DEVELOPMENT OF PROTOCOL FOR QUALITY CONTROL OF COMMERCIAL ORGANIC MANURES AND THEIR EVALUATION

GOWRI PRIYA

Thesis submitted in partial fulfillment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2008

Department of Soil Science and Agricultural Chemistry
College of Agriculture
Vellayani, Thiruvananthapuram-695 522

DECLARATION

I hereby declare that this thesis entitled "Development of protocol for quality control of commercial organic manures and their evaluation" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani

GOWRI PRIYA

(2005-21-113)

CERTIFICATE

Certified that this thesis entitled "Development of protocol for quality control of commercial organic manures and their evaluation" is a record of research work done independently by Ms. Gowri Priya (2005-21-113) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

Vellayani

Dr. K. Harikrishnan Nair
(Chairperson, Advisory Committee)
Professor and Head,
Department of Soil Science and Agricultural Chemistry
College of Agriculture, Vellayani.

Approved by:

Chairperson:

Dr. K. Harikrishnan Nair

Professor and Head,

Department of Soil Science and Agricultural Chemistry,

And Dean, College of Agriculture,

Vellayani.

Members:

1. Dr. Samuel Mathew
Professor,
AMPRS, Odakkali

2. Dr. K. Ushakumari,
Professor
Dept. of Soil Science and Agricultural chemistry,
College of Agriculture, Vellayani.

3. Dr. D. Geetha,
Professor,
Instructional Farm,
College of Agriculture, Vellayani.

4. Dr. Vijayaraghava Kumar
Professor,
Dept of Agricultural Statistics,
College of Agriculture, Vellayani.

External Examiner:

ACKNOWLEDGEMENT

I wish to express my heartfelt gratitude to Dr. K. Harikrishnan Nair, Professor and Head, Department of Soil Science and Agricultural Chemistry, and Dean, College of Agriculture, Vellayani, for his valuable guidance and constant encouragement throughout the course of this study as the Chairman of the advisory committee.

I owe my sincere thanks to Dr. K. Ushakumari, Professor, Department of Soil science and Agricultural Chemistry, Dr. Samuel Mathew, Professor, AMPRS, Odakkali, Dr. D. Geetha, Professor, Instructional Farm, College of Agriculture, Vellayani and Dr. Vijayaraghava Kumar, Professor, Dept of Agricultural Statistics, College of Agriculture, Vellayani, the members of the advisory committee without whose advice and help this study would not have been successful.

My sincere thanks are due to all my teachers in the Department of Soil science and Agricultural Chemistry for their help and kind encouragement throughout the period of the study.

I wish to express my sincere gratitude to Sri. Ajith C.E., Programmer, Department of Agricultural Extension, for his help in doing the statistical analysis of the results.

I also wish to thank all the non teaching staff members of the Department of Soil Science and Agricultural Chemistry for their timely help and co-operation during the course of this work.

With pleasure I express my thanks to my classmates and friends whose constant support could never be forgotten. I would also like to place on record my indebtedness to my family for the immense support given to me during the whole period of study.

I am grateful to Jawaharlal Nehru Memorial Fund, Teen Murti House, New Delhi, for granting me the Jawaharlal Nehru fellowship for Doctoral studies.

GOWRI PRIYA

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS USED

BI	: Biodegradability Index
BM	: Bone meal
C/N	: Carbon/Nitrogen
CC	: Conventional Compost
CD	: Critical Difference
COMs	: Commercial Organic Manures
DAI	: Days After Incubation
DOC	: Dissolved Organic Carbon
dSm^{-1}	:deci Siemens per metre
EC	: Electrical Conductivity
FM	: Fishmeal
FYM	: Farm Yard Manure
INM	: Integrated Nutrient Management
K	: Potassium
kg ha^{-1}	: kilograms per hectare
l ha^{-1}	: litres per hectare
LAI	: Leaf Area Index
LM	: Leather meal
MAT	: Months After Transplanting
mg kg^{-1}	: milligram per kilogram
Mg m^{-3}	: Mega grams per cubic metre
µg l^{-1}	:micro gram per litre
ml	: milli litre
MOP	: Muriate of Potash
N	: Nitrogen
NC	: Neem cake
N.D	: Non-detectable
OM	: Organic Matter
OMMs	: Organic Meal Mixtures
P	: Phosphorus

PC	: Phospho-compost
PM	: Pressmud
P.O.P	: Package of Practices
ppb	: parts pre billion
ppm	: parts per million
PUE	: Phosphorus Use Efficiency
RM	: Raw material
SCC	: Standard Coir pith Compost
SCMs	: Standard Compost Manures
SCWC	: Standard City Waste Compost
SE	:Standard Error of mean
SN	: Sample Number
SOM	: Soil Organic Matter
SVC	: Standard Vermicompost
$t\ ha^{-1}$	: tonnes per hectare
t	: tonnes
TOC	: Total Organic Carbon
TSS	: Total Soluble Solids
VC	: Vermicompost
WSC	: Water Soluble Carbohydrates
WSOC	: Water Soluble Organic Carbon

INTRODUCTION

1. INTRODUCTION

The world is now facing a grave food crisis which has affected developed and developing countries alike, thus posing a serious problem for the agricultural scientists to solve. Experts have been warning about an impending global food crisis for several years, due to increasing population, increasing purchasing power leading to higher consumption, increasing damage to the ecological foundations of agriculture, declining per capita availability of land and water and the absence of technologies that can further enhance the yield potential of major food crops (Swaminathan, 2000). The burgeoning population pressure had forced many countries to use chemicals and fertilizers to increase the farm productivity for meeting their food requirements. The prolonged and over usage of chemical has, however resulted in human and soil health hazards and pollution of environment. Farmers in developed countries are therefore being encouraged to convert their existing farms into organic farming (Chandra and Chauhan, 2004).

The Green Revolution launched in the mid-sixties became a landmark in transformation of agriculture in India. However, in the recent decades, despite the commendable progress made earlier, deceleration of growth and crop yield from green revolution technologies surfaced and caused serious concern and chain of several problems to be tackled. The cause for such serious concern was due to the unscientific, uncontrolled and indiscriminate use of input chemicals such as fertilizers, pesticides, fungicides, weedicides and growth promoters etc. aimed paradoxically to increase the yield of crops and multiply the profits (Ramanathan, 2006).

In this scenario, sustainable agriculture and organic farming have been hailed as the only remedies by several scientists and experts. According to the Consultative Group on International Agriculture Research (CGIAR), “Sustainable agriculture is the successful management of resources to satisfy the changing human needs, while maintaining or enhancing the quality of environment, and conserving natural resources”. Sustainable agriculture emphasizes the practice of integrated nutrient management which will assure balanced nutrition and sustainable yields through the combination of manmade fertilizers and native nutrient sources, viz., organic manures (Katyal, 1997). Organic farming may be defined comprehensively as environment friendly ecological production system that promotes and enhances biodiversity, biological cycles and biological activities. It is based on minimum use of off-farm inputs and management practices that restore, maintain and enhance ecological harmony (Narayanan, 2005).

Thus organic manures have achieved an important status because of the rising popularity of both sustainable agriculture and organic farming. The important problems faced by farmers in organic farming is the scarcity of organic manures coupled with their low nutrient content, the huge bulk needed for supplying required quantities of nutrients and the problems in transportation, storage and application of the manures. The estimated recyclable wastes available for organic farming in India are: urban solid wastes- 27.4 million tonnes per year, urban liquid wastes – 12145 million litres per day, sugar mill wastes (pressmud) – 9 million tonnes per year, wastes from food and food processing industries – 4.5 million tonnes per year, dairy wastes- 60 million litres per day and other agricultural wastes- 350 million tonnes per year (Selvaraj et al., 2005). The tappable potential of organic residues/wastes in India may be placed around 30 per cent of the total availability, because of the alternate uses of the organic wastes other than as manure (Katyal, 2000). Hence the farmers are compelled to use whatever organic wastes that are available such as sewage sludge, tannery wastes, immature composts, etc which may contain harmful materials damaging soil and crop quality.

In Kerala, there is an increasing awareness among farmers about the ill effects of chemical fertilizers and hence more farmers are gradually switching over to organic farming. They are also attracted by the premium price realized by organic produce. As a consequence, there is an escalating demand for organic manures, the most important input in organic farming. This situation is being exploited by a large number of firms mushrooming in the state advertising high performance organic manures. There are wide spread complaints that many such “organic” manures contain low grade wastes fortified with chemical fertilizers. The farmers are cheated by these fake products. If the quality of the organic manures is not properly maintained, it can harm the soil and environment in many ways. For example, the use of immature compost has adverse effects on crops, like nitrogen immobilization due to wide carbon / nitrogen ratio, heat generated during decomposition, production of phytotoxic compounds during decomposition, etc. The toxic elements derived from the raw materials can be harmful to plants and animal health, especially in the case of raw materials from municipal sewage, industrial effluents, agro- processing industrial wastes. They can have high levels of heavy metals like arsenic, cadmium and lead and can contaminate the food chain. Phytotoxic compounds like volatile acids are produced when wastes are stored under anaerobic conditions. Livestock manures can have high levels of copper and zinc since these are additives in livestock feed, especially for poultry.

The quality of organic manures is regulated by Government in countries like Korea, Thailand, Taiwan and Japan (Venugopal, 2004). At present, there is no regulatory mechanism to ensure fair practice in the trade of organic manures in Kerala. A sound analytical protocol is required to test the identity of important organic manures and to detect adulteration of organic manures with inorganic chemicals disallowed in organic farming.

There are a large number of firms in Kerala manufacturing organic manures using a wide variety of raw materials of diverse origin and chemical composition. The farmers are ignorant of the quality of these manures and their effects on soil health and crop quality. The presence of toxic adulterants in manures will lead to irrevocable contamination of the agricultural environment and human food chain. In order to safeguard the interests of our farmers, protect the health of the consumers and to conserve the purity of the environment, it is highly essential to regulate the quality of the organic manures produced and marketed. Development of protocol for quality evaluation of organic manures is hence a crucial step in this direction.

Amaranthus is a popular leafy vegetable in the homestead farms of Kerala. It is a short duration vegetable crop rich in nutrients like vitamin A (beta carotene), vitamin B, Vitamin C, iron, calcium, sodium, magnesium, phosphorus, potassium and sulphur. As the tender plants are consumed within a short period of planting, organic farming technique is preferred to ensure food free from chemicals. Even with organic farming, the quality of organic manures applied to the crop can influence its yield and quality. Hence it is necessary to ensure the quality of organic manures used for crop production.

In the above context, a research project was undertaken with the following objectives:

1. To identify the major commercial organic manures in Kerala and their quality evaluation
2. To develop quality control protocol for assessing quality and detecting adulteration in commercial organic manures
3. To study the mineralization pattern of major nutrients in important manures and to evaluate their comparative effect on crop performance.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Organic matter is essential for maintaining the soil fertility and productivity. It plays a vital role in soil by supplying plant nutrients, supporting microbial activity, maintaining favourable soil physical properties, preventing the loss of plant nutrients, alleviation of soil pollution and by many other functions. Therefore it is necessary to replenish the soil organic matter content as it gets decomposed. But intensive cultivation with continuous use of chemical fertilizers alone has deprived the soils of their organic matter fraction and thereby leaving them infertile. The application of organic manures and organic amendments along with chemical fertilizers is very important to maintain the fertility of our valuable soils. As organic manures can influence the soil quality and crop quality in many ways, it becomes necessary to ascertain that only manures of good quality are added to soil. The relevant research findings on the impact of organic manures on soil quality, crop yield, quality of the products and the factors affecting manure quality are reviewed in this chapter.

2.1 Organic manures

The term organic manures comprises of a variety of materials which include farm yard manure, various types of composts prepared using organic wastes, oil cakes, poultry manure, pig manure, wastes from agriculture-related industries like pressmud, wastes from other industries like leather meal, wastes from slaughter houses like blood and bone meal, fish meal, mushroom waste, and many such materials varying with the locality in different parts of the world. Some of these manures are rich in plant nutrients while others are poor nutrient suppliers. Some contain beneficial chemicals like alkaloids which improve their efficiency in maintaining soil fertility. The attributes of various organic manures are discussed hereunder.

Vermicomposting is a process by which organic wastes are converted to nutrient rich organic manure using earth worms as biological agent. Vermicompost contains major and minor nutrients in plant available forms, enzymes, antibiotics, vitamins and plant growth hormones. Vermicompost has definite advantage over other organic manures in respect of quality and shelf life of produce (Meerabai and Raj, 2001).

Bone meal is chiefly used as phosphorus fertilizer. Small quantities of nitrogen are also supplied to soil by bone meal. The availability of P from bone meal depends on particle size, the finer the particles, the greater will be the availability of P. The percentage of phosphoric acid and N varies with the quality of bones and age of the animal from which these are obtained. Normally bones of grown up animals contain more phosphoric acid and less N than those of young ones. According to standards laid down by the Indian Standards Institute, raw bone meal must pass wholly through 2.3mm I.S sieve of which not more than 30% shall be retained on 850 micron I.S sieve. Steamed bone meal decomposes more rapidly in soil than raw bone meal. According to ISI standards, not less than 90% of steamed bone meal material should pass through 1.18 mm I.S sieve (Panda and Hota, 2007).

