* were efficiently accelerating the degradation process by narrowing down C/N ratio to 39 : 1. Simultaneously it was observed that the dual culture of *Pleurotus sajor-caju* and *Trichoderma harzianum* ($T_5$) hastened the degradation of coffee waste within 60-70 days to a maximum extent to a C/N ratio of 22.8 and reached stabilization point within 70 days (Figure 3).

### 4.1.4. Microbial respiration as influenced by treatments during biodegradation of coffee waste (Tables 4a & 4b).

The microbial respiration was significantly affected during 40, 50 and 60$^{th}$

**Table 3a. Organic carbon as influenced by treatments during biodegradation of coffee waste (percent)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 41.09 | 41.01 | 39.97 | 39.34 | 36.94 | 35.21 | 33.16 | 33.10 | 31.70 | 36.83 |
| $T_2$ | 40.88 | 39.79 | 37.19 | 34.60 | 30.62 | 27.46 | 25.74 | 25.70 | 25.10 | 31.89 |
| $T_3$ | 40.83 | 39.28 | 37.37 | 35.32 | 31.95 | 29.05 | 27.45 | 27.00 | 27.00 | 32.81 |
| $T_4$ | 40.60 | 36.91 | 36.34 | 33.61 | 30.96 | 27.42 | 24.70 | 24.30 | 24.12 | 31.00 |
| $T_5$ | 39.57 | 35.47 | 33.81 | 30.92 | 29.95 | 24.69 | 22.76 | 22.50 | 22.37 | 29.12 |
| $T_6$ | 39.97 | 37.00 | 35.84 | 32.57 | 29.18 | 26.42 | 24.78 | 24.42 | 24.37 | 30.51 |
| $T_7$ | 39.84 | 36.89 | 35.00 | 32.62 | 28.85 | 27.07 | 25.51 | 25.08 | 25.02 | 30.65 |
| Mean | 40.40 | 38.10 | 36.50 | 34.24 | 31.21 | 28.20 | 26.30 | 26.00 | 25.70 | 31.83 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|
| 0.27 | 0.55 | 0.25 | 0.49 | 0.73 | 1.46 |

**Table 3b. Total nitrogen as influenced by treatments during biodegradation of coffee waste (percent)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 0.37 | 0.37 | 0.37 | 0.43 | 0.43 | 0.44 | 0.45 | 0.47 | 0.47 | 0.42 |
| $T_2$ | 0.38 | 0.42 | 0.45 | 0.51 | 0.61 | 0.71 | 0.83 | 0.88 | 0.88 | 0.63 |
| $T_3$ | 0.37 | 0.43 | 0.46 | 0.49 | 0.51 | 0.68 | 0.82 | 0.86 | 0.86 | 0.61 |
| $T_4$ | 0.38 | 0.44 | 0.46 | 0.50 | 0.59 | 0.70 | 0.87 | 0.88 | 0.88 | 0.63 |
| $T_5$ | 0.38 | 0.45 | 0.50 | 0.57 | 0.67 | 0.81 | 1.00 | 1.01 | 1.02 | 0.71 |
| $T_6$ | 0.37 | 0.43 | 0.47 | 0.53 | 0.62 | 0.74 | 0.86 | 0.90 | 0.91 | 0.65 |
| $T_7$ | 0.38 | 0.42 | 0.50 | 0.56 | 0.62 | 0.71 | 0.89 | 0.89 | 0.90 | 0.65 |
| Mean | 0.38 | 0.42 | 0.46 | 0.51 | 0.58 | 0.68 | 0.82 | 0.84 | 0.85 | 0.62 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.07 | 0.14 | 0.06 | 0.12 | 0.12 | 0.25 |

**Table 3c. C / N ratio as influenced by treatments during biodegradation of coffee waste**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 111.1 | 110.8 | 108.0 | 91.5 | 85.9 | 80.0 | 73.7 | 70.4 | 67.5 | 88.8 |
| $T_2$ | 107.6 | 95.0 | 82.6 | 67.8 | 50.2 | 45.0 | 31.0 | 29.20 | 28.50 | 59.7 |
| $T_3$ | 110.4 | 91.3 | 81.2 | 72.1 | 6.6 | 42.7 | 33.5 | 31.4 | 31.4 | 61.8 |
| $T_4$ | 106.8 | 84.0 | 79.0 | 67.2 | 52.4 | 39.2 | 28.4 | 27.6 | 27.4 | 57.0 |
| $T_5$ | 104.1 | 78.8 | 67.6 | 54.2 | 44.7 | 30.5 | 22.8 | 22.3 | 22.0 | 49.7 |
| $T_6$ | 108.0 | 86.0 | 76.3 | 61.5 | 47.1 | 35.7 | 28.8 | 27.1 | 26.8 | 52.3 |
| $T_7$ | 104.8 | 87.8 | 70.0 | 58.3 | 46.5 | 43.7 | 35.9 | 28.2 | 27.8 | 55.9 |
| Mean | 107.5 | 90.5 | 80.7 | 67.5 | 55.6 | 45.3 | 36.3 | 33.9 | 33.1 | 47.2 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.48 | 0.86 | 0.75 | 1.50 | 1.02 | 2.04 |

**Figure 3**
**C/N Ratio of coffee waste during biodegradation**

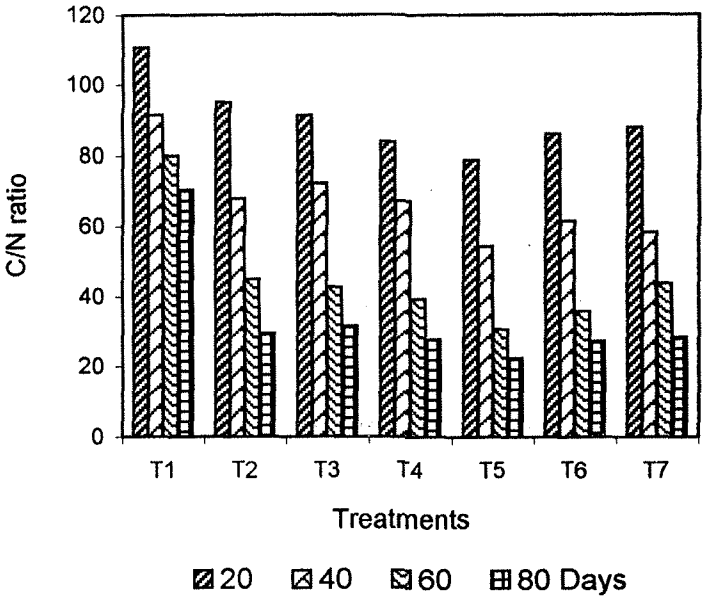



**Figure 4**
**Rate of $CO_2$ evolution during biodegradation of coffee waste**

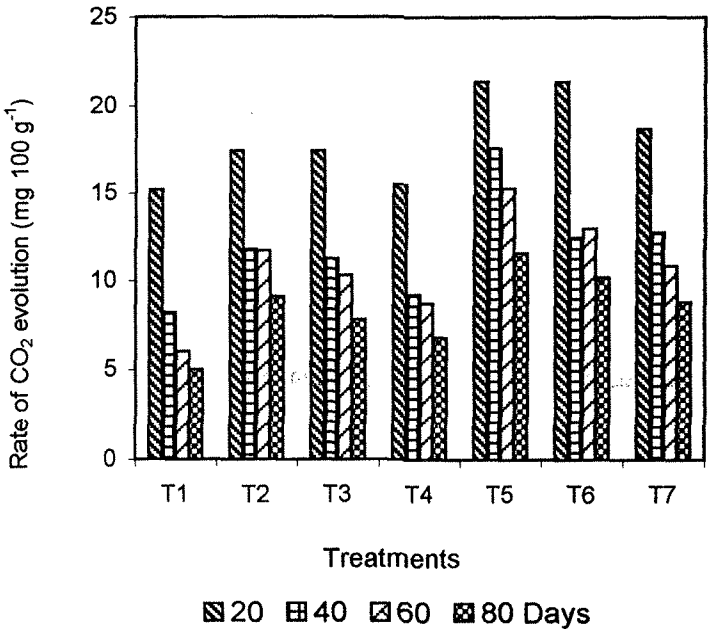


**Table 4a. Cumulative $CO_2$ evolution as influenced by treatments during biodegradation of coffee waste**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 201.0 | 304.3 | 308.7 | 326.8 | 343.0 | 357.4 | 360.7 | 394.8 | 417.1 | 334.9 |
| $T_2$ | 324.1 | 347.0 | 419.7 | 472.5 | 634.0 | 703.3 | 718.7 | 724.9 | 725.3 | 563.3 |
| $T_3$ | 300.9 | 348.5 | 389.6 | 451.7 | 570.9 | 615.4 | 625.0 | 625.3 | 628.0 | 506.1 |
| $T_4$ | 301.0 | 308.8 | 349.6 | 368.3 | 421.8 | 522.0 | 540.0 | 545.0 | 551.0 | 434.2 |
| $T_5$ | 360.8 | 428.1 | 510.5 | 705.4 | 779.0 | 916.4 | 918.1 | 925.3 | 925.7 | 718.8 |
| $T_6$ | 308.7 | 426.7 | 458.7 | 499.8 | 634.7 | 781.7 | 788.3 | 817.5 | 825.0 | 615.7 |
| $T_7$ | 301.6 | 374.5 | 470.4 | 511.4 | 587.0 | 651.8 | 655.1 | 702.1 | 738.8 | 554.7 |
| Mean | 299.7 | 362.5 | 415.3 | 476.6 | 567.2 | 649.7 | 658.0 | 676.4 | 687.3 | 532.5 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|
| 2.41 | 4.78 | 4.25 | 8.56 | 7.11 | 14.23 |

**Table 4b. Rate of $CO_2$ evolution as influenced by treatments during biodegradation of coffee waste (mg $100g^{-1}$)**

(Mean of three replications)

| Treatments | Incubation period (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | Mean |
| $T_1$ | 20.1 | 15.2 | 10.3 | 8.2 | 6.9 | 6.0 | 5.2 | 5.0 | 4.6 | 8.5 |
| $T_2$ | 32.4 | 17.4 | 14.0 | 11.8 | 12.7 | 11.7 | 10.3 | 9.1 | 8.1 | 14.2 |
| $T_3$ | 30.8 | 17.4 | 13.0 | 11.3 | 11.4 | 10.3 | 90.0 | 7.8 | 7.0 | 13.1 |
| $T_4$ | 30.1 | 15.5 | 11.7 | 9.2 | 8.4 | 8.7 | 7.7 | 6.8 | 6.1 | 11.6 |
| $T_5$ | 36.1 | 21.4 | 17.0 | 17.6 | 15.6 | 15.3 | 13.1 | 11.6 | 10.3 | 17.6 |
| $T_6$ | 30.9 | 21.4 | 15.3 | 12.5 | 12.7 | 13.0 | 11.3 | 10.2 | 9.2 | 15.2 |
| $T_7$ | 30.2 | 18.7 | 15.7 | 12.8 | 11.7 | 10.9 | 10.0 | 8.8 | 8.2 | 14.1 |
| Mean | 30.1 | 18.0 | 13.9 | 11.9 | 11.3 | 10.8 | 9.5 | 8.5 | 7.6 | 13.5 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) |
|---|---|---|---|---|---|
| 0.35 | 0.71 | 0.51 | 1.02 | 0.73 | 1.46 |

day of incubation by 115 per cent, 127 per cent and 156 per cent respectively in $T_5$ than control. After 60$^{th}$ day of incubation the respiratory rate was stabilized earlier in $T_5$ than control and all other treatments. Among single inoculum incorporated treatments, *Pleurotus sajor-caju* ($T_2$) influenced the respiratory rate to a higher extent of 85 per cent on 50$^{th}$ day and 97 per cent on 60$^{th}$ day of incubation (Figure 4).

## 4.2. ENRICHMENT OF AGRO-WASTES

### 4.2.1. Enrichment of bagasse (Table 5)

The enrichment of bagasse with urea, rock phosphate (Mussoorie) and microbes was assessed by the total microbial activity in terms of soil respiration through $CO_2$ evolution.

When compared to control, all other treatments significantly influenced the cumulative and rate of $CO_2$ evolution. Among the treatments, $T_6$, $T_7$ and $T_8$ were on par with each other from 20$^{th}$ day onwards and reached the stability on 50$^{th}$ day of incubation. The values ranged from 790 mg of $CO_2$ $100^{-1}$ g of soil to 926 mg of $CO_2$ $100^{-1}$ g of soil on 50$^{th}$ day of incubation in these treatments. The non-microbial inoculum added treatments were insignificantly influenced the respiratory rate.

The microbial respiration in terms of cumulative and rate of $CO_2$ evolution was distinctly increased to a greater extent during initial stages of $T_9$ and it

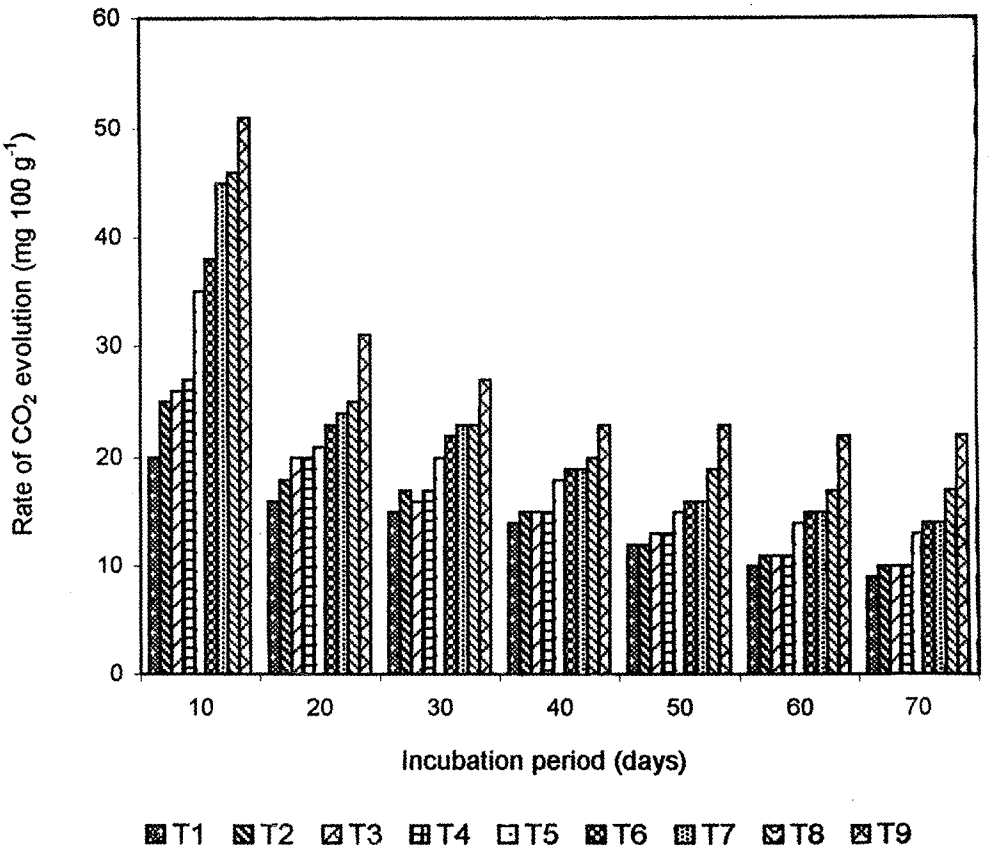
**Table 5. Microbial respiration as influenced by treatments during enrichment of bagasse (mg $100g^{-1}$)**

(Mean of three replications)

| Treat-ments | Incubation period (days) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cumulative $CO_2$ evolution | | | | | | | | Rate of $CO_2$ evolution | | | | | | | |
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | Mean | 10 | 20 | 30 | 40 | 50 | 60 | 70 | Mean |
| $T_1$ | 201 | 327 | 454 | 564 | 595 | 611 | 655 | 486.7 | 20 | 16 | 15 | 14 | 12 | 9 | 9 | 13.7 |
| $T_2$ | 254 | 355 | 499 | 591 | 620 | 660 | 678 | 522.4 | 25 | 18 | 17 | 15 | 12 | 10 | 10 | 15.4 |
| $T_3$ | 256 | 390 | 492 | 595 | 622 | 656 | 675 | 526.6 | 26 | 20 | 16 | 15 | 13 | 10 | 10 | 15.9 |
| $T_4$ | 267 | 398 | 500 | 601 | 626 | 663 | 678 | 533.3 | 27 | 20 | 17 | 15 | 13 | 10 | 10 | 16.1 |
| $T_5$ | 348 | 425 | 596 | 725 | 755 | 814 | 905 | 654.0 | 35 | 21 | 20 | 18 | 15 | 13 | 13 | 19.4 |
| $T_6$ | 376 | 460 | 655 | 750 | 799 | 892 | 965 | 699.6 | 38 | 23 | 22 | 19 | 16 | 14 | 14 | 21.0 |
| $T_7$ | 449 | 475 | 686 | 745 | 790 | 896 | 963 | 714.9 | 45 | 24 | 23 | 19 | 16 | 14 | 14 | 22.3 |
| $T_8$ | 456 | 499 | 700 | 806 | 926 | 1023 | 1156 | 795.4 | 46 | 25 | 23 | 20 | 19 | 17 | 17 | 23.9 |
| $T_9$ | 509 | 625 | 806 | 901 | 1136 | 1309 | 1520 | 972.3 | 51 | 31 | 27 | 23 | 23 | 22 | 22 | 28.4 |
| Mean | 346 | 439 | 599 | 698 | 763 | 831 | 911 | 656.1 | 35 | 22 | 20 | 18 | 14 | 13 | 13 | 19.6 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.52 | 6.04 | 5.01 | 10.02 | 7.46 | 14.93 | 0.58 | 1.16 | 1.70 | 3.40 | 2.11 | 4.22 |

**Figure 5**
**Microbial respiration during enrichment of bagasse**



reached stabilization after 30th day of incubation. Thus the combined inoculation of *Pleurotus sajor-caju* and *Trichoderma harzianum* on bagasse enriched with Mussoorie rock phosphate and urea profoundly influenced the respiratory rate when compared with control and other treatments (Figure 5).

### 4.2.2. Enrichment of coffee waste (Table 6 ; Plate C)

The efficacy of microbial activity was maximum from 20th day of incubation onwards in $T_9$ where dual inocula of *Pleurotus sajor-caju* and *Trichoderma harzianum* combined with urea and Mussoorie rock phosphate were added. In this treatments the initial respiratory rate was more and it declined to stabilization point earlier at 50th day of incubation than control and all other treatments.

Among the treatments, $T_2$ and $T_3$ were on par with each other in influencing the respiratory rate of $CO_2$ evolution. In these non microbial treatments, only urea and rock phosphate were added to soil + coffee waste mixture. Among the microbial inoculum added treatments, $T_6$, $T_7$ and $T_8$ were on par with each other where enrichment of soil and coffee waste + microbe mixture along with urea and rock phosphate significantly influenced this parameter when compared to control (Figure 6).

## 4.3. COMPOSTING OF BAGASSE (Plate D, E & F)

During composting of bagasse, the results for changes in temperature, pH

**Table 6. Microbial respiration as influenced by treatments during enrichment of coffee waste (mg $100g^{-1}$)**

(Mean of three replications)

| Treat-ments | Incubation period (days) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cumulative $CO_2$ evolution | | | | | | | Mean | Rate of $CO_2$ evolution | | | | | | | Mean |
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | | 10 | 20 | 30 | 40 | 50 | 60 | 70 | |
| $T_1$ | 252 | 413 | 578 | 599 | 625 | 682 | 685 | 547.71 | 25 | 21 | 19 | 15 | 13 | 11 | 10 | 16.28 |
| $T_2$ | 279 | 475 | 599 | 625 | 698 | 711 | 725 | 587.42 | 27 | 24 | 20 | 16 | 14 | 12 | 10 | 17.57 |
| $T_3$ | 305 | 578 | 608 | 711 | 787 | 798 | 801 | 655.42 | 31 | 29 | 29 | 18 | 16 | 13 | 11 | 19.71 |
| $T_4$ | 327 | 599 | 744 | 802 | 866 | 897 | 922 | 736.71 | 33 | 30 | 25 | 20 | 17 | 15 | 13 | 21.85 |
| $T_5$ | 401 | 701 | 876 | 977 | 992 | 1056 | 1075 | 868.28 | 40 | 35 | 29 | 24 | 20 | 18 | 15 | 25.85 |
| $T_6$ | 407 | 726 | 874 | 965 | 998 | 1045 | 1086 | 871.57 | 41 | 36 | 29 | 24 | 20 | 17 | 16 | 26.57 |
| $T_7$ | 408 | 725 | 889 | 982 | 1036 | 1081 | 1086 | 886.71 | 41 | 36 | 29 | 25 | 21 | 18 | 16 | 26.57 |
| $T_8$ | 429 | 827 | 962 | 1055 | 1098 | 1198 | 1368 | 991.00 | 43 | 41 | 32 | 26 | 22 | 20 | 20 | 29.14 |
| $T_9$ | 638 | 964 | 1056 | 1121 | 1321 | 1565 | 1786 | 1207.28 | 64 | 48 | 35 | 28 | 26 | 26 | 26 | 36.14 |
| Mean | 382.7 | 667.6 | 798.4 | 870.8 | 935.7 | 1003.7 | 1059.3 | 809.2 | 38.3 | 33.3 | 26.4 | 21.7 | 18.7 | 16.6 | 15.2 | 21.6 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.43 | 2.86 | 1.75 | 2.40 | 3.99 | 7.99 | 0.31 | 0.63 | 0.50 | 0.02 | 1.23 | 2.46 |

Plate C

**ENRICHMENT OF ORGANIC WASTES**


Enrichment of bagasse


Enrichment of coffee waste

**Figure 6**
**Microbial respiration during enrichment of coffee waste**

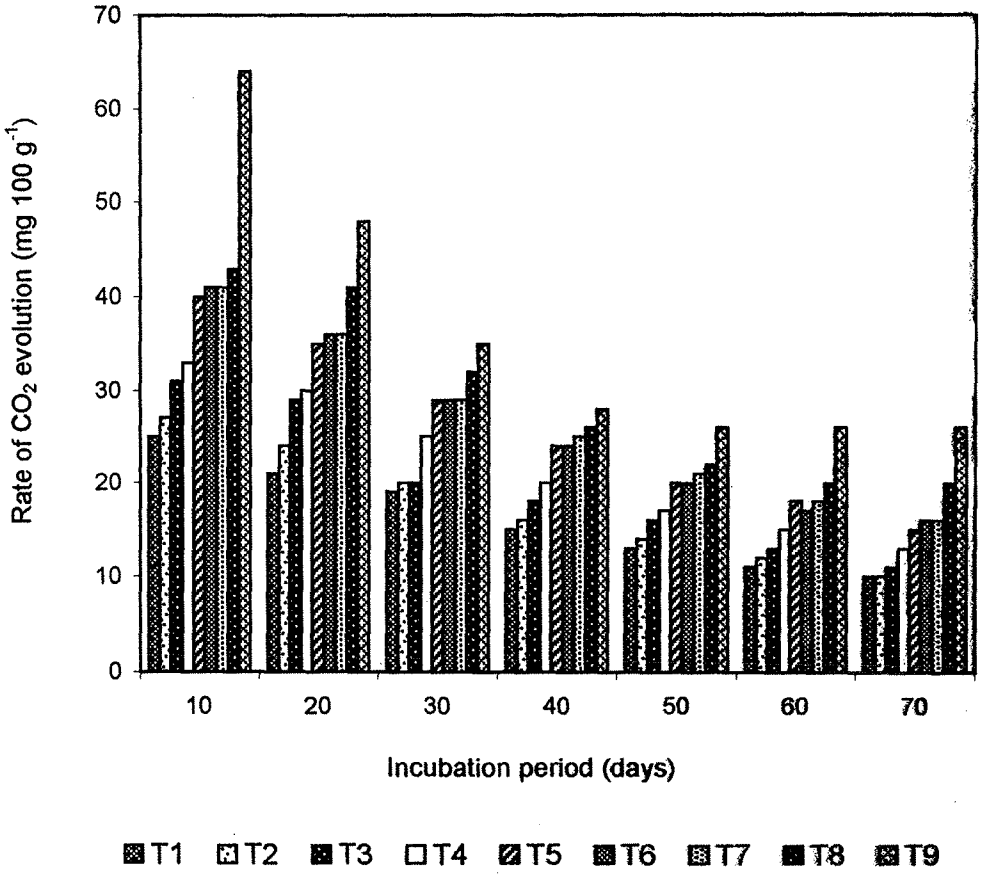


Plate D

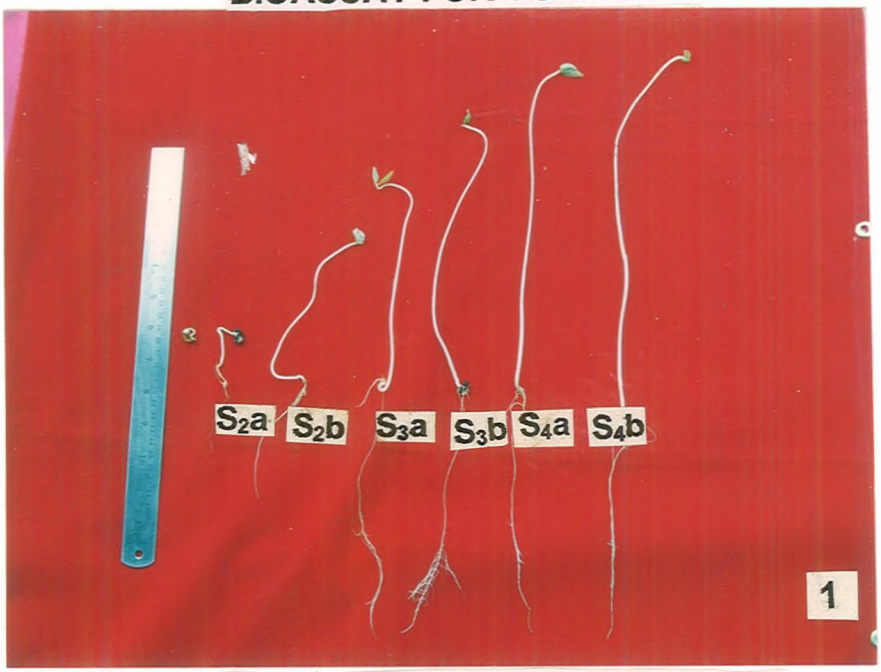
**COMPOSTING OF ORGANIC WASTES**


Composting of organic wastes by heap method

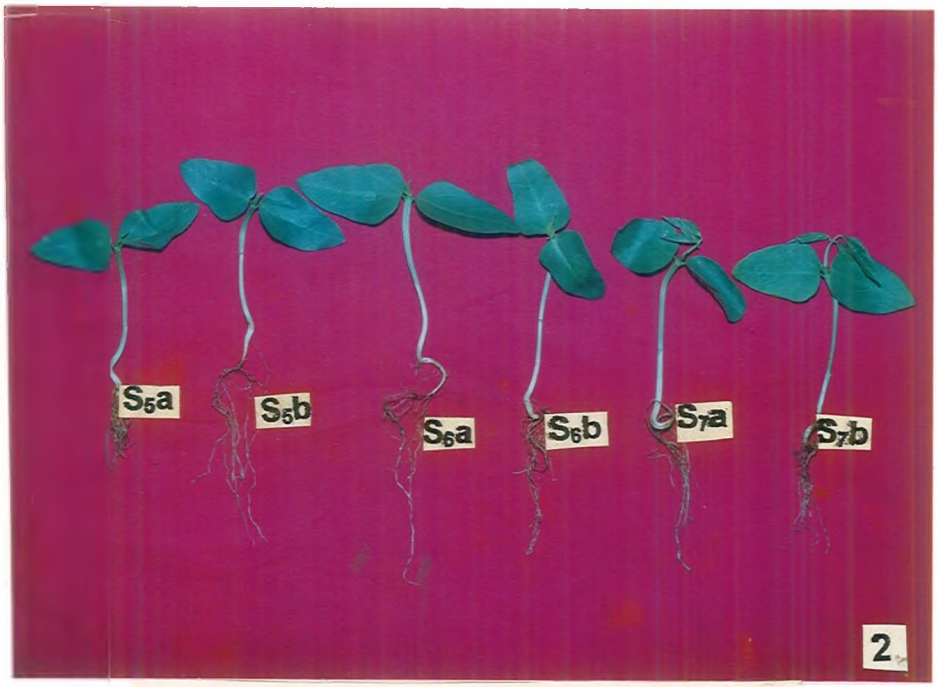

Maturity test for composts

Plate E

**BIOASSAY FOR COMPOSTS**




Cowpea seedlings in immature compost extracts




Cowpea seedlings in mature compost extracts

Plate F

**BIOCOMPOSTS FROM ORGANIC WASTES**


Fresh bagasse Biocompost


Fresh coffee waste Biocompost

and electrical conductivity (physical parameters); C/N ratio, macro and micronutrients and quality of compost (chemical parameters) and seedling development in compost extract (bioassay) are presented in Tables 7 and 8.

### 4.3.1. Physical parameters

#### 4.3.1.1. Temperature (Table 7 ; Figure 7a)

Ten days after composting, the temperature in the heap increased from 37 to 40°C. The rise in temperature was maximum upto 58 to 61°C during 4$^{th}$ week and it remained same for one week. After that the temperature decreased to existing ambient levels of about 30 to 28°C within 8 weeks which showed the maturity of composts.

#### 4.3.1.2. Percentage of hydrogen ion concentration (pH) (Table 7; Figure 7a)

pH is a parameter which greatly affects the composting process. During first week, there was a decrease in pH and after second week the pH value increased gradually. There was a maximum increase of pH upto 7.2 to 7.3 and stabilized at the same range during 6$^{th}$ and 7$^{th}$ week of composting period .

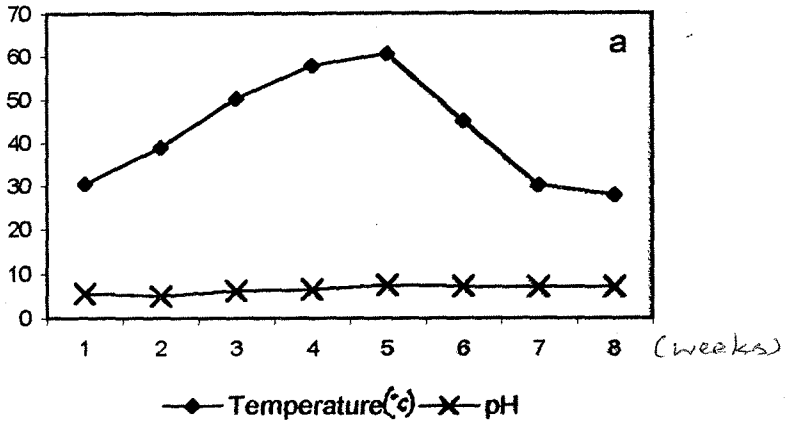
#### 4.3.1.3. Electrical conductivity (EC) (Table 7)

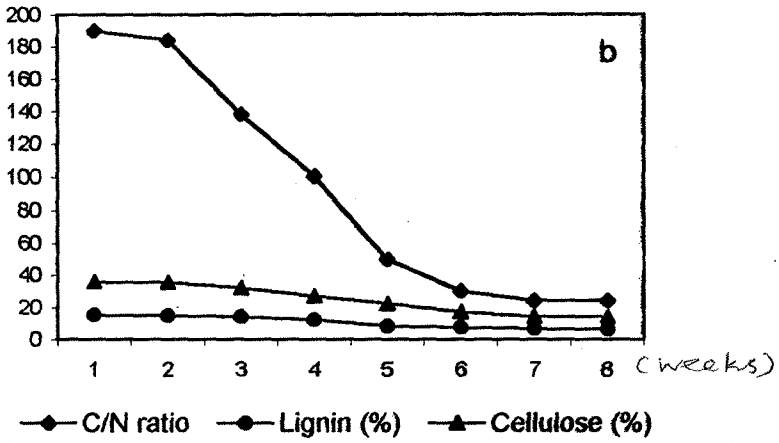
Electrical conductivity is another important character used to assess compost maturity. Right from the second week of composting period, gradual decrease in EC was observed and at 42-49$^{th}$ day, the stabilization point of 0.54 $dSm^{-1}$ was recorded.

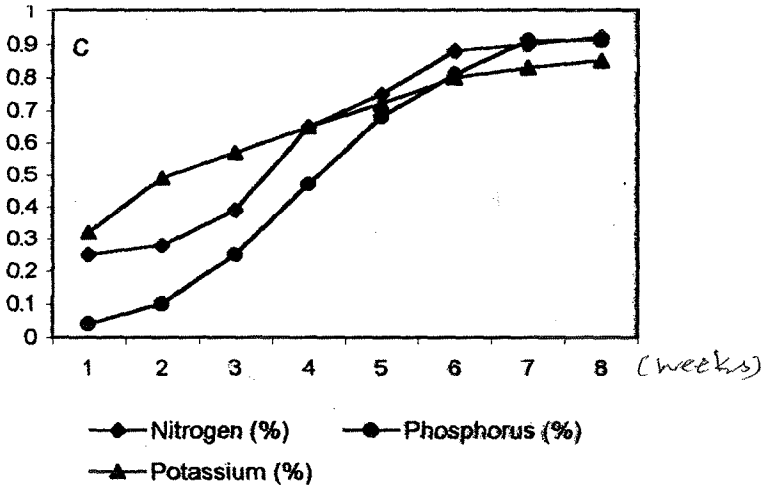
**Table 7. Nutrient dynamics during composting of bagasse**

| S.No. | Physico-chemical characteristics | Composting time (weeks) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1. | Temperature (°C) | 30.50 | 39.00 | 50.20 | 57.80 | 60.60 | 45.00 | 30.20 | 27.80 |
| 2. | pH | 5.60 | 5.00 | 6.10 | 6.50 | 7.50 | 7.20 | 7.10 | 7.10 |
| 3. | EC ($dSm^{-1}$) | 0.98 | 0.90 | 0.81 | 0.74 | 0.62 | 0.60 | 0.54 | 0.54 |
| 4. | C / N ratio | 190.00 | 184.00 | 138.10 | 100.05 | 50.09 | 30.00 | 24.12 | 24.00 |
| 5. | Lignin (%) | 15.20 | 15.00 | 14.10 | 12.20 | 8.00 | 7.30 | 6.50 | 6.20 |
| 6. | Cellulose (%) | 35.70 | 35.50 | 31.80 | 27.00 | 22.10 | 17.25 | 14.02 | 14.00 |
| 7. | Organic carbon (%) | 47.60 | 46.00 | 40.05 | 35.02 | 28.00 | 23.40 | 22.75 | 22.15 |
| 8. | Nitrogen (%) | 0.25 | 0.28 | 0.39 | 0.65 | 0.75 | 0.88 | 0.90 | 0.92 |
| 9. | Phosphorus (%) | 0.04 | 0.10 | 0.25 | 0.47 | 0.68 | 0.81 | 0.91 | 0.91 |
| 10. | Potassium (%) | 0.32 | 0.49 | 0.57 | 0.65 | 0.72 | 0.80 | 0.83 | 0.85 |
| 11. | Fe (ppm) | 0.01 | 0.01 | 0.05 | 0.10 | 0.16 | 0.16 | 0.16 | 0.16 |
| 12. | Mn (ppm) | 0.02 | 0.02 | 0.03 | 0.10 | 0.12 | 0.14 | 0.14 | 0.14 |
| 13. | Cu (ppm) | 0.07 | 0.07 | 0.17 | 0.28 | 0.42 | 0.44 | 0.45 | 0.45 |
| 14. | Zn (ppm) | 0.10 | 0.10 | 0.22 | 0.42 | 0.55 | 0.56 | 0.57 | 0.57 |

**Figure 7**
**Changes in physico-chemical parameters during composting of bagasse**



### 4.3.2. Chemical parameters (Table 7 ; Figure 7b)

The changes occurring in C/N ratio is an important indicator of compost maturity. During composting of bagasse the organic carbon was lost within 8 weeks and reduced to 24 per cent during the same period. Simultaneously there was a gradual increase in total nitrogen content of compost from third week onwards which increased upto 0.92 per cent.

The qualitative analytical results of bagasse compost revealed its maturity based on colour changes. In the first and second week of composting period there was no colour change. The filtrate of third and fourth week samples turned to pale blue colour. The filtrates of 5,6 and 7 weeks old compost samples turned to deep blue colour (Plate D2).

It is evident from the data that composting of bagasse consequently decreased the lignin to 6.5 per cent and cellulose to 14 per cent. The available micro and macronutrients increased significantly within 7 weeks.

### 4.3.3. Bioassay (Table 8a)

The seeds of cowpea were germinated in the extracts of undecomposed bagasse ($S_1a$, $S_2a$, $S_3a$, $S_4a$) and composted bagasse ($S_5a$, $S_6a$ and $S_7a$). The extract of fresh waste affect the germinability and seedlings developed from these extracts did not show good response. The cowpea seeds soaked in the extracts of composted bagasse germinated faster and seedling growth was enhanced

significantly in terms of hypocotyl length, epicotyl length, root length and number of lateral roots (Plate E1 & 2).

## 4.4. COMPOSTING OF COFFEE WASTE (Plate D, E & F)

During composting of coffee waste the fluctuations in temperature, pH and electrical conductivity, changes in chemical parameters and bio assay are presented in Tables 8b and 9.

### 4.4.1. Physical parameters

#### 4.4.1.1. Temperature (Table 9; Figure 8a)

The rise in temperature inside the heap was ranging from 59° - 67°C during 3rd and 4th week of composting. There was a decrease in temperature after a week 60-55°C and it was further decreased to a range of 43° - 32°C on 8th week. The stabilization in temperatures was recorded in the range between 29° and 28°C which showed maturity of compost.

#### 4.4.1.2. Percentage of hydrogen ion concentration (pH)

At initial stages, there was a fall in pH (from 5.9 to 4.9). Later from third week onwards the pH started increasing from 5.6 to 7.5 and stabilized on 8th week.

#### 4.4.1.3. Electrical conductivity (EC)

The trend of results for physical characteristics regarding electrical conductivity showed a decrease during third week onwards and it was stabilized on 8th week.