Poultry manure is a rich source of nutrients especially for vegetable production (Jose et al., 1988). Its higher efficiency is due to the large quantities of easily mineralisable N (Meerabai and Raj, 2001). Due to high content of NPK, it has been proved that 1 tonne of poultry manure is equal to 7 tonnes of FYM (Channabasavanna and Biradar, 2002).

Oil cake is concentrated organic manure and is comparatively richer in NPK. Neem cake is a non – edible oil cake. In addition to nutrients, it contains the alkaloids nimbin and nimbidin and certain sulphur compounds which effectively inhibit the nitrification process and improve nitrogen use efficiency in crops (Reddy and Prasad, 1985).

Coir pith, which is abundantly available in Kerala as a by product from coir industry is found to be a good source of organic matter after decomposing it with *Pleurotus eous* and *Schizophyllus commune* (Reeja,2002). Coir pith has high potassium content and low bulk density and particle density. The low particle density is due to its high specific surface which gives it high CEC (Mapa and Kumara, 1995). Coir pith has very high moisture retention capacity of 500-600 per cent. Composting of coir pith helps in detoxifying phenolic compounds reducing the bulkiness of the material and converting the plant nutrients to a form more readily available to plants.

Fishmeal is produced by drying non-edible fish or wastes from fish industry. It is a balanced organic manure containing both N and P in significant quantities. The manure however, has an extremely offensive odour which stands in the way of its wider use. The long coast line of the country offers a great scope for fuller exploitation of this highly valuable manure for increasing agricultural production (Panda and Hota, 2007).

Leather meal is another kind of organic manure obtained from tannery and leather processing industries. Leather wastes can be processed by heating in steam digesters and grinding to powder. The product obtained contains 7-8% N and has been used as nitrogenous manure (Panda and Hota, 2007).

Pressmud is an organic waste material from sugar industries and it contained about 33% organic Carbon, 0.8% N, 2% P, 1.1% K, 4.45% Ca, 1.12% Mg, 3100ppm Fe, 80ppm Cu, 150ppm Zn and 80ppm Mn with C:N ratio 41:1 (Palaniappan and Annadurai, 1998).

2.2 Effect of organic manure quality on soil quality

Soil organic matter plays a key role in the maintenance of soil fertility and productivity. The effect of organic matter may be either direct or indirect. Directly, organic matter acts as a source of plant nutrients and indirectly influences the physical, chemical and biological properties of soil at levels favourable for crop production. Increases in soil organic matter (SOM) for soils under organic management have widely reported (Reganold et al., 1993; Jordahl and Karlen., 1993; Scow et al., 1994; Nguyen et al., 1995; Deria et al., 1996; Gardner and Clancy, 1996; Gerhardt, 1997; Loes and Ogaard, 1997; Clark et al., 1998). Wander and Traina (1994) have also measured higher levels of carbon on the “light fraction” of soils under organic management which is thought to represent a more biologically active pool. Changes in OM drive many of the other changes in soil biological and physical properties.

2.2.1 *Effect of Organic Manures on Soil Physical Properties*

The favourable effects of FYM application on the structural properties of the soil were observed by several investigators (Biswas et al., 1969 and Muthuvel et al., 1982). In general, the nature and quality of organic matter in combination with mineral constituents decide soil physical properties. Organic matter is known to be related to soil bulk density and aggregate formation as well as its stability in soil. The organic residues added to soil decompose and release various organic acids and other products of decay which act as strong binding agents in the formation of large and stable soil aggregates. In this aspect, the action of gum components, polysaccharides and fulvic acid component of organic matter is important, as a result of which the soil structure is improved which is reflected by the reduced bulk density values and better water conducting properties of soil (Manickam, 1993).

2.2.1.1 *Effect of Organic Manures on Soil Moisture Content*

The water retention capacity of the soil is more pronounced with high organic matter content, basically due to its qualitatively higher negative charges and the dipolar nature of water molecule. Besides, the greatest influence of organic matter on water retention is attributed to the structural changes brought about by organic matter, through changes in pore size both within and between the soil aggregates (Larson and Clapp, 1984). Increase in WHC of soil due to coir pith application was reported by Bhowmic and Debnath (1985). Incorporation of composted coir pith increased the soil moisture content and improved other physical constants of soil compared to other organic amendments (Subbaraj and Ramaswamy, 1992). Gaur (1994) reported that the aggregation is quite often improved by organic manure application which is attributed to the action of gum components of organic matter. The water holding capacity of the soil was increased from 28 to 33.2 per cent under all organic manure treatments, whereas there was no change in WHC values under NPK alone and control treatments. In a study by Govindan et al. (2005) the results indicated that coir pith compost helps in soil moisture conservation and thus help plants from water stress.

2.2.1.2 *Soil Aggregation, Porosity and Bulk density*

The use of coir pith as a soil conditioner in tropical farming is well established (Nagarajan et al., 1990). Loganathan (1990) reported that the application of organic amendments viz., sawdust, groundnut shell powder, coir dust and FYM each @ 2.5 and 5 t ha^{-1} improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil with hard pan. A decrease in bulk density by the addition of organic residues over a long time was observed (Rasmussen and Collins, 1991). Aggregate stability is increased under organic management (Jordahl and Karlen., 1993; Gerhadt, 1997; Siegrist et al., 1998) while porosity also increased (Jordahl and Karlen, 1993; Logsdon et al., 1993; Gardner and Clancy , 1996; Gerhadt,1997).

In the All India Coordinated long-term fertilizer experiments, application of inorganic N continuously for 15 years increased bulk density and reduced soil water retention at different locations (Nambiar, 1994). Lower rates of run-off and soil erosion have also been measured in organic systems (Logsdon et al., 1993; Reganold et al., 1987). Increases in the depth of A horizon of soil have been recorded for organic systems which may result from reduced bulk density and/or reduced soil losses through erosion (Reganold et al., 1993; Gerhadt, 1997). However, several research studies have found no difference on soil physical properties between organic and conventional farming systems. Siegrist et al. (1998) found no difference in soil particle detachment between organic and conventional systems. It may take decades to establish measurable changes on soil physical properties.

Rajasree (1999) found that in bitter gourd, partial substitution of chemical fertilizers with poultry manure reduced the bulk density and particle density of soil and increased the water holding capacity as compared to full dose of chemical fertilizers. Application of coir pith to soil can improve hydraulic conductivity, porosity, water infiltration rate, WHC, and nutrient storage capacity (Prabhu and Thomas, 2002). It can also suitably reduce the bulk density of heavy soils. Nair (2003) observed that in a bitter gourd cultivated field, the lowest bulk density, maximum WHC and higher porosity was recorded by the application of 100% N as poultry manure and was on par with application of 100% N as FYM and 100% N as vermicompost.

In an experiment conducted in ginger (Sreekala, 2004), it was observed that soil physical characters like bulk density, particle density, water holding capacity and soil aggregation index were superior for FYM + green leaf treatment compared to that of vermicompost and neem cake. Sheeba (2004) recorded reduced bulk density of soil due to application of vermicompost.

The influence of two organic wastes viz.,cotton gin crushed compost, and poultry manure applied during a period of four years on a Xerollic Calciorthid under dryland conditions on soil physical properties (structural instability and bulk density) and soil loss (at 60 and 140 mm h^{-1}, respectively) were studied by Tejada and Gonzalez (2007). Both organic wastes reduced aggregate instability, bulk density and soil loss. These results are in agreement with those of Puget et al., 2000, Tejada and Gonzalez, 2004 and Tejada and Gonzalez, 2006, who found that a good soil structure was dependent on the content and nature of organic matter which promotes flocculation of clay minerals, the essential condition for the aggregation of soil particles. Humic acid-like are directly involved in clay–organic complex formation and the aggregate stability is correlated with the humic acid-like content rather than with fulvic acid-like content (Tejada and Gonzalez, 2006 and Tejada and Gonzalez, 2007). The positive effect of organic wastes on soil structure may be due to high concentrations of Ca^{2+} and humic acid-C.

2.2.2 ***Effect of organic manures on soil chemical properties***

Organic manures greatly influence the soil chemical properties like pH, EC, organic carbon and nutrient availability.

2.2.2.1 ***Soil Reaction***

Olsen et al. (1970) reported that addition of manures increased soil pH. Rabindra and Honnegowda (1986) opined that FYM has greater buffering capacity and helps to maintain soil pH. Lal and Mathur (1988) reported that application of NPK fertilizes reduced pH from 5.5 to 3.8, but FYM application maintained or increased the pH of soil while the combination of fertilizers and manures reduced pH. FYM application resulted in lowest acidity due to increase in exchangeable and soluble aluminium in soil (Nambiar, 1994 and Patiram, 1996).

Vermicompost treated soil samples showed a marked change in soil reaction, buffering it near neutrality and thus assuming an atmosphere conducive for better plant nutrition (Bijulal, 1997). Rajasree (1999) reported that when poultry manure was used in equal or higher proportion with chemical N source, it showed moderating effect on soil acidity.

Lekshmisree (2003) reported that pH of the treated soil increased after compost application. There will be conversion of organic nitrogen to NH_3 and further to NH_4 which will reduce the pool of H^+ ions in soil and thus increase the pH was due to increase in concentration of ammoniacal nitrogen (Haini and Hubta, 1990). The pH rise may also be due to ion exchange between organic acids and hydroxyl groups of Al or Fe hydroxides (Hue, 1992). Most of the well stabilized composts had a pH between 6.5 and 7.5 (Wilson, 1989).

Sanwal et al. (2007) reported that soil fertility was improved by the application of organic manures such as poultry manure, pig manure, neem cake powder, cow manure and rabbit manure and compost teas (Panchkavya and Amritpani). Application of organic manures increases the organic matter in soil, which is a store house of nutrients and contributes to improvement in biological activity that contributes to improved soil fertility. Compost teas contain large amounts of microbes which might have complemented the activity of native microbes and favoured decomposition of organic matter at a faster rate resulting in better transformation of nutrients and their availability to crops (Pathak and Ram, 2002). In a study, various livestock based bio-organic, bio-dynamic and integrated farming systems were compared at reduced and normal fertilization intensity in a 7 year crop rotation (Fließbach et al., 2007). Soil pH tended to increase in the organic systems, whereas the integrated systems had the lowest pH values. The results showed that the manure based farming systems were likely to favour an active and fertile soil and that the organic carbon and biological soil quality indicators were clearly depending on the quantity and quality of the applied manure types. The changes in soil quality in the two farming systems viz., organic system and conventional system after 8 years of management were studied by Lehocka et al. (2008). It was found that the soil pH was not statistically different between the 2 systems although a higher soil reaction was discovered in the organic farming system.

2.2.2.2 ***Nutrient Availability***

Organic manuring plays an important role on supplying major and minor nutrients besides increasing their availability and moisture holding capacity of soils. Integrated nutrient management through chemical fertilizers and organic manures plays a greater role in maintaining soil fertility and productivity (Grewal and Trehan, 1988). The CO_2 released during decomposition dissolves in water and helps to solubilise the minerals thereby releasing vital nutrients. The overall fertility status of cultivated soils is influenced by the organic fraction through exchange reactions, chelation and buffering. Incorporation of organic waste significantly increased soil pH and nutrient status of an acid soil (Lal et al., 2000). Along with nutrients, manure supplies valuable organic matter to help improve soil physical properties and increase the activity of beneficial soil microbes (Klausner et al., 1984). Srivastava (1985) reported that the increased use of nitrogenous fertilizers reduced the organic carbon content, total nitrogen, available phosphorous and potassium of soil whereas FYM addition increased all these parameters in soil.

Nutrient composition of ordinary vermicompost was found to be 1.83 per cent N, 1.37per cent P_2O_5, 2.66 per cent K_2O, 0.46 per cent Ca and 1.3 per cent Mg. Vermicompost enriched with rock phosphate increased the plant available N, P_2O_5 and K_2O in soil (Sailajakumari, 1999). The increase in N, P, and K uptake due to organic manure application could be attributed to higher availability of these nutrients and increased utilization of native P due to organic acids produced during decomposition of organic matter (Srikanth et al., 2000).

Nair (2003) reported that poultry manure recorded the highest availability of nutrients N, P and K among FYM, poultry manure and vermicompost. Available P and K have been shown to increase (Scow et al., 1994; Clark et al., 1998) and decline (Nguyen et al.,1995; Penfold et al., 1995; Deria et al., 1996) in soils under organic management.

Mathen et al. (1978) observed that the combined application of FYM and inorganic fertilizers had little influence on available N content of soil. Similar observation was reported by Nair (1988) that the application of FYM along with N fertilizer did neither influence soil physical properties, nor it had any effect on soil chemical properties such as available N, P_2O_5 and K_2O contents of soil after the harvest.