### 4.4.2. Chemical parameters (Table 9)

The trend of results for C/N ratio in table 9 showed that there was an increase in nitrogen content and decrease in carbon content of compost samples from 3rd week onwards. Hence the C/N ratio was reduced to a greater extent in 6 and 7 weeks old composts. The loss was maximum at 21 : 1 on 8th week .

Preferential degradation of lignin, cellulose and caffeine was enhanced by the microbial activity to an optimum level of 10, 11 and 0.24 per cent respectively at the end of composting time (Figure 8b & c).

The qualitative analysis of composts of initial stages showed that there was no colour change. The compost samples examined at 5th and 6th week turned to pale blue colour whereas the 7th and 8th week compost samples turned to deep blue in colour which showed the maturity of composted coffee waste.

There was an increasing trend from 4th week onwards for micro and macro nutrient contents of composted coffee waste.

### 4.4.3. Bioassay (Table 8b ; Plate E1& 2)

The cowpea seeds showed poor response to the extracts of fresh coffee waste ($S_1b$, $S_2b$, $S_3b$ and $S_4b$). The better response for seedling growth such as hypocotyl length, epicotyl length, root length and number of lateral roots in extracts of composted coffee waste ($S_5b$, $S_6b$ and $S_7b$) was observed.

**Table 8. Bioassay for composts**

(Mean of three replications)

| Growth parameters | Cowpea seedlings grown in compost extracts | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial stages | | | | | | | | Final stages | | | | | |
| | Bagasse | | | | Coffee waste | | | | Bagasse | | | Coffee waste | | |
| | $S_1a$ | $S_2a$ | $S_3a$ | $S_4a$ | $S_1b$ | $S_2b$ | $S_3b$ | $S_4b$ | $S_5a$ | $S_6a$ | $S_7a$ | $S_5b$ | $S_6b$ | $S_7b$ |
| Hypocotyl length (cm) | - | 3.2 | 3.7 | 7.8 | - | 2.8 | 8.0 | 8.7 | 3.8 | 5.4 | 6.0 | 2.2 | 3.0 | 5.0 |
| Epicotyl length (cm) | - | 2.1 | 3.0 | 6.2 | - | 2.4 | 4.0 | 4.8 | 3.0 | 3.8 | 4.3 | 1.3 | 2.2 | 3.4 |
| Root length (cm) | - | 3.7 | 4.3 | 7.5 | - | 4.2 | 8.1 | 8.3 | 4.2 | 5.1 | 6.0 | 4.5 | 5.6 | 6.2 |
| No.of lateral roots | - | 4.0 | 4.8 | 6.7 | - | 3.5 | 4.0 | 4.8 | 8.4 | 14.3 | 18.8 | 7.2 | 10.6 | 11.2 |

| SE | CD (5%) | SE | CD (5%) | SE | CD (5%) | SE | CD (5%) |
|---|---|---|---|---|---|---|---|
| 0.35 | 0.06 | 0.07 | 0.05 | 0.02 | 0.08 | 0.03 | 0.20 |
| 0.72 | 0.13 | 0.15 | 0.09 | 0.04 | 0.16 | 0.06 | 0.41 |

**Figure 8**
**Changes in physico-chemical parameters during composting of coffee waste**

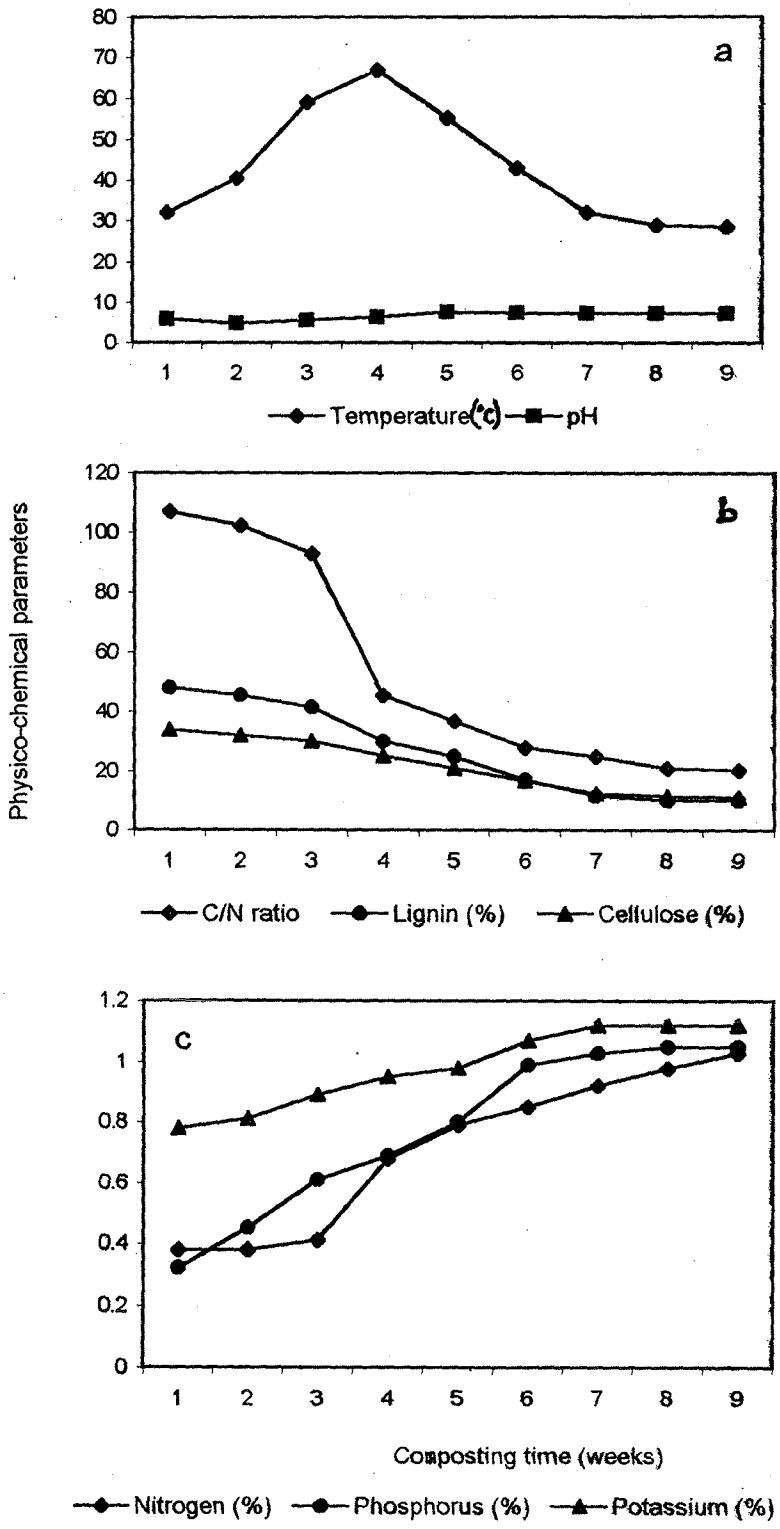


**Table 9. Nutrient dynamics during composting of coffee waste**

| S.No. | Physico-chemical characteristics | Composting time (weeks) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 1. | Temperature (°C) | 32.00 | 40.50 | 59.00 | 66.77 | 55.20 | 43.00 | 32.10 | 29.00 | 28.50 |
| 2. | PH | 5.90 | 4.90 | 5.60 | 6.40 | 7.60 | 7.40 | 7.30 | 7.30 | 7.30 |
| 3. | EC ($dSm^{-1}$) | 1.05 | 1.01 | 0.99 | 0.87 | 0.79 | 0.68 | 0.55 | 0.49 | 0.48 |
| 4. | C / N ratio | 107.11 | 102.50 | 92.70 | 45.60 | 36.90 | 27.90 | 24.80 | 20.90 | 20.30 |
| 5. | Lignin (%) | 48.15 | 45.75 | 41.50 | 30.10 | 24.80 | 17.12 | 11.50 | 10.10 | 10.00 |
| 6. | Cellulose (%) | 33.96 | 31.92 | 30.00 | 25.14 | 21.03 | 16.75 | 12.35 | 11.60 | 11.05 |
| 7. | Caffeine (%) | 0.79 | 0.76 | 0.68 | 0.59 | 0.45 | 0.33 | 0.26 | 0.24 | 0.24 |
| 8. | Organic carbon (%) | 40.97 | 40.68 | 37.00 | 31.02 | 27.00 | 22.01 | 21.15 | 20.50 | 20.00 |
| 9. | Nitrogen (%) | 0.38 | 0.38 | 0.41 | 0.68 | 0.79 | 0.85 | 0.92 | 0.98 | 1.03 |
| 10. | Phosphorus (%) | 0.32 | 0.45 | 0.61 | 0.69 | 0.80 | 0.99 | 1.03 | 1.05 | 1.05 |
| 11. | Potassium (%) | 0.78 | 0.81 | 0.89 | 0.95 | 0.98 | 1.07 | 1.12 | 1.12 | 1.12 |
| 12. | Fe (ppm) | 0.09 | 0.09 | 0.11 | 0.14 | 0.17 | 0.17 | 0.17 | 0.18 | 0.18 |
| 13. | Mn (ppm) | 0.04 | 0.04 | 0.05 | 0.05 | 0.07 | 0.09 | 0.13 | 0.15 | 0.15 |
| 14. | Cu (ppm) | 0.21 | 0.25 | 0.36 | 0.57 | 0.69 | 0.82 | 0.93 | 0.93 | 0.93 |
| 15. | Zn (ppm) | 0.23 | 0.29 | 0.33 | 0.48 | 0.53 | 0.70 | 0.85 | 0.85 | 0.85 |

## 4.5. INITIAL SOIL ANALYSIS (Table 10)

The initial experimental soil with a pH of 6.2 was assessed for its physico-chemical properties. The texture of the soil was sandy loam. The water holding capacity was 47.25 per cent, the bulk density and porosity were 1.28 g $cc^{-1}$ and 49.75 per cent respectively.

The organic carbon and organic matter content of the experimental soil were 1.08 per cent and 1.84 per cent respectively. The electrical conductivity of this soil was 0.47 $dSm^{-1}$.

The available nitrogen, phosphorus and potassium of the experimental soil were 4.30, 10.35 and 72.25 ppm respectively.

The available micronutrients such as iron, manganese, copper and zinc present in the experimental soil were 5.4, 4.0, 0.08 and 0.05 ppm respectively.

## 4.6. POT CULTURE EXPERIMENTS

### 4.6.1. Pot culture experiment-I (Plate G-*Vigna unguiculata* L. Walp.& Plate H-*Cyamopsis tetragonaloba* T.)

#### 4.6.1.1. Influence of treatments on the number of leaves of test crops (Table 11)

This parameter spectacularly increased with the application of 100 per cent NPK ($T_8$) over control in both the test crops during all the stages.

In cowpea, the composted bagasse along with 100 per cent NPK ($T_{11}$) and

**Table 10. Initial analysis of experimental soil**

| Parameters | |
|---|---|
| pH | 6.20 |
| Electrical conductivity ($dSm^{-1}$) | 0.47 |
| Organic carbon (%) | 1.08 |
| Organic matter (%) | 1.84 |
| Nitrogen (ppm) | 4.30 |
| Phosphorus (ppm) | 10.35 |
| Potassium (ppm) | 72.25 |
| Iron (ppm) | 5.40 |
| Manganese (ppm) | 4.00 |
| Copper (ppm) | 0.08 |
| Zinc (ppm) | 0.05 |
| Bulk density ($gcc^{-1}$) | 1.28 |
| Water holding capacity (%) | 47.25 |
| Porosity (%) | 49.75 |

Plate G

**COWPEA CROP IN POT CULTURE EXPERIMENT-I**

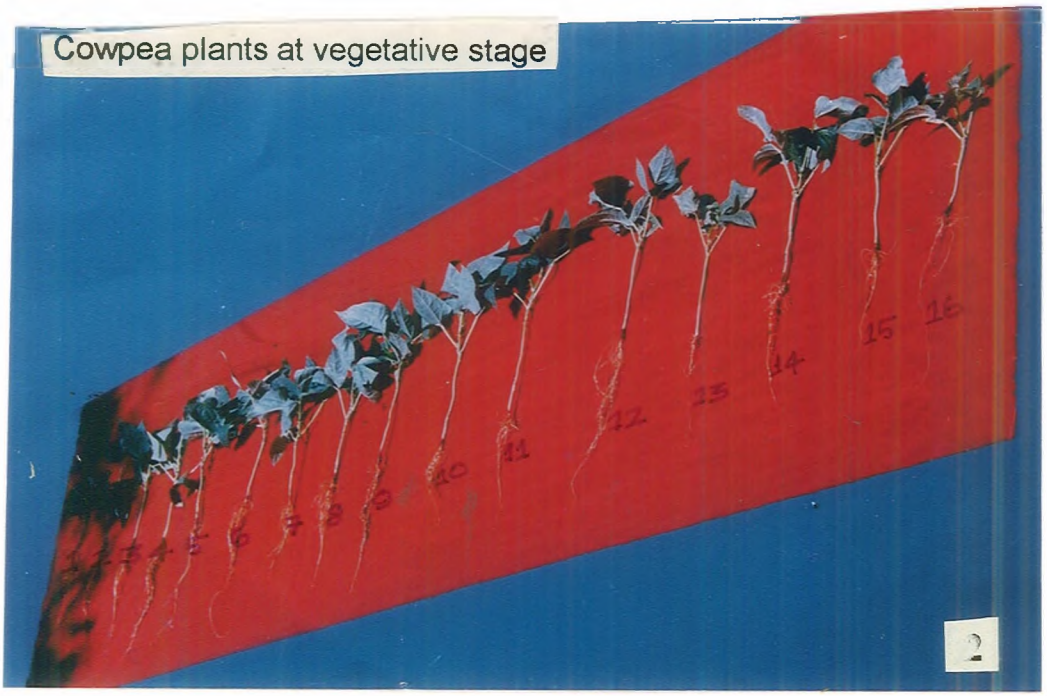
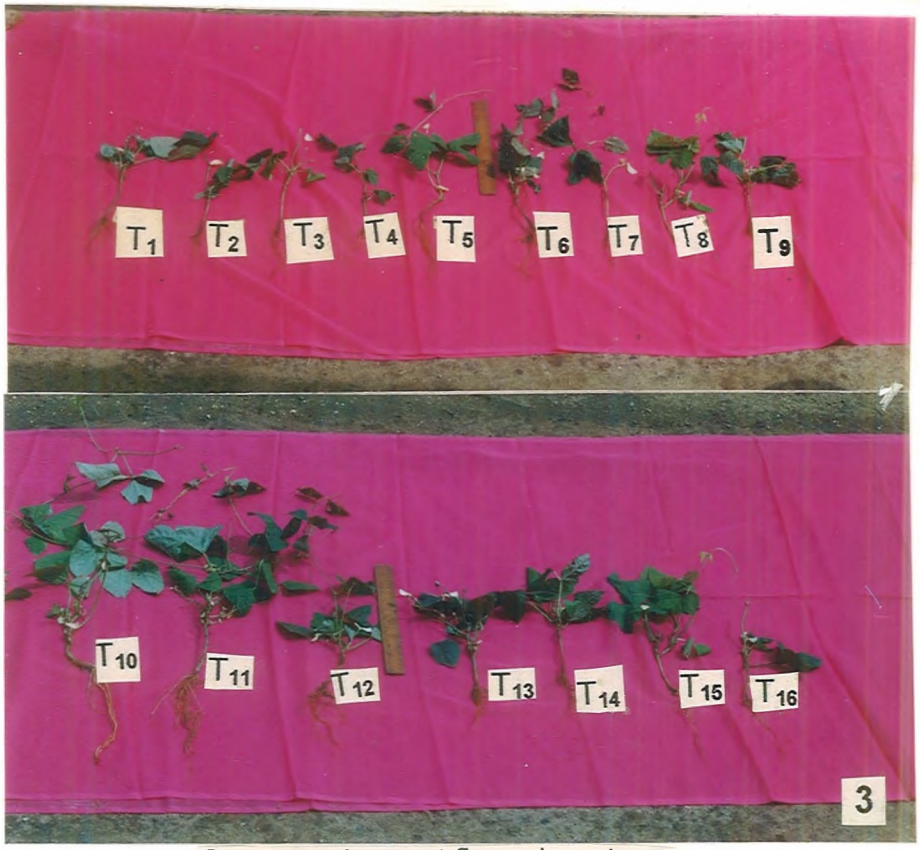



Plate G

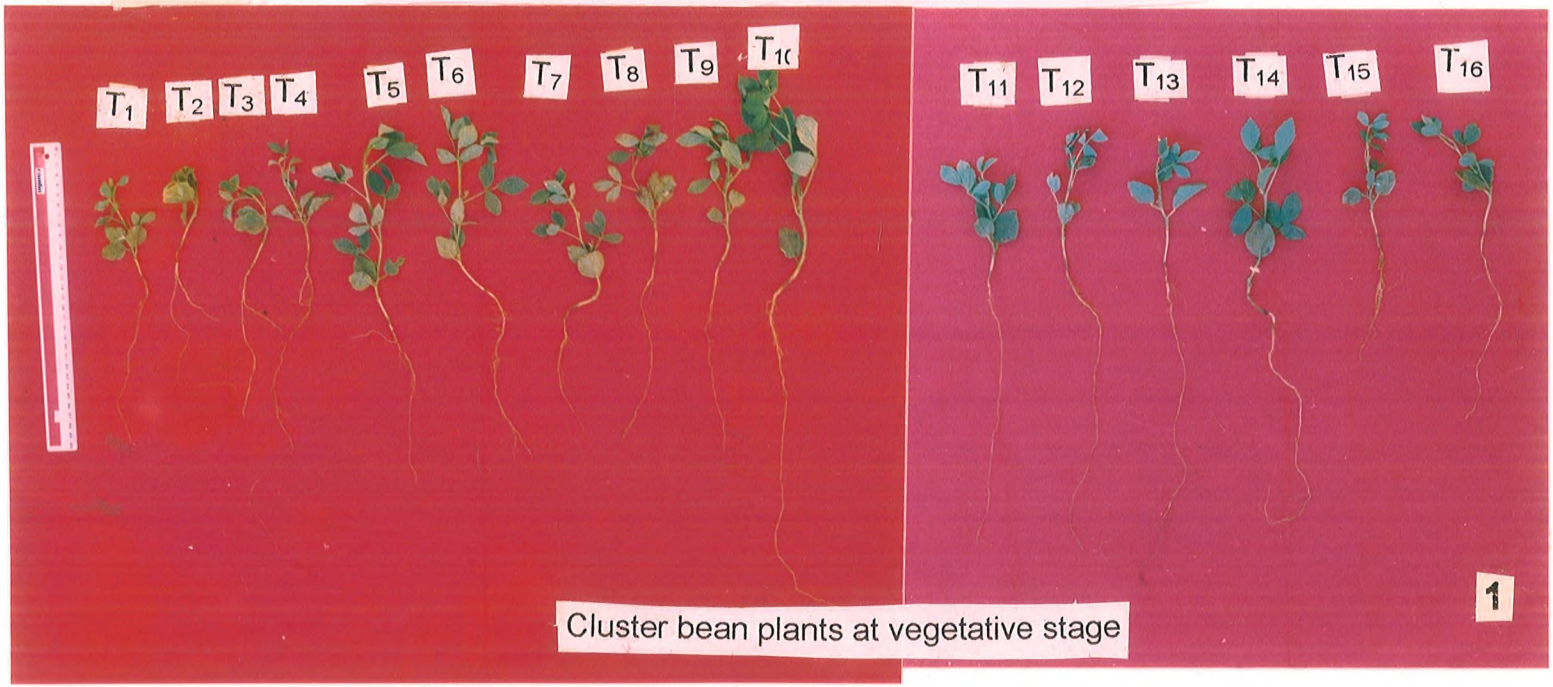



Cowpea plants at flowering stage

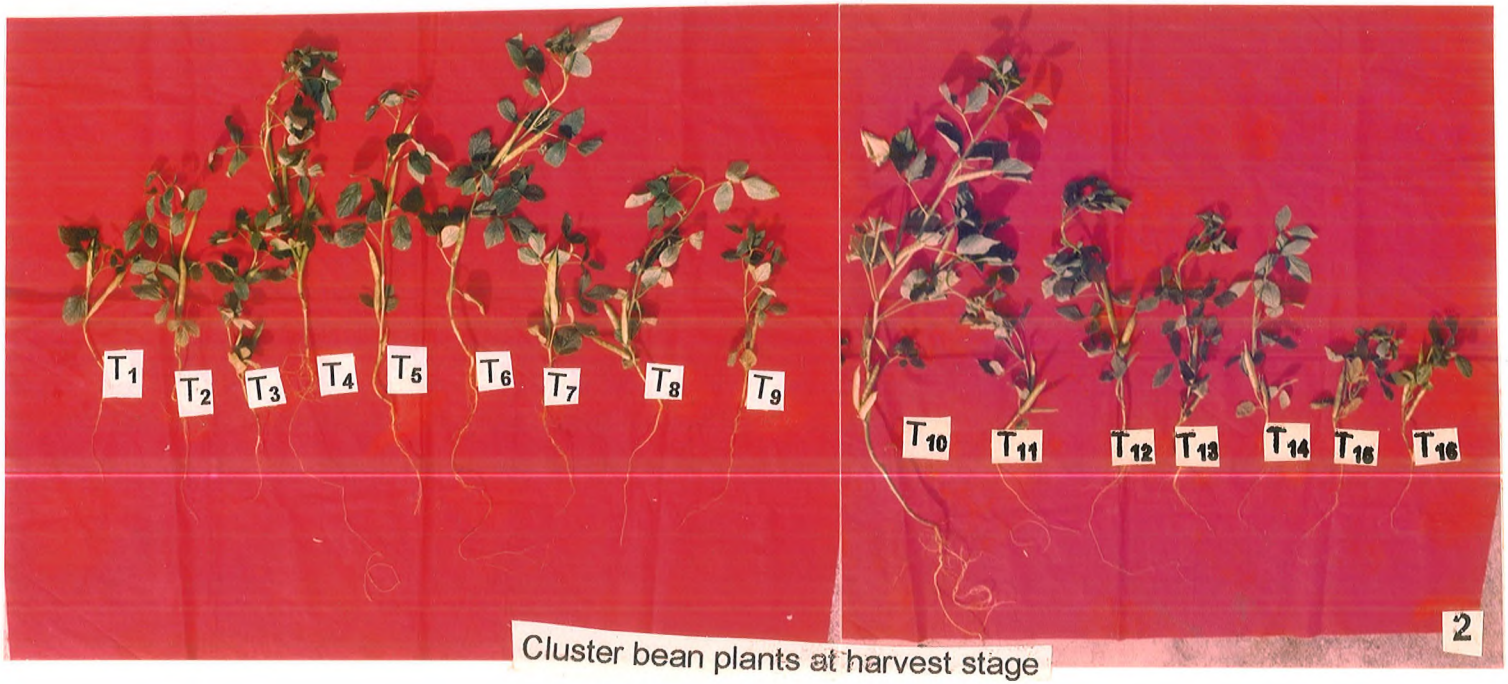

Cowpea plants at harvest stage

Plate H

## COWPEA CROP IN POT CULTURE EXPERIMENT-I




Cluster bean plants at vegetative stage




Cluster bean plants at harvest stage

**Table 11. Number of leaves of test crops as influenced by treatments**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 9.3 | 16 | 24 | 16.4 | 8.3 | 15.0 | 18.0 | 13.77 |
| $T_2$ | 9.3 | 16 | 21 | 15.4 | 9.3 | 15.0 | 19.3 | 14.53 |
| $T_3$ | 9.6 | 16 | 22 | 15.9 | 9.0 | 15.3 | 19.7 | 14.66 |
| $T_4$ | 12 | 21 | 32 | 21.7 | 14.7 | 18.7 | 27.0 | 20.13 |
| $T_5$ | 12 | 21 | 28 | 20.3 | 14.0 | 16.7 | 25.6 | 18.77 |
| $T_6$ | 12 | 21 | 28 | 20.3 | 17.0 | 20.0 | 27.0 | 21.33 |
| $T_7$ | 14 | 23 | 30 | 22.3 | 15.0 | 21.0 | 27.3 | 21.10 |
| $T_8$ | 16 | 23 | 35 | 24.7 | 17.0 | 21.0 | 29.7 | 22.56 |
| $T_9$ | 12 | 21 | 32 | 21.7 | 16.0 | 20.7 | 25.3 | 20.66 |
| $T_{10}$ | 12 | 21 | 35 | 22.7 | 16.0 | 18.3 | 29.0 | 21.10 |
| $T_{11}$ | 14 | 21 | 34 | 23.0 | 16.0 | 19.0 | 29.3 | 21.43 |
| $T_{12}$ | 14 | 21 | 33 | 22.7 | 16.0 | 20.0 | 27.6 | 21.20 |
| $T_{13}$ | 10 | 16 | 34 | 16.7 | 11.0 | 15.7 | 22.0 | 16.23 |
| $T_{14}$ | 9 | 17 | 23 | 16.3 | 11.0 | 16.0 | 22.3 | 16.43 |
| $T_{15}$ | 9 | 17 | 23 | 16.3 | 11.3 | 16.0 | 21.7 | 16.33 |
| $T_{16}$ | 9 | 17 | 24 | 16.7 | 10.0 | 16.7 | 21.3 | 16.00 |
| Mean | 11.45 | 19.75 | 28 | 19.56 | 12.23 | 17.82 | 24.51 | 18.51 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.56 | 1.11 | 0.52 | 1.06 | 1.33 | 2.70 | 0.51 | 1.05 | 0.23 | 0.46 | 0.49 | 0.98 |

the composted coffee waste along with 100 per cent NPK ($T_{12}$) profoundly increased this parameter. These two treatments were on par with each other and farm yard manure ($T_7$).

In cluster bean, composted coffee waste alone applied at the rate of 12.5 t $ha^{-1}$ ($T_6$) positively enhanced the number of leaves per plant when compared with the control and being on par with 100 per cent NPK ($T_8$) in which maximum number of leaves on plant was recorded.

The mean values for this parameter from vegetative to harvest stages ranged from 11.45 to 28 in cowpea and 12.23 to 24.51 in cluster bean.

**4.6.1.2. Influence of treatments on the root volume of test crops (Table 12)**

The root volumes of cowpea plants were significantly enhanced by the application of composted bagasse along with 100 per cent NPK ($T_{11}$) over control in the vegetative stage. During flowering stage, this parameter was positively enhanced by the composted coffee waste along with 100 per cent NPK ($T_{12}$) when compared to control and at harvest stage, composted coffee waste along with 50 per cent NPK ($T_{10}$) positively increased this parameter.

The mean values for the root volume of cowpea from vegetative to harvest stages ranged from 3.2 cc to 6.45 cc.

**Table 12. Root volume of the test crops as influenced by treatments (cc)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 1.4 | 2.0 | 3.9 | 2.4 | 0.8 | 1.2 | 2.1 | 1.36 |
| $T_2$ | 1.1 | 2.0 | 3.7 | 2.26 | 0.6 | 1.0 | 2.0 | 1.20 |
| $T_3$ | 1.2 | 2.1 | 3.8 | 2.36 | 0.5 | 1.1 | 1.9 | 1.16 |
| $T_4$ | 4.4 | 6.0 | 8.7 | 6.36 | 1.6 | 2.5 | 3.6 | 2.56 |
| $T_5$ | 4.2 | 5.9 | 7.5 | 5.86 | 1.8 | 2.6 | 3.7 | 2.70 |
| $T_6$ | 4.0 | 6.8 | 7.3 | 6.03 | 1.7 | 2.6 | 3.8 | 2.66 |
| $T_7$ | 4.3 | 6.5 | 7.8 | 6.20 | 1.8 | 2.7 | 3.7 | 2.73 |
| $T_8$ | 4.0 | 6.0 | 7.5 | 5.83 | 1.7 | 2.9 | 3.5 | 2.70 |
| $T_9$ | 4.0 | 6.1 | 7.7 | 5.93 | 1.7 | 2.7 | 3.7 | 2.70 |
| $T_{10}$ | 4.5 | 6.5 | 9.8 | 6.93 | 2.0 | 2.9 | 3.9 | 2.86 |
| $T_{11}$ | 4.6 | 6.7 | 9.6 | 6.96 | 1.9 | 2.7 | 3.9 | 2.83 |
| $T_{12}$ | 4.3 | 6.9 | 9.6 | 6.93 | 1.9 | 2.7 | 3.8 | 2.80 |
| $T_{13}$ | 2.3 | 3.5 | 4.1 | 3.30 | 1.0 | 1.5 | 2.3 | 1.60 |
| $T_{14}$ | 2.2 | 3.0 | 4.0 | 3.06 | 1.1 | 1.7 | 2.2 | 1.66 |
| $T_{15}$ | 2.2 | 2.9 | 4.2 | 3.10 | 1.2 | 1.7 | 2.3 | 1.73 |
| $T_{16}$ | 2.5 | 3.1 | 4.0 | 3.20 | 1.1 | 1.7 | 2.4 | 1.73 |
| Mean | 3.2 | 4.75 | 6.45 | 4.79 | 1.40 | 2.14 | 3.03 | 2.19 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.56 | 1.11 | 0.52 | 1.06 | 1.33 | 2.70 | 0.51 | 1.05 | 0.23 | 0.46 | 0.49 | 0.98 |

There is a gradual increase in the root volume of cluster bean crop as the stage advances with the mean values ranging from 0.5 cc to 2 cc in the vegetative stage, 1.0 cc to 2.9 cc in the flowering stage and 1.9 cc to 3.9 cc at harvest stage.

The composted coffee waste along with 50 per cent NPK ($T_{10}$) positively influenced this parameter over control in all the stages.

When compared to the undecomposed agro wastes ($T_2$, $T_3$, $T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) the composted agro wastes with and without 50% and 100% NPK had marked effect on root volume, being on par with each other and increased positively than the control.

**4.6.1.3. Influence of treatment on the nodule index of test crops (Table 13)**

The nodule index of cowpea plants was favourably increased by the treatment in which composted bagasse ($T_5$) was applied when compared to control at vegetative stage. During flowering stage, very significant results were obtained in composted bagasse with 100 per cent NPK ($T_{11}$) and composted coffee waste with 100 per cent NPK ($T_{12}$) over control

Farm yard manure ($T_7$), 100 per cent NPK ($T_8$), composted bagasse with 50 per cent NPK ($T_9$) and composted coffee waste with 50 per cent NPK ($T_{10}$) also had a marked influence on this parameter over control being on par with each other.

**Table 13. Nodule index of the test crops as influenced by treatments**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Mean | Vegetative stage | Flowering stage | Mean |
|---|---|---|---|---|---|---|
| $T_1$ | 0.92 | 1.07 | 1.0 | 0.97 | 1.03 | 1.00 |
| $T_2$ | 0.86 | 1.10 | 0.98 | 0.99 | 1.06 | 1.03 |
| $T_3$ | 0.90 | 1.05 | 0.98 | 1.00 | 1.10 | 1.05 |
| $T_4$ | 1.03 | 1.87 | 1.45 | 1.05 | 1.31 | 1.18 |
| $T_5$ | 1.21 | 1.90 | 1.56 | 1.00 | 1.30 | 1.15 |
| $T_6$ | 1.18 | 2.00 | 1.59 | 1.10 | 1.28 | 1.19 |
| $T_7$ | 1.09 | 2.10 | 1.60 | 1.00 | 1.32 | 1.16 |
| $T_8$ | 1.07 | 2.10 | 1.59 | 0.99 | 1.21 | 1.10 |
| $T_9$ | 1.18 | 2.10 | 1.64 | 1.00 | 1.21 | 1.11 |
| $T_{10}$ | 1.18 | 2.10 | 1.64 | 1.00 | 1.22 | 1.11 |
| $T_{11}$ | 1.12 | 2.40 | 1.76 | 1.03 | 1.22 | 1.13 |
| $T_{12}$ | 1.19 | 2.40 | 1.80 | 1.07 | 1.21 | 1.14 |
| $T_{13}$ | 0.87 | 1.10 | 0.99 | 0.99 | 1.04 | 1.02 |
| $T_{14}$ | 0.89 | 1.20 | 1.05 | 0.98 | 1.06 | 1.02 |
| $T_{15}$ | 0.89 | 1.16 | 1.02 | 0.96 | 1.04 | 1.00 |
| $T_{16}$ | 0.85 | 1.08 | 0.97 | 0.96 | 1.03 | 1.00 |
| Mean | 1.03 | 1.70 | 1.4 | 1.7 | 1.2 | 1.1 |
| | S | T | S x T | S | T | S x T |
| SE | 0.04 | 0.07 | 0.12 | 0.03 | 0.05 | 0.09 |
| **CD (5%)** | **0.08** | **0.14** | **0.23** | **0.06** | **0.10** | **0.19** |

The mean values for nodule index of cowpea varied from 0.85 to 1.21 in vegetative and 1.05 to 2.40 in flowering stages.

In cluster bean, the nodule index was significantly increased by the composted coffee waste ($T_6$) than control in vegetative stage. The other treatments also had a slight influence on this parameter but being on par with each other did not show any pronounced variations between them.

In flowering stage, the farm yard manure ($T_7$) showed a significant increase in nodule index over control being on par with the composted coirpith ($T_4$) and composted bagasse ($T_5$).

The undecomposed agro wastes at the rate of 12.5 t $ha^{-1}$ ($T_2$, $T_3$, $T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) had a very little effect on this parameter being on par with each other in vegetative and flowering stages, whereas the biocomposts at the same rate had a greater influence on nodule index over control and all other treatments.

The judicial combinations of biocomposts at the rate of 12.5 t $ha^{-1}$ along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) recorded maximum nodule index than control.

The mean values ranged from 0.96 to 1.10 in vegetative stage and 1.03 and 1.32 in flowering stage.

#### 4.6.1.4. Influence of treatments on the plant height of test crops (Table 14 ; Figure 9 ; Plate G)

Table 14, present the impact of treatments on the plant height of test crops. The mean values obtained from the vegetative stage to harvest stage of the two test crops for the plant height ranged from 49.51 cm to 73.14 cm in cowpea and 27.99 cm to 49.79 cm in cluster bean.

In cowpea, the addition of composted coffee waste along with 50 and 100 per cent NPK ($T_{10}$ and $T_{12}$) spectacularly increased the plant height over control, during its vegetative stage followed by the composted coffee waste applied at the rate of 12.5 t $ha^{-1}$ ($T_6$) and composted bagasse + 100 per cent NPK ($T_{11}$) .

The farm yard manure ($T_7$), 100 per cent NPK ($T_8$), composted bagasse ($T_5$) and composted bagasse along with 50 per cent NPK ($T_9$) also had a marked influence on this parameter over control, being on par with each other.

During vegetative stage, the undecomposed agrowastes applied at the rate of 12.5 t $ha^{-1}$ ($T_2$ and $T_3$) had insignificant influence on this parameter whereas the undecomposed agro wastes applied along with 50 and 100 per cent NPK ($T_{13}$, $T_{14}$ and $T_{15}$ and $T_{16}$) showed significant variation over control, being on par with each other. During flowering and harvest stages, the undecomposed agrowastes had a very little effect on the plant height, being on par with the control and did not show any specific variations.

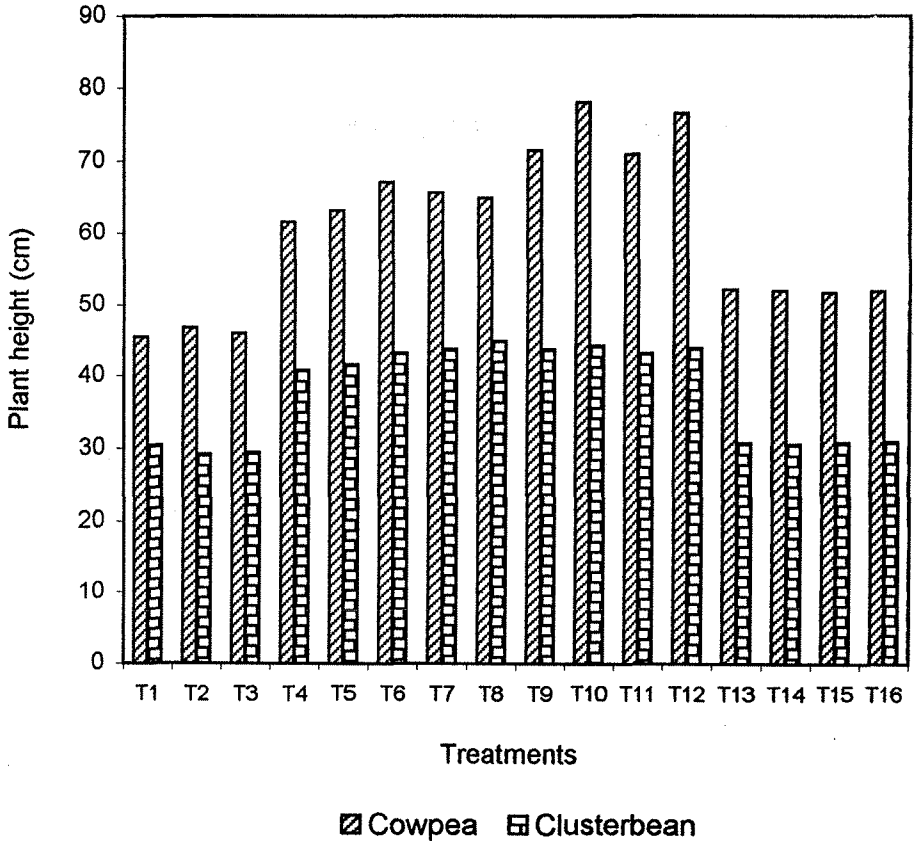
**Table 14. Plant height of test crops as influenced by treatments (cm)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 33.3 | 47.0 | 56.0 | 45.43 | 22.1 | 29.6 | 39.7 | 30.47 |
| $T_2$ | 32.5 | 48.7 | 57.7 | 46.30 | 21.8 | 28.7 | 37.2 | 29.23 |
| $T_3$ | 32.0 | 49.2 | 56.7 | 45.97 | 22.0 | 28.9 | 37.5 | 29.47 |
| $T_4$ | 52.6 | 60.1 | 72.0 | 61.57 | 30.6 | 37.5 | 54.5 | 40.87 |
| $T_5$ | 54.0 | 60.5 | 75.0 | 63.17 | 30.7 | 38.3 | 55.9 | 41.63 |
| $T_6$ | 59.6 | 62.7 | 79.1 | 67.13 | 31.1 | 38.9 | 59.6 | 43.20 |
| $T_7$ | 54.7 | 59.8 | 82.4 | 65.63 | 31.5 | 39.0 | 60.7 | 43.73 |
| $T_8$ | 54.3 | 60.0 | 80.5 | 64.93 | 33.8 | 39.6 | 61.3 | 44.90 |
| $T_9$ | 54.0 | 62.0 | 98.5 | 71.50 | 32.9 | 40.3 | 58.2 | 43.80 |
| $T_{10}$ | 61.0 | 85.0 | 88.0 | 78.00 | 33.2 | 40.6 | 59.2 | 44.33 |
| $T_{11}$ | 58.5 | 63.4 | 90.9 | 70.93 | 32.0 | 39.4 | 58.4 | 43.27 |
| $T_{12}$ | 61.0 | 70.5 | 98.2 | 76.57 | 32.3 | 40.5 | 59.0 | 43.93 |
| $T_{13}$ | 47.0 | 50.1 | 59.4 | 52.17 | 28.0 | 29.6 | 39.9 | 30.83 |
| $T_{14}$ | 45.7 | 50.2 | 60.1 | 52.00 | 23.3 | 29.3 | 39.4 | 30.67 |
| $T_{15}$ | 48.0 | 49.7 | 57.5 | 51.73 | 23.7 | 29.6 | 39.5 | 30.93 |
| $T_{16}$ | 47.5 | 50.0 | 58.2 | 51.90 | 23.9 | 29.8 | 39.2 | 30.97 |
| Mean | 49.51 | 58.12 | 73.14 | 60.26 | 27.99 | 34.88 | 49.79 | 37.55 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) | SE (D) | CD (5%) | SE (D) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.52 | 1.04 | 0.66 | 1.33 | 1.07 | 2.14 | 0.09 | 0.18 | 0.25 | 0.53 | 0.98 | 1.97 |

**Figure 9**
**Plant height of test crops as influenced by treatments**



The plant height of cowpea crop was significantly enhanced during flowering and at harvest stages, with the incorporation of composted bagasse along with 50 and 100 per cent NPK ($T_9$ and $T_{11}$) and composted coffee waste along with 50 and 100 per cent NPK ($T_{10}$ and $T_{12}$) when compared with the control.