Plant nutrient supplies available for crop growth in organic systems are often comparable and sometimes exceed those found in conventional systems. Yet, synchronizing the availability of those nutrients may be more difficult (Berry et al., 2002). Because composition of compost is notoriously variable, and mineralization of OM in the soil is mediated by a host of factors such as temperature, moisture, soil chemistry and microbial communities, predicting the timing and quality of nutrient supply in soil becomes difficult.

Lehocka et al. (2008) reported that microbial biomass was higher under organic system with the application of FYM than conventional management system. Microbial biomass is among the most labile pools of organic matter and it serves as an important reservoir of plant nutrients such as nitrogen and phosphorus. Microbial biomass, in response to environmental changes can have important implications for nutrient bioavailability. A similar result was obtained by Melero et al. (2006).The number of cellulolytic and ammonification bacteria was significantly higher in organic systems in comparison with the conventional system. The process of ammonification and nitrification run more intensively under organic management.

2.2.2.2.1 ***Availability of Nitrogen***

Addition of organic matter primarily provides N to the crops. The organically bound form of N becomes available to the crop after decomposition, followed by mineralization into inorganic forms (Tusneem and Patrick, 1971). Sathianathan (1982) found that in cassava, neem and mahua cake treatments were efficient in returning high nitrogen in the ammoniacal form under field condition. Thus these oil cakes reduced leaching losses and extended the period of availability of N to the crop from applied N.

Most of the non-edible oil cakes contain alkaloids which inhibit the nitrification process of N transformation in soils. Neem cake contains the alkaloids nimbin and nimbidin, which effectively inhibit the nitrification (Reddy and Prasad, 1985). Kale et al. (1992) recorded high level of total N in paddy plots applied with vermicompost and comparatively low quantity of fertilizers. They attributed this due to higher count of N fixers in the treated plots than in control plot.

Vermicompost analysed for nitrogen content showed that mineral nitrogen constituted 20.2 per cent of total N, easily hydrolysable 20 per cent, non- easily hydrolysable 32.4 per cent and non-hydrolysable 32.2 per cent. The vermicompost or earthworm casts are higher in bacteria, organic matter, total and nitrate nitrogen, available P and K (Brady, 1994). Prabhakumari et al. (1995) reported that vermicompost contains about 3 times more nutrients than FYM. The neem, mahua, karanj and castor oil cakes have great value as means of immobilizers, thus conserving the applied and soil N and mineralizing steadily over a longer period (Hulagur, 1996).

Asha (1999) reported that in an experiment with bhindi, available N content in soil was the highest for neem cake application as compared to that of FYM, poultry manure and compost. Sharu (2000) reported that highest level of poultry manure (5 t ha^{-1}) recorded the highest level of soil N compared to vermicompost, neem cake and Package of Practices recommendations in chilli. Lekshmisree (2003) reported that pH of the treated soil increased after compost application. In this suitable pH range the population of N fixing bacteria and actinomycetes will flourish resulting in increased

N content of soil (Brady, 1996).

Sheeba (2004) observed that enriching biowastes with neem cake and bone meal improved the manurial value of vermicompost and reduced the C: N ratio. The nutrient and non-nutrient effects of various rates and timings of mixed poultry litter-yard waste compost was compared with traditional organic fertilizer (poultry litter) and inorganic fertilizer on environmental soil attributes in an organic vegetable crop rotation. Soil organic C, total N, and available P increased 60 per cent, 68 per cent, and 225 per cent, respectively, above the control with the application of 144 Mg ha^{-1} compost during the 3-year study, but the low rate of compost (31 Mg ha^{-1}) did not affect soil C or N (Evanylo et al., 2008). Long-term poultry litter application or continuous cropping can sequester C and N in the soil compared with inorganic N fertilization or fallow, thereby increasing soil quality and productivity and reducing the potentials for N leaching and greenhouse gas emission (Sainju et al., 2008).

2.2.2.2.2 Availability of Phosphorus

Organic manures enhanced available P status of the soil which could be attributed to reduced fixation of added as well as native P by application of organic manures (Ghosh et al., 1981). Krishnaswamy et al. (1984) found that the application of FYM or compost (15 t ha^{-1}) had a significant effect on increasing the available P from the native and applied sources. Humus by virtue of its chelating properties increase the availability of N,P, S and other nutrients to plants growing in humus rich soil. The humus substrates increase P availability as they have very high exchange capacity (Gaur, 1994).

Chen et al. (1994) have investigated the effect of applied compost on the inorganic P sorption capacity of a strongly acidic soil (clay loam with a pH of 4.5), a slightly acidic soil (silty loam with a pH of 6.2) and a slightly alkaline soil (clay with a pH of 7.4). Two of the composts used were made from swine manure or cattle manure, while the third was composted straw. The results showed that all three types of compost were effective in reducing the inorganic P sorption capacity and P sorption percentage. The composted straw was found to have the greatest ability to reduce the inorganic P sorption capacity of the soil, followed by composted cattle manure and swine manure, in that order. In general, the higher the content of inorganic P and/or organic P, and the lower the ratio of C to organic P in the compost, the more significant was the effect in reducing the inorganic P sorption capacity. Therefore, the application of compost can enhance the availability of soil P and promote the efficiency of P fertilizers.

Many suggestions have been made to explain how compost reduces the P adsorption capacity. One possibility is that the iron, aluminum or calcium combines with humic or organic acids released by the decomposition of organic matter, thereby reducing P adsorption (Dalton et al., 1952; Moreno et al., 1960; Barrow, 1989). Another suggestion is that P adsorption sites become preoccupied by organic P, especially phytic acid (Anderson et al. 1974, Evans, 1985, Chen, 1996). It has also been suggested that adsorption sites may be preoccupied by inorganic P ions dissolved from organic fertilizer or released by the mineralization of organic P fractions (Chen, 1996). A fourth explanation is that the surface charge on soil colloids is variable after compost has been applied, because of changes in the soil pH. When compost is applied to strongly acidic soil, the P content of the compost should be considered, so that P deficiency does not become a limiting factor for normal crop growth.

Phosphorus uptake by cowpea was significantly higher in enriched vermicompost treatment while all other treatments viz., Bharath Meal. Haritha Super, Poabs Green and FYM were on par (Deepa, 2005).

In a four year long field trial to study the effects of organic waste on soil chemical and microbiological variables in a barley-oats crop rotation in Sweden, with compost from household waste, biogas residue from household waste, anaerobically treated sewage sludge, pig manure, cow manure or mineral fertilizer, where all were amended in rates corresponding to 100 kg N ha^{-1} $year^{-1}$. The results showed that compost increased pH, and that compost as well as sewage sludge increased plant available phosphorus; however, the chemical analysis showed few clear trends over the 4 years and few clear relations to plant yield or soil quality (Odlare et al., 2008). Despite rather large concentrations of heavy metals in some of the waste products, no negative effects could be seen on either chemical or microbiological soil properties.

2.2.2.2.3 ***Availability of Potassium***

Bharadwaj (1995) reported that most significant role of organic matter in supplying K. Basker et al. (1992) observed increased concentration of available and exchangeable K by vermicompost application.

Application of coirpith can enhance the availability of micro and macro nutrients and increase the yields. As coirpith is rich in potash and being acidic, its application can enhance the release of fixed and mineral K in soil and hence the quantity of K fertilizer can be reduced in agriculture (Savithri et al., 1993). As it decomposes slowly, potash will be available slowly for many years. Dhanorkar et al. (1994) found that the continuous use of FYM increased the available K content of soil by 1.3 to 5.4 times over control.

Potassium uptake was the highest in enriched vermicompost which was on par with Bharath Meal. Haritha Super, Poabs Green and FYM were on par with each other (Deepa, 2005).

2.2.2.2.4 ***Availability of Secondary and Micro Nutrients***

Olsen et al. (1970) inferred that the application of manures increased exchangeable Ca and Mg particularly at higher rates of their application.In a long term fertilizer experiment at Ranchi under wheat-maize rotation, available Zn, Cu, Mn and Fe contents increased considerably with the continuous use of FYM (Prasad and Singh, 1980). Swarup (1984) observed that the application of FYM improved the availability of both native and applied micronutrient cations. These cations form stable complexes with organic ligands which reduce their susceptibility to adsorption and fixation.

Selvi and Selvaseelan (2003) reported that the combined application of organics and inorganics in potato crop had a positive influence on Ca and Mg availability, possibly due to favourable microbial activity, but under NPK alone, the fertility levels failed to influence available Ca and Mg appreciably. The availability of micronutrients also was appreciably influenced by manurial treatments over NPK confirming their role as substitutes for individual micronutrient fertilizer application for the potato crop. This could be assigned to the higher contents of these micronutrients in the manures as well as their very favourable chelating and complexing reactions which enhance their availability, reducing their possibility of getting fixed.

2.2.2.2.5 ***Organic Carbon Content of Soil***

Soil carbon contents can be increased by land use practices in which rates of carbon inputs exceeds those of carbon oxidation. Rates of carbon inputs to soil can be increased by continuous cropping, especially with perennial legumes and by soil amendments, especially manure (Grant et al., 2001). Selvi and Selvaseelan (2003) inferred that organic manures significantly influenced soil organic carbon content based on a study in potato. Application of FYM had a marked influence on the organic carbon content of soil at both potato tuber initialization stage and post harvest stage which was closely followed by mushroom spent compost (MSC) and coir pith compost (CCP). The MSC and CCP having higher proportion of fibrous carbonaceous residues contributed towards increasing soil organic carbon content.

Sheeba (2004) reported that application of organic matter increased the organic carbon content, pH and EC of soil compared to that of chemical fertilizers. Among various organic sources enriched vermicompost was superior to that of FYM and ordinary vermicompost. Sreekala (2004) recorded increase in organic carbon content due to FYM application as compared to application of poultry manure and neem cake. Application of organics (pressmud cake, biogas slurry, vermicompost, sugarcane trash, *Trichoderma viride*) brought about substantial increase in organic carbon content (0.45-0.48 per cent) of the soil over initial value (0.32 per cent). Available major nutrients in soil after harvest of plant cane and subsequent ratoon crop recorded a positive effect due to the application of various treatments (Singh et al., 2007).

In an experiment to study the changes in chemical and biochemical soil properties induced by 11-year repeated additions of different organic materials in maize-based forage systems, the results showed that farmyard manure applications caused the greatest increase in soil organic matter content, potentially mineralizable N and potential soil microbial biomass. Also, the rate of C accumulation in the soil per unit of C applied was higher for farmyard manure application than for slurry and straw incorporation in the soil. Fertilization with only mineral N did not induce an increase in organic carbon and total nitrogen and even reduces soil N mineralization potential (Monaco et al., 2008).

Soil carbon content was significantly higher in systems receiving farmyard manure and concomitantly microbial biomass (fungi and bacteria) was increased. Microbial activity parameters, such as microbial basal respiration and nitrogen mineralization, showed an opposite pattern, suggesting that soil carbon in the conventional system was more easily accessible to microorganisms than in organic systems. Bacterivorous nematodes and earthworms were most abundant in systems that received farmyard manure, which is in line with the responses of their potential food sources viz., microbes and organic matter (Birkhofer et al., 2008). In the organic management system, the use of organic residues and FYM has shown to maintain high levels of soil organic matter than inorganic fertilization (Lehocka et al., 2008). Studies by Owen et al. (2008) showed that compost amendment affected the C and N content and the C/N ratio of the light fraction of the soil organic matter (LFSOM) compared with the synthetic fertilizer amendment. Though SOM parameters increased with compost application, the increase was not linear with the rate of application. In contrast to several reports, Monokrousos et al. (2008) reported that their data showed that, at least for some crops, indicators of soil quality (e.g. organic C and microbial biomass C) need not always improve with the duration of organic cultivation in a simple manner.

2.2.2.2.6 ***CEC of Soil***

Increase in CEC by the application of FYM alone or in combination with fertilizers or lime and decrease in CEC by application of fertilizers alone was noticed in a permanent manurial experiment conducted by Sharma et al. (1988) at Chotanagpur. Miller and Donahue (1992) reported that the application of organic matter increased the CEC of soil. Bijulal (1997) observed that application of vermicompost increased the CEC and EC of soil as compared that of FYM and ordinary compost.

Joseph (1998) observed that in snake gourd, the higher value of CEC (8.46 c mol kg^{-1}) was recorded in vermicompost treated plots as compared to that of FYM and poultry manure. Mbah and Pdilli (1998) recorded that high CEC of coir pith is attributed to its high specific surface. High CEC which varies from 38.9 to 60 meq/100g enables it to retain large amounts of nutrients and the adsorption complex has high contents of exchangeable K, Na, Ca and Mg. (Verhagen and Papadopoulos, 1997).

2.2.2.2.7 *Post harvest nutrient availability*:

Budhar et al.(1991) obtained increased post harvest nutrient status of soil to an extent of 217, 28 and 412 kg ha^{-1} NPK with the application of 5t ha^{-1} of poultry manure along with 100% recommended fertilizers.