In cluster bean, the addition of composts with and without 50 and 100 per cent NPK showed significant effect in increasing the plant height over control in all the stages of its growth.

The undecomposed agrowastes applied at the rate of 12.5 t $ha^{-1}$ ($T_2$ and $T_3$) did not show any marked influence on this parameter in all the stages, being on par with each other.

The undecomposed agrowastes along with 50 and 100 per cent NPK ($T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) applied treatments had a very little effect on plant height, being on par with each other and control, in all the stages of growth.

#### 4.6.1.5. Influence of treatments on the plant fresh weight of test crops (Table 15)

In cowpea plants, the composts applied at the rate of 12.5 t $ha^{-1}$ ($T_4$, $T_5$ and $T_6$) positively increased the plant fresh weight over control during vegetative stage, being on par with farm yard manure ($T_7$) and 100 per cent NPK ($T_8$).

**Table 15. Plant fresh weight of test crops as influenced by treatments (g)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 14.54 | 24.62 | 31.0 | 23.39 | 10.65 | 14.45 | 18.78 | 14.63 |
| $T_2$ | 14.75 | 25.85 | 30.5 | 23.70 | 10.80 | 14.39 | 17.95 | 14.38 |
| $T_3$ | 14.70 | 25.88 | 30.2 | 23.59 | 10.97 | 14.57 | 17.35 | 14.30 |
| $T_4$ | 16.12 | 28.53 | 42.6 | 29.08 | 14.83 | 18.42 | 21.32 | 18.19 |
| $T_5$ | 16.01 | 28.50 | 41.7 | 28.74 | 14.51 | 18.47 | 21.48 | 18.15 |
| $T_6$ | 16.15 | 27.98 | 44.0 | 29.38 | 14.71 | 18.51 | 21.47 | 18.23 |
| $T_7$ | 16.00 | 29.45 | 46.0 | 30.48 | 14.67 | 17.94 | 23.09 | 18.57 |
| $T_8$ | 16.11 | 29.50 | 46.5 | 30.70 | 14.77 | 19.65 | 25.08 | 19.83 |
| $T_9$ | 17.65 | 27.99 | 46.7 | 30.78 | 14.51 | 19.74 | 22.21 | 18.82 |
| $T_{10}$ | 18.51 | 28.74 | 49.6 | 32.28 | 14.84 | 19.57 | 22.24 | 18.88 |
| $T_{11}$ | 18.45 | 29.00 | 47.7 | 31.72 | 14.89 | 18.60 | 22.25 | 18.58 |
| $T_{12}$ | 18.74 | 29.09 | 47.9 | 31.91 | 14.76 | 18.81 | 22.36 | 18.64 |
| $T_{13}$ | 15.57 | 25.65 | 31.0 | 24.07 | 10.89 | 14.49 | 18.70 | 14.69 |
| $T_{14}$ | 15.61 | 25.72 | 31.5 | 24.28 | 10.76 | 14.47 | 18.08 | 14.44 |
| $T_{15}$ | 14.95 | 25.70 | 30.5 | 23.72 | 11.05 | 14.70 | 18.15 | 14.63 |
| $T_{16}$ | 14.99 | 25.71 | 31.0 | 23.90 | 11.09 | 14.75 | 18.91 | 14.92 |
| Mean | 16.19 | 27.37 | 39.28 | 27.61 | 13.04 | 16.97 | 20.59 | 16.87 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.56 | 1.12 | 0.90 | 1.80 | 1.57 | 3.12 | 0.26 | 0.52 | 0.18 | 0.36 | 0.52 | 1.64 |

The composted agrowastes with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) also significantly increased this parameter over control in all the stages.

The mean values for plant fresh weight of cowpea plants from vegetative to harvest stages ranged from 16.19 g to 39.28 g.

The fresh weight of cluster bean plants at vegetative stage was significantly enhanced by the composts ($T_4$, $T_5$ and $T_6$) and composts along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) over control, being on par with $T_7$ and $T_8$ in which farm yard manure at the rate of 12.5 t $ha^{-1}$ and 100 per cent NPK were added respectively.

The undecomposed agrowastes ($T_2$ and $T_3$) had a marginal effect on this parameter during all the stages.

From flowering to harvest stages, 100 per cent NPK ($T_8$) had a very significant increase on this parameter over control and all the other treatments.

The composted coirpith ($T_4$), composted bagasse ($T_5$) and composted coffee waste ($T_6$) also favourably influenced the plant fresh weight over control, being on par with each other from flowering stage to harvest stage.

The composts along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) showed a marked variation in this parameter over control at flowering and harvest stages.

The mean values for the plant fresh weight of cluster bean plants varied from 13.04 g to 20.5 g from vegetative to harvest stages.

**4.6.1.6. Influence of treatments on the plant dry weight of test crops (Table 16 ; Figure 10)**

During all the stages of growth of cowpea plants, the incorporation of composted bagasse and composted coffee waste along with 100 per cent NPK ($T_{11}$ and $T_{12}$) positively enhanced the plant dry weight than the control and other treatments.

The undecomposed agrowastes ($T_2$, $T_3$, $T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) showed marginal effect on this parameter, being on par with each other failed to show any significant differences when compared to control.

The mean values recorded for this parameter from vegetative to harvest stages ranged from 10.91 g to 24.92 g.

In cluster bean, during vegetative stage, the dry weight of plant was spectacularly increased with the application of farm yard manure ($T_7$), 100 per cent NPK ($T_8$), composted bagasse and coffee waste along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) when compared to control and other treatments.

The composted coirpith ($T_4$), composted bagasse ($T_5$) and the composted coffee waste ($T_6$) added treatments also significantly increased the plant dry weight over control.

**Table 16. Plant dry weight of test crops as influenced by treatments (g)**

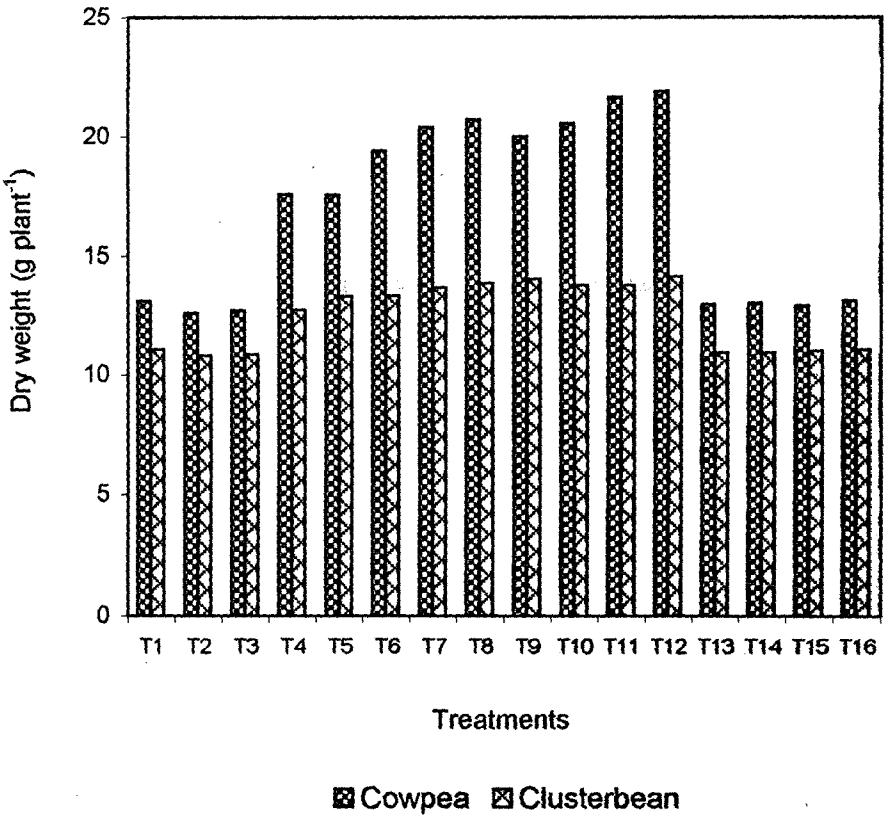
(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 8.93 | 11.97 | 18.50 | 13.13 | 7.67 | 10.89 | 14.06 | 11.04 |
| $T_2$ | 8.97 | 11.37 | 17.51 | 12.62 | 7.56 | 10.65 | 14.14 | 10.78 |
| $T_3$ | 8.92 | 11.44 | 17.80 | 12.72 | 7.61 | 10.75 | 14.15 | 10.84 |
| $T_4$ | 11.24 | 14.52 | 27.01 | 17.59 | 9.14 | 12.14 | 16.95 | 12.74 |
| $T_5$ | 10.98 | 14.74 | 27.00 | 17.57 | 9.96 | 12.99 | 17.04 | 13.33 |
| $T_6$ | 11.36 | 17.74 | 29.20 | 19.43 | 9.21 | 13.15 | 17.74 | 13.37 |
| $T_7$ | 11.67 | 17.57 | 32.00 | 20.41 | 10.48 | 13.10 | 17.58 | 13.72 |
| $T_8$ | 12.75 | 17.60 | 31.80 | 20.72 | 10.38 | 13.20 | 18.09 | 13.89 |
| $T_9$ | 12.92 | 17.62 | 29.50 | 20.01 | 10.35 | 13.35 | 18.54 | 14.08 |
| $T_{10}$ | 13.08 | 17.94 | 30.70 | 20.57 | 10.44 | 13.08 | 17.92 | 13.81 |
| $T_{11}$ | 14.10 | 18.91 | 31.90 | 21.64 | 10.20 | 13.15 | 18.07 | 13.81 |
| $T_{12}$ | 14.25 | 18.82 | 32.60 | 21.89 | 10.52 | 13.25 | 18.82 | 14.20 |
| $T_{13}$ | 8.75 | 12.02 | 18.22 | 13.00 | 7.94 | 10.76 | 14.05 | 10.92 |
| $T_{14}$ | 8.91 | 11.95 | 18.25 | 13.04 | 7.89 | 10.68 | 14.15 | 10.91 |
| $T_{15}$ | 8.75 | 11.92 | 18.15 | 12.94 | 7.80 | 10.95 | 14.21 | 10.99 |
| $T_{16}$ | 8.99 | 11.95 | 18.52 | 13.15 | 7.93 | 10.97 | 14.22 | 11.04 |
| Mean | 10.91 | 14.88 | 24.92 | 95.60 | 9.07 | 12.07 | 15.61 | 12.25 |

| | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD(5%) | SE (D) | CD (5%) | SE (D) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.02 | 2.05 | 1.67 | 3.34 | 2.05 | 4.10 | 0.98 | 1.96 | 1.00 | 2.01 | 1.21 | 2.43 |

**Figure 10**

**Plant dry weight of test crops as influenced by treatments**



From flowering to harvest stages, the composts applied alone ($T_4$, $T_5$ and $T_6$) or along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) positively enhanced this parameter over control being on par with farm yard manure ($T_7$) and 100 per cent NPK ($T_8$) .

The undecomposed agrowaste incorporated treatments did not show any marked effect on plant dry weight during flowering and harvest stages.

The mean values for this parameter ranged from 9.07 g to 15.61 g from vegetative to harvest stages in cluster bean plants.

#### 4.6.1.7. Influence of treatments on yield parameters of test crops (Table 17; Figures 11 & 12)

The yield parameters such as number of pods per plant, pod length, pod fresh weight, pod dry weight, number of grains per pod, haulm weight and grain yield were positively enhanced by the composted agro wastes without and with 50 and 100 per cent NPK ($T_4$, $T_5$, $T_6$, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) over control and other treatments in both the test crops.

##### 4.6.1.7.1. Influence of treatments on number of pods

In cowpea, the composted coffee waste along with 100 per cent NPK ($T_{12}$) spectacularly increased the number of pods per plant over control and being on par with 100 per cent NPK ($T_8$) added treatment. The other treatments that markedly

**Table 17. Yield parameters of test crops as influenced by treatments**

(Mean of three replications)

| Treat-ments | Cowpea | | | | | | | Cluster bean | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of pods/ plant | Pod length (cm) | Pod FW (g) | Pod DW (g) | No. of grains/ pod | Haulm weight (g) | Grain yield (gm) | No. of pods/ plant | Pod length (cm) | Pod FW (g) | Pod DW (g) | No. of grains/ pod | Haulm weight (gm) | Grain yield (gm) |
| $T_1$ | 16.7 | 13.5 | 35.77 | 28.87 | 12.5 | 13.0 | 12.45 | 14.3 | 8.9 | 24.98 | 11.75 | 8.3 | 6.11 | 5.01 |
| $T_2$ | 18.3 | 13.7 | 33.01 | 28.08 | 12.1 | 14.1 | 12.07 | 14.0 | 9.0 | 25.01 | 12.48 | 8.4 | 6.95 | 5.07 |
| $T_3$ | 18.6 | 13.5 | 34.98 | 29.03 | 12.6 | 14.3 | 12.61 | 13.7 | 9.0 | 24.75 | 12.43 | 8.3 | 7.00 | 5.09 |
| $T_4$ | 25.3 | 15.0 | 56.25 | 39.34 | 19.6 | 20.1 | 19.50 | 27.0 | 11.4 | 31.90 | 21.89 | 12.0 | 10.58 | 9.25 |
| $T_5$ | 24.0 | 15.2 | 52.98 | 38.41 | 18.3 | 20.1 | 18.27 | 25.0 | 10.9 | 30.40 | 20.64 | 14.0 | 9.75 | 9.26 |
| $T_6$ | 32.3 | 15.0 | 56.06 | 39.92 | 20.1 | 17.1 | 20.08 | 27.0 | 10.9 | 31.90 | 21.72 | 14.7 | 10.25 | 9.92 |
| $T_7$ | 36.0 | 15.5 | 53.75 | 36.75 | 19.8 | 16.5 | 19.75 | 27.0 | 11.5 | 35.40 | 24.50 | 11.7 | 10.75 | 9.95 |
| $T_8$ | 38.0 | 15.7 | 60.05 | 39.45 | 19.5 | 19.9 | 19.50 | 25.0 | 11.5 | 38.25 | 25.01 | 13.7 | 10.79 | 9.75 |
| $T_9$ | 26.7 | 15.7 | 59.44 | 39.25 | 19.1 | 19.0 | 19.05 | 25.0 | 11.5 | 35.39 | 24.11 | 14.0 | 9.64 | 9.80 |
| $T_{10}$ | 35.0 | 15.7 | 61.02 | 39.79 | 20.2 | 19.7 | 20.05 | 27.0 | 11.6 | 34.99 | 24.10 | 14.3 | 10.95 | 9.27 |
| $T_{11}$ | 30.3 | 15.9 | 60.10 | 39.75 | 20.0 | 18.5 | 20.00 | 26.0 | 11.6 | 35.75 | 25.01 | 14.0 | 11.01 | 10.80 |
| $T_{12}$ | 38.0 | 15.8 | 60.31 | 39.95 | 20.3 | 18.7 | 21.10 | 28.0 | 11.6 | 35.98 | 26.25 | 14.7 | 11.17 | 10.35 |
| $T_{13}$ | 17.3 | 13.9 | 35.75 | 29.22 | 12.2 | 14.1 | 13.05 | 14.0 | 9.0 | 23.98 | 12.75 | 10.0 | 6.92 | 5.48 |
| $T_{14}$ | 16.7 | 14.0 | 35.32 | 29.75 | 12.3 | 14.2 | 13.05 | 14.0 | 8.9 | 24.26 | 12.16 | 9.7 | 6.75 | 5.51 |
| $T_{15}$ | 17.7 | 14.0 | 36.09 | 28.90 | 12.3 | 14.2 | 13.11 | 14.0 | 8.9 | 24.68 | 12.11 | 10.0 | 6.61 | 5.64 |
| $T_{16}$ | 17.7 | 14.0 | 36.00 | 28.92 | 12.4 | 14.1 | 13.75 | 14.0 | 8.9 | 25.01 | 13.01 | 10.3 | 6.73 | 5.52 |
| Mean | 25.53 | 14.76 | 47.93 | 37.20 | 16.46 | 16.73 | 16.52 | 20.94 | 12.33 | 30.20 | 18.72 | 12.40 | 8.90 | 7.90 |
| SEd | 1.02 | 0.05 | 0.97 | 1.00 | 0.55 | 0.32 | 0.99 | 1.21 | 0.03 | 1.07 | 1.11 | 0.56 | 0.39 | 1.01 |
| CD (5%) | 2.05 | 0.12 | 1.95 | 2.01 | 1.10 | 0.65 | 1.98 | 2.42 | 0.07 | 2.14 | 2.23 | 1.12 | 0.78 | 2.02 |

**Figure 11**
**Yield parameters of cowpea as influenced by treatments**

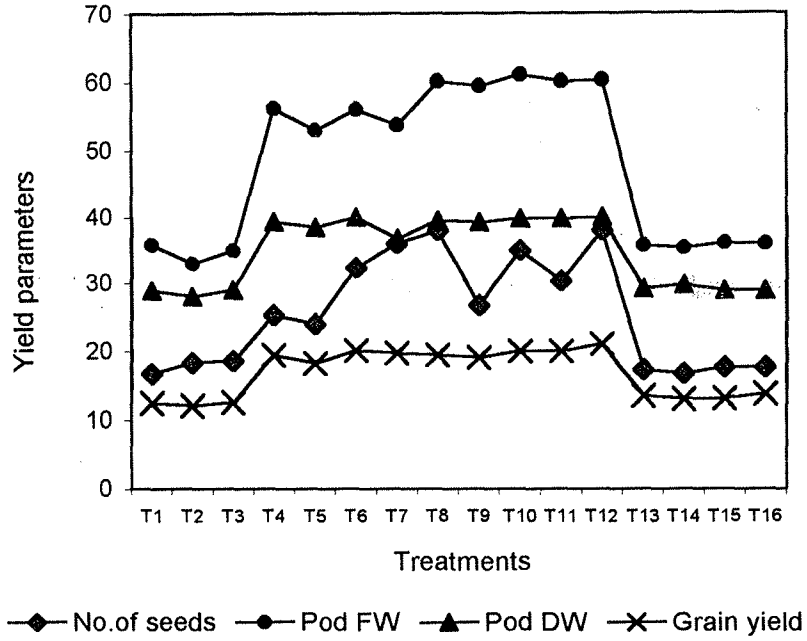
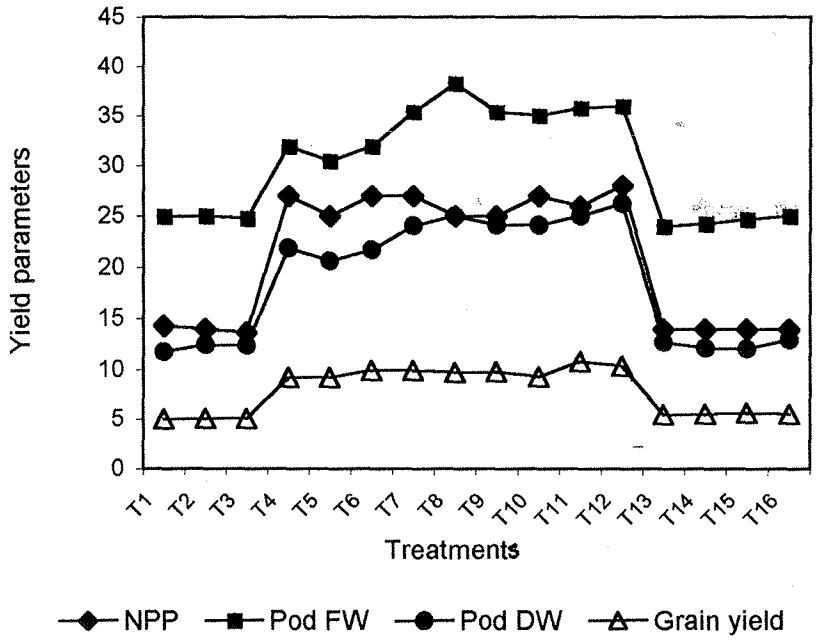



**Figure 12**
**Yield parameters of cluster bean as influenced by treatments**



influenced this parameter were the composts alone ($T_4$, $T_5$ and $T_6$), farm yard manure ($T_7$) ; composted bagasse with 50 and 100 per cent NPK ($T_9$ and $T_{11}$) and composted coffee waste with 50 per cent NPK ($T_{10}$) which showed variations among themselves.

In cluster bean, this parameter was significantly increased in the composted coirpith ($T_4$), composted bagasse ($T_5$), composted coffee waste ($T_6$), farm yard manure ($T_7$) and 100 per cent NPK ($T_8$) over control. The composts in combination with 50 and 100 per cent NPK also positively influenced this parameter over control.

All the other treatments were on par with the control and failed to show any marked variation between them.

**4.6.1.7.2. Influence of treatments on pod length**

The pod length of cowpea was markedly influenced by the composts alone at 12.5 t $ha^{-1}$ and along with 50 and 100 per cent NPK over control being on par with that of farm yard manure ($T_7$) and 100 per cent NPK ($T_8$). All the other treatments though had a marginal effect on this parameter but being on par with each other did not show any salient differences between them.

In cluster bean plants, this parameter was significantly influenced by all the treatments except the undecomposed agrowastes added treatments.

#### 4.6.1.7.3. Influence of treatments on pod fresh weight per plant

In cowpea, pod fresh weight per plant was significantly improved by all the treatments except the undecomposed agrowastes ($T_2$ and $T_3$) when compared with the control.

Pod fresh weight of cluster bean plants was positively enhanced by the composted agrowastes along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) over control.

#### 4.6.1.7.4. Influence of treatments on pod dry weight per plant

This parameter was positively enhanced by all the treatments over control except the undecomposed agrowastes alone at the rate of 12.5 t $ha^{-1}$ ($T_2$ and $T_3$) and along with 50 and 100% NPK ($T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) in cowpea and cluster bean plants.

#### 4.6.1.7.5. Influence of treatments on number of grains per pod

In cowpea, more number of grains per pod was recorded in the composted coffee waste along with 50 and 100 per cent NPK ($T_{10}$ and $T_{12}$) and composted bagasse along with 100 per cent NPK ($T_{11}$) over control and being on par with composted coffee waste alone applied at the rate of 12.5 t $ha^{-1}$ ($T_6$).

In cluster bean, this parameter was profoundly increased by the composted coirpith ($T_4$) composted bagasse ($T_5$) composted coffee waste ($T_6$), farm yard

manure ($T_7$) and 100 per cent NPK ($T_8$) over control and other treatments. The biocomposts along with 50 and 100 per cent NPK ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) also markedly influenced this parameter.

**4.6.1.7.6. Influence of treatments on haulm weight per plant**

The composted coirpith ($T_4$), composted bagasse ($T_5$) applied at the rate of 12.5 t $ha^{-1}$ were highly significant in improving the haulm weight over control and all the other treatments in cowpea plants.

The haulm weight of cluster bean plants was markedly influenced by all the treatments over control. The undecomposed agrowastes incorporated treatments (with and without 50 and 100 per cent NPK) also had a marginal effect on this parameter.

**4.6.1.7.7. Influence of treatments on grain yield per plant**

Grain yield of cowpea plants was enhanced spectacularly by the application of composted coffee waste at the rate of 12.5 t $ha^{-1}$ along with 100 per cent NPK ($T_{12}$). All the other treatments also had a marked effect on this parameter over control and they were comparable among themselves.

The undecomposed agrowastes at 12.5 t ha-1 ($T_2$ and $T_3$) insignificantly influenced this parameters whereas their combination with 50 and 100 per cent NPK had a marginal effect on grain yield.

The grain yield of cluster bean crop was positively enhanced in the composted bagasse ($T_{11}$) along with 100 per cent NPK and composted coffee waste along with 100 per cent NPK ($T_{12}$) over control and all the other treatments.

### 4.6.2. Post harvest soil analysis

#### 4.6.2.1. Influence of treatments on the soil reaction and electrical conductivity

The pH of first pot culture experimental soil samples varied from 6.5 to 7.3 at vegetative, 7.0 to 7.5 at flowering and 7.4 to 8.1 at harvest stages in cowpea; 6.4 to 7.0 at vegetative, 6.8 to 7.3 at flowering and 7.2 to 7.9 at harvest stages in cluster bean.

The electrical conductivity values ranged from 0.49 to 0.58 $dSm^{-1}$ at vegetative, 0.54 to 0.62 $dSm^{-1}$ at flowering and 0.57 to 0.65 $dSm^{-1}$ at harvest stages in cowpea; 0.48 to 0.53 $dSm^{-1}$ at vegetative, 0.50 to 0.55 $dSm^{-1}$ at flowering and 0.52 to 0.56 $dSm^{-1}$ at harvest stages in cluster bean.

#### 4.6.2.2. Influence of treatments on soil physical constants (Table 18)

The bulk density value was ranging from 1.10 $gcc^{-1}$ ($T_6$) to 1.29 $gcc^{-1}$ ($T_2$, $T_8$, $T_{14}$, $T_{15}$ and $T_{16}$) in cowpea and 1.12 g cc-1 ($T_5$) to 1.33 g cc-1 ($T_8$) in cluster bean.

The water holding capacity of experimental soil was ranging from 46.50 per cent ($T_{15}$) to 55.01 per cent ($T_7$) in cowpea and 47.05 per cent ($T_2$) to 53.75 ($T_6$) in cluster bean.

**Table 18. Soil physical constants for test crops as influenced by treatments**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | Bulk density (g $cc^{-1}$) | Water holding capacity (%) | Porosity (%) | Volume expansion on wetting (%) | Bulk density (g $cc^{-1}$) | Water holding capacity (%) | Porosity (%) | Volume expansion on wetting (%) |
| $T_1$ | 1.27 | 47.39 | 49.92 | 52.25 | 1.30 | 47.28 | 47.99 | 50.01 |
| $T_2$ | 1.29 | 46.75 | 50.00 | 52.40 | 1.31 | 47.05 | 48.01 | 51.25 |
| $T_3$ | 1.28 | 46.98 | 50.01 | 52.75 | 1.30 | 47.20 | 48.00 | 51.10 |
| $T_4$ | 1.12 | 53.75 | 57.21 | 43.33 | 1.15 | 51.55 | 53.91 | 45.10 |
| $T_5$ | 1.15 | 53.09 | 56.70 | 44.50 | 1.19 | 50.70 | 52.15 | 47.25 |
| $T_6$ | 1.10 | 53.73 | 58.15 | 43.06 | 1.12 | 51.02 | 53.75 | 45.00 |
| $T_7$ | 1.12 | 55.01 | 57.80 | 43.05 | 1.16 | 53.75 | 54.00 | 46.10 |
| $T_8$ | 1.29 | 47.05 | 49.85 | 53.20 | 1.33 | 47.12 | 47.50 | 51.00 |
| $T_9$ | 1.20 | 54.00 | 57.25 | 45.33 | 1.19 | 51.75 | 52.05 | 47.75 |
| $T_{10}$ | 1.18 | 54.75 | 57.55 | 44.25 | 1.16 | 52.01 | 53.55 | 48.00 |
| $T_{11}$ | 1.17 | 52.82 | 57.01 | 43.63 | 1.16 | 51.10 | 53.00 | 47.01 |
| $T_{12}$ | 1.18 | 53.15 | 56.98 | 43.65 | 1.16 | 51.25 | 52.98 | 47.15 |
| $T_{13}$ | 1.28 | 47.15 | 49.95 | 50.15 | 1.29 | 47.29 | 48.00 | 50.15 |
| $T_{14}$ | 1.29 | 47.00 | 50.01 | 51.70 | 1.30 | 47.35 | 48.15 | 51.01 |
| $T_{15}$ | 1.29 | 46.50 | 50.05 | 50.02 | 1.29 | 47.11 | 48.16 | 51.00 |
| $T_{16}$ | 1.29 | 46.75 | 50.07 | 51.79 | 1.31 | 48.00 | 48.42 | 52.12 |
| Mean | 1.22 | 50.35 | 53.66 | 47.82 | 1.23 | 49.47 | 50.59 | 48.87 |
| SEd | 0.03 | 0.37 | 2.06 | 0.05 | 0.04 | 0.21 | 0.35 | 0.46 |
| CD(5%) | 0.06 | 0.74 | 4.20 | 0.10 | 0.07 | 0.42 | 0.72 | 0.43 |

The soil porosity values ranged from 49.85 per cent ($T_8$) to 57.55 per cent ($T_{10}$) in cowpea and 47.48 per cent ($T_1$) to 53.91 per cent ($T_4$) in cluster bean.

The volume expansion of experimental soil was ranging from 43.05 per cent ($T_7$) to 53.20 per cent ($T_8$) in cowpea and 45 per cent ($T_6$) to 52.15 per cent ($T_{16}$) in cluster bean.

#### 4.6.2.3. Influence of treatments on soil organic carbon and organic matter content (Table 19)

The organic carbon content after harvesting the crop was ranging from 0.81 per cent ($T_{15}$ and $T_{16}$) to 1.07 per cent ($T_7$) in cowpea and 0.85 per cent ($T_2$, $T_{13}$ and $T_{15}$) to 1.02 per cent ($T_{12}$) in cluster bean. The organic matter content of the post harvest soil samples varied from 1.37 per cent ($T_{16}$) to 1.85 per cent ($T_7$) in cowpea and 1.44 per cent ($T_2$ and $T_{16}$) to 1.73 per cent ($T_{12}$) in cluster bean.

#### 4.6.2.4. Influence of treatments on soil available NPK status (Tables 20 & 21)

The trend of results obtained for available nitrogen in cowpea was decreasing as the stage advances. The nitrogen content was highly influenced by composted bagasse along with 100 per cent NPK ($T_{11}$) added treatment during all the stages.

The phosphorus content varied from 12.5 ppm ($T_2$) to 18.7 ppm ($T_{11}$) at vegetative stage 11.0 ppm ($T_1$) to 16.2 ppm ($T_{11}$) at flowering stage and 10.6 ppm ($T_2$) to 15.6 ppm ($T_{11}$) at harvest stage.

**Table 19. Soil organic carbon and organic matter for test crops as influenced by treatments (percent)**

(Mean of three replications)

| Treatments | Cowpea | | Cluster bean | |
|---|---|---|---|---|
| | Organic carbon | Organic matter | Organic carbon | Organic matter |
| $T_1$ | 0.93 | 1.60 | 0.89 | 1.51 |
| $T_2$ | 0.94 | 1.61 | 0.85 | 1.44 |
| $T_3$ | 0.92 | 1.59 | 0.88 | 1.50 |
| $T_4$ | 1.03 | 1.78 | 0.99 | 1.68 |
| $T_5$ | 1.01 | 1.73 | 1.0 | 1.70 |
| $T_6$ | 1.05 | 1.80 | 1.00 | 1.70 |
| $T_7$ | 1.07 | 1.85 | 0.99 | 1.68 |
| $T_8$ | 0.86 | 1.48 | 0.89 | 1.51 |
| $T_9$ | 1.00 | 1.70 | 1.00 | 1.70 |
| $T_{10}$ | 1.01 | 1.74 | 1.01 | 1.72 |
| $T_{11}$ | 1.00 | 1.72 | 1.00 | 1.70 |
| $T_{12}$ | 1.00 | 1.70 | 1.02 | 1.73 |
| $T_{13}$ | 0.82 | 1.41 | 0.85 | 1.45 |
| $T_{14}$ | 0.83 | 1.43 | 0.87 | 1.48 |
| $T_{15}$ | 0.81 | 1.39 | 0.88 | 1.50 |
| $T_{16}$ | 0.81 | 1.37 | 0.85 | 1.44 |
| Mean | 0.94 | 1.62 | 0.88 | 1.59 |
| SEd | 0.04 | 0.01 | 0.01 | 0.03 |
| CD(5%) | 0.08 | 0.03 | 0.02 | 0.06 |

**Table 20. Soil available NPK for cowpea as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Nitrogen | | | | Phosphorus | | | | Potassium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 5.1 | 4.8 | 4.5 | 4.8 | 12.7 | 11.0 | 10.7 | 11.5 | 89 | 85 | 80 | 84.5 |
| $T_2$ | 5.2 | 5.0 | 4.6 | 4.9 | 12.5 | 11.5 | 10.6 | 11.5 | 87 | 83 | 78 | 83.0 |
| $T_3$ | 5.5 | 5.2 | 5.0 | 5.2 | 13.0 | 12.2 | 11.0 | 12.1 | 89 | 87 | 83 | 86.8 |
| $T_4$ | 9.7 | 8.2 | 6.5 | 8.1 | 15.1 | 13.5 | 13.0 | 13.9 | 141 | 125 | 112 | 126.0 |
| $T_5$ | 8.9 | 8.0 | 7.2 | 8.0 | 15.0 | 14.2 | 13.5 | 14.2 | 138 | 120 | 110 | 122.7 |
| $T_6$ | 9.5 | 8.7 | 7.2 | 8.5 | 15.9 | 14.8 | 14.0 | 15.0 | 145 | 136 | 129 | 136.7 |
| $T_7$ | 9.2 | 8.5 | 7.2 | 8.3 | 15.5 | 14.2 | 13.5 | 14.4 | 147 | 136 | 129 | 137.3 |
| $T_8$ | 6.5 | 5.2 | 4.7 | 5.5 | 13.1 | 12.1 | 11.2 | 12.1 | 140 | 131 | 109 | 126.6 |
| $T_9$ | 9.9 | 8.7 | 7.5 | 8.7 | 16.5 | 15.7 | 14.1 | 15.4 | 145 | 135 | 127 | 135.7 |
| $T_{10}$ | 9.5 | 8.5 | 7.3 | 8.4 | 16.7 | 15.5 | 14.2 | 15.5 | 147 | 135 | 128 | 136.7 |
| $T_{11}$ | 10.1 | 9.2 | 7.7 | 9.0 | 18.7 | 16.2 | 15.6 | 16.9 | 143 | 130 | 115 | 129.3 |
| $T_{12}$ | 10.0 | 8.8 | 7.8 | 8.9 | 16.5 | 15.4 | 14.2 | 15.4 | 141 | 129 | 117 | 129.0 |
| $T_{13}$ | 5.7 | 5.2 | 4.7 | 5.2 | 12.6 | 11.9 | 11.2 | 12.0 | 101 | 95 | 88 | 95.0 |
| $T_{14}$ | 6.0 | 5.3 | 4.9 | 5.4 | 13.0 | 11.7 | 11.0 | 12.0 | 100 | 92 | 85 | 92.0 |
| $T_{15}$ | 5.8 | 5.1 | 4.8 | 5.2 | 12.8 | 12.0 | 11.5 | 12.1 | 105 | 96 | 90 | 97.0 |
| $T_{16}$ | 5.7 | 5.1 | 4.8 | 5.2 | 13.5 | 12.2 | 11.5 | 12.4 | 103 | 96 | 91 | 97.0 |
| Mean | 7.6 | 6.8 | 6.0 | 6.8 | 14.6 | 13.4 | 12.5 | 12.5 | 122.6 | 113.2 | 104.44 | 113.4 |

| | SED | CD(5%) | SED | CD(5%) | SED | CD(5%) |
|---|---|---|---|---|---|---|
| D | 0.06 | 0.12 | 0.11 | 0.22 | 0.87 | 1.74 |
| T | 0.10 | 0.20 | 0.15 | 0.31 | 1.26 | 2.52 |
| D x T | 0.15 | 0.32 | 0.26 | 0.58 | 2.28 | 4.57 |

**Table 21. Soil available NPK for cluster bean as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Nitrogen | | | | Phosphorus | | | | Potassium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.0 | 5.5 | 5.2 | 5.6 | 12.5 | 11.2 | 10.5 | 11.4 | 85 | 80 | 75 | 80 |
| $T_2$ | 6.5 | 6.0 | 5.4 | 6.0 | 13.0 | 12.0 | 11.1 | 12.0 | 85 | 81 | 75 | 80 |
| $T_3$ | 6.3 | 6.1 | 5.7 | 6.0 | 12.9 | 12.5 | 11.2 | 12.2 | 86 | 80 | 78 | 81 |
| $T_4$ | 8.8 | 7.6 | 7.0 | 7.8 | 17.0 | 15.1 | 12.9 | 15.0 | 99 | 90 | 86 | 92 |
| $T_5$ | 9.0 | 8.5 | 7.1 | 8.2 | 15.5 | 14.0 | 12.2 | 13.9 | 101 | 92 | 85 | 93 |
| $T_6$ | 8.8 | 7.8 | 7.1 | 7.9 | 18.7 | 16.2 | 14.7 | 16.5 | 115 | 102 | 94 | 104 |
| $T_7$ | 8.5 | 8.0 | 7.0 | 7.8 | 15.7 | 14.5 | 13.0 | 14.4 | 125 | 119 | 108 | 117 |
| $T_8$ | 8.3 | 7.0 | 6.0 | 7.1 | 15.0 | 14.2 | 12.1 | 13.8 | 100 | 90 | 82 | 91 |
| $T_9$ | 8.7 | 7.7 | 6.5 | 7.6 | 15.7 | 14.5 | 12.7 | 14.3 | 109 | 94 | 90 | 98 |
| $T_{10}$ | 8.8 | 7.7 | 6.9 | 7.8 | 16.0 | 15.1 | 13.2 | 14.8 | 120 | 115 | 95 | 110 |
| $T_{11}$ | 9.0 | 8.7 | 8.0 | 8.6 | 18.8 | 16.0 | 14.0 | 16.3 | 121 | 118 | 97 | 112 |
| $T_{12}$ | 9.0 | 8.7 | 8.1 | 8.6 | 19.0 | 15.8 | 14.2 | 16.3 | 127 | 120 | 115 | 121 |
| $T_{13}$ | 7.5 | 6.4 | 6.1 | 6.7 | 14.0 | 13.2 | 11.5 | 12.9 | 90 | 85 | 80 | 85 |
| $T_{14}$ | 7.4 | 6.2 | 5.9 | 6.7 | 13.9 | 12.9 | 11.7 | 12.8 | 91 | 84 | 81 | 85 |
| $T_{15}$ | 8.0 | 7.2 | 6.5 | 7.2 | 13.5 | 12.4 | 11.4 | 12.4 | 90 | 82 | 78 | 83 |
| $T_{16}$ | 8.0 | 7.0 | 6.4 | 7.1 | 13.5 | 12.5 | 11.5 | 12.5 | 91 | 85 | 80 | 85 |
| Mean | 8.03 | 7.25 | 6.55 | 7.3 | 15.29 | 13.9 | 12.4 | 13.8 | 102.9 | 95 | 87 | 95 |

| | SED | CD (5%) | SED | CD (5%) | SED | CD (5%) |
|---|---|---|---|---|---|---|
| S | 0.11 | 0.23 | 0.23 | 0.47 | 1.69 | 3.48 |
| T | 0.19 | 0.38 | 0.28 | 0.55 | 0.86 | 1.78 |
| S x T | 0.31 | 0.64 | 0.52 | 1.04 | 1.98 | 3.96 |

The available potassium values were ranging from 87 ppm ($T_2$) to 147 ppm ($T_7$ and $T_{10}$) at vegetative, 83 ppm ($T_2$) to 136 ppm ($T_6$ and $T_7$) at flowering and 78 ppm ($T_2$) to 129 ppm ($T_6$ and $T_7$) at harvest stages.

The available nitrogen values obtained for cluster bean has been ranging from 6.0 ppm ($T_1$) to 9.0 ppm ($T_5$, $T_{11}$ and $T_{12}$) at vegetative, 5.5 ppm ($T_1$) to 8.7 ppm ($T_{11}$ and $T_{12}$) at flowering and 5.2 ($T_1$) to 8.1 ppm ($T_{12}$) at harvest stages.

The values for the available phosphorus ranged from 12.5 ppm ($T_1$) to 19.0 ppm ($T_{12}$) at vegetative, 11.2 ppm ($T_1$) to 16.2 ppm ($T_6$) at flowering and 10.5 ppm ($T_1$) to 14.7 ppm ($T_6$) at harvest stages. Compared to all the other treatments, the $T_6$ in which composted coffee waste applied at the rate of 12.5 t $ha^{-1}$ had a positive influence on available phosphorus.

The potassium content of the soil was ranging from 85 ppm ($T_1$) to 127 ppm ($T_{12}$) at vegetative, 80 ($T_1$ and $T_3$) to 120 ppm ($T_{12}$) at flowering and 75 ppm ($T_1$) to 115 ppm ($T_{12}$) at harvest stages.

When compared to control, all the treatments had a favourable influence on this parameter. Among the treatments composted coffee waste without NPK ($T_6$) and with 100 per cent NPK ($T_{12}$) very significantly increased this parameter.

#### 4.6.2.5. Influence of treatments on soil available micronutrients (Tables 22 & 23)

After harvesting cowpea crop, an increase in available micronutrients such

**Table 22. Soil available micronutrients for cowpea as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Iron (Fe) | | | | Manganese (Mn) | | | | Copper (Cu) | | | | Zinc (Zn) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 7.1 | 6.2 | 5.3 | 6.2 | 5.2 | 4.5 | 4.0 | 4.6 | 0.15 | 0.12 | 0.09 | 0.12 | 0.14 | 0.09 | 0.04 | 0.09 |
| $T_2$ | 7.0 | 6.4 | 5.4 | 6.3 | 5.5 | 4.5 | 3.9 | 4.6 | 0.17 | 0.13 | 0.09 | 0.13 | 0.16 | 0.08 | 0.03 | 0.09 |
| $T_3$ | 7.3 | 6.3 | 5.3 | 6.3 | 5.4 | 4.4 | 3.9 | 4.6 | 0.19 | 0.14 | 0.11 | 0.15 | 0.18 | 0.09 | 0.05 | 0.11 |
| $T_4$ | 8.5 | 7.4 | 6.7 | 7.5 | 7.2 | 6.0 | 5.0 | 6.1 | 0.39 | 0.27 | 0.20 | 0.25 | 0.42 | 0.32 | 0.21 | 0.32 |
| $T_5$ | 8.8 | 7.6 | 6.8 | 7.7 | 7.3 | 6.1 | 5.2 | 6.2 | 0.40 | 0.28 | 0.20 | 0.29 | 0.44 | 0.30 | 0.18 | 0.31 |
| $T_6$ | 9.3 | 8.3 | 7.2 | 8.3 | 7.3 | 6.1 | 5.1 | 6.2 | 0.41 | 0.29 | 0.19 | 0.29 | 0.46 | 0.32 | 0.19 | 0.32 |
| $T_7$ | 9.5 | 8.4 | 6.9 | 8.3 | 7.5 | 6.2 | 5.7 | 6.5 | 0.42 | 0.30 | 0.24 | 0.32 | 0.60 | 0.41 | 0.22 | 0.41 |
| $T_8$ | 7.7 | 7.0 | 5.9 | 6.9 | 6.4 | 5.3 | 4.1 | 5.3 | 0.25 | 0.13 | 0.10 | 0.16 | 0.23 | 0.15 | 0.07 | 0.15 |
| $T_9$ | 8.9 | 7.8 | 6.0 | 7.6 | 7.3 | 6.1 | 5.1 | 6.2 | 0.40 | 0.29 | 0.18 | 0.29 | 0.52 | 0.34 | 0.19 | 0.35 |
| $T_{10}$ | 9.1 | 8.0 | 6.2 | 7.8 | 7.4 | 6.0 | 5.0 | 6.1 | 0.41 | 0.29 | 0.19 | 0.29 | 0.51 | 0.36 | 0.21 | 0.36 |
| $T_{11}$ | 9.2 | 7.9 | 6.1 | 7.7 | 7.5 | 6.0 | 5.1 | 6.2 | 0.41 | 0.29 | 0.19 | 0.29 | 0.50 | 0.35 | 0.20 | 0.35 |
| $T_{12}$ | 9.1 | 8.1 | 6.2 | 7.8 | 7.5 | 6.1 | 5.2 | 6.3 | 0.40 | 0.30 | 0.21 | 0.30 | 0.52 | 0.36 | 0.22 | 0.36 |
| $T_{13}$ | 7.4 | 6.5 | 5.5 | 6.5 | 5.6 | 4.8 | 4.1 | 4.8 | 0.20 | 0.15 | 0.11 | 0.15 | 0.21 | 0.15 | 0.08 | 0.15 |
| $T_{14}$ | 7.5 | 6.7 | 5.3 | 6.5 | 5.5 | 4.8 | 4.2 | 4.8 | 0.19 | 0.14 | 0.10 | 0.14 | 0.20 | 0.16 | 0.08 | 0.15 |
| $T_{15}$ | 7.7 | 6.8 | 5.6 | 6.7 | 5.6 | 4.9 | 4.2 | 4.9 | 0.20 | 0.15 | 0.10 | 0.15 | 0.23 | 0.14 | 0.06 | 0.14 |
| $T_{16}$ | 7.7 | 6.7 | 5.7 | 6.7 | 5.6 | 4.8 | 4.0 | 4.8 | 0.21 | 0.15 | 0.11 | 0.16 | 0.25 | 0.16 | 0.09 | 0.17 |
| Mean | 7.7 | 7.3 | 6.0 | 7.0 | 6.5 | 5.7 | 4.9 | 5.7 | 0.29 | 0.22 | 0.15 | 0.22 | 0.35 | 0.24 | 0.13 | 0.24 |

| | SE | CD (5%) | SE | CD (5%) | SE | CD (5%) | SE | CD (5%) |
|---|---|---|---|---|---|---|---|---|
| S | 0.04 | 0.09 | 0.03 | 0.06 | 0.02 | 0.04 | 0.04 | 0.08 |
| T | 0.02 | 0.05 | 0.05 | 0.11 | 0.04 | 0.08 | 0.07 | 0.13 |
| S x T | 0.07 | 0.15 | 0.09 | 0.18 | 0.07 | 0.14 | 0.09 | 0.29 |

**Table 23. Soil available micronutrients for cluster bean as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Iron (Fe) | | | | Manganese (Mn) | | | | Copper (Cu) | | | | Zinc (Zn) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.0 | 5.0 | 4.4 | 5.1 | 4.9 | 4.0 | 3.5 | 4.1 | 0.11 | 0.06 | 0.05 | 0.07 | 0.10 | 0.04 | 0.02 | 0.06 |
| $T_2$ | 6.2 | 5.4 | 5.2 | 5.6 | 5.4 | 5.0 | 4.3 | 4.9 | 0.15 | 0.10 | 0.07 | 0.11 | 0.12 | 0.06 | 0.04 | 0.07 |
| $T_3$ | 6.4 | 5.8 | 5.2 | 5.8 | 5.4 | 5.1 | 4.3 | 4.9 | 0.14 | 0.11 | 0.07 | 0.11 | 0.14 | 0.07 | 0.05 | 0.09 |
| $T_4$ | 8.9 | 7.8 | 6.8 | 7.8 | 7.2 | 6.0 | 5.0 | 6.1 | 0.28 | 0.20 | 0.15 | 0.21 | 0.21 | 0.14 | 0.11 | 0.15 |
| $T_5$ | 8.7 | 7.5 | 6.2 | 7.5 | 7.0 | 6.0 | 5.0 | 6.0 | 0.25 | 0.18 | 0.14 | 0.19 | 0.20 | 0.14 | 0.11 | 0.15 |
| $T_6$ | 9.1 | 8.3 | 7.0 | 8.1 | 7.5 | 6.1 | 5.2 | 6.3 | 0.29 | 0.21 | 0.17 | 0.22 | 0.28 | 0.18 | 0.14 | 0.20 |
| $T_7$ | 9.0 | 8.0 | 7.0 | 8.0 | 7.0 | 6.0 | 5.0 | 6.0 | 0.29 | 0.19 | 0.15 | 0.21 | 0.20 | 0.15 | 0.11 | 0.15 |
| $T_8$ | 7.8 | 6.5 | 5.7 | 6.7 | 6.2 | 5.1 | 3.7 | 5.0 | 0.23 | 0.14 | 0.06 | 0.14 | 0.14 | 0.06 | 0.04 | 0.08 |
| $T_9$ | 8.7 | 7.2 | 6.2 | 7.4 | 7.0 | 6.0 | 5.1 | 6.0 | 0.26 | 0.20 | 0.14 | 0.20 | 0.21 | 0.15 | 0.10 | 0.15 |
| $T_{10}$ | 8.8 | 7.1 | 6.8 | 7.6 | 7.1 | 6.0 | 5.0 | 6.0 | 0.27 | 0.20 | 0.15 | 0.21 | 0.22 | 0.16 | 0.12 | 0.17 |
| $T_{11}$ | 8.8 | 7.2 | 6.8 | 7.6 | 7.1 | 6.0 | 5.0 | 6.0 | 0.28 | 0.18 | 0.14 | 0.20 | 0.23 | 0.16 | 0.11 | 0.17 |
| $T_{12}$ | 8.9 | 7.2 | 6.7 | 7.6 | 7.3 | 5.9 | 5.0 | 6.1 | 0.28 | 0.19 | 0.15 | 0.21 | 0.23 | 0.16 | 0.05 | 0.17 |
| $T_{13}$ | 6.8 | 5.8 | 5.1 | 5.9 | 5.5 | 4.9 | 4.0 | 4.8 | 0.17 | 0.11 | 0.07 | 0.12 | 0.12 | 0.09 | 0.04 | 0.09 |
| $T_{14}$ | 6.8 | 5.7 | 5.2 | 5.9 | 5.7 | 4.9 | 4.2 | 4.9 | 0.17 | 0.11 | 0.06 | 0.11 | 0.12 | 0.08 | 0.04 | 0.08 |
| $T_{15}$ | 6.4 | 5.8 | 5.2 | 5.8 | 5.5 | 5.0 | 4.3 | 4.9 | 0.17 | 0.10 | 0.07 | 0.11 | 0.12 | 0.09 | 0.04 | 0.08 |
| $T_{16}$ | 6.5 | 5.7 | 5.3 | 5.8 | 5.7 | 5.1 | 4.3 | 5.0 | 0.18 | 0.10 | 0.08 | 0.12 | 0.12 | 0.09 | 0.08 | 0.08 |
| Mean | 7.7 | 6.6 | 5.9 | 6.7 | 6.3 | 5.4 | 4.6 | 5.4 | 0.22 | 0.15 | 0.13 | 0.17 | 0.17 | 0.11 | 0.08 | 0.12 |

| | SE | CD(5%) | SE | CD(5%) | SE | CD(5%) | SE | CD(5%) |
|---|---|---|---|---|---|---|---|---|
| S | 0.04 | 0.08 | 0.05 | 0.11 | 0.02 | 0.04 | 0.02 | 0.04 |
| T | 0.06 | 0.12 | 0.08 | 0.16 | 0.04 | 0.08 | 0.03 | 0.07 |
| S x T | 0.09 | 0.18 | 0.11 | 0.23 | 0.05 | 0.11 | 0.06 | 0.12 |

as Fe, Mn, Cu, Zn was evident at vegetative stage and as the stage advances, the micronutrient content was decreased.

When compared with control and all other treatments, farm yard manure applied at the rate of 12.5 t $ha^{-1}$ ($T_7$) prominently increased this parameter during all the stages.

In cluster bean, at vegetative stage, the available micronutrient content was increased in all the treatments and there was a trend of decrease in micronutrients as the stage advanced.

Among the treatments, the composted coffee waste applied at the rate of 12.5 t $ha^{-1}$ ($T_6$) distinctly increased the available micronutrient status of soil in all the stages over control and other treatments.

### 4.6.3. Pot culture experiment-II

**(Plates I-*Vigna unguiculata* L. Walp; J-*Cyamopsis tetragonaloba* T and K-*Abelmoschus esculentus* L. Moench)**

#### 4.6.3.1. Influence of treatments on number of leaves of legumes (Table 24 and Plate I & J)

In cowpea and cluster bean, the composted bagasse at the rate of 25 t $ha^{-1}$ ($T_2$) and the composted coffee waste at the rate of 25 t $ha^{-1}$ ($T_3$) incorporated treatments had a marginal effect on number of leaves being on par with each other and control ($T_1$ – 100 per cent NPK) from vegetative to harvest stages.

In cowpea, from vegetative to harvest stage the biocomposts along with

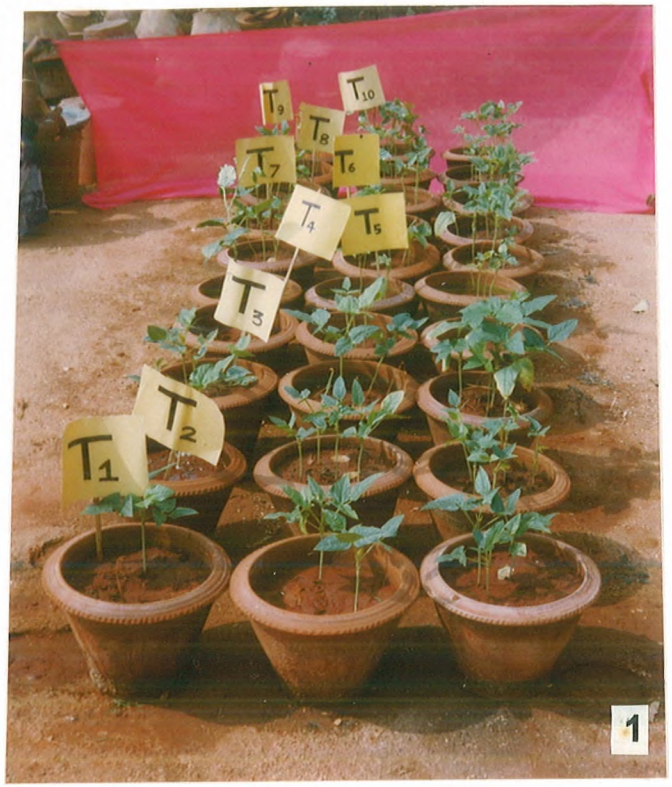
**Table 24. Number of leaves of legumes as influenced by treatments**

(Mean of three replications)

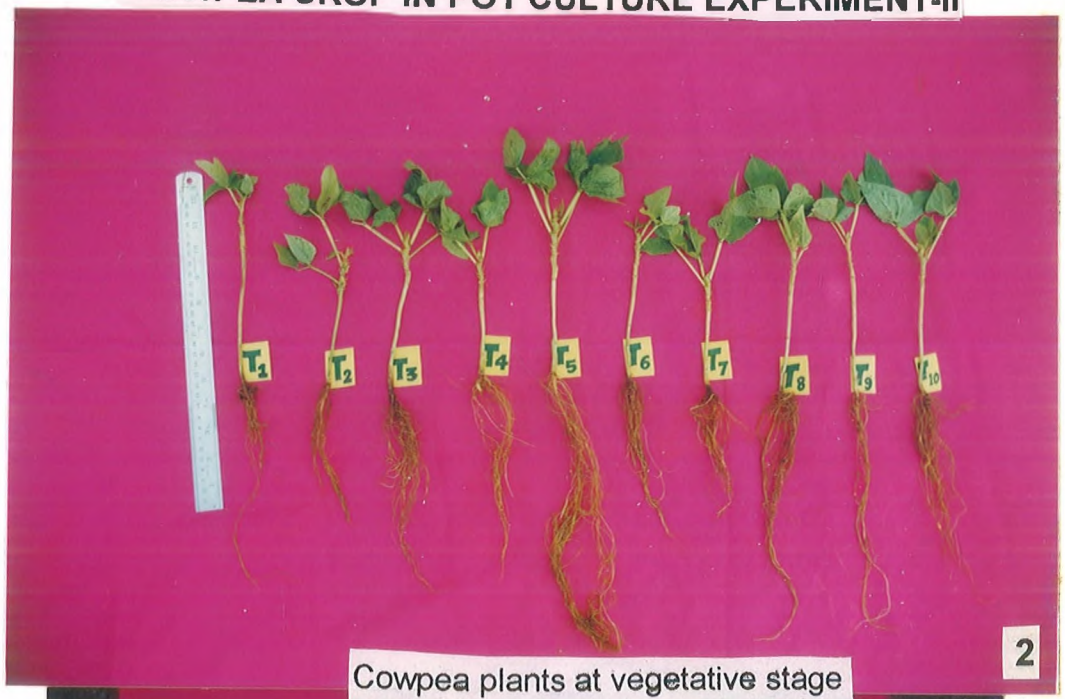
| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 17 | 23 | 36 | 25.33 | 18 | 21.7 | 29.3 | 23.00 |
| $T_2$ | 18 | 24 | 36 | 26.00 | 19 | 23.3 | 29.3 | 23.87 |
| $T_3$ | 17 | 27 | 36 | 26.70 | 19 | 22.7 | 29.6 | 23.87 |
| $T_4$ | 19 | 29 | 38 | 28.70 | 21 | 24.7 | 29.6 | 25.10 |
| $T_5$ | 19 | 30 | 37 | 28.70 | 18 | 25.0 | 31.0 | 24.70 |
| $T_6$ | 19.7 | 30 | 39 | 29.56 | 20 | 25.0 | 30.6 | 25.20 |
| $T_7$ | 19 | 30 | 39 | 29.33 | 18 | 24.3 | 29.3 | 23.87 |
| $T_8$ | 19.7 | 29 | 39 | 29.23 | 20 | 24.7 | 30.3 | 25.87 |
| $T_9$ | 21 | 29 | 39 | 29.70 | 20 | 26.3 | 31.3 | 25.87 |
| $T_{10}$ | 17 | 25 | 36 | 26.00 | 19 | 23.3 | 29.6 | 23.97 |
| Mean | 18.64 | 27.6 | 33.7 | 26.65 | 19.23 | 24.1 | 29.9 | 24.41 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **0.12** | **0.24** | **0.15** | **0.32** | **0.26** | **0.54** | **0.16** | **0.32** | **0.18** | **0.36** | **0.32** | **0.64** |

Plate I




## COWPEA CROP IN POT CULTURE EXPERIMENT-II




Cowpea plants at vegetative stage


Cowpea plants at flowering stage

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Plate I


Cowpea plants at harvest stage

Plate J


**CLUSTER BEAN IN POT CULTURE EXPERIMENT-II**


Cluster bean plants at harvest stage

biofertilizers favourably increased this parameter when compared with the control and all other treatments.

The mean values for number of leaves of cowpea plants varied from 18.64 to 33.7 from vegetative stage to harvest stage.

In cluster bean, during vegetative stage, more number of leaves were recorded in the composted bagasse at the rate of 25 t $ha^{-1}$ along with phosphobacteria at the rate of 2 kg $ha^{-1}$ ($T_4$) applied treatment than the control and all other treatments.

The composted bagasse along with VAM ($T_6$), composted coffee waste along with *Rhizobium* ($T_8$) and VAM ($T_9$) added treatments also had a pronounced effect on this parameter over control and being on par with each other.

During flowering and at harvest stages, this parameter was markedly increased by composted bagasse with *Rhizobium* ($T_5$) and composted coffee waste with VAM ($T_9$) applied treatments over control and other treatments.

The mean values for number of leaves of cluster bean ranged from 19.23 to 29.9 from vegetative to harvest stages.

**4.6.3.2. Influence of treatments on root volumes of legumes (Table 25)**

In cowpea this parameter was profoundly increased by composted bagasse with *Rhizobium* ($T_5$) over control and all the other treatments from vegetative to harvest stages.

**Table 25. Root volume of legumes as influenced by treatments (cc)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 4.8 | 6.1 | 7.2 | 6.03 | 1.7 | 2.4 | 3.7 | 2.60 |
| $T_2$ | 4.7 | 6.0 | 8.0 | 6.23 | 3.0 | 3.7 | 4.2 | 3.63 |
| $T_3$ | 4.9 | 6.1 | 7.9 | 6.30 | 3.2 | 4.0 | 5.1 | 4.10 |
| $T_4$ | 5.5 | 7.3 | 8.3 | 7.03 | 3.5 | 5.4 | 6.8 | 5.23 |
| $T_5$ | 6.5 | 8.7 | 9.8 | 8.33 | 3.7 | 6.3 | 7.5 | 5.83 |
| $T_6$ | 5.9 | 7.2 | 9.7 | 7.60 | 3.5 | 4.5 | 6.0 | 4.70 |
| $T_7$ | 5.5 | 7.5 | 9.7 | 7.57 | 4.0 | 4.7 | 6.2 | 4.97 |
| $T_8$ | 5.2 | 7.3 | 9.8 | 7.43 | 3.6 | 4.5 | 6.5 | 4.87 |
| $T_9$ | 6.0 | 7.2 | 10.0 | 7.73 | 3.7 | 6.0 | 7.5 | 5.73 |
| $T_{10}$ | 5.0 | 6.3 | 7.9 | 6.4 | 3.5 | 4.8 | 6.0 | 4.77 |
| Mean | 5.4 | 6.97 | 8.83 | 7.07 | 3.34 | 4.63 | 5.95 | 4.64 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.10 | 0.20 | 0.16 | 0.32 | 0.25 | 0.56 | 0.08 | 0.16 | 0.13 | 0.26 | 0.21 | 0.42 |

When compared to control all the biocomposts and their combinations with biofertilizers (from $T_2$ to $T_{10}$) positively increased this parameter during all the stages of the growth and the mean values ranged from 5.4 mm to 8.83 mm from vegetative to harvest stage.

Root volume of cluster bean plant was spectacularly increased by the composted bagasse with *Rhizobium* ($T_5$) in all the stages of its growth over control and all the other treatments.

When compared to control from vegetative to harvest stages, all the treatments markedly influenced this parameter and recorded a significant variation among them.

The mean values for this parameter from vegetative to harvest stages varied from 3.34 ccto 5.95 cc.

**4.6.3.3. Influence of treatments on nodule index of legumes (Table 26)**

In both the test crops, the nodule index was positively enhanced by all the treatments over control during all the stages of growth.

Nodule index of cowpea plants recorded during vegetative and flowering stages ranged from 1.76 to 2.14. At vegetative stage, composted bagasse along with VAM ($T_6$) significantly increased this parameter over control and all the other treatments. Later at flowering stage, the composted bagasse with *Rhizobium*

**Table 26. Nodule index of legumes as influenced by treatments**

(Mean of three replications)

| Treatments | Cowpea | | | Cluster bean | | |
|---|---|---|---|---|---|---|
| | V.S. | F.S. | Mean | V.S. | F.S. | Mean |
| $T_1$ | 1.08 | 2.07 | 1.58 | 1.00 | 1.21 | 1.11 |
| $T_2$ | 1.72 | 2.11 | 1.92 | 1.18 | 1.65 | 1.42 |
| $T_3$ | 1.81 | 2.09 | 1.95 | 1.15 | 1.66 | 1.41 |
| $T_4$ | 1.73 | 2.15 | 1.94 | 1.16 | 1.67 | 1.42 |
| $T_5$ | 1.94 | 2.21 | 2.08 | 1.18 | 1.86 | 1.52 |
| $T_6$ | 1.95 | 2.19 | 2.07 | 1.22 | 1.69 | 1.46 |
| $T_7$ | 1.92 | 2.14 | 2.03 | 1.17 | 1.75 | 1.46 |
| $T_8$ | 1.88 | 2.21 | 2.05 | 1.22 | 1.86 | 1.54 |
| $T_9$ | 1.93 | 2.20 | 2.07 | 1.11 | 1.76 | 1.44 |
| $T_{10}$ | 1.67 | 2.09 | 1.88 | 1.17 | 1.73 | 1.45 |
| Mean | 1.76 | 2.14 | 1.95 | 1.16 | 1.68 | 1.42 |

| | SE | CD (5%) | SE | CD (5%) |
|---|---|---|---|---|
| **D** | **0.07** | **0.14** | **0.03** | **0.06** |
| **T** | **0.03** | **0.06** | **0.02** | **0.04** |
| **D x T** | **0.09** | **0.18** | **0.05** | **0.09** |

($T_5$) and composted coffee waste with *Rhizobium* ($T_8$) prominently enhanced the nodule index of cowpea plants than the control and other treatments.

In cluster bean, though all the treatments showed a marked effect on this parameter the composted coffee waste with *Rhizobium* ($T_8$) spectacularly enhanced the nodule index at vegetative and flowering stages and the mean values at these stages ranged from 1.16 to 1.68.

**4.6.3.4. Influence of treatments on plant height of legumes (Table 27 ; Figure 13)**

In both the legumes, plant height was markedly influenced by the composts along with biofertilizers applied treatments during all the stages of growth.

In cowpea, the combination of composted coffee waste with phosphobacteria ($T_7$) positively enhanced the plant height than the control and all the other treatments during all the stages of the growth.

The mean values for this parameter ranged from 56.75 cm to 91.43 cm from vegetative to harvest stage.

In cluster bean, the judicial combination of composted bagasse with VAM ($T_6$) spectacularly increased the plant height in all the stages than the control and other treatments during all stages of its growth.

The mean values for plant height of cluster bean from vegetative to harvest stages varied from 35.35 cm to 66.10 cm.

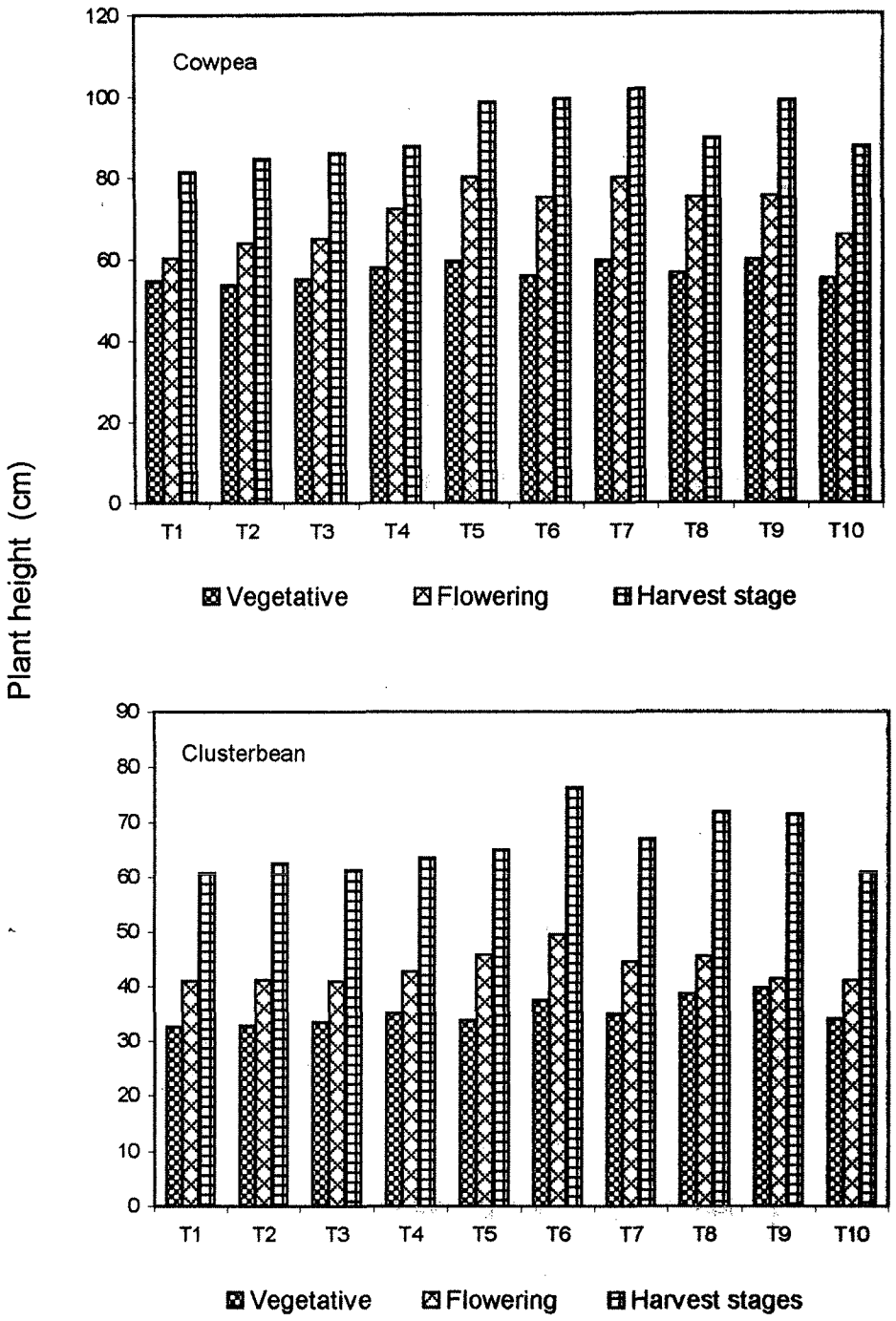
**Table 27. Plant height of legumes as influenced by treatments (cm)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 54.6 | 60.2 | 81.3 | 65.3 | 32.7 | 41.0 | 60.8 | 44.8 |
| $T_2$ | 53.7 | 63.9 | 84.6 | 67.4 | 32.9 | 41.2 | 62.5 | 45.5 |
| $T_3$ | 55.0 | 65.0 | 85.9 | 68.61 | 33.5 | 41.0 | 61.3 | 45.3 |
| $T_4$ | 57.8 | 72.1 | 87.6 | 72.5 | 35.2 | 42.7 | 63.5 | 47.1 |
| $T_5$ | 59.5 | 80.0 | 98.5 | 79.3 | 33.9 | 45.8 | 65.0 | 48.2 |
| $T_6$ | 55.7 | 75.0 | 99.2 | 76.6 | 37.5 | 49.6 | 76.4 | 54.5 |
| $T_7$ | 59.7 | 79.9 | 101.5 | 80.4 | 35.1 | 44.6 | 67.0 | 48.9 |
| $T_8$ | 56.5 | 74.9 | 89.5 | 73.6 | 38.7 | 45.6 | 72.0 | 52.1 |
| $T_9$ | 59.8 | 75.2 | 98.7 | 77.9 | 39.9 | 47.5 | 71.5 | 52.0 |
| $T_{10}$ | 55.2 | 65.9 | 87.5 | 69.5 | 34.2 | 41.2 | 61.0 | 45.5 |
| Mean | 56.75 | 71.21 | 91.43 | 73.11 | 35.35 | 44.02 | 66.10 | 48.49 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD(5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.01 | 4.02 | 2.55 | 3.11 | 3.42 | 6.84 | 1.75 | 3.50 | 2.04 | 2.08 | 2.63 | 3.32 |

**Figure 13**
**Plant height of legumes as influenced by treatments**



#### 4.6.3.5. Influence of treatments on plant fresh weight of legumes (Table 28)

The composted coffee waste in combination with phosphobacteria ($T_7$) spectacularly increased the plant fresh weight of cowpea in all the stages over control and other treatments. All the treatments had a positive influence on this parameter when compared with the control.

The mean values for this parameter varied from 21.30 g to 53.67 g from vegetative to harvest stages of its growth.

The plant fresh weight of cluster bean crop was positively enhanced by the composted bagasse with VAM ($T_6$) in all the stages of growth when compared to control and other treatments. The composted coffee waste with *Rhizobium* ($T_8$) and VAM ($T_9$) also had a marked influence on this parameter and showed a significant differences between them.

The mean values varied from 19.32 g to 29.98 g from vegetative to harvest stages of its growth.