Application of FYM @ 10t ha^{-1} increased the post harvest content of organic carbon and available micronutrients compared to no FYM treatment. These improvements may be mainly because of addition of organic manure. Besides release of nutrients present in organic form which upon its decomposition by micro organisms are released in soil, increased root proliferation due to FYM addition which were left in soil after harvests or arial parts is also in part responsible for such improvement in post harvest availability of micronutrients (Chand and Somani, 2003).

In a study to evaluate the efficiency of commercial organic manures viz., Haritha Super (4.0:4.4: 2.0 NPK), Poabs Green (2.7: 1.2: 2.0 NPK) and Bharath Meal (1.5 : 2.2: 2.5 NPK) in comparison with enriched vermicompost in cowpea, the post harvest analysis of soil showed that available N and P_2O_5 contents of soil were highest in Haritha Super treated plots which was significantly higher than all other organic manures. Available P_2O_5 status of soil was in the order of Haritha Super > Bharath Meal > enriched vermicompost > Poabs Green > FYM. Post harvest available K_2O status was highest in Poabs Green which was significantly higher than that on all other organic manures. Post harvest level of K_2O in soil was in the order of Poabs Green> Bharath Meal> Haritha Super> FYM > enriched vermicompost. All the five organic manures increased the organic carbon content of the soil and they differed significantly with respect to post harvest organic carbon level in soil. Poabs Green and FYM were found to cause about three fold increase in carbon content of soil (Deepa, 2005).

Nutrient uptake by tomato plant, quality of tomato fruits and availability of nutrients in soil after the harvest of tomato crop was more in treatments with organic sources of nutrients through neem and vermicompost in variable amounts and alone. Application of 75 per cent of N requirement through neem cake and 25 per cent N through vermicompost was found to be more effective in improving the nutrient value of soil after harvest of the first crop (Sable et al., 2007a).

2.2.2.2.8 ***Residual effect of organic manures***

In contrast to chemical fertilizers, the availability of nutrients present in bulky organic manures such as FYM is quite slow. In case of FYM only ½ of nitrogen, 1/6 of the phosphorus and a little more than ½ of the K alone are readily available to plant during the first season of application (Thamapan, 1993). The rest of the plant nutrients become available to the subsequent crop. The low availability of nutrients present in FYM, compost etc. is beneficial in the sense that the availability is spread over a number of crop seasons and as such, the nutrients are well protected from different forms of losses.

About less than 30% of N and small fraction of P and K in organic manures may become available to immediate crop and rest to subsequent crop (Gaur, 1982). The residual availability of N, P, K and organic carbon as a result of vermicompost application was reported by Kadam (2000). Sharu (2000) observed high residual soil K in plots which received higher level of neem cake along with chemical fertilizers (3:1). Yaduvanshi (2000) reported that the application of FYM to kharif crop gave significant residual effect on the grain yield of succeeding wheat crop. NPK fertilizers with either 10 t ha^{-1} FYM, 5t ha^{-1} gypsum or 10t ha^{-1} pressmud significantly increased the grain yield of rice and wheat and improved soil health under sodic water irrigated conditions. Singh et al. (2001) studied the response of brown sarson to residual effect of FYM and rice straw found that seed yield, yield attributes, silique per plant, 1000 grain weight and nutrient uptake of brown sarson increased significantly as a result of residual effect of application of organic manure and nitrogen on preceding rice.

The residual effect of FYM, fertilizers and biofertilizers on wheat during 2 seasons was studied by Patidar and Mali (2002). Application of 10 t ha^{-1} FYM and 75% or 100% recommended dose of fertilizer (N and P) to sorghum during rainy season had significant residual effect on succeeding wheat crop and increased grain yield of wheat.

The influence of N level and residual effect of organic manures on growth, yield and essential oil in ratoon crop of Davana under 2 irrigation regimes was investigated (Chalapathi et al., 2003). The residual effect of FYM resulted in higher fresh herbage yield of 12.21 t ha^{-1} and it was on par with residual effect of vermicompost.

In a study conducted by Purohit et al. (2003) in a cowpea-wheat crop sequence using integrated nutrient management, it was found that the addition of FYM @ 10t ha^{-1} increased N, P and K uptake by cowpea. Similarly the NPK uptake by succeeding wheat also increased due to the residual effect of FYM. The residual effect of FYM, gypsum and pressmud was significant on wheat yields after 5 years. There was substantial improvement in organic carbon, and available N, P, K and Zn in soil over the initial status. The treatments also reduced soil pH (Yaduvanshi and Swarup, 2006).

2.2.2.2.9 ***Effect of Organic Manures on Nutrient Economy***

Kale et al. (1991) studied the influence of vermicompost application on growth and yield of some vegetable crops. The results indicated that levels of chemical fertilizers could be brought down to 25 to 50% when applied with vermicompost. They opined that the quantity of organic manures could be brought down to 50% when vermicompost is used as the source of organic manure. Sarawad et al. (1996) reported application of 1t of vermicompost could substitute 25-50% recommended dose of fertilizers. The yield of radish, spinach, and green peas were better with 50% dose of NPK through chemical fertilizers and the rest through vermicompost (Jambhakar, 1996). Jiji et al. (1996) found that the requirement for chemical fertilizers in cowpea variety Malika and bitter gourd variety Preethi was significantly reduced when the recommended dose of FYM was substituted by an equal quantity of vermicompost.

In a study conducted by Purohit et al. (2003) in a cowpea-wheat crop sequence, it was observed that a saving of 25-50% in use of fertilizers could be made by applying FYM along with chemical fertilizers. Geetha et al. (2005) reported that in banana, fertilizer dose can be reduced to half by the addition of coir pith compost @ 15 kg $plant^{-1}$.

In a study to evaluate the efficiency of commercial organic manures viz., Haritha Super (4.0:4.4: 2.0 NPK), Poabs Green (2.7: 1.2: 2.0 NPK) and Bharath Meal (1.5 : 2.2: 2.5 NPK) in comparison with enriched vermicompost in cowpea, the B:C ratio was maximum in enriched vermicompost. From growth and yield point, FYM can be substituted with the commercial organic manures such as Haritha Super, Poabs Green and Bharath Meal. But FYM is more desirable from the economic point of view (Deepa, 2005).

2.2.2.2.10 Effect of Organic Manures on Soil and Water Pollution

The recent trend of using industrial or municipal wastes in producing organic manures sometimes result in soil and crop damage due to salt accumulation or heavy metals or toxic organic compounds present (Lee and Kim, 1997). Manures like sewage sludge and composts from industrial/urban wastes contain pollutants (e.g. heavy metals, pathogenic microbes) which would lead to contamination of soil as well as ground water (Saha, 2005). The influence of two organic wastes viz., cotton gin crushed compost(CC) and poultry manure (PM) applied during a period of four years on a Xerollic Calciorthid under dryland conditions on nutrient losses (organic carbon, NO_3^-–N, NH_4^+–N, P and K) in runoff water with the intention of observing possible eutrophication risks in waters, and sediments were studied by Tejada and Gonzalez (2007). Nutrient losses in the runoff water and sediments were higher in organic-amended soils than in the control soil, particularly in the case of the PM-amended soils. The lower N/P ratios in runoff water produced by CC and PM treatments suggested a lower eutrophication risk in water.

2.2.2.2.11 Effect of Organic Manures on Nutrient Release Pattern in Soil

The nutrient release pattern of different organic manures was studied by various workers. Rubins and Bear (1942) have indicated the relationship between C/N ratio and N immobilisation in soil. They have shown that when plant materials with a wide C/N are added to soil, the quantity of N immobilised in microbial cells was increased to levels that may seriously deplete the soil of the mineral nitrogen for plant growth. Allison and Klein (1945) observed that the immobilization of nitrogen proceeds very rapidly during the first seven days and then at constantly decreasing rate. According to Rao and Mikkleson (1976) materials with a wide C: N ratio cause immobilization of nitrogen initially resulting in beneficial effect to be noticed later. Parr and Papendick (1978) suggested that nitrogen immobilization potential and maximum decomposition rate of a substrate maybe characterized by the C: N ratio of the organic material added to soil.

Shivananda (1986) carried out a laboratory study to find out the rate of nitrogen mineralization in soils amended with castor cake, FYM, maize straw and paddy straw. Among these, castor cake was mineralized rapidly and it released high amounts of NH_4-N and NO_3-N. An increase in the available N content of soil upto 20 days after FYM application and a decrease thereafter was noticed in a long term field experiment with wheat (Gupta et al., 1988).

Alexander (1977) suggested that organic carbon to organic phosphorus ratio of soil and the added substrate may be used to predict net immobilization and mineralization of P in soil. If the ratio is 300:1 or more, immobilization occurs. The critical value of P in organic material to serve as a balance between immobilization and mineralization is calculated to be about 0.2%. The result of the study carried out at Central Research Institute for Dry Land Agriculture, Hyderabad during 1994 to evaluate the release pattern and availability of P from different soil types of Ranga Reddy district of AP shows that increasing the level of FYM and applied P increased the available P in all types of soils. The P availability was increased at 30 days of incubation as compared to 15 days with FYM whereas without FYM it increased with the progress in incubation (Saravanapandian, 1998).

Debnath and Hajra (1972) observed from their incubation studies that available K_2O content increased upto 16th day, a decrease on 30th day followed by an increase and then stabilized when FYM and daincha were used.

In an incubation study, Hulagar (1996) found that the amount of mineralized N from neem cake increased upto 7 days after incubation. Recovery of mineral nitrogen from neem cake diminished at 14th day of incubation and thereafter there was gradual increase.

In an incubation study using vermicompost, Bijulal (1997) observed that available N content increased upto 90 days of incubation and declined thereafter. The release of available P increased steadily upto 120 days of incubation. In contrast to other nutrients, available K reached its peak within a shorter span of 60 days, which decreased thereafter. In all cases, application of enriched vermicompost (enriched with rock phosphate) recorded higher nutrient contents as compared to FYM and ordinary compost.

In an incubation study conducted with FYM, poultry manure and vermicompost, Nair (2003) observed a progressive increase in the availability of N and P_2O_5 till 90th day for all 3 manures. Sheeba (2004) inferred from an incubation experiment that available N, P_2O_5, K_2O contents of soil increased upto 45 days of incubation, and then the availability slowly decreased. She also reported that the available nutrient contents were higher for vermicompost enriched with neem cake and bone meal as compared to that of ordinary vermicompost and FYM.

N mineralization of mixed poultry litter-yard waste compost was not synchronous with sweet corn N assimilation, resulting in excess root zone nitrate that would have posed a leaching risk (Evanylo et al., 2008).

2.3 Effect of Organic Manures on Yield and Quality of Crops

Organic manures have been proven to be capable of improving the fertility and productivity of soil. Efficiency of various organic manures in improving the growth, yield and quality of crops are reviewed hereunder.

2.3.1 *Effect of Organic Manure on Yield and Quality of Vegetables*

2.3.1.1 Effect of organic manures on nutrient uptake by vegetables:

Zachariah (1995) reported that in chilli plants supplied with enriched vermicompost recorded the highest yield and N, P, Mg, Mn, Zn and Cu uptake as compared to ordinary compost. Pushpa (1996) and Rajalekshmi (1996) reported increased uptake of nutrients and higher yields in tomato and chillies respectively by vermicompost application. Anitha (1997) observed the better uptake of N in poultry manure treated chilli plants as compared to control.

Vermicompost coated cowpea seeds showed maximum uptake of N, P, K at peak flowering stage and at harvest. Soil application of vermicompost showed highest uptake of Ca, Mg, Cu, and Mn during peak flowering stage (Meera, 1998). In bhindi, N and P uptake and available N in soil were highest for neem cake application as compared to FYM, poultry manure and compost (Asha, 1999). According to Sailajakumari (1999) the uptake of N, P, K, Ca and Mg in cowpea was highest in enriched vermicompost treated plants as compared to those treated with ordinary compost.

Sheeba (2004) reported that vermicompost enriched with neem cake resulted in the highest N uptake in amaranthus; P uptake was highest for bone meal enriched vermicompost whereas K uptake was highest with vermicompost enriched with neem cake and bone meal as compared to ordinary vermicompost. In an experiment for evaluating the efficiency of three commercial organic manures viz., Haritha Super, Bharath Meal, and Poabs Green in comparison with FYM and enriched vermicompost, the nitrogen uptake by cowpea was significantly higher in enriched vermicompost application than the other four organic manures. It was significantly lower in Haritha Super. Nitrogen uptake was on par in the treatments with FYM, Bharath Meal, and Poabs Green (Deepa, 2005).

2.3.1.2 Effect of organic manures on growth characters of vegetables

Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites particularly gibberellins, cytokinins, auxins and group B vitamins which can be applied alone or in combination with organic or inorganic fertilizers so as to get better growth, yield and quality of diverse crop (Tomati et al., 1990).