#### 4.6.3.6. Influence of treatments on plant dry weight of legumes (Table 29 ; Figure 14)

The plant dry weight of cowpea crop was spectacularly increased by the combined application of composted coffee waste with phosphobacteria ($T_7$) during all stages of its growth. Among the combinations of biofertilizers with composted

**Table 28. Plant fresh weight of legumes as influenced by treatments(g)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S | F.S | H.S | Mean |
| $T_1$ | 16.55 | 27.52 | 46.9 | 30.32 | 15.76 | 18.01 | 25.05 | 19.61 |
| $T_2$ | 16.42 | 29.45 | 46.5 | 31.00 | 16.50 | 18.75 | 24.50 | 20.00 |
| $T_3$ | 16.50 | 28.01 | 48.7 | 31.07 | 16.85 | 18.82 | 25.00 | 20.22 |
| $T_4$ | 19.75 | 31.65 | 57.9 | 36.43 | 17.88 | 19.65 | 28.70 | 22.05 |
| $T_5$ | 18.82 | 37.00 | 59.6 | 38.47 | 17.66 | 20.38 | 28.97 | 22.27 |
| $T_6$ | 19.53 | 39.55 | 53.8 | 37.63 | 19.52 | 22.95 | 37.25 | 25.91 |
| $T_7$ | 29.70 | 38.29 | 64.2 | 44.06 | 17.50 | 20.48 | 35.40 | 24.50 |
| $T_8$ | 23.33 | 38.43 | 54.2 | 38.65 | 18.25 | 10.95 | 35.26 | 24.82 |
| $T_9$ | 24.77 | 37.62 | 55.0 | 39.13 | 18.75 | 20.40 | 34.22 | 24.60 |
| $T_{10}$ | 17.62 | 30.04 | 49.6 | 32.42 | 17.00 | 18.95 | 25.66 | 20.54 |
| Mean | 21.30 | 33.16 | 53.67 | 35.92 | 19.32 | 22.01 | 29.98 | 23.77 |

| | SE | CD (5%) | SE | CD (5%) |
|---|---|---|---|---|
| D | 0.62 | 1.24 | 0.56 | 1.12 |
| T | 0.98 | 1.96 | 0.92 | 1.84 |
| D x T | 1.70 | 3.39 | 1.55 | 3.10 |

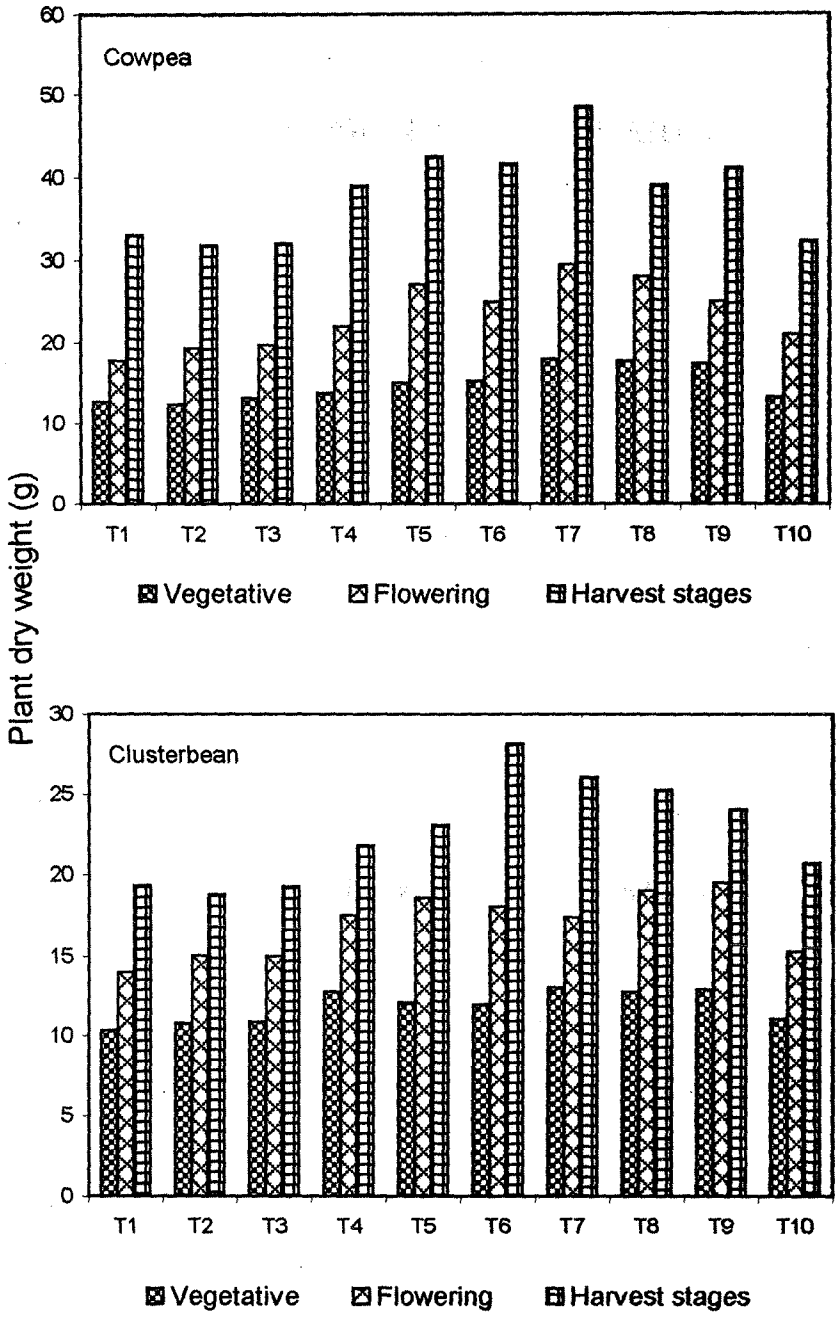
**Table 29. Plant dry weight of legumes as influenced by treatments (g)**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | |
|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 12.66 | 17.70 | 32.99 | 21.11 | 10.35 | 14.00 | 19.30 | 14.55 |
| $T_2$ | 13.33 | 19.30 | 31.77 | 21.13 | 10.76 | 15.02 | 18.75 | 14.84 |
| $T_3$ | 13.11 | 19.70 | 32.00 | 21.60 | 10.85 | 15.00 | 19.22 | 15.02 |
| $T_4$ | 13.77 | 22.01 | 39.00 | 24.92 | 12.77 | 17.48 | 21.78 | 17.34 |
| $T_5$ | 15.00 | 27.09 | 42.50 | 28.19 | 12.06 | 18.55 | 23.05 | 17.88 |
| $T_6$ | 15.25 | 25.00 | 41.70 | 27.31 | 11.95 | 18.01 | 28.14 | 19.36 |
| $T_7$ | 17.91 | 29.42 | 48.50 | 31.70 | 13.05 | 17.36 | 26.03 | 18.81 |
| $T_8$ | 17.75 | 27.99 | 39.10 | 28.25 | 12.75 | 18.99 | 25.25 | 18.99 |
| $T_9$ | 17.39 | 25.08 | 41.20 | 27.89 | 12.92 | 19.47 | 24.03 | 18.80 |
| $T_{10}$ | 13.25 | 21.03 | 32.30 | 22.19 | 11.03 | 15.25 | 20.67 | 15.65 |
| Mean | 14.84 | 23.43 | 38.11 | 25.43 | 11.85 | 16.91 | 22.62 | 17.12 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD(5%) | SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.22 | 2.45 | 1.40 | 3.40 | 2.02 | 4.04 | 0.98 | 1.96 | 1.02 | 2.05 | 1.16 | 2.32 |

**Figure 14**
**Plant dry weight of legumes as influenced by treatments**



bagasse the *Rhizobium* added treatment ($T_5$) had a positive influence on this parameter over control.

The combined effect of composted bagasse and composted coffee waste at the rate of 12.5 t $ha^{-1}$ each ($T_{10}$) was more prominent than the individual applications ($T_2$ and $T_3$).

In cluster bean, during vegetative stage, the composted coffee waste with phosphobacteria ($T_7$) incorporated treatment favourably increased the plant dry weight when compared to control.

During flowering stage, composted coffee waste at the rate of 25 t $ha^{-1}$ along with 2 kg $ha^{-1}$ VAM ($T_9$) significantly increased the plant dry weight over control.

During harvest time, 25 t $ha^{-1}$ of composted bagasse in combination with 2 kg $ha^{-1}$ of VAM ($T_6$) had a spectacular influence on this parameter over control and other treatments.

The mean values for this parameter varied from 14.84 g to 38.11 g in cowpea and 11.85 g to 22.62 g in cluster bean from vegetative to harvest stages.

#### 4.6.3.7. Influence of treatments on yield parameters of legumes (Table 30 ; Figure 15)

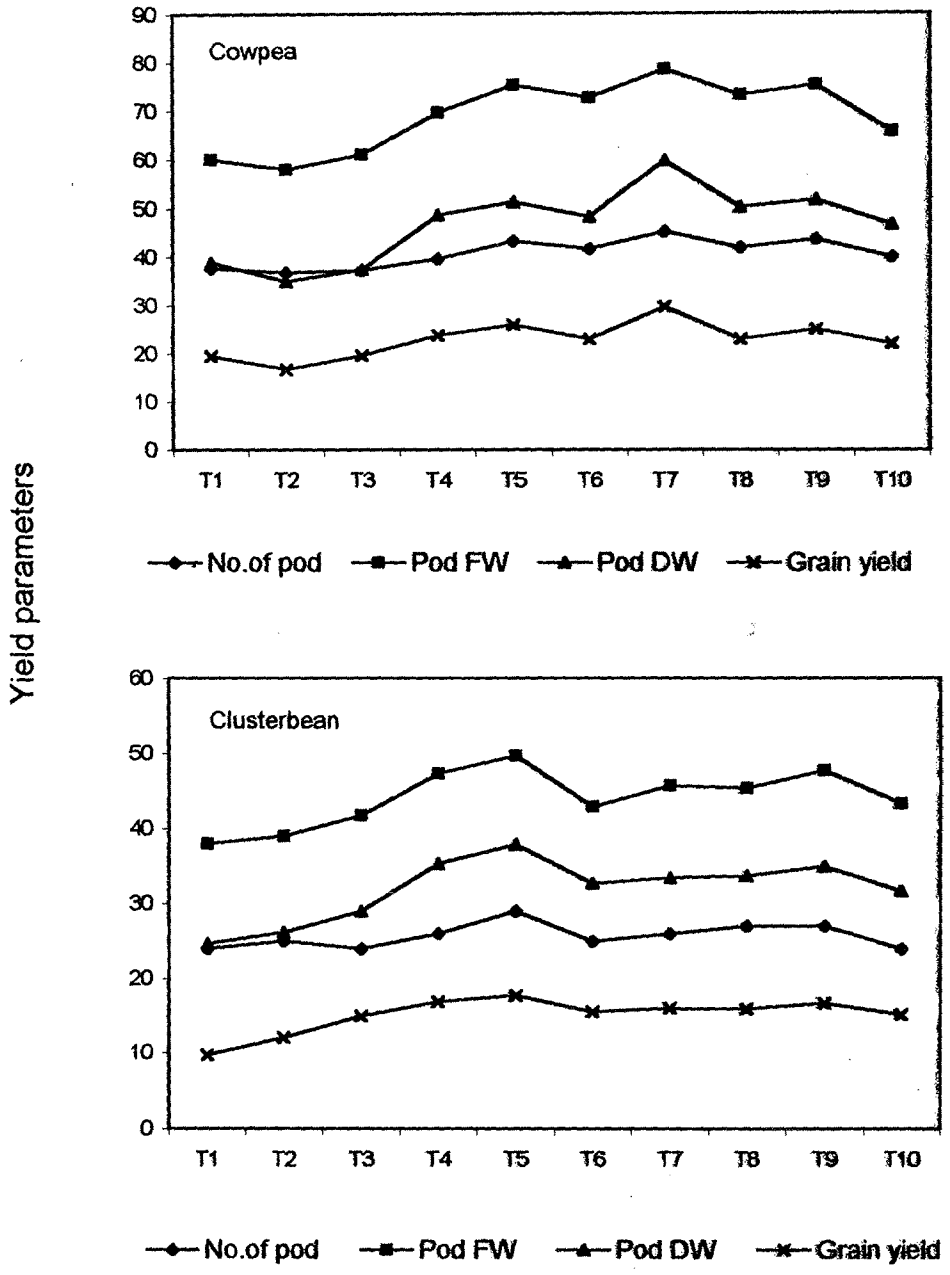
In cowpea, the individual applications of composts ($T_2$ and $T_3$) at the rate of 25 t $ha^{-1}$ had a marginal effect on the yield parameters when compared to the

**Table 30. Yield parameters of legumes as influenced by treatments**

(Mean of three replications)

| Treat ments | Cowpea | | | | | | | Cluster bean | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of pods/ plant | Pod length (cm) | Pod FW (gm) | Pod DW (gm) | No. of grains/ pod | Haulm weight (gm) | Grain yield (gm) | No. of pods/ plant | Pod length (cm) | Pod FW (gm) | Pod DW (gm) | No. of grains/ pod | Haulm weight (gm) | Grain yield (gm) |
| $T_1$ | 37.7 | 15.7 | 60.0 | 38.9 | 19.5 | 19.2 | 19.5 | 24 | 11.4 | 38.0 | 24.7 | 14.0 | 10.5 | 9.6 |
| $T_2$ | 36.8 | 15.6 | 57.9 | 34.9 | 19.0 | 17.5 | 16.7 | 25 | 11.4 | 39.0 | 26.2 | 14.0 | 14.2 | 12.0 |
| $T_3$ | 37.3 | 15.7 | 61.1 | 37.5 | 19.3 | 17.4 | 19.6 | 24 | 11.3 | 41.7 | 29.0 | 13.7 | 14.0 | 14.9 |
| $T_4$ | 39.7 | 16.0 | 69.7 | 48.7 | 21.0 | 24.0 | 23.7 | 26 | 11.5 | 47.3 | 35.3 | 14.3 | 17.7 | 16.9 |
| $T_5$ | 43.3 | 16.1 | 75.2 | 51.3 | 21.0 | 24.5 | 26.0 | 29 | 11.7 | 49.7 | 37.9 | 14.7 | 18.3 | 17.7 |
| $T_6$ | 41.7 | 16.0 | 72.7 | 48.3 | 20.3 | 23.7 | 22.9 | 25 | 11.5 | 42.9 | 32.7 | 14.3 | 17.0 | 15.5 |
| $T_7$ | 45.3 | 16.5 | 78.5 | 59.7 | 21.6 | 29.5 | 29.7 | 26 | 11.7 | 45.7 | 33.5 | 14.7 | 16.7 | 16.0 |
| $T_8$ | 42.0 | 16.0 | 73.2 | 50.2 | 21.0 | 27.1 | 23.0 | 27 | 11.7 | 45.3 | 33.7 | 14.3 | 16.5 | 15.9 |
| $T_9$ | 43.7 | 16.3 | 75.3 | 51.7 | 21.3 | 25.7 | 25.0 | 27 | 11.5 | 47.7 | 35.0 | 14.7 | 17.3 | 16.7 |
| $T_{10}$ | 40.0 | 16.0 | 65.7 | 46.7 | 20.0 | 20.2 | 22.0 | 24 | 11.5 | 43.3 | 31.7 | 14.0 | 15.5 | 15.2 |
| Mean | 40.75 | 15.99 | 68.93 | 46.79 | 20.40 | 22.88 | 22.81 | 25.7 | 11.52 | 44.06 | 31.97 | 14.27 | 15.77 | 15.05 |
| SEd | 1.06 | 0.45 | 0.75 | 1.02 | 0.56 | 1.25 | 1.33 | 1.02 | 1.32 | 0.75 | 1.57 | NS | 0.02 | 0.55 |
| CD (5%) | 2.12 | 0.91 | 1.56 | 2.05 | 1.12 | 2.50 | 2.67 | 2.04 | 2.64 | 0.55 | 1.10 | NS | 0.04 | 1.10 |

**Figure 15**
**Yield parameters of legumes as influenced by treatments**



control, whereas their combined application at the rate of 12.5 t $ha^{-1}$ each ($T_{10}$) on cowpea crop recorded a significant increase in all the parameters of yield at harvest time.

The number of pods per plant, pod length, pod fresh and dry weight per plant, number of grains per pod, haulm weight and grain yield per plant of cowpea crop were spectacularly increased by the composted coffee waste at the rate of 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_7$) over control and all the other treatments.

The yield parameters of cluster bean crop were spectacularly increased by the composted bagasse at the rate of 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_5$) when compared with the control and all the other treatments.

#### 4.6.3.8. Influence of treatments on number of leaves of bhendi (Table 31 ; Plate K)

The composted bagasse along with *Azospirillum* ($T_5$) significantly enhanced the number of leaves during vegetative stage. Later during flowering and harvest stages this parameter was spectacularly increased by the composted bagasse with phosphobacteria ($T_4$).

The composts alone at the rate of 25 t $ha^{-1}$ ($T_2$ and $T_3$) did not show any marked variation between them being on par with the control ($T_1$).

**Table 31. Number of leaves of bhendi as influenced by treatments**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Harvest stage | Mean |
|---|---|---|---|---|
| $T_1$ | 9.3 | 13.7 | 19.3 | 14.1 |
| $T_2$ | 9.0 | 13.3 | 19.0 | 13.8 |
| $T_3$ | 10.0 | 13.3 | 19.3 | 14.2 |
| $T_4$ | 14.0 | 20.7 | 26.7 | 20.5 |
| $T_5$ | 16.3 | 18.3 | 25.3 | 20.0 |
| $T_6$ | 14.3 | 18.6 | 25.0 | 19.3 |
| $T_7$ | 15.7 | 18.7 | 24.7 | 19.7 |
| $T_8$ | 16.0 | 20.3 | 24.7 | 20.3 |
| $T_9$ | 14.3 | 20.0 | 23.7 | 19.4 |
| $T_{10}$ | 14.0 | 18.3 | 21.0 | 17.8 |
| Mean | 13.3 | 17.52 | 22.87 | 17.9 |

| SE (D) | CD (5%) | SE (D) | CD (5%) | SE (D) | CD (5%) |
|---|---|---|---|---|---|
| 0.43 | 0.86 | 0.60 | 1.26 | 0.79 | 1.66 |

Plate K

## BHENDI IN POT CULTURE EXPERIMENT-II



Bhendi plants at flowering stage

Bhendi plants at harvesting stage

The mean values for number of leaves of bhendi ranged during vegetative stage from 9 to 16.3, during flowering stage from 13.3 to 20.7 and at harvest stage from 19 to 26.7.

**4.6.3.9. Influence of treatments on root volume of bhendi (Table 32)**

The mean values for root volume of bhendi ranged from 4.39 cc to 24.41 cc from vegetative to harvest stage.

During vegetative stage, though all the treatments had a marked effect on this parameter, a spectacular increase was observed in the composted coffee waste at the rate of 25 t $ha^{-1}$ along with VAM at the rate of 2 kg $ha^{-1}$ applied treatment ($T_9$) when compared with the control.

During flowering stage, the composted bagasse with *Azospirillum* ($T_5$), composted coffee waste with *Azospirillum* ($T_8$) and composted coffee waste with VAM ($T_9$) significantly enhanced the root volume of bhendi than the control and other treatments.

At harvest time, the root volume was prominently increased by the composted bagasse with VAM ($T_6$) when compared with the control. All the other treatments also had a positive influence on this parameter and showed a marked variation between them.

**Table 32. Root volume of bhendi as influenced by treatments (cc)**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Harvest stage | Mean |
|---|---|---|---|---|
| $T_1$ | 3.27 | 6.5 | 10.3 | 6.69 |
| $T_2$ | 3.40 | 6.4 | 10.4 | 6.73 |
| $T_3$ | 4.26 | 9.3 | 13.4 | 8.99 |
| $T_4$ | 5.13 | 10.2 | 24.8 | 13.38 |
| $T_5$ | 4.33 | 10.6 | 20.3 | 11.74 |
| $T_6$ | 4.80 | 9.8 | 29.8 | 14.80 |
| $T_7$ | 5.00 | 10.2 | 24.7 | 13.30 |
| $T_8$ | 4.60 | 10.7 | 25.3 | 13.54 |
| $T_9$ | 5.63 | 10.7 | 24.3 | 13.54 |
| $T_{10}$ | 4.07 | 9.6 | 13.7 | 9.12 |
| Mean | 4.39 | 9.35 | 24.41 | 12.72 |

| SE (D) | CD (5%) | SE (D) | CD (5%) | SE (D) | CD (5%) |
|---|---|---|---|---|---|
| 0.23 | 0.46 | 0.46 | 0.93 | 0.54 | 1.13 |

#### 4.6.3.10. Influence of treatments on plant height of bhendi (Table 33 ; Figure 16)

The mean values for plant height of bhendi crop varied from 53.09 cm to 102.16 cm from vegetative stage to harvest time.

When compared with the control ($T_1$ – 100 per cent NPK) the combined application of composted coffee waste with VAM ($T_9$) followed by compared bagasse with phosphobacteria ($T_4$) showed a marked influence on this parameter during vegetative stage.

At flowering and harvest stage, the composted bagasse with the VAM incorporated ($T_6$) treatment significantly increased the plant height over control and all other treatments.

#### 4.6.3.11. Influence of treatments on plant fresh weight of bhendi (Table 34)

Table 34 depict the impact of treatments on plant fresh weight of bhendi. This parameter was markedly increased by the application of composted coffee waste along with VAM ($T_9$) over control and other treatments during vegetative stage.

During flowering and harvest stages, the composted bagasse with VAM ($T_6$) positively increased the plant fresh weight over control and all the other treatments. The mean values for this parameter ranged from 11.34 g to 76.61 g from vegetative to harvest stages.

**Table 33. Plant height of bhendi as influenced by treatments (cm)**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Harvest stage | Mean |
|---|---|---|---|---|
| $T_1$ | 42.77 | 62.03 | 86.34 | 63.71 |
| $T_2$ | 48.60 | 62.01 | 86.37 | 65.66 |
| $T_3$ | 51.90 | 65.06 | 89.90 | 68.95 |
| $T_4$ | 57.96 | 82.73 | 110.53 | 83.74 |
| $T_5$ | 55.60 | 80.80 | 109.86 | 82.09 |
| $T_6$ | 51.96 | 87.17 | 116.96 | 85.36 |
| $T_7$ | 54.26 | 80.10 | 109.24 | 81.20 |
| $T_8$ | 54.60 | 74.84 | 115.20 | 81.55 |
| $T_9$ | 59.67 | 83.83 | 110.26 | 84.59 |
| $T_{10}$ | 53.44 | 69.06 | 94.63 | 72.38 |
| Mean | 53.09 | 73.76 | 102.16 | 76.34 |

| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (DxT) | CD (5%) |
|---|---|---|---|---|---|
| **0.98** | **1.97** | **1.22** | **2.45** | **1.95** | **3.90** |

**Figure 16**
**Plant height of bhendi as influenced by treatments**

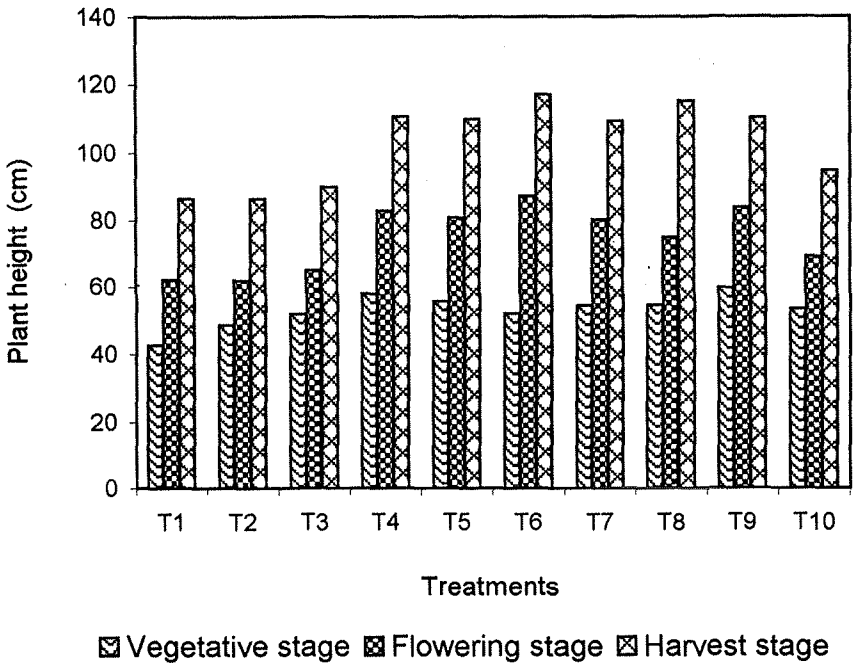



**Figure 17**
**Plant dry weight of bhendi as influenced by treatments**

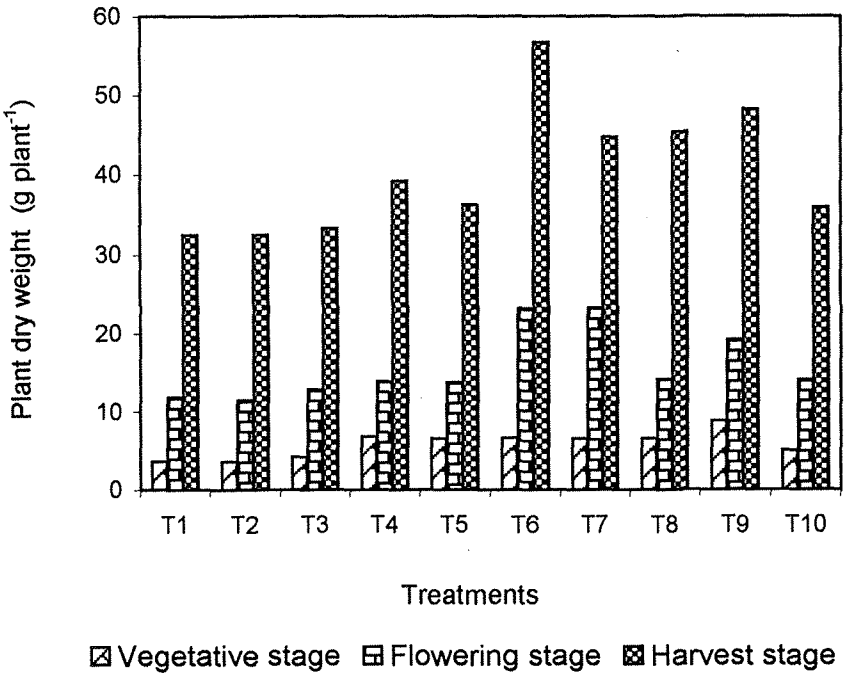


**Table 34. Plant fresh weight of bhendi as influenced by treatments (g)**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Harvest stage | Mean |
|---|---|---|---|---|
| $T_1$ | 8.96 | 27.07 | 64.54 | 33.52 |
| $T_2$ | 8.94 | 28.39 | 63.78 | 33.70 |
| $T_3$ | 10.88 | 29.60 | 65.82 | 35.43 |
| $T_4$ | 12.84 | 35.13 | 71.31 | 39.76 |
| $T_5$ | 11.11 | 32.39 | 69.59 | 39.70 |
| $T_6$ | 12.13 | 42.54 | 97.00 | 50.56 |
| $T_7$ | 11.93 | 31.16 | 84.32 | 42.47 |
| $T_8$ | 12.71 | 36.10 | 96.79 | 48.53 |
| $T_9$ | 14.23 | 42.50 | 96.03 | 50.92 |
| $T_{10}$ | 10.46 | 31.17 | 71.89 | 37.84 |
| Mean | 11.39 | 32.37 | 76.61 | 40.12 |

| SE (D) | CD (5%) | SE (D) | CD (5%) | SE (D) | CD (5%) |
|---|---|---|---|---|---|
| 0.65 | 1.30 | 1.05 | 2.09 | 1.80 | 3.61 |

#### 4.6.3.12. Influence of treatments on plant dry weight of bhendi (Table 35 ; Figure 17)

The composted coffee waste at the rate of 25 t $ha^{-1}$ along with VAM at the rate of 2 kg $ha^{-1}$ ($T_9$) markedly enhanced this parameter over control and other treatments in the vegetative stage.

At flowering stage, the composted coffee waste with phosphobacteria ($T_7$) and at harvest stage, the composted bagasse with VAM ($T_6$) were spectacularly enhanced the plant dry weight over control.

The mean values from vegetative stage to harvest stage varied from 6.05 g to 39.41 g.

#### 4.6.3.13. Influence of treatments on yield parameters of bhendi (Table 36 ; Figure 18)

When compared to the control ($T_1$) and individual applications of composts ($T_2$ and $T_3$), the application of composts in combination with biofertilizers ($T_4$ to $T_9$) recorded maximum number of fruits per plant, fruit length and fruit circumferences and higher fruit yield during harvest time.

The composted bagasse with phosphobacteria ($T_4$) composted bagasse with VAM ($T_6$) and composted coffee waste with *Azospirillum* ($T_8$) significantly enhanced the number of fruits per plant over control and being on par with each other. The composted bagasse with *Azospirillum* ($T_5$), the composted coffee waste

**Table 35. Plant dry weight of bhendi as influenced by treatments (g)**

(Mean of three replications)

| Treatments | Vegetative stage | Flowering stage | Harvest stage | Mean |
|---|---|---|---|---|
| $T_1$ | 3.55 | 11.82 | 32.42 | 15.93 |
| $T_2$ | 3.56 | 11.38 | 32.40 | 15.78 |
| $T_3$ | 4.12 | 12.81 | 33.16 | 16.70 |
| $T_4$ | 6.69 | 13.84 | 39.22 | 19.91 |
| $T_5$ | 6.44 | 13.79 | 36.16 | 18.80 |
| $T_6$ | 6.58 | 23.16 | 56.70 | 28.81 |
| $T_7$ | 6.45 | 23.21 | 44.67 | 24.78 |
| $T_8$ | 6.51 | 14.17 | 45.32 | 22.00 |
| $T_9$ | 8.73 | 19.19 | 48.21 | 25.38 |
| $T_{10}$ | 4.96 | 14.05 | 35.83 | 18.28 |
| Mean | 6.05 | 13.74 | 39.41 | 19.73 |

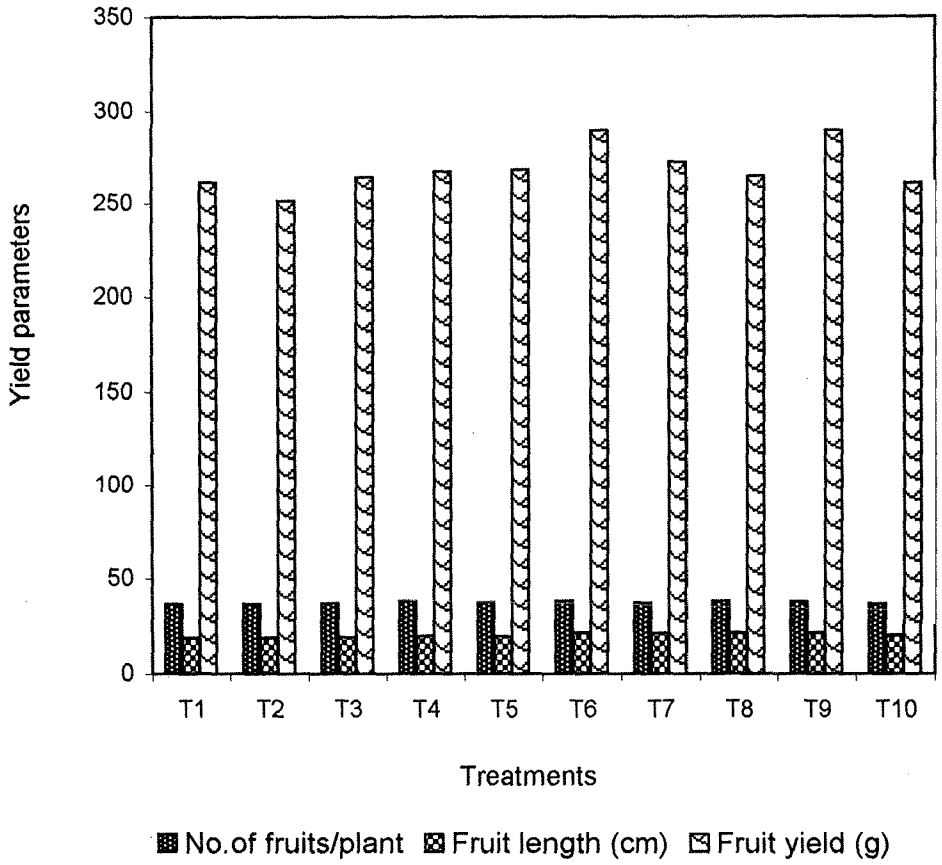
| SE (D) | CD (5%) | SE (T) | CD (5%) | SE (D x T) | CD (5%) |
|---|---|---|---|---|---|
| **1.25** | **2.50** | **1.39** | **2.78** | **2.01** | **4.02** |

**Table 36. Yield parameters of bhendi as influenced by treatments**

(Mean of three replications)

| Treatments | No. of fruits / plant | Fruit length (cm) | Fruit circumference (cm) | Fruit yield / plant (g) |
|---|---|---|---|---|
| $T_1$ | 36.33 | 18.83 | 6.27 | 261.53 |
| $T_2$ | 36.33 | 18.80 | 6.20 | 261.36 |
| $T_3$ | 36.66 | 18.87 | 6.20 | 264.45 |
| $T_4$ | 38.00 | 19.87 | 7.07 | 267.48 |
| $T_5$ | 37.33 | 19.20 | 6.20 | 268.46 |
| $T_6$ | 38.00 | 21.30 | 7.56 | 289.58 |
| $T_7$ | 37.00 | 21.20 | 7.70 | 272.45 |
| $T_8$ | 38.00 | 21.33 | 7.73 | 265.04 |
| $T_9$ | 37.66 | 21.33 | 6.80 | 289.50 |
| $T_{10}$ | 36.66 | 20.03 | 6.73 | 261.37 |
| Mean | 37.73 | 20.05 | 6.75 | 266.52 |
| **SEd** | **2.41** | **1.01** | **0.98** | **6.25** |
| **CD (5%)** | **4.82** | **2.02** | **1.96** | **12.50** |

**Figure 18**
**Yield parameters of bhendi as influenced by treatments**



with phosphobacteria ($T_7$) and VAM ($T_9$) added treatments also had a marked effect on number of fruits per plant when compared to the control and being on par with each other. The other treatments ($T_2$, $T_3$ and $T_{10}$) were also slightly influenced this parameter, being on par with the control.

Fruit length was significantly increased in the composted coffee waste and biofertilizers added treatments ($T_7$, $T_8$ and $T_9$) over control and being on par with the composted bagasse with VAM ($T_6$) applied treatment.

Though there was a marginal influence on the fruit circumference by all the treatments, a significant influence was recorded in the composted bagasse with VAM ($T_6$), composted coffee waste with phosphobacteria ($T_7$) and composted coffee waste with VAM ($T_8$) incorporated treatments when compared to control.

The fruit yield per plant was spectacularly enhanced by the composted bagasse + VAM ($T_6$) than the control and being on par with the composted coffee waste + VAM ($T_9$) .

All the other treatments had a marked influence on the fruit yield per plant over control and showed a significant differences among them.

### 4.6.4. Post harvest soil analysis

#### 4.6.4.1. Influence of treatments on soil reaction and electrical conductivity

The pH of second pot culture experimental soil samples varied from 6.7 to 7.6 at vegetative, 7.1 to 7.7 at flowering, 7.5 to 8.0 at harvest stages in cowpea;

6.5 to 7.2 at vegetative, 7.0 to 7.5 at flowering, 7.4 to 7.7 at harvest stages in cluster bean and 6.3 to 6.9 at vegetative, 6.6 to 7.2 at flowering, 7.0 to 7.4 at harvest stages in bhendi crops.

The electrical conductivity was ranging from 0.47 to 0.56 $dSm^{-1}$ at vegetative, 0.49 to 0.59 $dSm^{-1}$ at flowering, 0.50 to 0.61 $dSm^{-1}$ at harvest stages in cowpea; 0.49 to 0.59 $dSm^{-1}$ at vegetative, 0.51 to 0.63 $dSm^{-1}$ at flowering, 053 to 0.65 $dSm^{-1}$ at harvest stages in cluster bean; 0.49 to 0.53 at vegetative, 0.52 to 0.55 $dSm^{-1}$ at flowering and 0.53 to 0.58 $dSm^{-1}$ at harvest stages in bhendi crops.

**4.6.4.2. Influence of treatments on soil physical properties (Table 37)**

In cowpea, the bulk density and porosity were improved to greater extent by the composted coffee waste + VAM ($T_9$) added treatment than the (100 per cent NPK – $T_1$) control, whereas the water holding capacity and volume expansion were distinctly influenced by the composted bagasse at the rate of 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_5$) over control.

The values ranged from 0.98 g $cc^{-1}$ ($T_9$) to 1.30 $gcc^{-1}$ ($T_1$) for bulk density; 47.09 per cent ($T_1$) to 59.98 per cent ($T_5$) for water holding capacity; 49.86 per cent ($T_1$) to 60.5 per cent ($T_9$) for porosity and 40.95 per cent ($T_5$) to 53.39 per cent ($T_1$) for volume expansion.

In cluster bean, the bulk density and volume expansion were positively reduced by the bagasse compost + *Rhizobium* added treatment ($T_5$) while the water

**Table 37. Soil physical constants for test crops as influenced by treatments**

(Mean of three replications)

| Treatments | Cowpea | | | | Cluster bean | | | | Bhendi | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Volume expan-sion on wetting (%) | Bulk density (g $cc_{-1}$) | Water holding capacity (%) | Porosity (%) | Volume expan-sion on wetting (%) | Bulk density (g $cc_{-1}$) | Water holding capacity (%) | Porosity (%) | Volume expan-sion on wetting (%) | Bulk density (g $cc_{-1}$) | Water holding capacity (%) | Porosity (%) |
| $T_1$ | 1.30 | 47.09 | 49.86 | 53.39 | 1.29 | 47.11 | 48.75 | 50.2 | 1.34 | 47.28 | 48.01 | 49.70 |
| $T_2$ | 1.09 | 57.00 | 59.30 | 42.15 | 1.10 | 55.07 | 56.25 | 45.5 | 1.12 | 50.75 | 52.12 | 47.00 |
| $T_3$ | 1.05 | 57.25 | 59.15 | 41.01 | 1.09 | 54.75 | 55.60 | 45.75 | 1.15 | 51.00 | 52.01 | 47.00 |
| $T_4$ | 1.02 | 57.95 | 59.79 | 41.25 | 1.07 | 56.10 | 57.75 | 43.05 | 1.10 | 52.75 | 53.75 | 47.05 |
| $T_5$ | 1.02 | 54.98 | 60.01 | 40.95 | 1.05 | 56.00 | 57.25 | 40.00 | 1.07 | 52.25 | 53.00 | 47.15 |
| $T_6$ | 1.01 | 57.76 | 60.25 | 41.80 | 1.09 | 55.75 | 56.50 | 42.25 | 1.07 | 52.00 | 53.75 | 47.10 |
| $T_7$ | 1.00 | 58.01 | 59.75 | 41.25 | 1.09 | 56.15 | 57.55 | 41.11 | 1.11 | 54.50 | 53.01 | 45.20 |
| $T_8$ | 1.00 | 58.25 | 59.92 | 41.20 | 1.09 | 57.61 | 58.75 | 42.10 | 1.11 | 52.00 | 53.50 | 46.25 |
| $T_9$ | 0.98 | 58.27 | 60.50 | 41.05 | 1.05 | 55.60 | 56.75 | 41.10 | 1.09 | 54.25 | 53.75 | 45.00 |
| $T_{10}$ | 1.02 | 57.25 | 59.01 | 41.55 | 1.09 | 55.00 | 56.05 | 42.75 | 1.13 | 52.00 | 53.00 | 47.00 |
| Mean | 0.95 | 56.88 | 58.75 | 42.54 | 1.10 | 54.91 | 56.12 | 43.57 | 1.13 | 51.12 | 52.47 | 46.84 |
| SEd | 0.02 | 0.11 | 0.09 | 0.06 | 0.03 | 0.09 | 0.05 | 0.09 | 0.05 | 0.03 | 0.02 | 0.03 |
| CD (5%) | 0.04 | 0.23 | 0.18 | 0.12 | 0.16 | 0.18 | 0.11 | 0.18 | 0.10 | 0.06 | 0.04 | 0.07 |

holding capacity and porosity were profoundly improved by the coffee waste compost + *Rhizobium* added treatment ($T_8$) over control and all other treatments.

The values varied from 1.05 g $cc^{-1}$ ($T_5$ and $T_9$) to 1.29 $gcc^{-1}$ ($T_1$) for bulk density; 47.11 per cent ($T_1$) to 57.61 per cent ($T_8$) for water holding capacity; 48.75 per cent ($T_1$) to 58.75 per cent ($T_8$) for porosity and 50.2 per cent ($T_1$) to 40 per cent ($T_5$) for volume expansion.

In bhendi crop, the bulk density was improved by the composted bagasse along with *Azospirillum* ($T_5$) and VAM ($T_6$) added treatments; water holding capacity was higher in the composted coffee waste + phosphobacteria ($T_7$) and VAM ($T_9$) incorporated treatments total porosity was more in the composted bagasse along with phosphobacteria ($T_4$) and VAM ($T_6$) and also composted coffee waste + VAM ($T_9$) incorporated treatments. The volume expansion was distinctly improved by the $T_9$ in which composted coffee waste was applied along with VAM.

The values ranged from 1.07 $gcc^{-1}$ ($T_5$ and $T_6$) to 1.34 g $cc^{-1}$ ($T_1$) for bulk density; 47.28 per cent ($T_1$) to 54.5 per cent ($T_7$) for water holding capacity ; 48.01 per cent (T1) to 53.75 per cent ($T_4$, $T_6$ and $T_9$) for total porosity and 45 per cent ($T_9$) to 49.7 per cent ($T_1$) for volume expansion.

#### 4.6.4.3. Influence of treatments on soil organic carbon and organic matter content (Table 38)

When compared to control and other treatments, the judicial combinations of composted coffee waste along with phosphobacteria, *Rhizobium* (for legumes), *Azospirillum* (for bhendi) and VAM ($T_7$, $T_8$ and $T_9$) prominently influenced the organic carbon and organic matter content of post harvest experimental soils in cowpea, cluster bean and bhendi crops.

The organic carbon and organic matter content values ranged from 0.98 per cent ($T_1$) to 1.6 per cent ($T_7$) and 1.68 per cent ($T_1$) to 2.9 per cent ($T_7$) in cowpea; 0.94 per cent to 1.49 per cent ($T_8$) and 1.6 per cent ($T_1$) to 2.47 per cent ($T_8$) in cluster bean and 0.92 per cent ($T_1$) to 1.25 per cent ($T_9$) and 1.59 per cent ($T_1$) to 2.15 per cent ($T_9$) in bhendi crop respectively.

#### 4.6.4.4. Influence of treatments on soil available NPK status (Tables 39,40, 41)

In cowpea, the available NPK status was higher at vegetative stage, as the stage advanced, the NPK content decreased. The nitrogen content was positively enhanced by the composted coffee waste and phosphobacteria added treatment ($T_7$) whereas the phosphorus and potassium contents were profoundly increased by the composted coffee waste and *Rhizobium* applied treatment ($T_8$) at all the stages over control and other treatments (Table 39).

**Table 38. Soil organic carbon and organic matter for test crop as influenced by treatments (percent)**

(Mean of three replications)

| Treatment | Cowpea | | Cluster bean | | Bhendi | |
|---|---|---|---|---|---|---|
| | Organic Carbon | Organic matter | Organic Carbon | Organic matter | Organic Carbon | Organic matter |
| $T_1$ | 0.98 | 1.68 | 0.94 | 1.61 | 0.92 | 1.59 |
| $T_2$ | 1.22 | 2.12 | 1.10 | 1.90 | 0.99 | 1.71 |
| $T_3$ | 1.25 | 2.15 | 1.17 | 2.03 | 1.05 | 1.80 |
| $T_4$ | 1.27 | 2.17 | 1.23 | 2.12 | 1.05 | 1.79 |
| $T_5$ | 1.28 | 2.17 | 1.22 | 2.11 | 1.10 | 1.90 |
| $T_6$ | 1.27 | 2.17 | 1.35 | 2.45 | 1.20 | 1.99 |
| $T_7$ | 1.60 | 2.90 | 1.24 | 2.17 | 1.20 | 2.10 |
| $T_8$ | 1.45 | 2.55 | 1.49 | 2.47 | 1.19 | 2.00 |
| $T_9$ | 1.58 | 2.70 | 1.34 | 2.35 | 2.25 | 2.15 |
| $T_{10}$ | 1.50 | 2.58 | 1.25 | 2.25 | 1.03 | 1.76 |
| Mean | 1.34 | 2.32 | 1.23 | 2.15 | 1.20 | 1.88 |
| SEd | 0.01 | 0.22 | 0.06 | 0.09 | 0.04 | 0.07 |
| CD (5%) | 0.03 | 0.44 | 0.12 | 0.19 | 0.08 | 0.14 |

**Table 39. Soil available NPK for cowpea as influenced by the treatments (ppm)**

(Mean of three replications)

| Treatments | Nitrogen | | | | Phosphorus | | | | Potassium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.5 | 5.5 | 5.0 | 5.60 | 14.5 | 13.7 | 12.7 | 13.63 | 142 | 135 | 110 | 129.0 |
| $T_2$ | 10.5 | 9.3 | 8.0 | 9.26 | 16.9 | 14.8 | 13.5 | 15.06 | 140 | 139 | 125 | 134.6 |
| $T_3$ | 10.4 | 9.2 | 8.1 | 9.23 | 15.9 | 14.5 | 13.7 | 14.70 | 145 | 135 | 128 | 136.0 |
| $T_4$ | 11.7 | 10.8 | 9.5 | 10.60 | 15.8 | 14.8 | 13.5 | 14.70 | 147 | 138 | 129 | 138.0 |
| $T_5$ | 11.8 | 10.5 | 9.2 | 10.50 | 16.9 | 14.9 | 13.7 | 15.16 | 151 | 140 | 132 | 141.0 |
| $T_6$ | 14.2 | 12.9 | 10.2 | 12.43 | 18.2 | 17.0 | 16.2 | 17.13 | 150 | 141 | 130 | 140.3 |
| $T_7$ | 14.6 | 13.0 | 11.5 | 13.03 | 17.9 | 16.8 | 16.0 | 16.90 | 148 | 135 | 122 | 135.0 |
| $T_8$ | 12.5 | 11.7 | 10.5 | 11.56 | 18.6 | 17.1 | 16.5 | 17.40 | 155 | 140 | 135 | 143.3 |
| $T_9$ | 12.7 | 11.8 | 10.6 | 11.70 | 18.1 | 16.7 | 16.0 | 16.93 | 155 | 138 | 129 | 140.6 |
| $T_{10}$ | 11.8 | 10.6 | 9.5 | 10.63 | 16.5 | 15.5 | 14.7 | 46.70 | 148 | 136 | 122 | 135.3 |
| Mean | 11.67 | 9.53 | 9.21 | 10.45 | 16.93 | 15.58 | 14.65 | 18.83 | 148.1 | 137.7 | 126.2 | 137.3 |
| SEd | | | | 0.31 | | | | 0.37 | | | | 0.81 |
| CD (5%) | | | | 0.61 | | | | 0.74 | | | | 1.63 |

**Table 40. Soil available NPK for cluster bean as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Nitrogen | | | | Phosphorus | | | | Potassium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 8.5 | 7.2 | 6.3 | 7.30 | 15.7 | 14.2 | 13.5 | 14.46 | 101 | 92 | 85 | 92.6 |
| $T_2$ | 8.7 | 7.5 | 6.5 | 7.56 | 15.9 | 14.7 | 13.5 | 14.70 | 115 | 102 | 95 | 104.0 |
| $T_3$ | 9.2 | 8.5 | 7.2 | 8.30 | 15.7 | 14.5 | 13.6 | 14.60 | 127 | 116 | 99 | 114.0 |
| $T_4$ | 9.1 | 8.4 | 7.4 | 8.30 | 15.9 | 14.2 | 13.5 | 14.53 | 129 | 120 | 108 | 119.0 |
| $T_5$ | 9.0 | 8.4 | 7.5 | 8.30 | 16.5 | 15.4 | 14.0 | 15.30 | 131 | 120 | 106 | 119.0 |
| $T_6$ | 8.8 | 8.0 | 7.1 | 7.96 | 16.2 | 15.3 | 14.5 | 15.33 | 142 | 121 | 106 | 122.6 |
| $T_7$ | 8.8 | 8.2 | 7.3 | 8.10 | 16.6 | 15.6 | 14.9 | 15.70 | 145 | 126 | 108 | 126.3 |
| $T_8$ | 9.9 | 8.7 | 7.7 | 8.76 | 16.5 | 15.2 | 14.8 | 15.50 | 142 | 124 | 108 | 124.6 |
| $T_9$ | 9.1 | 8.5 | 8.0 | 8.53 | 14.5 | 16.1 | 15.0 | 15.20 | 140 | 122 | 104 | 122.0 |
| $T_{10}$ | 8.7 | 8.1 | 7.8 | 8.20 | 16.5 | 15.5 | 14.2 | 15.40 | 132 | 118 | 107 | 119.0 |
| Mean | 8.98 | 8.15 | 8.01 | 8.13 | 15.9 | 15.07 | 14.15 | 15.07 | 130.4 | 116.1 | 102.5 | 116.3 |
| SEd | | | 0.27 | | | | 0.34 | | | | 0.54 | |
| CD (5%) | | | 0.54 | | | | 0.68 | | | | 1.08 | |

**Table 41. Soil available NPK for bhendi as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Nitrogen | | | | Phosphorus | | | | Potassium | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.2 | 5.5 | 4.9 | 5.53 | 12.5 | 11.2 | 10.5 | 11.40 | 85 | 80 | 73 | 79.3 |
| $T_2$ | 5.7 | 5.9 | 4.8 | 5.46 | 12.5 | 11.6 | 10.7 | 11.60 | 83 | 78 | 72 | 77.6 |
| $T_3$ | 6.0 | 5.7 | 4.7 | 5.46 | 12.2 | 11.2 | 10.9 | 11.43 | 88 | 79 | 75 | 80.6 |
| $T_4$ | 8.9 | 6.5 | 5.7 | 7.03 | 14.9 | 13.9 | 12.5 | 13.76 | 91 | 83 | 79 | 84.3 |
| $T_5$ | 8.9 | 7.2 | 6.0 | 7.36 | 14.5 | 13.7 | 11.9 | 13.36 | 90 | 85 | 79 | 84.6 |
| $T_6$ | 7.5 | 6.3 | 5.2 | 6.33 | 14.7 | 13.2 | 11.7 | 13.20 | 91 | 85 | 78 | 84.6 |
| $T_7$ | 8.2 | 7.2 | 6.1 | 7.16 | 13.6 | 12.8 | 11.5 | 12.63 | 95 | 89 | 82 | 88.6 |
| $T_8$ | 8.5 | 7.5 | 6.4 | 7.46 | 12.9 | 11.7 | 10.7 | 11.76 | 92 | 86 | 80 | 86.0 |
| $T_9$ | 9.0 | 8.2 | 6.8 | 8.00 | 14.5 | 13.8 | 11.9 | 13.40 | 91 | 86 | 79 | 85.3 |
| $T_{10}$ | 8.0 | 6.8 | 5.7 | 6.83 | 13.5 | 12.4 | 11.3 | 12.40 | 89 | 78 | 75 | 80.6 |
| Mean | 7.69 | 6.68 | 5.63 | 6.66 | 13.58 | 12.55 | 11.36 | 12.49 | 89.5 | 82.9 | 77.2 | 83.15 |
| SEd | | | | 0.44 | | | | 0.52 | | | | 2.10 |
| CD (5%) | | | | 0.90 | | | | 1.06 | | | | 4.21 |

In cluster bean the available nitrogen status was spectacularly influenced by the $T_8$ in which composted coffee waste along with *Rhizobium* was added, whereas the phosphorus and potassium contents were distinctly enhanced by the $T_7$ in which the composted coffee waste along with phosphobacteria was added (Table 40).

In bhendi, the available nitrogen was markedly increased in the composted coffee waste + VAM incorporated treatment ($T_9$), the phosphorus was more in composted bagasse + phosphobacteria added treatment ($T_4$) and the potassium content was higher in composted coffee waste + phosphobacteria applied treatment ($T_7$) over control and other treatments in all the stages (Table 41).

#### 4.6.4.5. Influence of treatments on soil available micronutrient status (Tables 42, 43, 44)

In cowpea, the iron and zinc contents were more in the composted coffee waste + phosphobacteria added treatment ($T_7$) at vegetative and flowering stages, the manganese and copper contents were more in the composted bagasse + VAM added treatment ($T_6$) at vegetative and flowering stages than the control and other treatments. At harvest time, in $T_7$ the ferrous and manganese contents were higher and in $T_6$, the copper and zinc contents were higher than control and other treatments (Table 42).

**Table 42. Soil available micronutrients for cowpea as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Iron (Fe) | | | | Manganese (Mn) | | | | Copper (Cu) | | | | Zinc (Zn) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 8.0 | 7.1 | 5.8 | 7.0 | 6.5 | 5.2 | 3.8 | 5.2 | 0.75 | 0.62 | 0.49 | 0.62 | 0.42 | 0.30 | 0.26 | 0.33 |
| $T_2$ | 8.2 | 7.0 | 5.6 | 7.0 | 6.7 | 5.4 | 3.9 | 5.3 | 1.3 | 0.95 | 0.77 | 1.0 | 0.61 | 0.40 | 0.33 | 0.45 |
| $T_3$ | 8.4 | 7.1 | 5.6 | 7.0 | 6.9 | 5.4 | 3.8 | 5.4 | 1.3 | 1.00 | 0.75 | 1.0 | 0.62 | 0.41 | 0.31 | 0.45 |
| $T_4$ | 8.4 | 7.3 | 5.8 | 7.0 | 7.2 | 6.0 | 4.5 | 5.9 | 1.7 | 1.2 | 0.77 | 1.2 | 0.65 | 0.45 | 0.34 | 0.48 |
| $T_5$ | 10.2 | 8.9 | 6.0 | 8.4 | 7.5 | 6.5 | 4.9 | 5.9 | 2.0 | 1.5 | 0.98 | 1.5 | 0.69 | 0.47 | 0.37 | 0.51 |
| $T_6$ | 10.5 | 8.0 | 6.2 | 8.2 | 7.2 | 6.2 | 4.4 | 5.9 | 1.7 | 1.2 | 0.79 | 1.2 | 0.67 | 0.44 | 0.35 | 0.49 |
| $T_7$ | 10.8 | 8.9 | 6.2 | 8.7 | 7.6 | 6.7 | 5.0 | 6.4 | 1.9 | 1.5 | 0.95 | 1.5 | 0.69 | 0.45 | 0.38 | 0.51 |
| $T_8$ | 10.1 | 7.9 | 6.0 | 8.0 | 7.3 | 6.4 | 4.9 | 6.2 | 1.7 | 1.2 | 0.82 | 1.2 | 0.70 | 0.44 | 0.37 | 0.50 |
| $T_9$ | 10.0 | 7.9 | 6.1 | 8.0 | 7.4 | 6.5 | 4.9 | 6.3 | 1.7 | 1.2 | 0.83 | 1.24 | 0.70 | 0.44 | 0.37 | 0.50 |
| $T_{10}$ | 9.1 | 7.5 | 5.7 | 7.4 | 7.0 | 6.0 | 4.3 | 5.8 | 1.4 | 1.0 | 0.77 | 1.06 | 0.63 | 0.41 | 0.34 | 0.46 |
| Mean | 9.4 | 7.8 | 5.9 | 7.7 | 7.1 | 6.0 | 4.4 | 5.8 | 1.4 | 1.2 | 0.82 | 1.1 | 0.65 | 0.43 | 0.35 | 0.51 |
| SEd | | | | 0.07 | | | | 0.05 | | | | 0.07 | | | | 0.05 |
| CD (5%) | | | | 0.14 | | | | 0.11 | | | | 0.14 | | | | 0.10 |

**Table 43. Soil available micronutrients for cluster bean as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Iron (Fe) | | | | Manganese (Mn) | | | | Copper (Cu) | | | | Zinc (Zn) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.8 | 6.0 | 5.7 | 6.2 | 6.2 | 5.4 | 3.9 | 5.2 | 0.55 | 0.40 | 0.29 | 0.41 | 0.31 | 0.20 | 0.10 | 0.20 |
| $T_2$ | 7.2 | 6.5 | 6.0 | 6.6 | 6.5 | 5.2 | 4.0 | 5.2 | 0.95 | 0.87 | 0.73 | 0.85 | 0.44 | 0.34 | 0.25 | 0.34 |
| $T_3$ | 7.0 | 6.4 | 5.8 | 6.5 | 6.4 | 5.3 | 4.1 | 5.3 | 0.95 | 0.86 | 0.75 | 0.85 | 0.46 | 0.35 | 0.25 | 0.35 |
| $T_4$ | 7.5 | 6.5 | 6.0 | 6.7 | 6.8 | 5.7 | 4.5 | 5.7 | 0.98 | 0.88 | 0.76 | 0.87 | 0.49 | 0.37 | 0.28 | 0.38 |
| $T_5$ | 7.9 | 6.7 | 6.0 | 6.9 | 7.0 | 5.7 | 4.4 | 5.7 | 0.98 | 0.88 | 0.75 | 0.87 | 0.49 | 0.38 | 0.29 | 0.39 |
| $T_6$ | 7.9 | 6.8 | 6.1 | 6.9 | 7.0 | 5.7 | 4.3 | 5.7 | 0.96 | 0.88 | 0.75 | 0.86 | 0.51 | 0.41 | 0.30 | 0.41 |
| $T_7$ | 8.2 | 7.0 | 6.3 | 7.2 | 7.1 | 5.8 | 4.4 | 5.8 | 0.97 | 0.89 | 0.76 | 0.87 | 0.50 | 0.42 | 0.30 | 0.41 |
| $T_8$ | 8.0 | 7.1 | 6.6 | 7.6 | 7.0 | 5.8 | 4.5 | 5.8 | 0.97 | 0.89 | 0.76 | 0.87 | 0.51 | 0.42 | 0.34 | 0.44 |
| $T_9$ | 8.1 | 7.0 | 6.1 | 7.1 | 7.1 | 5.7 | 4.4 | 5.7 | 0.97 | 0.87 | 0.76 | 0.87 | 0.51 | 0.42 | 0.30 | 0.41 |
| $T_{10}$ | 7.0 | 6.3 | 5.9 | 6.4 | 6.6 | 5.5 | 4.2 | 5.4 | 0.96 | 0.87 | 0.71 | 0.86 | 0.50 | 0.40 | 0.27 | 0.39 |
| Mean | 7.6 | 6.6 | 6.0 | 6.8 | 6.8 | 5.6 | 4.3 | 5.6 | 0.96 | 0.87 | 0.75 | 0.86 | 0.48 | 0.38 | 0.28 | 0.38 |
| SEd | | | | 0.05 | | | | NS | | | | 0.04 | | | | 0.05 |
| CD (5%) | | | | 0.10 | | | | NS | | | | 0.08 | | | | 0.11 |

**Table 44. Soil available micronutrients for bhendi as influenced by treatments (ppm)**

(Mean of three replications)

| Treatments | Iron (Fe) | | | | Manganese (Mn) | | | | Copper (Cu) | | | | Zinc (Zn) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean | V.S. | F.S. | H.S. | Mean |
| $T_1$ | 6.5 | 5.3 | 5.0 | 5.6 | 5.9 | 4.6 | 3.6 | 4.7 | 0.25 | 0.20 | 0.15 | 0.20 | 0.2 | 0.13 | 0.09 | 0.14 |
| $T_2$ | 6.7 | 5.7 | 5.1 | 5.8 | 6.3 | 5.7 | 4.7 | 5.6 | 0.30 | 0.22 | 0.17 | 0.23 | 0.27 | 0.20 | 0.14 | 0.20 |
| $T_3$ | 6.8 | 5.7 | 5.1 | 5.9 | 6.2 | 5.5 | 4.6 | 5.4 | 0.32 | 0.24 | 0.17 | 0.24 | 0.27 | 0.22 | 0.16 | 0.22 |
| $T_4$ | 7.4 | 5.9 | 5.3 | 6.4 | 6.5 | 5.6 | 4.8 | 5.7 | 0.42 | 0.32 | 0.21 | 0.32 | 0.35 | 0.25 | 0.18 | 0.26 |
| $T_5$ | 7.3 | 6.1 | 5.2 | 6.2 | 6.6 | 5.6 | 4.9 | 5.7 | 0.41 | 0.30 | 0.20 | 0.30 | 0.34 | 0.25 | 0.17 | 0.25 |
| $T_6$ | 7.1 | 6.1 | 5.2 | 6.1 | 6.4 | 5.6 | 4.8 | 5.6 | 0.41 | 0.31 | 0.20 | 0.31 | 0.37 | 0.26 | 0.17 | 0.25 |
| $T_7$ | 7.3 | 6.2 | 5.3 | 6.3 | 6.5 | 5.7 | 4.9 | 5.7 | 0.40 | 0.30 | 0.21 | 0.30 | 0.36 | 0.26 | 0.17 | 0.26 |
| $T_8$ | 7.2 | 6.1 | 5.2 | 6.2 | 6.5 | 5.6 | 4.9 | 5.7 | 0.40 | 0.30 | 0.21 | 0.30 | 0.35 | 0.24 | 0.18 | 0.26 |
| $T_9$ | 7.1 | 6.0 | 5.2 | 6.1 | 6.5 | 5.6 | 4.9 | 5.7 | 0.41 | 0.30 | 0.21 | 0.31 | 0.35 | 0.25 | 0.17 | 0.26 |
| $T_{10}$ | 7.0 | 6.0 | 5.1 | 6.0 | 6.4 | 5.5 | 4.7 | 5.5 | 0.38 | 0.27 | 0.18 | 0.28 | 0.29 | 0.22 | 0.17 | 0.23 |
| Mean | 7.0 | 5.9 | 5.2 | 6.0 | 6.4 | 5.5 | 4.7 | 5.5 | 0.37 | 0.28 | 0.19 | 0.28 | 0.32 | 0.23 | 0.16 | 0.24 |
| SEd | | | | 0.07 | | | | 0.06 | | | | 0.04 | | | | 0.07 |
| CD (5%) | | | | 0.14 | | | | 0.12 | | | | 0.09 | | | | 0.15 |

In cluster bean, at vegetative and harvest stages, the iron, manganese, copper and zinc contents were prominently enhanced by the composted bagasse + VAM added treartment ($T_6$) whereas at flowering stage, the manganese and copper contents were significantly attenuated in $T_9$ in which composted coffee waste was applied along with VAM than the control and all other treatments (Table 43).

In bhendi, at vegetative stage, the iron and zinc contents were more in $T_8$ (composted coffee waste + *Azospirillum*) and manganese and copper contents were more in $T_7$ (composted coffee waste + phosphobacteria) than control and other treatments.

At flowering stage, iron, manganese and copper contents were recorded higher in $T_5$ (composted bagasse + *Azospirillum*) whereas zinc was more in $T_8$ (composted coffee waste + *Azospirillum*) than control and other treatments.

At harvest stage, iron and manganese contents were positively enhanced by the composted coffee waste + VAM added treatment ($T_9$); copper was higher in composted bagasse along with *Rhizobium* ($T_5$) and VAM ($T_6$) incorporated treatments, the zinc content was higher in the composted bagasse + VAM ($T_6$) and composted coffee waste + phosphobacteria ($T_7$) added treatments than the control and the other treatments (Table 44).

# DISCUSSION

# CHAPTER-5

# DISCUSSION

Towards realizing the objectives enumerated in the introduction, investigations were carried out in respect of microbial degradation of bagasse and coffee waste; effect of microbial consortia along with urea and rock phosphate; changes in physico-chemical characteristics of agro-wastes during composting and pot culture experiments to elicit information on the impact of biocomposts on test crops and on soil health. The results reported in the investigation are discussed in this Chapter.

## 5.1. MICROBIAL DEGRADATION OF AGRO-WASTES

### 5.1.1. C/N ratio as influenced by treatments during biodegradation of bagasse

During biodegradation, the organic carbon of bagasse decreased gradually and an increasing trend in total nitrogen was observed. In control ($T_1$ - uninoculated), the loss of organic carbon was only 8.4 per cent on 60$^{th}$ day and it required further time for degradation. When compared to single microbial inoculum added treatments, the dual inoculum added treatments ($T_5$, $T_6$ and $T_7$) performed better in degrading the bagasse in terms of C/N ratio. On 60$^{th}$ day of incubation the loss in organic carbon was maximum (47 per cent) in $T_5$ where dual culture of *Pleurotus sajor-caju* and *Trichoderma harzianum* were added. Simultaneously, the total nitrogen content of bagasse also increased to a greater extent in the same treatment. Hence the consortia of *Pleurotus sajor-caju* + *Trichoderma harzianum* brought down the C/N ratio of bagasse from 190:1 to 29:1 within 60 days when compared with control and other treatments.

### 5.1.2. Microbial respiration as influenced by treatments during biodegradation of bagasse

Carbon-di-oxide evolution from the substrate is one of the important parameter for determining the rate and extent of degradation of any organic material. In the present study, maximum response for microbial respiration in terms of cumulative and rate of $CO_2$ evolution was recorded (1002 to 1016 mg of $CO_2$ 100 $g^{-1}$ g bagasse) in the *Pleurotus sajor-caju* + *Trichoderma harzianum* added treatment ($T_5$).

Due to synergistic effects, the dual culture of *P. sajor-caju* + *T. harzianum* hastened the biodegradation of bagasse which substantiated the above results by lowering the wide C/N ratio to 29:1 and increasing the respiratory rate within 60 days of total incubation period.

Similar findings have been reported by Negro, (1992) and Kakezawa *et al.*, (1992).

### 5.1.3. C/N ratio as influenced by treatments during biodegradation of coffee waste

When compared to uninoculated control, the combined inoculum of *Pleurotus sajor-caju* and *Trichoderma harzianum* ($T_5$) significantly enhanced the total nitrogen and efficiently lowered the organic carbon content of coffee waste. Thus the reduction of C/N ratio was to an optimum level of 23:1 within 70 days of incubation in the same treatment.

### 5.1.4. Microbial respiration as influenced by treatments during biodegradation of coffee waste

The cumulative and rate of $CO_2$ evolution revealed the microbial activity of organic waste. The control (uninoculated) evolved less amount $CO_2$ than the microbial treatments ($T_2$ to $T_7$) throughout the period of incubation. The $CO_2$ evolution is considered as a measure of heterotrophic microbial activity which determined the mineralization. Thus the influence of *Pleurotus sajor-caju* + *Trichoderma harzianum* was significant on 70$^{th}$ day of incubation. The mean values for cumulative and rate of $CO_2$ evolution in $T_5$, $T_6$ and $T_7$ indicated that the combined effects were very much conspicuous in the presence of consortia microbes. This was evident from the mean values of $CO_2$ evolution in single microbial treatments as compared to dual combination.

Among the treatments, $T_5$ was superior to other treatments throughout the period of incubation. Hence within a period of 60-70 days degradation of coffee waste was enhanced by these two fungi without addition of any adjunctants like urea or phosphorus.

Increase of this kind of decomposition velocity can be attributed to lignin and cellulose degrading capacity of fungi *Pleurotus sajor-caju* and *Trichoderma harzianum*.

This is in accordance with the findings of Viesturs *et al.*, (1981); Bisaria and Ghose, (1981) and McCarthy, (1987).

## 5.2. ENRICHMENT OF AGRO-WASTES

The present experiment was undertaken to improve the method of composting by hastening the process of composting by inoculating the ligno-cellulolytic fungi, cheap source of rock phosphate (Mussoorie rock phosphate) and urea. The total microbial activity in terms of soil respiration during composting was determined in the laboratory experiment for $CO_2$ evolution.

### 5.2.1. Influence of treatments on microbial respiration during enrichment of bagasse

The microbial inoculum added treatments on bagasse ($T_5$ to $T_9$) significantly influenced the cumulative and rate of $CO_2$ evolution throughout the incubation period when compared to control and non-microbial treatments ($T_1$ to $T_4$).

Enrichment of bagasse with *Pleurotus sajor-caju* + *Trichoderma harzianum*, urea and rock phosphate (Mussoorie) significantly attenuated the respiratory rate between 80-92 per cent over control and all other treatments within 50 days.

The single and combined effect of urea and Mussoorie rock phosphate enriched bagasse (non-microbial treatments - $T_2$ and $T_4$) recorded a marginal increase of respiratory rate between 13 to 25 per cent at early stages and 10 per cent at later stages of incubation. The microbial inoculated treatments performed better than other treatments on cumulative and rate of $CO_2$ evolution.

At initial stages of enrichment period, the rate of respiration increased from 32 per cent ($T_5$) to 94 per cent ($T_9$) and at later stages, a spectacular increase of 25 per cent ($T_5$) to 92 per cent ($T_9$) was recorded on $50^{th}$ day of incubation.

### 5.2.2. Influence of treatments on microbial respiration during enrichment of coffee waste

In coffee waste, the single and combined effect of urea and rock phosphate without microbe ($T_1$ to $T_4$) influenced the rate of respiration by 27 to 33 per cent at initial stages and by 9 to 36 per cent at final stages after enrichment.

The microbial inoculated treatments ($T_5$ to $T_9$) along with urea and rock phosphate profoundly increased the rate of decomposition by 40 to 64 per cent during early stages of incubation. Within 60 days, a spectacular increase in respiratory rate from 55 per cent ($T_6$) to 136 per cent ($T_9$) was recorded.

In both the agro-wastes, as soon as the organic material along with urea and rockphosphate were added to the soil, the microbial activity shoot up which resulted in corresponding increase of $CO_2$ evolution. The combined effect of *Pleurotus sajor-caju, Trichoderma harzianum*, urea and rock phosphate enrichment ($T_9$) revealed superiority in cumulative and rate of $CO_2$ evolution over all other treatments and uninoculated control.

This finding is in accordance with the results of Ishac *et al.*, (1987) and Manna *et al.*, (1996).

## 5.3. COMPOSTING OF BAGASSE AND COFFEE WASTE

Composting organic residues and biological wastes with phosphate rocks has been practiced widely as a low input technology to improve the fertilizer value of the manures which enhances the solubility of phosphate rocks (Mishra and Bangar, 1986; Singh and Amberger, 1991).

Maturity of composts critically affects their successful utilization in agriculture. Immature composts with a wide range of C/N ratio causes nitrogen immobilization. Excessively low C/N ratio composts cause ammonium toxicity. Both extremes interfere with plant growth (Inbar *et al.*, 1990).

### 5.3.1. Evaluation of compost maturity based on physical parameters

Temperature inside the composting heaps increased rapidly reaching values from 58°C to 61°C for bagasse and 59°C to 67°C for coffee waste. It was controlled by periodic mixing and water addition. The temperature drop and gradual stabilization to existing ambient levels between 28°C and 30°C in both the organic wastes were an indication that the composts have matured.

This may be attributed to the inactivation of any pathogens possibly present initially in the raw material. Similar findings have been reported by De Bertoldi and Zucconi, (1980) and Bollen, (1984).

The optimum pH values for bacterial development are 6.0-7.5 while fungi prefer an environment in the range of 5.5-8.0. During composting the pH values are

initially low. Then pH increases and at the final stage of composting a slight decrease in pH is expected (Verdonck, 1988). This pattern was observed in the present investigation too. The pH stabilization for bagasse (7.1 to 7.5) within 40-45 days and for coffee waste ( 7.6 to 7.3) within 56 days was observed.

There was a gradual reduction in electrical conductivity and volume in both the organic wastes, noticed periodically. Being essentially, a digestion process composting causes reduction in the quantity of biomass. Hence in the present study, there was a reduction in the volume by 40-50 per cent in both the organic wastes.

These results are in line with the findings of Polo *et al.*, (1988); Branch and Hendrick, (1992); Baca *et al.*, (1993) and Hutasoit and Toharisman, (1994).

**5.3.2. Evaluation of compost maturity based on chemical parameters**

The diphenyl amine test is a simple method in which qualitative analyses are conducted on nitrate nitrogen, the substance generated by nitrification in the composting process (Harada, 1991). In the present investigation, compost filtrates of bagasse and coffee waste at initial stages did not turn blue. The compost filtrates at the end of composting period turned deep blue colour due to the high nitrate nitrogen concentration indicating the compost maturity.

The C/N ratio is often used as in index of compost maturity. A decrease from an initial C/N value of 35-40 or higher to a final level of 18-28 implies an advanced degree of stabilization (Zucconi and De Bertoldi, 1987). In the present study, the C/N

ratio of composted bagasse was decreased from 190 to 24 within 7 weeks. In coffee waste an advanced degree of stabilization for C/N ratio was reached at 20.3 within 8 weeks.

Simultaneously, degradation of complex components such as lignin (15.2 to 6.5 per cent), cellulose (35.7 to 14 per cent) and an increase in macro and micro nutrients were recorded in bagasse. In coffee waste, apart from lignocellulosic components, caffeine has also found to be toxic which affects the plant growth and environment (Bressani, 1979 and Martinez *et al.*, 1985). In the present work lignin, cellulose and caffeine contents were decreased from 48.2 per cent to 10.1 per cent, 33.96 per cent to 11.6 per cent and 0.79 per cent to 0.25 per cent respectively. There was an increasing trend in nitrogen, phosphorus and potassium which revealed the manurial value of coffee waste compost. Simultaneously the micronutrient status was also improved to a greater extent by the microbial activity.

### 5.3.3. Evaluation of compost maturity based on bioassay

The adverse effects of addition of raw organic material to the soil are avoidable by composting organic material before using it as an amendment (Nogales *et al.*, 1982; Inoko, 1985 and Riffaldi *et al.*, 1986). Negative effects may however persist if the compost is not ripe enough (Juste, 1980). Among large number of procedures to determine the degree of maturity of composts, biological assays provide most reliable information (Hadar *et al.*, 1985 and Morel *et al.*, 1985).

In the present study, a bioassay using cowpea as test plant was applied to assess the impact of bagasse and coffee waste compost maturity on germination and seedling development.

During early stages of composting process of both agro-wastes, the extracts of compost samples inhibited the growth of seedlings. It may be due to the presence of water soluble phytotoxic substances. In addition, competition for nitrogen, other nutrients and oxygen also play a role in immature compost (Chanyasak *et al.*, 1983). Well developed seedlings (Healthy) were grown in the compost extracts of later stages of composting period.

The cowpea seedling growth was markedly enhanced in the extracts from $5^{th}$ week to $8^{th}$ week compost samples during which noticeable decrease in temperature inside the heap was observed. This kind of result indicated the steady rise in maturity of both organic wastes.

According to Zucconi and De Bertoldi, (1986), most phytotoxic substances are destroyed during thermophilic phase, once these substances disappear plant growth is markedly enhanced. Similar observations of the present work that concur with the findings of Baca *et al.*, (1990) and Inbar *et al.*, (1990).

## 5.4. POT CULTURE EXPERIMENTS

The modern agriculture depends mostly on chemical fertilizers. The escalating prices of fertilizers and their unavailability in the appropriate time, besides the

availability of agro-industrial wastes for recycling, warrant the approach of integrated nutrient management (INM) and to prevent the environmental pollution in a phased manner. It is imperative to increase the productivity of crops and to maintain the soil health through the balanced use of fertilizers, organics and bio-inoculants.

Hence in the present investigation, the concept of integrated nutrient management was followed by the best blending of trio-modes in pot culture experiments conducted in phase I and Phase II.

## 5.5. POT CULTURE EXPERIMENT-I

In the first phase of pot experiment, cowpea (*Vigna unguiculata* L. Walp) and cluster bean (*Cyamopsis tetragonaloba* T.) were selected as test crops. In countries like India, Leguminous seeds provide majority of protein that is required for human nutrition to supplement the carbohydrates of the cereals (Langer and Hill, 1982). Farm yard manure, composted coirpith, composted bagasse and composted coffee wastes as organics; urea, superphosphate and potash as inorganics were utilized as different modes of nutrient integration in the potculture experiment-I.

### 5.5.1. Influence of treatments on number of leaves

The number of leaves of cowpea and cluster bean were enhanced by 51 per cent in cowpea and 64 per cent in cluster bean in 100 per cent NPK ($T_8$) incorporated treatment followed by organics applied treatments. The enhancement in these treatments ranged from 24 per cent to 40 per cent in cowpea and 36 per cent to 56 per cent in cluster bean.

This is due to the higher nutrient availability caused by the incorporation of composts, farmyard manure and inorganic fertilizers to the soil which inturn had increased the number of leaves of the legumes. Similar results have been reported by Duraisamy, (1992) and Selvakumari *et al.*, (1992).

The effect of combined and individual application of undecomposed agro-wastes along with inorganic NPK on this parameter was insignificant in cowpea and marginal in cluster bean. This adverse effect may be due to the complex components present in the raw agro wastes. This is in line with the findings of Lovett and Jessop, (1982).

**5.5.2. Influence of treatments on root volume**

The effect of combined and individual incorporation of composts on cowpea increased the root volume by 144 to 190 per cent where as in $T_8$ (100 per cent NPK) the enhancement was 142 per cent. Similarly in cluster bean, the root volume markedly influenced in the organics added treatments by 80-110 per cent than control and other treatments. Increase in root volume may be due to the favourable soil physical environment provided by the organic manures. This view is supported by Anand Kumar *et al.*, (1997) and Singh, (1997).

**5.5.3. Influence of treatments on nodule index**

Though all the treatments influenced the nodule index of the test crops during their vegetative and flowering stages, the effects of farm yard manure, organics with and without inorganics were much pronounced when compared with that of control.

In cowpea during vegetative and flowering stages, the incorporation of composted coffee waste at the rate of 12.5 t $ha^{-1}$ along with 100 per cent NPK ($T_{12}$) prominently enhanced this parameter to a greater extent (80 per cent) than the control and all other treatments.

In cluster bean, application of composted coffee waste alone at the rate of 12.5 t $ha^{-1}$ ($T_6$) increased the nodule index by 19 per cent over control and all other treatments.

These results showed the positive role of composts in increasing the nodule index of legumes. This could be attributed to the increased nutrient content of organics which favoured the nodulation of the legumes. This is concurred with the experimental results of Sandhu, (1992) and Selvakumari *et al.*, (1992).