Som et al. (1992) recorded maximum plant height in brinjal with neem cake application (50 q ha^{-1}) as compared to other oil cakes tried. Sharma and Bhalla (1993) observed enhancement of biometric parameters like plant height, leaves, branches, length of fruits of okra when supplied with integrated nutrient management treatments like combination of compost @10t ha^{-1} and fermented cowdung slurry as compared to chemical fertilizers. Thamburaj (1994) observed that organically grown tomato plants were taller with more number of branches. They yielded 28.28 t ha^{-1} which was on par with that of the recommended dose of FYM and NPK (20:100:100). Application of *Eudrillus* compost inoculated with *Azospirillum* and phosphate solubilising organisms has the highest plant height, number of leaves, and shoot-root ratio (Zachariah, 1995). Anitha (1997) recorded in chilli that various growth attributes like plant height, number of branches, dry matter production and yield and yield attributes were better with poultry manure application as compared to FYM or vermicompost.

Arunkumar (1997) found that FYM application was superior to vermicompost in inducing better plant height, root biomass production, leaf area index and yield in amaranthus. Suharban et al. (1997) in a pot culture experiment with bhindi reported that plant height was influenced by the coir pith compost treatment, where the maximum plant height of 1.37m was noted in coir pith compost treated plants and the lowest was (0.97m) under POP recommendation. Joseph (1998) observed that in snake gourd, growth characteristics viz., weight of root per plant, and dry matter production ha^{-1} were highest in FYM treated plant as compared to poultry manure or vermicompost treated plant.

Arunkumar (2000) observed that highest level of FYM and vermicompost (150% POP) maintained their superiority at all growth stages with regard to plant height, number of leaves and number of branches of amaranthus. Sharu (2000) reported that in chilli, growth characters like plant height, number of branches and dry mater accumulation as a result of neem cake application was found to be on par with that of the POP recommendation of K.A.U.

Growth parameters like plant height, number of primary branches per plant, LAI and Dry Matter Production were significantly influenced by different organic manures. These growth parameters recorded maximum values in enriched vermicompost applied crop and the least values were in Haritha Super applied crop. All other organic manures (Poabs Green, Bharath meal and FYM) were on par with respect to improving growth parameters. DMP was in the order of enriched vermicompost> Bharath meal > FYM > Poabs Green > Haritha Super. Pest incidence was least in enriched vermicompost followed by Bharath meal, FYM, Poabs Green and Haritha Super respectively (Deepa, 2005).Data indicated that among organic nitrogen sources, poultry manure stimulated better response than FYM and neem cake at different levels and combinations. Application of 25% nitrogen through neem cake and 75% through poultry manure turned to be the best treatments for increasing growth, yield, shelf life and other quality parameters of bitter gourd (Mulani et al., 2007). Organic manures such as poultry manure, pig manure, neem cake powder, cow manure and rabbit manure, in combination with compost teas (Panchkavya and Amritpani) were evaluated in an experiment with ginger as test crop. The organic manures and compost teas treatments significantly improved the plant height, side suckers, leaves/plant and chlorophyll a in ginger compared with inorganic fertilizers (Sanwal et al., 2007).

2.3.1.3 Effect of organic manures on yield attributes and yields of vegetables

Pushpa (1996) and Rajalekshmi (1996) observed increased uptake of nutrients and higher yields in tomato and chilli by the application of vermicompost. Ushakumari et al. (1996) found that the POP recommendation with cattle manure and vermicompost as organic sources along with half the recommended dose of inorganic fertilizers and vermicompost as sole source of nutrients, all recorded almost same yield in bhindi.

Staffella and Graetz (1996) reported that total tomato yield was higher in plots amended with sugarcane filter cake compost as compared to control plots without compost. Anitha (1997) reported that in chilli, yield and yield attributes were better with poultry manure application as compared to FYM or vermicompost. Suharban et al. (1997) in a pot culture experiment with bhindi reported that the treatment with coir pith alone gave the maximum yield of 5.92 kg plant^{-1} followed by the treatment with half the recommended dose of coir pith and fertilizers (5.13 kg plant^{-1}).

Niranjana (1998) recorded higher dry matter yield till 45 days in amaranthus with vermicompost application. Joseph (1998) observed that in snake gourd, yield attributing characters like length, weight and number of fruits per plant were highest in FYM treated plant as compared to poultry manure or vermicompost treated one.

Asha (1999) observed that growth characters like plant height, LAI, DMP, yield attributes like fruit number plant^{-1}, fruit weight, fruit length and fruit yield of bhindi were higher in organic manure treated plots. FYM+ neem cake recorded maximum number of fruit plant^{-1}. FYM+ neem cake and FYM+ green leaf recorded comparable and maximum yield of 158 and 153 qha^{-1} respectively. She also reported that the application of neem cake and poultry manure registered higher yields and produced quality fruits in bhindi as compared to that of POP recommendation and FYM.

Rajasree (1999) reported that when the highest level of nitrogen (300kg) was supplied through 2:1 ratio of organic -chemical nitrogen substitution using poultry manure as organic source, it effectively increased the fruit yield and number of fruit per plant in bitter gourd. Sailajakumari (1999) recorded that the application of enriched vermicompost increased the plant height, number of branches, nodule number and yield in cowpea.

Arunkumar (2000) reported that in amaranthus, application of neem cake produced higher yield as compared to that of chemical fertilizers on equivalent N basis, but was inferior to that of FYM, vermicompost and poultry manure. However, he reported that the application of coir pith compost recorded lower green yield in amaranthus as compared to FYM, poultry manure, vermicompost and POP recommendation on equivalent N basis. Meerabai et al. (2003) observed that in chilli, substitution of recommended N with organic manures like neem cake, poultry manure or green manures like cow pea or glyricidia can give comparable yields and net returns as that of present POP recommendation by Kerala Agricultural University.

Application of organic matter in the form of FYM @ 10 t ha^{-1} increased cowpea and wheat yield by 17.47 and 8.96 % respectively over no- FYM treatment (Purohit et al., 2003). Such increases in yields are associated with release of macro and micro nutrients during the course of microbial decomposition (Singh and Ram, 1982). The results indicated that the use of FYM in the absence of chemical fertilizers has remarkable effect in improving the crop yield. Lekshmisree (2003) reported that lower yield was obtained in amaranthus crop receiving only organic manures at higher rates compared to other treatments which received combinations of organics + inorganics.

Sheeba (2004) observed that the application of enriched vermicompost (enriched with 2% neem cake) + full NPK as organics produced almost similar yield as that of FYM + full dose of NPK as inorganics in amaranthus. Yield attributing characters in vegetable cowpea including number of flowers and number of pods per plant, fresh weight of pod and length of pod were also significantly influenced by organic manures. The maximum values were recorded in enriched vermicompost > Poabs Green> Bharath meal> FYM>Haritha Super respectively (Deepa, 2005). Application of poultry manure increased the fresh pod yield, stem height, leaf area, number of leaves and number of branches plant^{-1} in okra. At all growth stages, the total dry matter distribution into shoots and roots increased as the rate of poultry manure increased, which also increased the fresh pod weight. The application of poultry manure @ 8 t ha^{-1} gave the highest pod yield, 12 t ha^{-1} showed reduced yield (Odeleye et al., 2005).

Organic mode of plant nutrition in tomato through various combinations of neem cake and vermicompost was found superior over chemical fertilizers alone, in terms of increasing number of branches and fruit yield in tomato (Sable et al., 2007b).

2.3.1.4 *Effect of organic manures on quality of vegetables*

It has long been acknowledged that improper use of raw manure can adversely affect the quality of such vegetable crops as potatoes, cucumbers, squash, turnips, cauliflower, cabbage, broccoli, and kale. As it breaks down in the soil, manure releases chemical compounds such as skatole, indole, and other phenols. When absorbed by the growing plants, these compounds can impart off-flavours and odours to the vegetables (Kinsey, 1994). Anecdotal evidence suggests that food produced by using organic methods tastes better and contains a better balance of vitamins and minerals than conventionally grown food (Stockdale et al., 2001). However, there is no clear scientific evidence with some studies showing increases in vitamin C, minerals and proteins (Lampkin, 1990). A tasting panel convened by the Consumer Association in the United Kingdom did not consistently favour the taste of organic fruits and vegetables (Anon, 1992). The vitamin and mineral contents of crop is controlled by a complex interaction of factors, including soil type and the ratios of minerals in added composts, manures and fertilizers. It is therefore difficult to separate the influences of the environment and farming system (Warman and Harvard, 1998).

Kansal et al. (1981) reported that the application of 20 t FYM ha^{-1} increased the ascorbic acid control in spinach leaves. In a field experiment, Evangelista (1986) reported that the application of pure earthworm cast showed significant effect on N, P, Ca and Mg contents of lettuce leaves. Tomati et al. (1990) observed incorporation of vermicompost increased protein synthesis in lettuce and radish by 24 and 322 % respectively. Montegue and Gosh (1990) found that fruit colour of tomato was significantly increased as a result of application of organic manure of animal origin. Organic manures like FYM, compost, oil cakes, green leaves, poultry manure, etc. improve the yield as well as quality of vegetable crop like tomato, onion, gourds, chillies etc. Abusaleha (1992) recommended equal quantity or more organic form of N for getting good quality okra fruit.

Alfred and Gunathilagaraj (1996) noticed more N content in amaranthus plant due to the application of earthworm into the soil. Increase of ascorbic acid content in tomato, pyruvic acid in onion and minerals in gourds are the impact of application of organic manures to vegetable crops. (Rani et al., 1997). Anitha (1997) reported that chilli plants treated with poultry manure recorded maximum ascorbic acid content of fruits compared to vermicompost and control treatments. Phoebe (1997) reported that the total soluble salts, vitamin C and total sugars were highest in snake gourd fruits receiving vermicompost application. The shelf life of fruits also increased with the same treatments.

Joseph (1998) reported that poultry manure treated snake gourd recorded the highest crude protein and lowest crude fibre content as compared to that of vermicompost and FYM treated plants, while TSS, vitamin C and total sugars were highest in fruits from plants treated with vermicompost.

According to Sharu (2000), poultry manure application registered the maximum keeping quality of fruits compared to vermicompost, neem cake and POP recommendation. Arunkumar (2000) found that in amaranthus the maximum protein content was obtained with poultry manure application as compared to that of FYM, vermicompost, coir pith compost and POP recommendation. He also observed that application of vermicompost to amaranthus crop recorded significantly high ascorbic acid content as compared to Package of Practices recommendations for Crops, K.A.U. Bhadoria et al. (2002) reported that protein and total mineral content of okra fruit was increased when it was treated with FYM. Omae et al. (2003) noticed increased freshness and vitamin C content in melon due to cattle compost application. Nair (2003) reported that the quality attributes like ascorbic acid and Fe contents were highest when chemical fertilizers were substituted with poultry manure in 1:1 ratio. Application of vermicompost enriched with neem cake and bone meal improved the quality parameters like β–carotene, protein and oxalate content in amaranthus (Sheeba, 2004).

The crude protein content of cowpea pods and shelf life of pods were significantly influenced by organic manures. Protein content was highest in enriched vermicompost which was significantly higher than all others. Haritha Super produced pods with the lowest protein content. The shelf life of pods in enriched vermicompost and Bharath meal were the same and 14% higher than that in FYM and significantly higher than other 3 organic manures (Deepa, 2005).

Nutrient uptake by tomato plant, quality of tomato fruits and availability of nutrients in soil after the harvest of tomato crop was more in treatments with organic sources of nutrients through neem and vermicompost alone and in variable amounts. More TSS, vitamin C and shelf life were noticed in the treatments where 50% N through neem cake and 50% through vermicompost as well as 75% N through neem cake and 25% N through vermicompost were given together (Sable et al., 2007a).

Mulani et al. (2007) observed that the application of organic manures, green manures and biofertilizers to bitter gourd might lead to decreased respiration which in turn resulted in higher storage life. The vines grown under inorganic fertilizer might have accelerated the catabolism of the fruit and thus possibly higher respiration which in turn resulted in lower shelf life. Similar results obtained by Nair and Peter (1990) in green chilli and Mali (2004) in cucumber. Significant increase in dry matter of rhizomes of ginger was found with the application of organic manures such as poultry manure, pig manure, neem cake powder, cow manure and rabbit manure and compost teas viz., Panchkavya and Amritpani used in North Eastern states of India compared to inorganic fertilizers. Compost teas with poultry manure or cow manure significantly increased oleoresin content compared to other treatments. All organic manure treated plants had higher oleoresin contents compared to other treatments (Sanwal et al., 2007).

The effects of earthworm-processed sheep-manure (vermicompost) on the growth, productivity and chemical characteristics of tomatoes (*Lycopersicum esculentum* c.v. Rio Grande) were investigated in a greenhouse experiment. Addition of vermicompost increased plant heights significantly, but had no significant effect on the number of leaves or yields 85 days after transplanting. Addition of sheep-manure vermicompost decreased soil pH, titratable acidity and increased soluble and insoluble solids, in tomato fruits compared to those harvested from plants cultivated in unamended soil. Sheep-manure vermicompost as a soil supplement increased tomato yields and soluble, insoluble solids and carbohydrate concentrations (Gutiérrez-Miceli et al., 2007).