**5.5.4. Influence of treatments on plant height**

In cowpea, the plant height was profoundly increased by 36 to 72 per cent in the composts added treatment. The inorganic fertilizers at the rate of recommended dose enhanced these parameters by 42 per cent over control. In cluster bean, growth parameter was distinctly influenced by 47 per cent in the 100 per cent NPK applied treatment ($T_8$) and in the composts added treatments the enhancement of plant height was from 34 to 44 per cent over control. The trend of results obtained during all the stages for the test crops showed the positive impact of the organic manures on the growth of legumes.

In both the test crops, the plant height was insignificantly influenced by the raw agro-wastes and only a marginal effect was observed when these wastes were combined with inorganic fertilizers. This adverse effect might be due to the wide C/N ratio and other toxic components present in the agro-wastes.

This is in accordance with the findings of Thilagavathi and Mathan, (1995). The increased nutrient availability due to the application of composted bagasse, composted coirpith, composted coffee waste and farm yard manure in the soil would have promoted the plant growth. This is in line with the findings of Krishnan, (1986) and Veerabadran, (1992).

**5.5.5. Influence of treatments on the plant fresh weight**

The plant fresh weight in cowpea crop was profoundly increased from 23 per cent to 38 per cent in the organic manures added treatments especially in the composted bagasse and coffee waste along with 50 and 100 per cent NPK added treatments ($T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) and 31 per cent in the 100 per cent NPK alone added treatment ($T_8$) when compared with the control.

In cluster bean, enhancement of plant fresh weight from 24 to 29 per cent in the organics incorporated treatments and 36 per cent in the $T_8$ over control.

In both the test crops, the effect of undecomposted agro wastes along with and without inorganic fertilizers was marginal or on par with the control.

The increase in plant fresh weight could be due to the favourable soil physical environment provided by the nutrient rich composts. This is in accordance with the results of Anabayan and Palaniappan, (1991); Duraisamy, (1992); Jayakumar and Shaji, (1993) and Gaonker and Sreenivasa,(1994).

**5.5.6. Influence of treatments on the plant dry weight**

The composted bagasse and coffee waste along with 100 per cent NPK ($T_{11}$ and $T_{12}$) increased this parameter to a greater extent of 67 per cent in cowpea and 29 per cent in cluster bean than control and all other treatments. The increased dry matter production of crops could be attributed due to the integrated nutrient approach. This is in agreement with the findings of Kataria and Grover, (1987); Bhosekar and Raikhelkar, (1990); Singh and Amberger, (1995) and Bherghe, (1996).

In this present study, the plant dry weight of cowpea and cluster bean positively related with grain yield with the 'r' values being 0.943** and 0.963** respectively (Table 45 & 46).

**5.5.7. Influence of treatments on the yield parameters of legumes**

In cowpea, the $T_8$ and $T_{12}$ recorded maximum number of pods in which 100 per cent NPK alone and combined application of composted coffee waste along with inorganic fertilizers were incorporated respectively. Pod length of cowpea enhanced by 18 per cent in the combination of bagasse compost along with 100 per cent NPK added treatment ($T_{11}$). The pod fresh weight was increased (by 71 per cent over

control) spectacularly in the composted coffee waste along with 50 per cent NPK applied treatment ($T_{10}$).

Pod dry weight was profoundly increased upto 38 per cent in $T_4$, $T_6$ and $T_{12}$ in which composted coirpith, composted coffee waste, composted coffee waste along with 100 per cent NPK were added respectively.

The number of grains per pod was more in composts with and without inorganic fertilizers incorporated treatments and the enhancement was upto 62 per cent than the control.

Haulm weight was profoundly influenced by 55 per cent in the coir compost ($T_4$) and bagasse compost ($T_5$) applied treatments.

Grain yield was prominently enhanced by 70 per cent in the composted coffee waste along with 100 per cent NPK ($T_{12}$) when compared to control and all other treatments.

All the undecomposed agro wastes added treatments had only marginal effect on the yield parameters of cowpea.

In cluster bean, the biocomposts ($T_4$ to $T_{12}$) enhanced the number of pods per plant from 75 to 96 per cent over control. The pod length was profoundly influenced from 19 to 30 per cent in the treatments $T_4$ to $T_{12}$ when compared with the control. The pod fresh and dry weights were spectacularly increased in the composted coffee waste along with 100 per cent NPK ($T_{12}$) 53 per cent and 123 per cent respectively over control and all other treatments.

Number of grains per pod and haulm weight were increased by 77 per cent and 83 per cent in the composted coffee waste alone ($T_6$) and in combination with 100 per cent NPK ($T_{12}$) incorporated treatments respectively over control.

The grain yield was enhanced (by 116 per cent over control) spectacularly in the bagasse compost and coffee waste compost applied treatments ($T_{11}$ and $T_{12}$).

The direct incorporation of raw agro-wastes along with and without inorganic fertilizers on soil to cluster bean crop had only marginal effect on yield parameters.

The judicial combinations of organics along with inorganic fertilizers favourably enhanced the yields of cowpea and cluster bean. This kind of integrated nutrient approach is important to sustain crop productivity and soil fertility. This view is concurred with the results of Selvakumari *et al.*, (1992); Selvi Ranganathan and Augustine Selvaseelan, (1994).

### 5.5.8. Post harvest soil analysis

#### 5.5.8.1. Influence of treatments on soil physical constants

The influence of organics (coir compost, farm yard manure, bagasse compost and coffee waste compost) incorporation in improving the physical constants of experimental soil was very favourable.

The bulk density and volume expansion on wetting were observed higher in the undecomposed organic wastes along with and without inorganic fertilizers ($T_2$, $T_3$, $T_{13}$, $T_{14}$, $T_{15}$ and $T_{16}$) in both the test crops. This result may be attributed to the direct

incorporation of raw organic wastes on soil which inturn affected the biometrics and yield parameters of the test crops.

In cowpea and cluster bean, the farm yard manure ($T_7$) and composts applied treatments ($T_4$, $T_5$, $T_6$, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) profoundly reduced the bulk density when compared with control and all other treatments. This property provided a favourable physical environment in soil which boosted the yield of legumes.

The water holding capacity and porosity of the experimental soils increased by 16 and 17 per cent in cowpea; 14 and 13 per cent in cluster bean in the organics and farm yard manure applied treatments respectively over control.

The trend of results showed that the application of composts and farm yard manure favourably increased the physical constants of the experimental soils. The reduction in volume expansion on wetting and bulk density; improvement in the water holding capacity and porosity were caused by the incorporation of composts to the soil. These results can be assigned to the beneficial effects in improving the soil structure and provided favourable soil environment for root growth and nutrient uptake.

Similar results have been reported by Durai and Rajagopal, (1983); Ramaswamy and Sree Ramulu, (1985) and Kandaswamy, (1993).

**5.5.8.2. Influence of treatments on soil organic carbon and organic matter**

In the first phase of pot culture experiment the organic carbon and organic matter contents were distinctly increased from 7 to 16 per cent and 8 to 15 per cent

respectively by the application of coir compost ($T_4$), bagasse compost ($T_5$), coffee waste compost ($T_6$) and farm yard manure ($T_7$) in cowpea.

Similarly in the post harvest soil samples of cluster bean, the organic carbon and organic matter contents were increased from the range of 11 to 15 per cent in the composts and farm yard manure added treatments when compared to control and all other treatments. These treatments may have acted as a good carrier for biological activity which indicated the health of soil and sustained the crop productivity.

Similar results were reported by Adhikari *et al.*, (1997) who monitoried the effect of phosphocompost on growth and yield of rice and blackgram crops and higher organic carbon content in the compost treated post harvest soils. Similar results have been reported by Selvi and Selvaseelan, (1992) and Abdul Kalam, (1998).

In this present investigation, the organic carbon and organic matter of post harvest soil for cowpea (Table 45) was found to be significantly related with the grain yield with the 'r' values being 0.730** and 0.719** respectively.

The organic carbon and organic matter in soil after harvest the cluster bean crop (Table 46) was positively correlated with the number of pods per plant, pod dry weight and grain yield with 'r' values, 0.921**, 0.916**; 0.858*, 0.853** and 0.891**, 0.887** respectively.

### 5.5.8.3. Influence of treatments on the soil available NPK status

At present scenario, it is essential to improve soil organic matter content and to enhance the nutrient status, through integrated use of organics with inorganic fertilizers.

With this stand point of view, the results obtained in the present study for cowpea clearly establishes the beneficial effect of combined application of composted bagasse at the rate of 12.5 t $ha^{-1}$ and 100 per cent NPK ($T_{11}$) on available nitrogen and phosphorus contents by 88 per cent and 62 per cent during all the stages of growth over control and all other treatments. Similarly the available potassium also spectacularly increased by 62 per cent in farmyard manure applied treatment ($T_7$) at the rate of 12.5 t $ha^{-1}$ when compared with control and other treatments. The composted coffee waste alone at the rate of 12.5 t $ha^{-1}$ ($T_6$) and along with 50 per cent NPK ($T_{10}$) added treatments showed on parity with $T_7$.

In cluster bean, the composted coffee waste with and without 100 per cent NPK $T_6$ and $T_{12}$) significantly increased the available NPK status of soil by 54, 43 and 51 per cent respectively over control during all the stages.

This increased NPK status of soil samples could be attributed to the addition of composts with increased nutrient contents and also a higher microbial activity which prevails under these treatments leading to favourable nutrient transformation and interaction with soil. Similar findings have been reported earlier by Bhiruguvanshi, (1988); Lavanya and Manickam, (1991); Toor and Bishnoi, (1996).

In cowpea, the soil available NPK status (table 45) had a significant influence on grain yield per plant with 'r' values being 0.806**, 0.890** and 0.975** and in cluster bean, the grain yield per plant with 'r' values (Table 46) 0.870**, 0.902**, and 0.849** respectively.

**5.5.8.4. Influence of treatments on soil available micronutrients**

In cowpea, among the soil available micronutrients, iron content was attenuated to a greater extent of 26 per cent during all the stages by the composted coffee waste along with 50 per cent NPK ($T_{10}$) than control and all other treatments. A spectacular increase in zinc content was recorded in the combined application of composted coffee waste and 100 per cent NPK ($T_{12}$).

Application of farm yard manure ($T_7$) at the rate of 12.5 t $ha^{-1}$ showed a phenomenal increase in the manganese (by 41 per cent) and copper (by 166 per cent) contents during all the stages over control and all other treatments.

In cluster bean, composted bagasse alone ($T_5$) and along with 100 per cent NPK ($T_{11}$) attenuated the zinc and iron contents to the extent of 0.22 ppm and 0.20 ppm respectively.

Among the soil micronutrients, manganese and copper contents were available at higher level in $T_6$ in which composted coffee waste alone applied at the rate of 12.5 t $ha^{-1}$.

Micronutrient demands (Zn, Cu, Fe and Mn) have been more important from the view point of not only the productivity of crops but also from the health of soil.

**Table 45. Simple correlation matrix between various yield parameters of cowpea in pot culture experiment-I**

| | DMP | NPP | PL | Pod FW | Pod DW | No.G/P | H.wt | Gy |
|---|---|---|---|---|---|---|---|---|
| DMP | - | | | | | | | |
| NPP | 0.893** | - | | | | | | |
| P.L. | 0.896** | 0.971** | - | | | | | |
| Pod FW | 0.867** | 0.946** | 0.990** | - | | | | |
| Pod DW | 0.909** | 0.948** | 0.985** | 0.987** | - | | | |
| No.G/P | 0.754** | 0.891** | 0.927** | 0.937** | 0.901** | - | | |
| H.wt | 0.914** | 0.959** | 0.983** | 0.983** | 0.993** | 0.893** | - | |
| Gy | 0.943** | 0.977** | 0.976** | 0.953** | 0.970** | 0.846** | 0.973** | - |
| | | | | | | | | |
| O.C. | - | 0.615* | 0.617* | 0.695** | 0.727** | 0.778** | 0.606* | 0.730** |
| O.M. | - | 0.609* | 0.603* | 0.684** | 0.717** | 0.771** | 0.597* | 0.719** |
| N | - | 0.720** | 0.821** | 0.786** | 0.782** | 0.798** | 0.625** | 0.806** |
| P | - | 0.744** | 0.891** | 0.887** | 0.880** | 0.882** | 0.760** | 0.890** |
| K | - | 0.876** | 0.947** | 0.959** | 0.956** | 0.970** | 0.858** | 0.975** |
| Fe | - | 0.787** | 0.837** | 0.844** | 0.864** | 0.899** | 0.718** | 0.908** |
| Mn | - | 0.787** | 0.897** | 0.903** | 0.918** | 0.938** | 0.817** | 0.941** |
| Cu | - | 0.729** | 0.842** | 0.853** | 0.870** | 0.896** | 0.769** | 0.899** |
| Zn | - | 0.733** | 0.855** | 0.844** | 0.848** | 0.879** | 0.737** | 0.891** |

**Table 46. Simple correlation matrix between various yield parameters of cluster bean in pot culture experiment-I**

| | DMP | NPP | PL | Pod FW | Pod DW | No.G/P | H.wt | Gy |
|---|---|---|---|---|---|---|---|---|
| DMP | - | | | | | | | |
| NPP | 0.982** | - | | | | | | |
| P.L. | 0.928** | 0.970** | - | | | | | |
| Pod FW | 0.971** | 0.992** | 0.984** | - | | | | |
| Pod DW | 0.906** | 0.892** | 0.861** | 0.910** | - | | | |
| No.G/P | 0.981** | 0.984** | 0.951** | 0.982** | 0.893** | - | | |
| H.wt | 0.979** | 0.979** | 0.949** | 0.982** | 0.931** | 0.974** | - | |
| Gy | 0.963** | 0.978** | 0.973** | 0.988** | 0.931** | 0.956** | 0.978** | - |
| | | | | | | | | |
| O.C. | - | 0.921** | 0.882** | 0.781** | 0.858** | 0.835** | 0.864** | 0.891** |
| O.M. | - | 0.916** | 0.878** | 0.775** | 0.853** | 0.834** | 0.860** | 0.887** |
| N | - | 0.834** | 0.806** | 0.731** | 0.817** | 0.883** | 0.830** | 0.870** |
| P | - | 0.886** | 0.845** | 0.783** | 0.860** | 0.882** | 0.886** | 0.902** |
| K | - | 0.841** | 0.825** | 0.808** | 0.855** | 0.776** | 0.850** | 0.849** |
| Fe | - | 0.956** | 0.916** | 0.823** | 0.898** | 0.870** | 0.931** | 0.938** |
| Mn | - | 0.889** | 0.845** | 0.731** | 0.828** | 0.842** | 0.861** | 0.874** |
| Cu | - | 0.937** | 0.900** | 0.800* | 0.884** | 0.869** | 0.912** | 0.916** |
| Zn | - | 0.873** | 0.812** | 0.700** | 0.801** | 0.842** | 0.833** | 0.854** |

Organic manure, as a source of micronutrient helps in increasing the yield of different crops as well as favouring the beneficial microbial population. (Raju and Kandaswamy, 1988 ; Kumaresah *et al.*, 1989 ; Deb, 1997 and Muralidhar and Raghuramulu, 1997).

In the present study, greater availability of micronutrients especially the application of composts on soil ($T_4$, $T_5$, $T_6$ and $T_7$) significantly increased the yield of legumes besides sustaining the soil fertility.

In cowpea and cluster bean the soil available micronutrients viz., Fe, Mn, Cu and Zn positively correlated with crop yields with 'r' values 0.908**, 0.941**, 0.899** and 0.891** (Table 45) and 0.938**, 0.874**, 0.916** and 0.854** (Table 46) respectively.

## 5.6. POT CULTURE EXPERIMENT-II

Biofertilizers are inexpensive and environment friendly. Their use helps in harnessing atmospheric nitrogen and soil bound phosphorus. Hence, in the present investigation, the efficacy of enriched organic manures along with biofertilizers on cowpea (*Vigna unguiculata* L. Walp), cluster bean (*Cyamopsis tetragonaloba* T.) and bhendi (*Abelmoschus esculentus* L. Moench) and on soil was assessed in pot culture experiment-II.

### 5.6.1. Influence of treatments on number of leaves of legumes

Among the treatments, the composted coffee waste at the rate of 25 t $ha^{-1}$ and VAM at the rate of 2 kg $ha^{-1}$ enhanced the number of leaves by 17 per cent over control and all other treatments during all the stages of growth in cowpea crop.

In cluster bean, the biofertilizers *Rhizobium* and VAM at the rate of 2 kg $ha^{-1}$ in judicial combination with coffee waste compost at the rate of 25 t $ha^{-1}$ ($T_8$ and $T_9$ respectively) distinctly increased this parameter by 13 per cent over control (100 per cent NPK – $T_1$).

This may be attributed to the beneficial microbial inoculants such as biofertilizers provided the nutrients which are available to boost the plant growth.

This is in line with the findings of Anandkumar *et al.*, (1997); Singh, (1997) and Abdul Kalam, (1998).

### 5.6.2. Influence of treatments on root volume of legumes

Higher root volume by 38 per cent in cowpea and 24 per cent in cluster bean was evident in the composted bagasse at the rate 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ added treatment ($T_5$) than control and all other treatments.

This may be attributed to the favourable soil physical environment due to the application of *Rhizobium* which enhanced the nodulation of legumes.

Similar findings have been reported by Yadav *et al.*, (1992) and Chakraborty (1998).

### 5.6.3. Influence of treatments on nodule index of legumes

Atmospheric N-fixers such as *Rhizobium* along with bagasse compost ($T_5$) favourably increased the nodule index of cowpea and cluster bean by 32 per cent and 39 per cent respectively over control.

From the results it becomes evident that the *Rhizobium* along with composts has a positive role in protecting the soil and environment.

This is in accordance with the findings of Muthuvel *et al.*, (1985); Hajra *et al.*, (1994).

### 5.6.4. Influence of treatments on plant height of legumes

The composted coffee waste at the rate of 25 t $ha^{-1}$ along with phosphobacteria at the rate 25 kg $ha^{-1}$ ($T_7$) prominently increased the height of cowpea plants by 23 percent over control. In cluster bean the increase in plant height by 22 per cent was evident in the composted bagasse along with VAM added treatment ($T_6$).

The increased nutrient availability due to the application of composts at higher dose along with biofertilizers in the soil would have produced such increase in the plant growth.

This in agreement with the results of Shanthi, (1987) and Saravanapandian, (1990).

### 5.6.5. Influence of treatments on plant fresh weight of legumes

The increase in plant fresh weight by 45 per cent ($T_7$) in cowpea and 32 per cent ($T_6$) in cluster bean was evident due to the incorporation of composts in combinations with phosphobacteria and VAM respectively.

The increase in plant fresh weight due to the nutrients supplied by composts tailoring with VAM and phosphobacteria. Similar findings have been reported by Balasubramanian and Kumar, (1987) and Mercykutty Joseph, (1990).

### 5.6.6. Influence of treatments on plant dry weight of legumes

In cowpea, the composted coffee waste along with phosphobacteria ($T_7$) enhanced the plant dry weight by 52 per cent over control ($T_1$ – 100 per cent NPK) and in cluster bean, the enhancement was upto 29 per cent by the composted bagasse + VAM added treatment ($T_6$).

Increase in dry matter production could be attributed to the favourable effects caused by the higher available micro and macronutrient status under the incorporation of composted coffee waste bagasse along with biofertilizers. Similar results have been reported by Gaonker and Sreenivasa, (1994) and Senaratne and Ratnasinghe, (1995).

In cowpea and cluster bean the dry matter production significantly enhanced of grain yield with 'r' values 0.956** and 0.642** respectively (Table 47 & 48).

### 5.6.7. Influence of treatments on yield parameters of legumes

The composted coffee waste at the rate of 25 t $ha^{-1}$ along with phosphobacteria at the rate of 2 kg $ha^{-1}$ ($T_7$) distinctly enhanced the number of pods per plant, pod

length, pod fresh weight, pod dry weight, number of grains per pod, haulm weight and grain yield by 20 per cent, 5, 31, 54, 11, 54 and 52 per cent respectively over control in cowpea crop.

The composted bagasse at the rate of 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_5$)spectacularly increased all the yield parameters such as number of pods per plant by 21 per cent, pod length by 3 per cent, pod fresh weight by 31 per cent, pod dry weight by 53 per cent, number of grains per pod by 5 per cent, haulm weight by 74 per cent and grain yield by 83 per cent over control in cluster bean crop.

The addition of biofertilizers along with 25 t $ha^{-1}$ of composts increased not only the yield of legumes but also gain advantages in soil fertility and plant disease management to overcome the fertilizer bill and pollution hazards.

This eco-friendly approach is supported by Dhindwal *et al.*, (1992); Tiwari *et al.*, (1995); Verma and Thampan, (1995) and Jagdev *et al.*, (1997).

The dry matter production had a significant bearing with the number of pods per plant, pod length, pod fresh weight, pod dry weight, number of grains per pod, haulm weight and grain yield with the 'r' values being 0.954**, 0.974**, 0.960**, 0.919**, 0.908**, 0.934** and 0.956** in cowpea (Table 47) and 0.757*, 0.830**, 0.792**, 0.817**, 0.723*, 0.664* and 0.642* in cluster bean (Table 48) respectively.

### 5.6.8. Influence of treatments on biometrics of bhendi

The growth parameters of bhendi such as number of leaves, root volume, plant height, plant fresh weight and plant dry weight were increased by 45 per cent in

composted bagasse along with phosphobacteria ($T_4$), 121 per cent in composted bagasse along with VAM ($T_6$), 34 per cent in the composted bagasse along with VAM ($T_6$), 52 per cent in the composted coffee waste + VAM ($T_9$) and 81 per cent in the composted bagasse + VAM ($T_6$) added treatments respectively over control (Tables 25, 26, 27, 28 and 29).

The higher and healthy plant growth was resulted in the biofertilizer along with composts ($T_4$ to $T_9$) especially in VAM added treatments which attributed to increase in phosphorus content, other micro and macro nutrients. These interacting factors clearly evident that the composts contain all plant nutrients and other growth promoting principles like enzymes and hormones which no synthetic chemical fertilizers can supply all these together.

This perspective is one of the needs for organic approach to farming which is concurred with the views of Anabayan and Palaniappan, (1991); Bryan and Lance, (1991); Rita Joseph *et al.*, (1996); Vassilev *et al.*, (1996) and Anandkumar *et al.*, (1997).

### 5.6.9. Influence of treatments on yield parameters of bhendi

More [illegible] fruits per plant (5 per cent over control) was evident in the composted coffee waste along with *Azospirillum* applied treatment ($T_8$). This result showed on parity with the $T_4$ and $T_6$ in which composted bagasse with phosphobacteria and VAM were added respectively.

Fruit length was markedly influenced in the composted coffee waste + *Azospirillum* applied treatment ($T_8$) by 16 per cent over control being on par with $T_6$ and $T_9$ in which composted bagasse and composted coffee waste were applied along with VAM.

Fruit circumference was increased by 23 per cent over control in the composted coffee waste along with *Azospirillum* ($T_8$).

Fruit yield was higher in the composted bagasse + VAM added treatment ($T_6$) and the enhancement was 11 per cent over control.

The higher dosage of 2 kinds of composts (25 t $ha^{-1}$) in all the treatments profoundly increased the yield parameters of bhendi when compared with the 100 per cent NPK applied control ($T_1$).

Increase in the crop yield may be attributed due to the phospho-nitro composts along with bioinoculum enhanced the decomposition process and produced well humified organic matter which is many fold slow releases than direct incorporation of agro-wastes and other chemical fertilizers.

The judicious combination of biofertilizers with organic manures through the process of decomposition and humification gives humus which helps to maintain soil health and plant nutrient supply for sustainable crop productivity.

This eco-friendly alternative organic approach is corroborating the experimental results of Barea *et al.*, (1980); Kucey, (1987); Bryan and Lance, (1991); Rajasekaran *et al.*, (1995) and Vassilev *et al.*, (1996).

The dry matter production of bhendi crop (Table 49) significantly correlated with the number of fruits per plant, fruit length, fruit circumference and fruit yield with the 'r' values being 0.706*, 0.670*, 0.654* and 0.718* respectively.

### 5.6.10. Post harvest soil analysis

#### 5.6.10.1. Influence of treatments on soil physical constants

In cowpea, higher values for water holding capacity and total porosity were evident in the judicial combination of bagasse compost at the rate of 25 t $ha^{-1}$ and *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_5$) being on par with combined application of coffee waste compost and VAM at the same rate in $T_9$.

The bulk density and volume expansion on wetting were reduced to a beneficial level in the coffee waste compost + VAM ($T_9$) and bagasse compost + *Rhizobium* ($T_5$) incorporated treatments in cowpea.

In cluster bean, a phenomenal reduction in bulk density and volume expansion was noticed in the bagasse compost + *Rhizobium* applied treatment ($T_5$) whereas noticeable increase in water holding capacity and total porosity was recorded in the composted coffee waste + *Rhizobium* applied treatment ($T_8$).

In bhendi, the integrated use of composts (from bagasse and coffee waste) along with phosphobacteria, *Rhizobium* and VAM prominently proved good in improving the soil physical constants.

**Table 47. Simple correlation matrix between yield parameters of cowpea in pot culture experiment – II**

| | DMP | NPP | PL | Pod FW | Pod DW | No.G/P | H.wt | Gy |
|---|---|---|---|---|---|---|---|---|
| DMP | - | | | | | | | |
| NPP | 0.954** | | | | | | | |
| P.L. | 0.974** | 0.924** | - | | | | | |
| Pod FW | 0.960** | 0.967** | 0.963** | - | | | | |
| Pod DW | 0.919** | 0.920** | 0.954** | 0.958** | - | | | |
| No.G/P | 0.908** | 0.876** | 0.929** | 0.919** | 0.931** | - | | |
| H.wt | 0.934** | 0.951** | 0.913** | 0.949** | 0.905** | 0.894** | - | |
| Gy | 0.956** | 0.888** | 0.967** | 0.927** | 0.909** | 0.971** | 0.917** | - |
| | | | | | | | | |
| O.C. | - | 0.726* | 0.797** | 0.680* | 0.727* | 0.670* | 0.685* | 0.684* |
| O M | - | 0.726* | 0.801** | 0.673* | 0.735* | 0.666* | 0.715* | 0.705* |
| N | - | 0.762* | 0.755* | 0.802** | 0.767** | 0.702* | 0.776** | 0.729* |
| P | - | 0.685* | 0.639* | 0.669** | 0.646* | 0.549 | 0.651* | 0.514 |
| K | - | 0.548 | 0.401 | 0.658* | 0.488 | 0.572 | 0.577 | 0.385 |
| Fe | - | 0.937** | 0.821** | 0.895** | 0.846** | 0.753* | 0.827** | 0.847** |
| Mn | - | 0.925** | 0.928** | 0.942** | 0.940** | 0.936** | 0.933** | 0.863** |
| Cu | - | 0.815** | 0.772** | 0.840** | 0.808** | 0.767** | 0.780** | 0.869** |
| Zn | - | 0.709* | 0.664* | 0.765* | 0.688* | 0.683* | 0.721* | 0.697* |

**Table 48. Simple correlation matrix between yield parameters of cluster bean in pot culture experiment – II**

| | DMP | NPP | PL | Pod FW | Pod DW | No.G/P | H.wt | Gy |
|---|---|---|---|---|---|---|---|---|
| DMP | - | | | | | | | |
| NPP | 0.757* | - | | | | | | |
| P.L. | 0.830** | 0.688* | - | | | | | |
| Pod FW | 0.792** | 0.712* | 0.980** | - | | | | |
| Pod DW | 0.817** | 0.786** | 0.783** | 0.760* | - | | | |
| No.G/P | 0.723* | 0.640* | 0.897** | 0.943** | 0.708* | - | | |
| H.wt | 0.634* | 0.576 | 0.930** | 0.956** | 0.610 | 0.946** | - | |
| Gy | 0.642* | 0.731* | 0.713* | 0.781** | 0.796** | 0.791** | 0.720* | |
| | | | | | | | | |
| O.C. | - | 0.465 | 0.563 | 0.607 | 0.691* | 0.429 | 0.745* | 0.739* |
| O.M. | - | 0.379 | 0.498 | 0.587 | 0.691* | 0.426 | 0.766** | 0.751* |
| N | - | 0.540 | 0.484 | 0.752* | 0.761* | 0.364 | 0.723* | 0.842** |
| P | - | 0.424 | 0.482 | 0.788** | 0.552 | 0.608 | 0.551 | 0.523* |
| K | - | 0.486 | 0.628 | 0.767** | 0.832** | 0.570 | 0.875** | 0.904** |
| Fe | - | 0.672* | 0.757* | 0.598 | 0.623 | 0.657* | 0.653* | 0.602* |
| Mn | - | 0.704* | 0.807** | 0.835** | 0.879** | 0.807** | 0.848** | 0.817** |
| Cu | - | 0.404 | 0.345 | 0.603 | 0.652* | 0.317 | 0.824** | 0.805** |
| Zn | - | 0.511 | 0.585 | 0.701* | 0.772** | 0.503 | 0.880** | 0.859** |

**Table 49. Simple correlation matrix between yield parameters of bhendi in pot culture experiment – II**

| | DMP | N.F.P. | F.L. | F.C. | F.Y. |
|---|---|---|---|---|---|
| DMP | - | | | | |
| N.F.P. | 0.706* | - | | | |
| F.L. | 0.670* | 0.888** | - | | |
| F.C. | 0.654* | 0.721* | 0.470 | - | |
| F.Y. | 0.718* | 0.909** | 0.782** | 0.891** | - |
| | | | | | |
| O.C. | - | 0.397 | 0.578 | 0.177 | 0.713* |
| O.M. | - | 0.631 | 0.855** | 0.649* | 0.749* |
| N | - | 0.542 | 0.703* | 0.501 | 0.677* |
| P | - | 0.685* | 0.438 | 0.300 | 0.645* |
| K | - | 0.720* | 0.631 | 0.797** | 0.767** |
| Fe | - | 0.401 | 0.595 | 0.638* | 0.767** |
| Mn | - | 0.595 | 0.519 | 0.442 | 0.305 |
| Cu | - | 0.630 | 0.659* | 0.744* | 0.862** |
| Zn | - | 0.523 | 0.615 | 0.698* | 0.769** |

From the results, it becomes evident that the addition of composts and biofertilizers improved the water holding capacity of the soil due to the formation of crumb structure in the soil with more pore space between the soil particles.

This kind of organic approach in improving soil physical properties has been supported by Ganal and Singh, (1988); Lal and Greenland, (1989); Rinno and Ebert, (1989); Anabayan and Palaniappan, (1991).

**5.6.10.2. Influence of treatments on soil organic carbon and organic matter**

In the event of wide-spread energy crisis, it is highly desirable for making massive efforts to adopt organic matter recycling into soil for source of bioenergy and for soil productivity (Adhikari *et al.*, 1997).

The composts along with biofertilizers added treatments ($T_4$ to $T_9$) maintained higher organic carbon and organic matter content in post harvest soils. This significant increase was due to the application of composted coffee waste (25 t $ha^{-1}$) + phosphobacteria (2 $kg^{-1}$)($T_7$) in cowpea (by 72.6 per cent); composted coffee waste + *Rhizobium* ($T_8$) in cluster bean (by 53.4 per cent) and composted coffee waste + VAM ($T_9$) in bhendi (by 35.2 per cent) over control ($T_1$ – 100 per cent NPK).

Hence incorporation of biocomposts prepared from bagasse and coffee waste along with bioinoculants on soil enhanced the decomposition process and produced well humified organic matter which has been many fold beneficial than the inorganic fertilizers.

This finding is in accordance with the results of Anon (1988); Muthuvel (1989) and Gaur and Dhingra (1991).

In cowpea, crop productivity in terms of number of pods plant, pod length, pods fresh weight, pods dry weight, number of grains per pod, haulm weight and grain yield per plant was profoundly enhanced by the organic carbon content with 'r' values being 0.726*, 0.797**, 0.680*, 0.727* 0.670* 0.685* and 0.684* and by the organic matter content with 'r' values being 0.726*, 0.801**, 0.673*, 0.735*, 0.666*, 0.715* and 0.705* respectively (Table 47). The grain yield of cluster bean crop was prominently increased by the organic carbon and organic matter with the 'r' values being 0.739* and 0.751* respectively (Table 48).

In bhendi organic carbon and organic matter significantly correlated with the fruit yield with r values, 0.713* and 0.749* respectively (Table 49).

**5.6.10.3. Influence of treatments on soil available NPK status**

The availability of NPK in the organic manures along with and without biofertilizers applied treatments was significantly higher in $T_2$ to $T_{10}$ than the 100 per cent NPK alone added control. ($T_1$) in all the test crops. In these treatments, the highest available NPK status was observed at vegetative stage, which tended to decrease with advancement of crop age. This may be due to favourable effects of these organics and biofertilizers added treatments on soil which regulated the nutrients diffusion as well as reduced the surface area of contact of fertilizers with soil particles thereby helping in increasing the availability of nutrients throughout the period of crop growth.

This finding corroborates the experimental results of Ravikumar and Krishnamoorthy, (1983); Kumaresan *et al.*, (1984); Honora, (1990); Kalidurai and Kannaiyan, (1990) and Muthuswamy *et al.*, (1990).

In cowpea, cluster bean and bhendi the soil available NPK contents significantly correlated with the crop yield with 'r' values being 0.802**, 0.669**, 0.658*; 0.752*, 0.788**, 0.767** and 0.677*, 0.645*, 0.767** respectively (Tables 47, 48 & 49).

**5.6.10.4. Influence of treatments on soil available micronutrients**

In cowpea, cluster bean and bhendi crops the availability of micronutrients such as iron, manganese, copper and zinc was higher at their vegetative stage and a trend of decrease was noticed as the stage of growth advances. When compared with control ($T_1$), the enhancement of Fe, Mn, Cu and Zn in $T_7$ of cowpea crop was 24.3 per cent, 23.1 per cent, 142 per cent and 55 per cent respectively. In cluster bean, 22.5 per cent, 11.5 per cent, 112 per cent and 120 per cent increase of Fe, Mn, Cu and Zn was recorded in $T_8$ respectively whereas in bhendi, the $T_4$ enhanced this by 14.2 per cent, 21.2 per cent, 85.7 per cent and 60 per cent respectively over control.

Attenuation of higher micronutrient status after harvesting crops can be attributed to the higher available micronutrient status of organic manures obtained from bagasse and coffee waste in association with biofertilizers.

Similar findings have been reported by Manhaes, (1993); Gaonker and Sreenivasa, (1994) and Baca *et al.*, (1995).

The micronutrients in soil favourably increased the cowpea grain yield with 'r' values, 0.847**, 0.863**, 0.869**, 0.697*; cluster bean grain yield with 'r' values 0.602*, 0.817**, 0.805**, 0.859** and bhendi fruit yield with 'r' values, 0.767**, 0.862**, 0.769** respectively (Tables 47, 48 & 49).

# SUMMARY AND CONCLUSION

# CHAPTER-6

# SUMMARY AND CONCLUSION

The Present investigation entitled "**Eco-friendly recycling of organic wastes for sustainable soil health and enhanced crop productivity**" was carried out to study the efficiency of microbes in degrading sugarcane bagasse and coffee waste; nutrient dynamics during composting of organic waste; influence of composts along with chemical and biofertilizers on test crops as well as soil physico-chemical properties. A quint essence of the findings is reported herein.

## 6.1. MICROBIAL DEGRADATION OF AGRO-WASTES

### 6.1.1. Microbial degradation of bagasse

Compared to uninoculated control, the dual culture of *Pleurotus sajor-caju* and *Trichoderma harzianum* ($T_5$) significantly reduced the C/N ratio by 82 per cent and increased the respiratory rate by 147 per cent within minimum period of (60 days) incubation.

### 6.1.2. Microbial degradation of coffee waste

The synergistic effect of *Pleurotus sajor-caju* and *Trichoderma harzianum* was conspicuous on coffee waste and it was evident from the lowest C/N ratio (22.8) and the highest cumulative $CO_2$ evolution (918 mg 100 $g^{-1}$) in $T_5$, on 70$^{th}$ day.

## 6.2. ENRICHMENT OF AGRO-WASTES

The combined effects of *Pleurotus sajor-caju* and *Trichoderma harzianum*, urea and rockphosphate enrichment ($T_9$)on bagasse and coffee waste revealed overall improvement in the rate of microbial respiration by 80 per cent on 40$^{th}$ day and 100 per cent on 50$^{th}$ day of decomposition period respectively. This treatment was superior to the control and all other treatments which showed desirable trends on decomposition of bagasse and coffee waste within 40 to 50 days. Hence the composting period could be standardised based on the enrichment of organic wastes using microbial consortia along with urea and low grade rockphosphate.

## 6.3. COMPOSTING AND MATURITY EVALUATION OF AGRO-WASTES

### 6.3.1. Bagasse compost

Considered within a wider context, the results provided by physical, chemical and biological assays during composting of bagasse along with microbes, urea and rock phosphate suggest that a series of phases can be distinguished. Initially, compost ripens slowly during the thermophilic phase; after a transitional period, the maturation reached its peak during the mesophilic phase. This period itself, an increase in maturity (5$^{th}$–6$^{th}$ week) followed by a substage of stabilization (6$^{th}$–7$^{th}$ week).

A marked increase in temperature inside the (50-61°C) compost heap indicate the composting activity. The subsequent fall of ambient temperature is an indication of compost maturity.

The qualitative analysis of compost extract indicate nitrification process during composting. The matured bagasse compost filtrate turned to deep blue colour due to the higher nitrate nitrogen concentration.

The degree of maturity was also observed in bagasse compost due to lesser C/N ratio (24:1), lignin (6.5 per cent), cellulose (14 per cent) and higher macro and micronutrients.

Hence from the results of maturity assays it is inferred that the unripe compost may be detrimental for the agricultural use. It is obvious that the matured composts stimulate the growth of plants and incorporation of composts into soil rejuvenates the soil by sustaining its health.

### 6.3.2. Coffee waste compost

For composting 1 ton coffee waste, 2 kg each *Pleurotus sajor-caju* and *Trichoderma harzianum*, 10 kg urea and 25 kg rock phosphate were utilized. Periodical analyses of compost samples based on physical, chemical and biological assays indicate the maturity status.