2.3.1.5 *Effect of organic manures on antinutritional factors of vegetables*

Even though amaranthus is a highly nutritious vegetable, the presence of antinutrients like oxalates and nitrates is a main problem according to health experts. Excess of oxalates combine with the dietary calcium forming calcium oxalate crystals which leads to kidney stone problems. Oxalate content of leaves and stems were 5.00 and 0.63% respectively (Marderosian et al., 1980). Most of the Ca in amaranthus is unlikely to be available to the body. The soluble oxalates in amaranthus can interfere with Ca availability from other food sources. Sheeba (2004) reported that the application of organic manures reduced the oxalate content in amaranthus.

2.3.2 *Effect of organic manure application on yield and quality of other crops*

Performance of Kacholam under varying levels of organic and inorganic fertilizers was studied by Bai and Augustine (1998). An increase in oil yield from 18.9 to 28.4 l ha^{-1} was noticed by the use of organic manures. In turmeric, application of organic manures favoured increase in curcumin and oleoresin contents (Nampoothiri, 2001).

FYM @ 10t ha^{-1} increased the uptake of Fe, Cu, Mn, and Zn by 16.9, 29.2, 24.3 and 27.5 per cent respectively in mustard. Also FYM @ 10t ha^{-1} in mustard increased seed yield, stover yield and oil content (Chand and Somani, 2003). Kumar et al. (1999) recorded 24.1 to 84.7 per cent increase in seed yield of mustard due to integrated nutrient management. Prasad (1999) reported that 5t ha^{-1} of FYM is expected to contribute 575 mg Zn, 1270 mg Fe, 275 mg Cu and1280 mg Mn.

The compost prepared with organic additives like cowdung, garden weeds, green manure (sunhemp) and inorganic additives like rock phosphate and micro nutrients along with fungal inoculants *Pleurotus sajor- caju* recorded least lignin, lignin/ N ratio and C/N ratio and was superior with respect to nutrient composition. Application of this compost @ 10t/ha along with 50% recommended NPK fertilizers for maize crop recorded 12.5% increase in grain yield over control which received recommended nutrients alone in the form of chemical fertilizers. The high value compost could be an important component of INM with 50% savings of fertilizers (Kadalli et al., 2000). Suja (2001) found that tuber quality of white yam in terms of starch and crude protein content were markedly improved by coir pith compost application.

Venkitaswamy (2003) reported that the application of 100% of the requirements of nutrients in coconut as composted coir pith recorded highest value of leaf N and K status as compared to that of fertilizer treated plots. This would have been due to better uptake of N and K with composted coir pith application due to increased availability.

Refuse tea is a by-product of tea removed during tea processing and it comprises mainly of fibre and stalks removed from driers, winnowers and colour separators in the factory. Refuse- tea content is generally 5% of dried tea. Refuse-tea application increased leaf K, chlorophyll, shoot water potential and yield. Refuse-tea released K in slow and sustainable manner. Leaves were darker due to higher content of chlorophyll. Turgidity also enhanced due to better K content of cells. (Wijeratne and Premathunga, 2005). The availability and uptake of P from four organic manures viz., FYM, poultry manure, vermicompost and sewage sludge, in a ground nut- corn sequence was studied using radio tracer technique by Mohanty et al.(2006). In both the crops, the organic fertilizer had a significant effect on the uptake of P as compared to the single super phosphate and control. The highest P content and uptake in ground nut was due to sewage sludge application. Poultry manure accounted for the highest P uptake from soil. In residual corn, the P uptake was more for organic fertilizers than for single super phosphate obviously due to greater availability and P release from organic sources. The highest P uptake, and therefore the highest P use efficiency, was due to FYM.

A field experiment conducted on the suitability of FYM, sewage sludge and urban compost in sweet sorghum raised in a red sandy clay loam soil revealed that application of urban compost @ 11 t ha^{-1} was significantly superior in grain yield and stover yield. Besides plant height, number of leaves, LAI, and total dry matter production were also significantly more. The increase in grain and straw yield was attributed to higher intake and recovery of nutrients from the combined application of urban compost, sewage sludge and FYM (Reddy et al., 2007).

Vermicompost application increased plant spread (10.7%), leaf area (23.1%) and dry matter (20.7%), and increased total fruit yield (32.7%) in straw berry. Fruit harvested from plant receiving vermicompost were firmer, have higher TSS, ascorbic acid content and lower acidity, and have attractive colour (Singh et al., 2008).

As a bioinoculant, vermicompost increased nitrogen and phosphorous availability by enhancing biological nitrogen fixation and phosphorous solubilisation. Vermicompost amended acid soil significantly improved the yield, biometric character and quality of banana, cassava and cow-pea. Vermicompost application stimulated root growth, facilitating nutrient absorption and thereby favouring higher yield (Prabha et al., 2008).

2.3.3 Effect of Organic Manures on Nutrient Use Efficiency of Crops:

In rice and wheat, the nitrogen use efficiency under long term fertilizer experiment was highest under NPK+ FYM treatment which was closely followed by the balanced NPK treatment. The increase in nitrogen use efficiency over nitrogen fertilization was 7-21 % in NPK+FYM treatments in rice. In the case of phosphorus use efficiency also, the same trend was observed. It was improved appreciably with the incorporation of FYM along with NPK fertilizers. Experimental results with legume crop also showed similar trends. Incorporation of FYM along with NPK fertilizers enhanced potassium use efficiency of rice, wheat, maize in almost all the soils under study (Nambiar, 1994).

2.3.4 *Effect of Organic Manures on Pest and Disease Incidence*

Broadbent and Baker (1975) recorded that the application of fowl manure along with lime and inorganic fertilizers reduced the losses from *Phytophthora* root rot in avocado. Dayarkar et al. (1995) recorded that when FYM was applied along with 50:50 NP fertilizers the population of pigeon pea pod borers was lower than that under the use of straight inorganic fertilizer alone. In strawberry, substitution of vermicompost drastically reduced the incidence of physiological disorders like albinism (16.1–4.5%); fruit malformation (11.5–4.0%) and occurrence of grey mould (10.4–2.1%) in strawberry indicating that vermicompost had significant role in reducing nutrient-related disorders and disease like Botrytis rot, and thereby increasing the marketable fruit yield up to 58.6% with better quality parameters (Singh et al., 2008). Application of compost can result in a faster initial development of the potato crop. This is important in organic farming when leaf blight rapidly becomes fatal for crop because of limited crop protection measures (Willekens et al., 2008).

2.3.5 Adverse impact of organic manures on crop production

There are several incidents on farms where poor quality organic manures have caused crop damage. Immature composts contain microorganisms with high oxygen demand which injures crops (Lee and Kim, 1997). Immature compost has adverse effects on crops, like nitrogen immobilization due to wide C/N ratio, heat generated during decomposition and presence of phytotoxic compounds during decomposition (Venugopal, 2004).

Sheep- manure compost could be a promising amendment for the low fertility soils and it is recommended to use as compost for lettuce (Radics et al., 2008). At the higher doses, however, beyond the optimal level for organic conditions, there could be a potential risk of nitrate accumulation. Mineral content of lettuce strongly increased under high doses of compost on sandy soil.

Negative effects of compost on crop yield may be attributed to the application of large amounts of compost with high heavy metals levels, causing phytotoxic phenomena in the plants or affecting certain biochemical processes which regulate nutrient availability (Andersson, 1977; Giordano et al., 1975; Chaney, 1983); excessive supply of soluble salts through the application of large amounts of compost, causing an increase of the electrical conductivity of the soil (Hortenstine and Rothwell, 1972; Stewart and Meek, 1977).

The most outstanding effect of the application of insufficiently mature compost is the biological blockage of soil-available nitrogen by microbial populations (Ahrens and Farkasdy, 1969; Duggan, 1973; Juste, 1980). This may give rise to serious N-deficiencies in the plant, and consequently N starvation and depressive effects on crop plants may occur, as has been shown by many authors (Bengtson and Cornette, 1973; Hortenstine and Rothwell, 1973; Terman et al., 1973). The immobilization of soil mineral nitrogen is due to the high C/N ratio which usually characterizes an immature compost. This causes a considerable increase of soil microorganisms to decompose the excess of carbon compounds and they assimilate the soil nitrogen for their growth and metabolism (Alexander, 1977).

Besides contributing to an excess of carbon substances, the rapid decomposition of an immature compost may cause other serious damages in the soil and plants. Thus, Ahrens and Farkasdy (1969) pointed out a decrease of the O_2

concentration and soil Eh and therefore the creation of anaerobic and strongly-reducing environments at the level of the root system. Cottenie (1981) reports that the creation of reducing conditions in the soil increases the solubility of several heavy metals and it is known that the reduced forms are more soluble than their oxidized forms. When reducing conditions become more severe and the soil Eh reaches -150mV, sulphide may be formed and this precipitates most of the heavy metals. The increase of heavy metals solubility in the soil may cause an increase in their absorption and concentration in the plant, which may reach phytotoxic levels. Thus, Van Assche and Uyttebroeck (1981) show that Cu concentration in the plant increases considerably up to toxic levels through the application, in high amounts, of non-fermented compost. This does not occur with well-matured compost. At the same time, as other authors indicate (Hunt, 1970; Hunt et al, 1972; Volk et al., 1973), the creation of these reducing environments, together with the increase of soil temperature at radicular level to values incompatible with normal physiological root function, and the production of phytotoxic substances by the decomposing compost, may give rise to an inhibition of plant seed germination. The plant reacts to the inhibitory environment conditions by lowering its metabolic rate, reducing root respiration, decreasing nutrient absorption and, as Bonneau and Souchier (1980) reported, slowing the gibberellin and cytokinin synthesis and transport to the aerial parts. The presence of phytotoxic compounds is another of the causes of the damages noted on the application of immature compost to the soil. Similar effects have been observed with other types of residue: animal manure (Maureen et al., 1982) and sewage sludge (Sabey and Hart, 1975).

The studies made by Zucconi et al. (1981a,b, 1985), Devleeschauwer et al (1981), Wong (1985) and Wong and Chu (1985) revealed that the phytotoxic effect of immature compost is due, among other causes, to the emission of ammonia (Golueke, 1977; Wong, 1985). The presence of ammonia in the soil, even in small quantities, has been described as toxic to the roots and normal development of plants (Van der Eerden, 1982) and to seed germination (Okuda and Takahasi, 1961). Wong (1985) reported that ethylene oxide, synthesized during the decomposition in the soil of immature compost, took part in the phytotoxic effect. Ethylene oxide toxicity had previously been shown to inhibit seed germination (Roy and Jana, 1975).

The presence of organic acids in the immature compost has also been described as the cause of its phytotoxicity. Devleeschauwer et al. (1981) showed that the toxic effect on plant growth is due to acetic acid when its content in the compost is above 300 ppm. The phytotoxic effect of acetic acid has also been shown with non-composted plant residues (Lynch, 1978). Chanyasak et al. (1983a,b) proved that the immature compost phytotoxicity is due to propionic and n-butyric acids, as well as to acetic acid. Therefore, it is essential to determine the degree of maturity by means of quick methods to avoid all these possible serious effects.

2.4 Quality of organic manures

Organic manures not only act as sources and sink for nutrients but also provide a favourable environment which accelerates the chemical and biological processes in soil (Singh, 2005c). Hence the quality of organic manures added to soil is an important factor determining the soil quality. There are instances of complete crop damage due to inferior quality of organic manures applied to agricultural fields in countries like Korea. In USA, continuous use of poultry manure turned soils infertile due to extreme imbalance of nutrients. There are also reports of soil and water pollution due to leaching of nutrients and heavy metals from organic manures applied to crop lands. Such adverse impacts have led to enforcement of strict laws in some countries on the quality of organic manures produced commercially, the permissible levels of impurities, the permitted raw materials, regular inspection of manure producing units, their packing and labeling etc.

Quality parameters for composts are different for different uses like nursery raising, high value crop, field crops, horticulture, bioremediation and landscaping (Singh, 2005b). Compost for nursery should be low in electrical conductivity and highly mature whereas for field crops, compost with a relatively high EC and low maturity could be used. Compost quality depends upon waste characteristics and conditions maintained during the composting process. Good compost is free of pathogens and weeds. The value of organic manure is not just based on nutrient composition but has to be seen as a source of carbon to sustain the life of the soil especially in dry tropical climate (Parr and Colacicco, 1987). One of the most important future research needs in the field of efficient utilization of organic wastes in India is the establishment of quality standards for organic manures for quality control and maintaining soil health (Singh, 2005b).

2.4.1 Factors determining manure quality

There is a need for development of a suitable technique for preparing good quality compost at the shortest possible time from organic residues of farm and city waste. Different farmers conceive the aspect of manure quality differently. For instance, some farmers believe that a completely composted manure heap with a characteristic fungal smell is the best manure. Others may not judge the quality until the results are seen in the final crop yield obtained after application of such manures. It has been reported by Motavalli et al. (1994), from a survey conducted in the semi-arid tropics of India, that farmers conceptualise farmyard manure quality in diverse ways. They judge the manure from the physical composition, which determines its workability and its effect on crop development, and edaphic and biotic factors. Simple indices of manure quality are required that will enable farmers to combine manure more effectively with strategic quantities and placements of inorganic fertilisers and so more precisely meet the nutritional needs of crops (Lekasi et al., 2001). The high variability of some important compost and vermicompost parameters suggests an urgent need for establishing quality assurance procedures in order to classify the available materials. The organic amendments prepared from different organic wastes (raw materials), with different kind (composting or vermicomposting) and time of process, produce a final product which differs in its quality. Analytical results showed a wide variation in some parameters such as total organic carbon (TOC), germination index (GI), pH, total nitrogen (TN), and water soluble carbon, which depend on the characteristics of each process (Campitelli and Ceppi, 2008). Some of the proposed maturity level assays for composts are: water soluble carbon, water soluble carbohydrates, CEC, respiration, lignin/cellulose ratio (Chanyasak and Kubota, 1981; Harada and Inoko, 1980; Baeca et al.,1995).

In general, compost quality attributes are grouped into 4 different classes. These are physical chemical and microbiological and plant bio assays. Moisture content, bulk density, odour, colour and particle size are some of the important physical attributes determining the compost quality. Biological parameters such as heat production, respiratory activity, presence of enteric group of bacteria and weeds are important attributes influencing compost quality. Stable compost usually has less than 1mg CO_2 g^{-1} dw day^{-1} .The pathogenic bacteria and weeds are killed during the thermophilic stage of composting. Good compost is free from pathogens and weeds.

Plant bio assays using fast growing seed are also used to determine compost quality. But these are time consuming (Venugopal, 2004). The chemical composition or quality of organic residues exerts a significant control over their decomposition and N mineralization (Vityakon and Dangthaisong, 2005). The stability and maturity of sediments were evaluated Aparna et al. (2008) by assessing parameters like C/N ratio, nitrification index (NH_4-N/NO_3-N), water-soluble organic carbon concentration, CO_2 evolution rate, cation exchange capacity and indices such as humification index, *E*4/*E*6 ratio, compost mineralization index (ash content/oxidizable carbon), germination index, dehydrogenase, polyphenoloxidase activities and FTIR spectroscopy. The results showed that the changes in the above chemical and biological parameters can be employed as reliable indicators of stability and maturity.

Jimenez and Garcia (1989) reported that the different criteria or methods that have been proposed to establish the degree of maturity of compost may be grouped into five types. (1) Physical tests: temperature, odour and colour. (2) Study of microbial activity parameters: measuring metabolic activity, biomass count and the study of the easily biodegradable constituents. These include: respirometric studies, ATP and hydrolytic enzyme activity determinations, hydrolysable polysaccharide content, relation between total organic carbon and soluble glucides, and ratio of carbon in reducing sugars to total carbon. (3) Study of humified organic matter: determining the richness in total humus and the degree of polymerization of humic compounds by means of paper chromatography and photocolorimetric methods. (4) Chemical methods: C/N ratio in solid phase and in water extracts, pH, cation-exchange capacity and tests for ammonia, hydrogen sulphide, nitrates and nitrites. (5) Biological methods: based on the determination of the germination index of seeds incubated in water extracts of the compost.

2.4.1.1 Colour of manure

During composting of domestic refuse, a gradual darkening or melanization of the material takes place. The final product, after a sufficiently long period of maturation, is a dark brown or almost black colour. It is possible to monitor visually the gradual process of compost darkening (Jimenez and Garcia, 1989). Sugahara et al. (1979) proposed a simple technique to determine the degree of darkness with greater precision in which the relative spectral reflectance of the compost is measured in a colour analyser.

The undecomposed material consisting of heterogeneous mixture of organic materials differing in colours will give a mottled appearance. As the decomposition process progresses such materials could be expected to be more homogeneous appearing a uniform dark brown or black at maturity (Lekasi et al., 2001). Dark deep brownish colour of compost with earthy smell is an indicator of good quality (Venugopal, 2004).

2.4.1.2 Odour of manure

Jager and Jager (1980) described the odour emissions from city refuse composting. During the mesophilic phase of the bio-oxidation phase fatty acids are the most frequently formed intermediate metabolites, followed by alcohols, aldehydes and ketones. The natural ventilation of the compost heap induces an ascending airflow which contains, among other substances, ethanol, diacetyl and acetoin. During the thermophilic phase, at high temperature, thermal-chemical reactions take place which give rise to volatile compounds like pyridine and pyrazine. The volatile sulphur compounds which appear in greatest amount are dimethylsulphide, dimethyldisulphide and dimethyltrisulphide. Hydrogen sulphide acid only appears under completely anaerobic conditions.

Chanyasak et al. (1982) stated that lower volatile fatty acids were one of the major components causing the obnoxious odour of domestic refuse. The lower fatty acids in the refuse decreased significantly during the course of composting, especially in the later stage. Acetic acid was the main component detected; other acids detected were propionic, butyric, valeric and caproic. At the end of the composting process, when optimal maturation is achieved, the unpleasant odour should be absent in a compost heap, and not appear with the turning of the material. Appreciable amounts of lower fatty acids should not be detected. On the contrary, a characteristic odour similar to that of damp forest ground should be noted. According to De Bertoldi and Zucconi (1980) this odour is a consequence of the excretion of geosmine**,** a secondary metabolite produced by mesophilic actinomycetes which predominate during the cooling phase of the bio-oxidative period and the maturation phase.

Fresh animal manure has as strong smell of ammonia and other organic matter also gives of strong smell of putrefaction during early stages of decomposition. Later ammonia is lost by volatilization and ammonium salts are converted to odorless compounds, and the organic decomposition products generally have little smell. Mature compost is expected to have only a slight earthy and inoffensive smell **(**Lekasi et al., 2001).

2.4.1.3 Moisture Content of manure

Compost with less than 20-25% moisture is often dusty and difficult to handle. High moisture content is not a desirable attribute and also leads to foul smell during storage of immature compost (Venugopal, 2004).

2.4.1.4 ***C/N ratio as a factor of manure quality***

Carbon/ nitrogen ratio is the criterion traditionally used to determine the degree of maturity and define its agronomic quality. Many authors report that a C/N ratio below 20 is indicative of an acceptable maturity (Poincelot, 1974, 1975; Cardenas and Wang, 1980; Golueke, 1981), a ratio of 15 or even less being preferable (Juste, 1980). Sometimes this value may be above 20 in relatively mature compost since part of the organic carbon may be in the form of compounds more resistant to biodegradation (fundamentally lignin), and not immediately available to micro-organisms (Regan and Jeris, 1970; Jeris and Regan, 1973).

As Hirai et al. (1983) stated the C/N ratio of compost cannot be used as an absolute indicator of the state of maturation since the C/N ratio found in well-composted materials presents great variability due, above all, to the type of original material. Morel et al. (1985) noted that C/N ratios below 20 were often found in materials not yet degraded, due to the relative N-richness of the original material. This was frequent when the fermentable fraction of domestic refuse is composted with sewage sludge. Therefore, a C/N ratio less than 20 can only be considered a necessary, but not sufficient, condition for establishing the degree of maturity. Because of this fact, Morel et al. (1985) noted that it is necessary to carry out a periodic monitoring of the C/N ratio during composting until stability is reached, to establish more certainly compost maturity, and propose as the surest criterion the ratio: (Final C/N)/(Initial C/N)

Most of researchers in India reported that the chemical parameters like C/N ratio, weight loss and ash content are the indicators of compost maturity. (Bharadwaj and Gaur 1985, Gaur 1983, 1987, Hazra et al., 1994). Lekasi et al. (2001) noted that the difference in field trials between iso-N applications of manure with C:N = 25 and those with C:N = 19 represented maize grain yield improvements of 113 and 216%, respectively, above the plots without manure in the first season after application, and 18 and 61%, respectively, in the second season after application. They also recorded that the C:N ratio of the 288 samples of manure ranged from 5.3 to 81.3, representing materials with C:N ratios similar to soil at the one extreme to a material with a C:N ratio twice that of cereal straw or 40% that of sawdust at the other extreme. The C/N ratio of conventional compost was wide and NPK content was less than those of enriched composts. The composts prepared by heap or pit method did not differ significantly in WSC, TOC and C/N ratio.

The immobilization of soil mineral nitrogen can be caused by the high C/N ratio of manure which usually characterizes an immature compost. This causes a considerable increase of soil microorganisms to decompose the excess of carbon compounds and they assimilate the soil nitrogen for their growth and metabolism (Alexander, 1977).

The C/N ratio itself can not be regarded as a reliable indicator of maturity since the raw materials vary widely in their chemical composition (Garcia et al., 1992). Manna et al. (2000) concluded that the chemical parameters such as WSC, CEC, CEC/TOC, BI, lignin/cellulose ratio may be used as compost maturity indices irrespective of organic raw materials than C:N ratio only.

2.4.1.5 Maturity of compost

Kimber (1973) observed that the aim of maturation process was to eliminate phytotoxic substances of the raw materials which were harmful to germination and growth of plants. Spohn (1978) proposed that the presence of reducing compounds, such as ammonia and hydrogen sulphide indicated anaerobic condition in the compost heap which showed that the residues were still in a period of decomposition and so the compost was immature. Biological methods including germination index of seeds in compost extracts (Zucconi et al., 1981b) and seedling tests (Kawada, 1981 and Hoitink and Kuter, 1986) are used to characterize compost maturity. According to Chefetz et al. (1996) low molecular weight organic acids induced phytotoxicity in addition to competition for oxygen and nutrients due to the high rates of organic matter decomposition in immature composts.

2.4.1.6 Total organic carbon (TOC)

Morel et al. (1979) reported that Total Organic Carbon (TOC) which represented all available organic compounds was one of the two variables which characterized the index of degradability of compost. TOC decreased and C/N ratio narrowed down to a range of 21.5 to 29.5 percent by the application of bio inoculum. The CEC/TOC ratio can be useful as an index of maturity since all mature composts reach the values between 3.5 to 4 at 120 days regardless of the source of raw materials. CEC/TOC increased to more than 3.5 upto 120 days of decomposition (Manna et al., 2000). Total organic carbon values were slightly lower in enriched composts.

2.4.1.7 Ash content

Organic matter is an important component of manure and compost, which influences many soil properties (Nelson and Sommers, 1996). To understand organic matter dynamics during composting, it is essential to distinguish mineral constituents, which are likely to persist and are designated as the ash content, from organic constituents that are potentially susceptible to decomposition. Losses of organic matter, carbon, nitrogen, phosphorus and other nutrients during composting are often estimated by using initial and final ash contents and the assumption that the mass of ash remains constant during composting (Bernal et al., 1998). In addition, accurate methods for the determination of ash content and its reciprocal, organic matter content can identify the quality and maturity of compost (Matthiessen et al., 2005). Ten samples of compost produced in Italy were analysed by Genevini et al. (1987) for fertilizing elements and heavy metals. There was a high variability in composition even with composts of similar origin. Compost is comparable to farmyard manure (FYM) in organic content but has lower potassium and higher ash and silica contents. Atagana (2008) reported that ash components of the compost mixtures changed slightly from 4.62 to 4.60 in the sewage sludge compost and 6.37 to 6.41 in the control, which indicated that there was no significant change in the mineral components of the manure applied soil at the end of the experiment.

2.4.1.8 Water soluble carbohydrates (WSC)

The WSC represent the most easily biodegradable C fraction during the composting process because it consists of sugars, organic acids and phenols, apart from the soluble fraction of fulvic acids (Garcia et al., 1991). Morel et al. (1979) reported that the content of water soluble sugars which represents the organic compounds that are most rapidly fermentable was one of the two variables which characterize the index of degradability of compost. The concentration of WSC declined with composting time. The greatest decline occurred in the first days of composting and continued even when the material was transferred to the maturation area (Singh, 2005a). WSC (%) decreased with days of decomposition process, indicating that easily biodegradable carbon diminished much faster than resistant carbon materials. Water- soluble carbohydrates (WSC) content was found to be significantly lower in phosphocompost (PC), N- enriched phosphocompost (NPC) and vermicompost (VC) as compared to conventional compost (CC).

2.4.1.9 Water Soluble Organic Carbon (WSOC)

Water soluble organic carbon content had been selected as a parameter for estimating maturity of composts by several workers. Water-soluble organic C concentration rapidly increased to a maximum at day 18 of composting of separated pig manure and declined thereafter (Hsu and Lo, 1999). Sellami et al. (2008) used the ratio of water soluble organic carbon to total organic nitrogen as one of the indices for humification in composting. The results showed that the time required to reach maturity was dependant on the chemical properties of the initial raw materials used. Bustamante et al. (2008) also monitored water soluble carbon among the different parameters considered for measuring compost maturity.