The raise in temperature inside the heap upto 67°C ensured inactivation of any pathogens and hasten the degradation process. The temperature drop and gradual stabilization at 29°C indicate the maturity of compost.

At the end of composting period, stabilisation of pH at 7.3 and EC at 0.49 $dSm^{-1}$ was resulted in good quality compost.

Higher nitrate nitrogen concentration by diphenyl ammine test revealed the fairly matured compost from coffee waste which is suitable for agricultural purposes.

Better mineralization in the compost may be due to the addition of key nutrients such as urea and rock phosphate. Increase in decomposition velocity can be attributed to lignin and cellulose degrading capacity of the consortia of microbes *Pleurotus sajor-caju* + *Trichoderma harzianum*.

Composting by the addition of microbes along with low grade rock phosphate and urea reduced the C/N ratio to 20:1. The lignin, cellulose and caffeine contents were substantially brought down to 10.1 per cent, 11.6 per cent and 0.24 per cent in 8 weeks. The essential nutrients such as N,P,K and available micronutrients Fe, Mn, Cu and Zn also boosted to a greater extent due to the microbial activity.

From the bioassay, both phytotoxicity as well as seedling growth enhancement was assessed. Due to the presence of water soluble phytotoxic substances in the compost extract of initial stages, the seed germination was affected. In later stages of composting, release of mineral nutrients and physical characteristics of mature compost, seedling growth with well developed leaves and roots was exhibited.

In the light of present study, it is suggested that the compost prepared from coffee waste enriched with urea and rock phosphate could be used after 50 days of decomposition for sustainable crop production.

## 6.4. POT CULTURE EXPERIMENT-I

### 6.4.1. Biometrical parameters as influenced by treatments

The composted bagasse and coffee waste incorporated treatments (at the rate of 12.5 t $ha^{-1}$) significantly enhanced the number of leaves by 24 to 40 per cent in cowpea and 36 to 56 per cent in cluster bean.

The root volume of cowpea and cluster bean was profoundly increased by the judicial combination of composted bagasse along with 100 per cent NPK ($T_{11}$) and composted coffee waste along with 50 per cent NPK ($T_{10}$) respectively.

It was evident that the nodule index of both the test crops at vegetative and flowering stage was markedly increased by composted coffee waste applied treatments ($T_6$ and $T_{12}$).

It was seen that the plant height of cowpea crop prominently enhanced by 72 per cent over control in the composted coffee waste with 100 per cent NPK ($T_{12}$). The plant height of cluster bean was markedly increased by 44 per cent over control in the 100 per cent NPK ($T_8$) being on par with the application of composted coffee waste along with 50 per cent NPK ($T_6$).

The composted bagasse and coffee waste along with and without 50 per cent and 100 per cent NPK incorporated treatments ($T_5$, $T_6$, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) spectacularly increased the plant fresh weight of cowpea (by 23 to 38 per cent) and cluster bean (by 24 to 29 per cent).

The dry matter production (DMP) was spectacularly increased to 67 per cent in cowpea and 29 per cent in cluster bean by the composted bagasse and coffee waste at the rate of 12.5 t $ha^{-1}$ along with 100 per cent NPK ($T_{11}$ and $T_{12}$).

### 6.4.2. Yield parameters as influenced by treatments

#### 6.4.2.1. Cowpea (*Vigna unguiculata* L. Walp)

From this investigation it has been seen that more number of pods per cowpea plant was recorded in the 100 per cent NPK added treatment ($T_8$) being on par with the composted coffee waste with 100 per cent NPK applied treatment ($T_{12}$).

Though all the treatments had a similar effect on pod length the combination of bagasse compost and 100 per cent NPK application ($T_{11}$) markedly influenced the pod length of cowpea.

The organics incorporated treatments ($T_4$, $T_5$, $T_6$, $T_7$, $T_9$, $T_{10}$, $T_{11}$ and $T_{12}$) spectacularly enhanced the pod fresh and dry weights upto 71 per cent and 38 per cent respectively over control and all other treatments.

It is evident that the number of grains per pod and haulm weight enhanced to a greater extent of 62 per cent and 55 per cent respectively by the addition of composts than the control and 100 per cent NPK application.

Coffee waste compost in combination with 100 per cent NPK ($T_{12}$) spectacularly increased the grain yield by 70 per cent over control and all other treatments.

From the results obtained for the yield parameters of cowpea it became evident that the addition of composts with and without 50 per cent and 100 per cent NPK could result in equal effect as that of 100 per cent NPK application. Hence integrated use of chemical fertilizers together with organic manures increased the crop productivity as well as minimized the use of inorganic fertilizers.

**6.4.2.2. Cluster bean (*Cyamopsis tetragonaloba* T.)**

The incorporation of organics (composted coirpith, farmyard manure, composted bagasse and coffee waste) profoundly increased the number of pods per plant and pod length when compared to control and 100 per cent NPK added treatment ($T_8$).

The yield parameters such as pod fresh weight, pod dry weight, number of grains per pod and haulm weight were markedly enhanced by 53, 123 and

77 per cent in the composted coffee waste at the rate of 12.5 t $ha^{-1}$ and along with 100 per cent NPK ($T_6$ and $T_{12}$) over control and all other treatments.

The crop productivity in terms of grain yield was spectacularly increased upto 116 per cent over control in the composted bagasse ($T_{11}$) and coffee waste ($T_{12}$) applied treatments.

## 6.5. SOIL PROPERTIES OF POT CULTURE EXPERIMENT-I

### 6.5.1. Soil physical constants

After harvesting cowpea and cluster bean, the soil physical constants were favourably improved by the farm yard manure and composts applied treatments.

The bulk density and volume expansion on wetting were lower where as the water holding capacity and porosity were higher in the farm yard manure and composts added treatments (from $T_4$ to $T_{12}$ excluding $T_8$) in both the test crops.

### 6.5.2. Soil organic carbon and organic matter

Organic carbon and organic matter contents of experimental soil were significantly (from 7 to 16 per cent and 8 to 15 per cent respectively) increased by the organics added treatments (coir compost, FYM, composted bagasse and coffee waste) after harvesting cowpea crop. In cluster bean the enhancement was from 11 to 15 per cent in the post harvest soils due to the addition of organics.

### 6.5.3. Soil available NPK and micronutrient status

From the results it has been observed that the beneficial effect of individual and combined application of bagasse compost and coffee waste compost along with 50 per cent and 100 per cent NPK spectacularly increased the availability of nitrogen, phosphorus, potassium and micronutrients such as iron, manganese, copper and zinc in the experimental soils after harvesting the test crops.

## 6.6. POT CULTURE EXPERIMENT-II

### 6.6.1. Biometrical parameters of legumes as influenced by treatments

The judicial combination of composted coffee waste at the rate of 25 t $ha^{-1}$ with 2 kg $ha^{-1}$ of VAM ($T_9$) positively increased the number of leaves of cowpea by 17 per cent over 100 per cent NPK ($T_1$). In cluster bean, more number of leaves were recorded in composted coffee waste in association with *Rhizobium* ($T_8$) and VAM ($T_9$) applied treatments.

In cowpea and cluster bean,the enhancement in root volume (by 38 and 24 per cent respectively) and nodule index (by 32 and 39 per cent respectively) were highly significant in the bagasse compost at the rate of 25 t $ha^{-1}$ along with *Rhizobium* at the rate of 2 kg $ha^{-1}$ ($T_5$).

The incorporation of composted coffee waste + phosphobacteria ($T_7$) markedly increased the plant height of cowpea upto 23 per cent and the

incorporation composted bagasse + VAM ($T_6$) profoundly enhanced the plant height of cluster bean upto 22 per cent.

In cowpea, the plant fresh and dry weights were significantly increased to an extent of 45 per cent and 52 per cent respectively by the addition of composted coffee waste along with phosphobacteria ($T_7$) and in cluster bean the plant fresh and dry weights were positively enhanced by 32 per cent and 29 per cent over control in the composted bagasse + VAM added treatment ($T_6$).

### 6.6.2. Yield parameters of legumes as influenced by treatments

The productivity of cowpea crop in terms of number of pods per plant, pod length, pod fresh and dry weight, number of grains per pod, haulm weight and grain yield was boosted positively by the incorporation of composted coffee waste at the rate of 25 t $ha^{-1}$ along with phosphobacteria at the rate of 2 kg $ha^{-1}$ ($T_7$).

The yield parameters of cluster bean were spectacularly enhanced by the combined application of composted bagasse + *Rhizobium* ($T_5$).

### 6.6.3. Biometrical parameters of bhendi as influenced by treatments

The growth parameters of bhendi crop such as number of leaves, root volume, plant height, plant fresh and dry weight were significantly increased by the application of composted bagasse + phosphobacteria ($T_4$), composted bagasse

+ VAM ($T_6$) and composted coffee waste + VAM ($T_9$) at the rate of 25 t $ha^{-1}$ and 2 kg $ha^{-1}$ respectively.

### 6.6.4. Yield parameters of bhendi

Number of fruits per plant, fruit length and fruit circumferences were significantly increased by the composted coffee waste and *Azospirillum* added treatment ($T_8$)while the fruit yield was higher in the composted bagasse along with VAM added treatment ($T_6$) over 100 per cent NPK applied control ($T_1$).

It has been confirmed from these results that the addition of composts at higher dosage with biofertilizers to the soil significantly increased the productivity of test crops than the inorganic chemical fertilizers. This brings to focus the favourable synergistic effect of composts and biofetilizers on soil health.

## 6.7. SOIL PROPERTIES OF POT CULTURE EXPERIMENT-II

### 6.7.1. Soil physical constants

Addition of biofertilizers along with organics (from $T_4$ to $T_9$) in cowpea, cluster bean and bhendi crops recorded higher values for water holding capacity and total porosity. Simultaneously a decreasing trend in bulk density and volume expansion on wetting revealed the efficiency of composts and biofertilizers in sustaining the soil health.

### 6.7.2. Soil organic carbon and organic matter

Application of phospho-nitro composts along with bioinoculum enhanced the decomposition process and produced well humified organic matter into soil which is an appealing feature in sustaining the soil health. An increase in soil organic carbon and organic matter by the application of composted coffee waste + phosphobactreia ($T_7$) in cowpea (by 73 per cent), composted coffee waste + *Rhizobium* ($T_8$) in cluster bean (by 53 per cent) and composted coffee waste + VAM ($T_9$) in bhendi (by 35 per cent) over control revealed the soil productivity.

### 6.7.3. Soil available NPK and micronutrient status

Addition of composted bagasse and coffee waste with and without biofertilizers to the test crops, regulated the nutrients diffusion to the plants as well as maintained the availability of NPK throughout the period of growth of test crops. Comparative efficacy of composts along with biofertilizers enhanced the availability of micronutrient contents in post harvest soil which ensure the higher productivity of crops.

# CONCLUSION

Waste agro-products can be degraded by biological processes avoiding soil contamination. The utilization of such biosystems involving organic materials and microorganisms for rock phosphate solubilization and improvement of crop productivity is believed to be an important part of the concept of sustainable agriculture.

Microorganisms are the source of minerals and trace elements and they synthesize essential vitamins and other growth factors boosting the availability of nutrients already present in the raw organic wastes. With this appealing feature, the ligno-cellulolytic fungi viz., *Pleurotus sajor-caju* and *Trichoderma harzianum* could be utilized along with low grade rock phosphate and urea for composting bagasse and coffee waste successfully.

In this present investigation, technologies for biocomposting bagasse and coffee wastes have been standardized. Composting these organic wastes with phosphate rocks is a low-input technology to improve the fertilizer value of the manures.

Evaluation of maturity of composts based on physical, chemical and biological assays resulted in obtaining good quality composts which has wide range of advantages to the environment.

From the pot culture experiment-I it has become evident that the composted bagasse and coffee waste at the rate of 12.5 t $ha^{-1}$ could be utilized as an effective soil amendment for increasing the productivity of cowpea and cluster bean crops and soil fertility which paved an eco-friendly approach to the sustainable agriculture.

From the pot culture experiment-II, it has become proved that the addition of composted bagasse and coffee waste at the rate of 25 t $ha^{-1}$ in association with phosphobacteria, *Rhizobium* and VAM for cowpea (*Vigna unguiculata* L. Walp.) and cluster bean (*Cyamopsis tetragonaloba* T.) phosphobacteria, *Azospirillum* and VAM for bhendi (*Abelmoschus esculentus* L. Moench) substantially increased not only their yield but also soil organic matter and available NPK status. The micronutrient availability for test crops and soil physical structures were also improved to a greater extent due to the judicial combinations of organics with bioinoculants.

Hence recycling of organic wastes have been exercised in crop productivity with concomitant build-up in soil fertility for preventing air-water-soil pollution. Agro-industrial wastes can be recycled and used as cheaper sources of organic nutrients under fertilizer constraints. Integrated nutrient management alleviates the effect of inorganic elements responsible for toxicity hazards and prevents the physico-chemical degradation of soil thereby contributes to the restoration of soil health.

## RECOMMENDATIONS FOR FURTHER RESEARCH

1) Use efficiency of fresh and composted bagasse and coffee waste in the production of single cell protein

2) Evaluating the content and role of humic and fulvic acids of biocomposted organic wastes on soil fertility

3) Utilization of composted bagasse and coffee waste for bioremediating polluted habitats

4) Microbial assay of fresh and composted organic wastes

5) Recovery of ligno-cellulose degrading enzymes from the biocomposts and evaluating its use on biodegradation of pollutants of ecosystem

6) To study the dynamics of C/N ratio in various organic wastes with reference to environmental health

7) Use of organic wastes as soil substitutes for indoor floriculture and horticulture in home gardens

8) Use of bagasse and coffee waste as substrates for cultivation of mushrooms

9) Increase the commercial value of biocomposts prepared from organic wastes by training the rural and urban women for their empowerment.

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# APPENDICES

## APPENDIX-I

## EVOLUTION OF CARBON-DI-OXIDE FROM THE SUBSTRATE

### (PRAMER AND SCHMIDT, 1964)

**Reagents**

1) 1 N potassium hydroxide solution {56.11 g / 1000 ml distilled water)
2) 0.1 N hydrochloric acid (8.3 ml / 1000 ml distilled water)
3) 50 per cent barium chloride solution (50 g in 100 ml distilled water)
4) Phenolphthalein indicator dissolve 0.5 g of phenolphthalein in 100 ml of 95 per cent alcohol.

**Procedure**

Weigh 100 g of substrate in conical flask. Dispense 2 ml of inocula to each and keep a control simultaneously.

Place 5 ml of 1 N KOH in the penicillin vial and suspend in the flask. Make the setup air tight. At alternate day, determine the quantity of $CO_2$ evolved by volumetric titration procedure as detailed below :

Open one flask at a time. Transfer the contents in the penicillin vial into a beaker. Added 3-4 drops of phenolphthalein (Wash thoroughly with distilled water) and 1 ml of 50 per cent Barium chloride to the contents in the beaker. Titrate slowly with 0.1 N HCl and stirr gently with a glass rod until the pink colour just disappear. Record the amount of acid required. Reset the flask and continue the analysis till the required period.

**Calculation**

$2\ CO_2 + 2\ KOH \rightarrow K_2CO_3 + H_2O$

$2\ KOH = 1\ CO_3$

100 ml of 1 N KOH = 30 g of $CO_3$

1 ml of 1 N KOH = 0.03 g of $CO_3$

In terms of $CO_2$ = 0.03 x 0.73 g $CO_2$

1 ml of 0.1 N KOH = 0.003 x 0.73 g $CO_2$

x ml of 0.1 N KOH = 0.003 x 0.73 x X

= x g X 1000

## APPENDIX-II

## ESTIMATION OF ORGANIC CARBON

### (WALKEY AND BLACK, 1934)

### Principle

Organic carbon present in organic matter is oxidized by chromic acid in the presence of Conc. $H_2SO_4$. Potassium dichromate on reaction with $H_2SO_4$ provides nascent oxygen which combines with carbon and form $CO_2$. The $H_2SO_4$ enables easy digestion of organic matter by rendering heat of dilution. Only a certain quantity of chromic acid is used for oxidation. The excess chromic acid left unused by the organic matter is determined by back titration with 0.5 N ferrous sulphate or ferrous ammonium sulphate using diphenylamine indicator.

### Reagents

1. 1 N potassium dichromate : Exactly 49.04 g of $K_2Cr_2O_7$ was dissolved in one litre of distilled water
2. Diphenylamine indicator : 0.5 g of diphenylamine was dissolved in 20 ml of water and 100 ml of Conc. $H_2SO_4$ was added.
3. 0.5 N Ferrous sulphate or Ferrous ammonium sulphate : 139.0 g of Ferrous sulphate or 196.1 g of ferrous ammonium sulphate was dissolved in 800 ml of distilled water. 20 ml of Conc. $H_2SO_4$ was added and the volume was made up to one litre.
4. Conc. $H_2SO_4$
5. Phosphoric acid (orthophosphoric acid 85%)

## Procedure

Exactly 0.5 g of soil (passed through 0.2 mm sieve) was weighed and transferred to a 500 ml conical flask. 10 ml of 1 N $K_2Cr_2O_7$ was added and mixed well by swirling the flask. Added 20 ml of Conc. $H_2SO_4$ mixed by gentle rotation for one minute to ensure complete contact of the reagent with the soil. Allowed the contents to stand for 20-30 minutes. Kept the flask on an asbestos sheet to avoid burning of table due to intense heat. Added 200 ml of water after 30 minutes. Then added 10 ml of phosphoric acid and 1 ml of diphenylamine indicator. Titrated the solution with 0.5 N ferrous ammonium sulphate. As the titration proceeds the dull green colour shifted to a turbid blue and at the end point bright green colour developed. Conducted simultaneously a blank titration (without soil) and the volume of 0.5 N ferrous ammonium sulphate consumed was noted.

## Calculation

| | | |
|---|---|---|
| Weight of soil taken | = | 0.5 g |
| Volume of 1 N $K_2Cr_2O_7$ used | = | 10 ml |
| Volume of 0.5 N ferrous ammonium sulphate used for blank titration | = | X ml (sample T.V.) |
| Volume of 0.5 N ferrous ammonium sulphate used for sample titration | = | Y ml (sample T.V.) |
| X ml of $FeSO_4$ reduces 10 ml of 1 N $K_2Cr_2O_7$. Therefore Y ml of $FeSO_4$ reduces | = | Y/X x 10 ml |
| Hence actual quantity of 1 N $K_2Cr_2O_7$ used for oxidation of organic matter | = | 10 – (10 x Y/X) ml |
| 1 ml of 1 N $K_2Cr_2O_7$ | = | 0.003 g of 'C' |
| Therefore 10 – (10 x Y/X) ml of 1 N $K_2Cr_2O_7$ | = | 10 – (10 x Y/X) x 0.003 |
| This is present in 0.5 g of soil therefore in 100 g | = | 10 – (10 x Y/X) x 0.003 x 100/0.5 |
| Organic matter (surface soil) | = | Organic carbon x 1.724 |
| Organic matter (sub surface soil) | = | Organic carbon x 2.5 |

## APPENDIX-III

## ESTIMATION OF TOTAL NITROGEN

### (MICROKJELDHAL METHOD – HUMPHRIES, 1956)

**Principle**

Total nitrogen is the sum of ammonia nitrogen and organic nitrogen. This does not include nitrite nitrogen and nitrate nitrogen. Nitrogen of organic matter is converted to ammonium sulphate when treated with sulphuric acid. An excess of alkali is then added to liberate ammonia and distilled. The distillate is titrated with standard sulphuric acid after absorption in boric acid solution.

**Reagents**

1. Diacid – 4:1 ratio of sulphuric acid and perchloric acid
2. Mixed indicator – Dissolved 0.5 g bromocresol green and 1 g of methyl red in 100 ml ethyl alcohol.
3. N/50 sulphuric acid
4. 40% sodium hydroxide
5. 2% Boric acid

**Procedure**

Took 0.5 g of seed flour in a microkjeldhal flask with 12 ml of diacid. Digested the sample over a sand bath. Made up the volume to 100 ml with distilled water. Pipetted out 10 ml of the aliquot into a microkjeldhal distillation apparatus kept at the delivery end, 10 ml of 2 per cent boric acid with mixed indicator in a 100 ml beaker. Added 10 ml of 40% sodium hydroxide into the microkjeldhal distillation apparatus and steamed the distillate until a blue colour was reached. After distillation, titrated against N/50 sulphuric acid until a red wine colour was got.

**Calculation**

Nitrogen content (g%) = 0.00028 x titre value x 100 x 100/10 x 0.5

## APPENDIX IV

## ESTIMATION OF LIGNINS

**(A.O.A.C., 1980)**

### Principle

Refluxing the sample material with acid detergent solution removes the water solubles and materials other than the fibrous component. The left-out material is weighed after filtration, dried, treated with 72% $H_2SO_4$ and filtered, dried and ashed. The loss of weight on ignition gives the acid detergent lignin.

### Materials

1. Acid detergent solution – Dissolve 25 g of acetyl trimethyl ammonium bromide in one litre of 1N sulphuric acid
2. 72% $H_2SO_4$ (w/v)
3. Acetone
4. Round Bottom Flask and Refluxing Set
5. Muffle Furnace
6. Sintered Glass Curcible-G2

### Procedure

**a. Acid Detergent Fibre (ADF)**

1. Place 1 g of powdered sample in a round bottom flask and 10 mL of acid detergent solution. Heat to boil in 5 to 10 min. Reduce heat to avoid foaming as boiling begins. Reflux for 1 h after the onset of boiling. Adjust boiling to slow, even level.
2. Remove container, swirl and filter the contents through a preweighed sintered glass crucible (G-2) by suction and wash with hot water twice.

3. Wash with acetone and break up the lumps. Repeat acetone washing until the filtrate is colourless.
4. Dry at 100°C for overnight.
5. Weight after cooling in a desiccator
6. Express ADF content in percentage *i.e.*, W/S x 100, where W is the weight of the fibre and S is the weight of the sample.

**b. Determination of Acid Detergent Lignin (ADL)**

1. Transfer ADF to a 100 mL beaker with 25-50 mL of 72% sulphuric acid. Add 1 g asbestos. Allow it to stand for 3 h with intermittent stirring with a glass rod.
2. Dilute the acid with distilled water and filter with preweighed Whatman No.1 filter paper. Wash the glass rod and the residue several times to get rid of the acid.
3. Dry the filter paper at 100°C and weight after cooling in a desiccator.
4. Transfer the filter paper to a preweighed silica crucible and ash the filter paper with the content in a muffle furnace at 550°C for about 3 h.
5. Cool the crucible in a desiccator and weight. Calculate the ash content
6. For blank take 1 g asbestos, add 72% $H_2SO_4$ and follow the steps 2 to 5.

**Calculation**

$$\% \text{ ADL} = \frac{\begin{array}{c}\text{Weight of 72\% } H_2SO_4 \\ \text{Washed Fibre} \\ \text{(Test - Asbestos blank)}\end{array} - \begin{array}{c}\text{Ash} \\ \text{(Test – Asbestos blank)}\end{array}}{\text{Weight of sample}} \times 100$$

## APPENDIX V

## ESTIMATION OF CELLULOSE

## (A.O.A.C., 1980)

### Principle

Cellulose undergoes acetolysis with acetic/nitric reagent forming acetylated cellodestrins which get dissolved and hydrolyzed to form glucose molecules on treatment with 67% $H_2SO_4$. This glucose molecule is dehydrated to form hydroxymethyl furfural which forms green coloured product with anthrone and the colour intensity is measured at 630 nm.

### Materials

1. Acetic/Nitric Reagent : Mix 150 mL of 80% acetic acid and 15 mL of concentrated nitric acid
2. Anthrone reagent : Dissolve 200 mg anthrone in 100 mL concentrated sulphuric acid. Prepare fresh and chill for 2 h before use.
3. 67% sulphuric acid

### Procedure

1. Add 3 mL acetic/nitrate reagent to a known amount (0.5 g or 1 g) of the sample in a test tube and mix in a vortex mixer.
2. Place the tube in a water bath at 100°C for 30 min.
3. Cool and then centrifuge the contents for 15-20 min.
4. Discard the supernatant.
5. Wash the residue with distilled water.
6. Add 10 mL of 67% sulphuric acid and allow it to stand for 1 h.
7. Dilute 1 Ml of the above solution to 100 mL
8. To 1 mL of this diluted solution, add 10 mL of anthrone reagent and mix well
9. Heat the tubes is a boiling water bath for 10 min.

10. Cool and measure the colour at 630 nm

11. Set a blank with anthrone reagent and distilled water

12. Take 100 mg cellulose in a test tube and proceed from step No.6 for standard. Instead of just taking 1 mL of the diluted solution (Step 7) take a series of volumes (say 0.4 to 2 mL corresponding to 40-200 µg of cellulose) and develop the colour.

**Calculation**

Draw the standard graph and calculate the amount of cellulose in the sample.

## APPENDIX-VI

## DETERMINATION OF CAFFEINE CONTENT

## (A.O.A.C., 1980)

### L-1. Reagents

**L-1.1. Magnesium Oxide** – Powdered

**L-1.2. Dilute Sulphuric Acid** – 1:9 obtained by diluting concentrated sulphuric acid of sp. Gr. 1.84.

**L-1.3. Chloroform** – Redistilled

**L-1.4. Potassium Hydroxide Solution** – One per cent (w/v)

**L-1.5. Potassium sulphate** – Crystals, nitrogen-free

**L-1.7. Concentrated Sodium Hydroxide Solution** – Dissolve about 225 g of sodium hydroxide in 500 ml of water.

**L-1.8. Standard Sulphuric Acid** – 0.05 N.

**L-1.9. Methyl Red Indicator** _ Dissolve one gram of methyl red in 200 ml of rectified spirit (95 per cent by volume).

**L-1.10. Standard Sodium Hydroxide Solution** – 0.1 N.

### L-2. Procedure

**L-2.1.** Weigh accurately about 5 g of the materials, transfer to a 250 ml Erlenmeyer flask, add 3 g of magnesium oxide and 100 ml of distilled water. Weigh the flask with contents and boil under a reflux condenser for 45 min, shaking occasionally. Cool and weight the flask again and add water till the original weight is obtained. Mix well and filter through a dry filter paper directly into a 50 ml graduated flask

until exactly 50 ml of the solution (equivalent to half the quantity of the material taken for the test) is obtained. Transfer the solution to a 125 ml separator. Wash the graduated flask with 2 ml water and add the washing to the separator. Add 4 ml of dilute sulphuric acid. Extract with five 10 ml portions of chloroform, shaking vigorously for one minute for each extraction. Let the emulsion break; then drain the chloroform into a 125 ml separator. Add 5 ml of potassium hydroxide solution. Shake vigorously for one minute, let the emulsion break and drain the chloroform through a cotton plug into a 100 ml Kjeldahl flask. Extract the potassium hydroxide solution with 5 ml of chloroform and add to the Kjeldahl flask. To the digestion flask add 1.30 ± 0.50 g of potassium sulphate and 40±5 mg of mercuric oxide. Rinse down the neck of the flask with 3 ml of chloroform. Place the flask on the digestion rack and concentrate chloroform to about 20 ml. Distil off chloroform. Add 2.0±0.1 ml of concentrated sulphuric acid of sp. Gr. 1.84. Digest for one hour after the acid begins to boil. Cool and add the minimum quantity of water to dissolve solids. Cool and place at thin film of vaseline on the rime of the flask. Transfer the digest and boiling chips to the distillation apparatus and rinse the flask 5 or 6 times with one to two millilitre portions of water. Place a 125 ml beaker containing a known quantity of standard sulphuric acid. Add 6 ml of concentrated sodium hydroxide solution carefully through the side to the still so that it does not mix, and assemble the distillation apparatus immediately taking care that the dip tube extends well within the standard sulphuric acid contained in the beaker. Mix the contents of the distillation flask and distill until all ammonia has passed over into the standard

sulphuric acid. Shut off the heater and immediately detach the flask from the condenser. Rinse the condenser thoroughly with water into the beaker. Wash the dip tube carefully so that all traces of the condense are transferred to the beaker. When all the washings have drained into the beaker, add two or three drops of methyl red indicator solution and titrate with the standard sodium hydroxide solution.

**L-2.2.** Carry out a blank determination using all the reagent in the same quantities but without the material.

**L-3.** Caffeine (on dry basis),

$$\text{Percent by weight} = \frac{484.96\ (B-A)\ N}{W\ (100-M)}$$

Where

B = volume in ml of the standard sodium hydroxide used to neutralize the acid in the blank determination,

A = volume in ml of the standard sodium hydroxide used to neutralize the excess of acid in the test with the material

N = Normality of the standard sodium hydroxide solution,

W = Weight in g of the material in the aliquot, and

M = the percentage of moisture.

## APPENDIX-VII

## ESTIMATION OF AVAILABLE NITROGEN IN SOIL (BY ALKALINE PERMANGANATE METHOD)

## (SUBBIAH AND ASIJA, 1956)

### Principle

A known weight of soil is mixed with excess of alkaline permanganate and distilled. Organic matter present in soil is oxidized by the nascent oxygen liberated by $KMnO_4$ in the presence of NaOH and thus ammonia is released. This released ammonia is absorbed in a known volume of boric acid (2%) containing double indicator and converted to ammonium borate. This ammonium borate is titrated against standard $H_2SO_4$.

### Reagents

1. 0.32% $KMnO_4$ solution (3.2 g of $KMnO_4$ dissolved in 1 litre of distilled water)
2. 2.5% NaOH solution (25 g of NaOH dissolved in 1 litre of distilled water)
3. 2.0% boric acid (20 g of boric acid dissolved in 1 litre of distilled water)
4. N/50 $H_2SO_4$ (3 ml of conc. $H_2SO_4$ is diluted to 1 litre with distilled water and standardized by titration with N/10 $Na_2CO_3$. This gives N/10 $H_2SO_4$. From this N/50 $H_2SO_4$ is prepared by dilution.
5. Double indicator (Bromocresol green (0.5 g) and methyl red (0.1 g) dissolved in 100 ml and ethyl alcohol.

**Procedure**

Weighed 20 g of soil and transferred into a distillation flask. Added 30 ml of distilled water to moist the soil and 1 ml of liquid paraffin. Added few pieces of glass beads to avoid frothing. Added 100 ml of freshly prepared 0.32% $KMnO_4$ and 100 ml of 2.5% NaOH to the soil in the distillation flask. A 100 ml beaker containing approximately 20 ml of 2% boric acid with double indicator was kept below the delivery end of the condenser in the distillation set. Distilled the contents and the liberated ammonia was collected in boric acid. Distillation continued until the release of ammonia. Titrate the ammonia collected in boric acid with N/50 $H_2SO_4$.

**Calculation**

| | | |
|---|---|---|
| Weight of the soil taken | = | 20 g |
| Volume of N/50 $H_2SO_4$ | = | X ml (titre value) |
| 1 ml of N/10 $H_2SO_4$ | = | 0.0014 g N |
| Therefore, 1 ml of N/50 $H_2SO_4$ | = | 0.00028 g N |
| X ml of N/50 $H_2SO_4$ | = | 0.00028 x X g N |
| This is present in 20 g of soil. | = | 0.00028 (X/20) x $10^6$ |
| Therefore, N present in kg/ha | | |

## APPENDIX-VIII

## ESTIMATION OF AVAILABLE PHOSPHORUS

### (BRAY 1 METHOD-JACKSON, 1973)

**Principle**

The combination of HCl and $NH_4F$ extracts acid soluble forms of phosphorus such as mono calcium phosphate. The fluoride ion has the special property of complexing $Al^{+++}$ and $Fe^{+++}$ ions in acid solution with consequent release of phosphorus held in the soil by these ions. The phosphorus so released into the soil solution is estimated colorimetrically as available phosphorus.

**Reagents**

1. $NH_4F$ solution (1N) : 37 g of $NH_4F$ was dissolved in 1 litre of distilled water
2. HCl (0.05 N) : 20.2 ml Conc. HCl diluted to 500 ml with distilled water
3. Bray No.1 extractant (0.03 N $NH_4F$ and 0.02 N HCl) : 15 ml of 1 N $NH_4F$ and 25 ml of 0.5 N HCl are mixed and the volume was made up to 500 ml with distilled water.
4. Ascorbic acid

**Procedure**

Weighed 5 g of soil and transfer to a 100 ml polythene shaking bottle. Added 50 ml of Bray-1 extractant. Shake the contents in a reciprocatory mechanical shaker for one minute. Filtered the contents through Whatman No.40 filter paper. Simultaneously conducted a blank. Pipetted out 5 ml of filtrate into 25 ml volumetric flask. Added 4 ml of reagent B as in Olsen's method and made up the

volume to 25 ml. The intensity of the colour developed was measured in a photoelectric colorimeter using red filter (660 nm).

**Calculation**

| | | |
|---|---|---|
| Weight of the soil taken | = | 5 g |
| Volume of $NaHCO_3$ | = | 50 ml |
| Volume of extractant solution used for phosphorus estimation (aliquot) | = | 5 ml |
| Colorimeter reading | = | T |
| Concentration of phosphorus read from standard graph for the reading T | = | X ppm |
| | = | X ug/ml |
| | = | $X/10^6$ g/ml |
| Therefore, in 25 ml of solution | = | $X/10^6$ x 25 g |

This is present in 50 ml of the extractant solution and 5 g of soil

Therefore, available $P_2O_5$ in kg/ha = $\frac{Xx25x50x2x10^6}{10^6x5x5}$

## APPENDIX-IX

## ESTIMATION OF AVAILABLE POTASSIUM IN SOIL

### (STANDFORD AND ENGLISH, 1949)

**Principle**

The potassium ions in the exchange sites are replaced with $NH_4^+$ and $K^+$ is released. The concentration of K ions in the solution is then determined using Flame Photometer.

**Reagents**

1. 1 N Ammonium acetate (Neutral in pH) : Dissolved 77 g of AR grade ammonium acetate in 1000 ml of distilled water. pH adjusted to 7.0.

**Procedure**

Transferred 5 g of soil into a polythene shaking bottle. Added 25 ml of 1 N ammonium acetate and contents shacked in a mechanical reciprocating shaker for 5 minutes. Contents filtered through Whatman No.40 filter paper. Filtrates were fed into the flame photometer and readings recorded. Using a standard curve available potassium content was calculated.

**Calculation**

| | | |
|---|---|---|
| Weight of soil taken | = | 5 g |
| Volume of extractant used | = | 25 ml |
| Flame photometer reading | = | T |
| Concentration of k in the standard curve | = | X ppm |
| | = | X ug/ml |
| | = | $X/10^6$g/ml |
| Therefore, in 25 ml solution | = | $X/10^6$ x 25 g |
| This is percent in 5 g of soil. Therefore, available K in soil in kg/ha | = | $X/10^6$x25x2x$10^6$/5 |

## APPENDIX-X

## ESTIMATION OF AVAILABLE MICRONUTRIENTS

### (LINDSAY AND NORWELL, 1978)

The soils were extracted with DTPA extract. The extractant was prepared by mixing 0.005 M diethylene triamine penta acetic acid (DTPA) with 0.1M triethonolamine (TEA) and 0.01M calcium chloride in the ratio of 1:2, taken for 2 hours. This extract was used for all the cationic micronutrient estimations.

**Available Copper**

The DTPA extract was aspirated into the atomic absorption spectrophotometer, varian (AA120) wavelength of 2347.5 nm to estimate the available copper content.

**Available Zinc**

The DTPA extract was aspirated into the AA120 at the wave length of 2138.6 nm to estimate the available zinc.

**Available Manganese**

The DTPA extract was aspirated into the AA120 at the wave length of 2794.8 nm to estimate the available manganese content.

**Available Iron**

The DTPA extract was fed into the AA120 at the wavelength of 2483.3 nm, to estimate the available iron content.

## APPENDIX-XI

## DETERMINATION OF PHYSICAL CONSTANTS OF SOIL (KEEN RACZKOWSKI, 1921)

### Principle

A known quantity of soil is allowed to fully saturate and equilibrate with water and from the water held in the single value constants *viz.*, bulk density, particle density, volume expansion on wetting, maximum water holding capacity and pore space are determined gravimetrically using Keen Raczkowski box.

### Materials required

Keen Raczkowski box (circular brass box having an internal diameter of 5-6 cm and a height of 1.6 cm) with perforated bottom having numerous holes of 0.75 mm diameter spaced at 4 mm apart. Each box has split ring which serves to hold the filter paper in position over the perforated bottom.

### Procedure

A thin filter paper (Whatman No.1) was placed on the perforated bottom of the box and fit in position with the help of the split ring. The box with filter paper was weighed. Using a spatula, small portions of air dry soil to be estimated was transferred to the box and the soil was packed by tapping the box gently on a hard surface. The addition of soil and tapping the box systematically was continued until it was full. By running a sample knife over the rim of the box the excess soil was removed. The weight of the box plus air dry soil was determined. The box was placed in a petridish and water was added to the dish until the water level reaches about half the height of the box and kept overnight.

Next day morning the box was removed and the water on outside of the box was wiped out and the weight recorded. Then the expanded soil was removed by running a knife over the rim of the box and the soil thus removed was placed in a weighed watch glass. Again the weight of the watch glass and expanded soil was taken. Then the soil in box and the watch glass was dried in an electrical air oven at 105°C for 10-12 hours. The box was cooled in a desiccator and recorded the weight. From the weights obtained the single value constants were calculated.

**Calculation**

| | | |
|---|---|---|
| Weight of the box + filter paper | = | a g |
| Weight of air dry soil + box (filter paper) | = | B g |
| Weight of the box + wet saturated soil | = | C g |
| Weight of the box +wet residual soil | = | D g |
| Weight of the box + dry residual soil | = | E g |
| Weight of empty watch glass | = | F g |
| Weight of watch glass + wet expanded soil | = | G g |
| Weight of watch glass + dry expanded soil | = | H g |
| The volume of the box | = | V ml |
| 1. Bulk density | = | b-a/v-(d-e) |
| 2. Absolute specific gravity | = | e-a/v-(d-e) |
| 3. Maximum water holding capacity | = | (e-a)-(b-a)/(b-a) x 100 |
| 4. Per cent pore space | = | (d-a)-(e-a)/v x 100 |
| 5. Volume expansion | = | (g-h)+(h-f)/sp.g/v x 100 |