2.4.1.10 Lignin content

The percentage of lignin in composts increased with maturity, along with decrease in cellulose giving rise to higher lignin/cellulose ratio (Manna et al., 2000). While lignin and polyphenols are important intrinsic factors in plant materials, the relatively low values in the manures analysed render the parameter less influential in the decomposition processes. Melillo et al. (1982) found that when plant materials contain higher concentrations of lignin, there was little mineralization of N in spite of high N concentrations in the plant tissue. Palm and Sanchez (1991) reported threshold values of lignin as 15% and 3% for polyphenols in leaves of tropical legumes for net N mineralization to occur immediately. In the short term, the lignin content did not affect the N mineralization but became important in the later stages. Cattle browsing on shrubs may have manure of higher lignin contents. Pathak and Sarkar (1994) found a significant negative relationship between N mineralized and lignin concentration. Reddy (2005) reported that there may be interaction between polyphenols and lignin of the organic residues in their influence on carbon break down. Materials high in either lignin or polyphenol alone but high N released more of their initial carbon than those high in both lignin and polyphenols. Most materials high in both N and polyphenol (but low in lignin) immobilized N for sometime or throughout the study period of 28 days while those high in N and lignin (low in polyphenols) mineralized N throughout the study period.

2.4.1.11 Biodegradability index (BI)

Biodegradability index is the function of total organic carbon and water soluble carbohydrates with the course of time and it was proposed by Morel et al. (1979). These authors deduced the following equation which correlated compost age, total organic carbon content and soluble sugars to the index of degradability or maturity:

ID = 3.166 - (0.011 AGE) + (0.059 TOC) +(0.832 PHs) where, ID = Index of degradability, AGE = Days of maturation, TOC = Total Organic Carbon, PHs = Sugars extractable by hot water. They found out that with ID values less than 2.4, compost may be considered sufficiently mature. Above 2.7 the maturation of compost is insufficient.

BI of composts decreased with days of maturation and further decreased when bio inocula were used (Manna et al., 2000).They found that the values of BI in mature composts ranged between 3.5 to 4.6 in uninoculated and 3.1 to 3.9 in inoculated composts during 120 days of decomposition.

2.4.1.12 pH of manure

The compost pH is a good indicator of the development of composting (Jimenez and Garcia, 1989). During the first hours it descends slightly to values of about 5, and later rises as the material gradually decomposes and stabilizes, finally staying at values between 7 and 8 (Gray et al., 1971a; Finstein and Morris, 1975; Cardenas and Wang, 1980). Acid pH values of compost indicate a lack of maturity due to short composting time or the occurrence of anaerobic processes in the heap.

According to Wilson (1989), most well stabilized composts had a pH between 6.5 and 7.5. Adjusting the pH downwards to near neutral reduced the volatilization of NH_3 and other odorous compounds.

2.4.1.13 CEC of manure

Another parameter widely used as an index of compost maturity is CEC. Significant increase in CEC was observed with increase in time of decomposition and application of bio inoculum. At maturity there was significant increase in CEC and decrease of WSC indicting that the compost is fully matured (Manna et al., 2000).

2.4.1.14 Total phenol content

Oglesby and Fownes (1992) found a negative relationship between polyphenols and N mineralization from organic residues. The increase in phenol is one of the indicators of completion of humification and the composts having reached maturity level (Singh, 2005a). The ash content and total phenol content were also higher in phosphocompost (PC), N- enriched phosphocompost (NPC) and vermicompost (VC) as compared to conventional compost (CC). The polyphenol contents of manures were low. As manure passes through the alimentary canal, polyphenols react and form other products through condensation reactions. Measured values from samples collected from communal grazing areas are all less than 1% (Palm et al., 2001). The effect of polyphenols in plant materials applied to the soil has been those of reduced N release through their protein binding capacity. They also bind enzymes which catalyse mineralization, in the nitrification process in particular. However, under aerobic conditions most polyphenols are quickly degraded (Paul et al., 1994).

Residues with high concentrations of N and low concentrations of lignin and polyphenol are categorized as high quality residues while those with low N concentration and high lignin and polyphenol concentrations are categorized as low quality residues (Mafongoya et al., 1998). Immobilization of N in high quality residues during the initial period of incubation could be due to the large demand for N by microorganisms proliferating rapidly in response to the availability of easily decomposable carbon compounds. Palm (1995) indicated that polyphenol/N ratio may serve as an index of short term mineralization/ immobilization patterns whereas lignin+ polyphenol /N ratio may serve as an index for long term release patterns.

Reddy (2005) reported that polyphenols appeared to play a bigger role in limiting C breakdown than lignin. Also, polyphenols had a higher influence in limiting N mineralization than lignin.

The pathogen content from poultry manure decreased with composting as did phytotoxic compounds. Phenols and lipids were reduced, respectively, by 40% and 84% while germination index increased with composting progress (Hachicha et al, 2008). Composting produced a degradation of the phytotoxic compounds, such as polyphenols, to give composts without a phytotoxic character (Bustamante et al., 2008).

2.4.1.15 Nutrient content as a factor of manure quality:

Although nutrient concentrations are valuable indicators of manure quality, these measurements do not reflect the total amount of nutrients that could be potentially available in the farms. It is quite possible that manures with low nutrient concentration could also have high heap mass, resulting in potentially higher nutrient cycling capability. The full impact of livestock and manure management practices on nutrient cycling can only be determined if mass balances are recorded (Lekasi et al., 2001). There are many pathways that lead to nutrient loss, especially nitrogen, from composting manure heaps. These include gaseous and leaching losses (Dewes, 1994). There is a need to apply collection and storage management strategies that minimise these losses so that efficient nutrient cycling can be achieved. Net nitrogen mineralisation, has been considered as a measure of nitrogen availability of organically bound N in soils. The amount of N mineralised or immobilised from manure and compost depends on soil mineralogy (Beckwith and Parsons, 1980), chemical and physical characteristics of organic materials (Castellanos and Pratt, 1981; Janssen, 1996) and environmental conditions (Adriano et al., 1974; Virgil and Kissel, 1995). A good manure should synchronise mineral N (Min-N) release and plant demand such that the peak Min-N release coincides with peak plant biomass development and hence peak N requirements (Myers et al., 1994). Different crops may exhibit highest nutrient demands at different times of manure nutrient mineralisation. Therefore, a good understanding of manure nutrient mineralisation patterns could be used as a guide on deciding the time of application (Lekasi et al., 2001).

Relationships between the mineralization of N from manure and indices to describe manure quality have not been examined in detail. Crop response work done in a greenhouse demonstrated that crop uptake gives a good account of the quality of manure (Mugwira, 1984). Studies done on green manures and agroforestry species show that it is possible to use the release patterns, laboratory chemical indices and textural indices to describe quality of materials and predict rates of decomposition and N release (Melillo et al., 1982; Frankenberg and Albdelmagid, 1985; Palm and Sanchez, 1991; Handayanto et al., 1997; Mafongoya et al., 1997). The rate of net N mineralization of manures and other organics must be known to optimise use and predict supplementation rates of mineral fertilizers (Constantinides and Fownes, 1994; Hadas and Portnoy, 1994). The N content or C/N ratio, lignin content and polyphenol contents are the major determinants of organic residue quality (Mafongoya et al., 1998). A high N content in the materials favours net mineralization and N concentrations less than 1.7- 2.0 % generally cause net immobilization (Constantinides and Fownes, 1994). Recous et al. (1995) suggested that when N is low in residues, the N availability controls the decomposition and N mineralization.

Mugwira and Mukurumbira (1986) reported a depression in yields in the first two weeks followed by significant plant growth increases after two weeks of planting in manured pots. Tanner and Mugwira (1984) also observed a crop yield depression in the first 4 weeks in a greenhouse study using manures from other small holder areas. Much longer periods of immobilization from cattle manure up to 105 days have been observed (Fauci and Dick, 1994). These results are contrary to the observation by Pathak and Sarkar (1994) who reported cattle manure with 0.79 per cent N, C: N 26 and ash content 27.5 per cent mineralised throughout the entire study period.

The C: N ratio of the manure was an important index for indicating the occurrence of a net N immobilization period. Manures with C: N ratio less than 20 immobilized N, in agreement with results of Castellanos and Pratt (1981) who reported immobilization from manures with C: N ratio of 15.9 and N content of 2 percent. However this contrasts with reports from workers who used plant materials with C: N ratio of 23 as the threshold for net mineralization (Frankenberger and Abdelmagid, 1985; Janssen, 1996; Quemada and Cabrera, 1995; Swift et al., 1979). The implication is that neither N per cent nor C: N can on its own be used to explain the mineralization patterns in manures.

The positive correlation between mineral N and the N per cent and the C per cent during the immobilization period shows their importance in determining the extent of mineralization in manures. The organic carbon content of manures is an important determinant of the mineralization/ immobilisation processes. This is shown by positive correlation with mineralization at these initial stages of decomposition. Nitrogen and carbon are the primary needs for soil microbes for energy and biomass accumulation. These results corroborate studies on other organic materials in which N and C have been identified as important indices of mineralization (Constantinides and Fownes, 1994; Janssen, 1996). Hadas and Portnoy (1994) also report that % N, % C and efficacy with which C is assimilated are important in determining mineralization patterns of organic materials. The low percentage of the variance that is explained suggests that indices have different overall effects on the mineralization trends with time as the substrate concentration and composition changes. After 14 and 28 days of incubation, the % ash, lignin and C: N ratio become important indices of mineralization of these manures together with the % C and % N. This shows that indices change in importance as the decomposition process progresses. When simple correlations were worked between initial residue quality parameters and the per cent N mineralized from all the residues at different periods during incubation, residue carbon content was found to be poorly correlated with N mineralized but there was a strong positive relationship of residue N concentration with per cent N mineralized (Srinivas et al., 2006).

Phosphorus deficiency of crops may sometimes be found where compost is applied to strongly acidic soils with a high P-fixing capacity. In such cases, chemical P fertilizers must be added to meet the P requirement of the crop (Chen, 1995). Several studies have demonstrated that rock phosphate in composted livestock manure increased both the uptake of P by crops and the yield. This increase is probably because of the increase in the available P in the rock phosphate (Singh and Amberger, 1991). Mahimairaja et al. (1995) evaluated the results from field experiments, and suggested that composting poultry manure with sulfur and rock phosphate not only reduces the environmental pollution from manure application, but also increases the agronomic effectiveness of the compost.

Asha (1999) reported that available N, P_2O_5 and K status of enriched FYM (FYM+ neem cake) was high. The available P content in FYM+ poultry manure was comparable with FYM + enriched compost. Livestock manure is often rich in plant nutrients. Studies have shown that about 70 - 80% of the nitrogen (N), 60 - 85% of the phosphate (P_2O_5), and 80% of the potassium (K_2O) fed to animals are excreted in the manure (Klausner et al. 1984). However, the nutrient content of manure can vary, according to what has been fed to the animals, and the methods of collecting, handling and storage.

The application of bio inoculum significantly increased the available nutrient status such as NO_3-N, NH_4^+-N, water soluble P, citrate soluble P and total P over uninoculated control. The enhanced use of bio inoculum in combination with chemical amendments accelerated the compost maturity and shortened the usual period of composting (Manna et al., 2000).

Trace elements viz; Mn, Zn, Fe and Cu were higher in enriched composts in comparison to conventional composts (CC). The dehydrogenase activity was chosen as an index of microbiological activity because it refers to a group of mostly endocellular enzymes which catalyse the oxidation of soil organic matter. Dehydrogenase activity of phosphocompost (PC) and vermicompost (VC) produced either in heap or in pit method was lesser as compared to CC, this is because the CC was still being decomposed and hence it exhibited higher microbial activity. The decomposition period was lesser by 70 days in chemically enriched as well as vermicompost as compared to CC (Singh, 2005a).

Kalaiselvi and Ramasamy (1996) in their review on compost maturity listed out the following characters as criteria for quality of compost.

1. Mature compost should have tea brown colour, no noxious smell and good stability, which could no longer produce high temperature.
2. Maximum diameter should not exceed 10mm, with 5mm as optimum and water holding capacity below 30%
3. Most common pH value ranged from 6.5 to 8.0.
4. Total salinity should not exceed 2 g salt.
5. C:N ratio of mature compost should be less than 20 and CEC should be more than 70meq/100g ash free material.

6. At least 10% of the total organic carbon present in original material should be humified at the end of composting.

Good quality compost should contain minimum levels of toxic components and non –biodegradable materials.

2.4.1.16 Specifications of organic fertiliser as given in Fertilizer Control Order

According to the Fertilizer (Control) Amendment Order, 2006, “no person shall manufacture any organic fertilizer unless such organic fertilizer conforms to the standards set out in the part A of Schedule -IV”. In Part A of Schedule IV, the specifications of organic fertilizer are given as:

2.4.1.16.1. City compost

1	Moisture, Per cent by weight	15.0 - 25.0
2	Colour	Dark brown to black
3	Odour	Absence of foul order
4	Particle size	Minimum 90% material should pass through 4.0mm IS Sieve
5	Bulk density (g cm^{-3})	0.7 – 0.9
6	Total Organic Carbon, Per cent by weight, Minimum	16.0
7	Total Nitrogen (as N) Per cent by weight, Minimum	0.5
8	Total Phosphates (as P_2O_5) Per cent by weight, Minimum	0.5
9	Total Potash (as K_2O) Per cent by weight, Minimum	1
10	C: N ratio	20:1 or less
11	pH	6.5 – 7.5
12	Conductivity (as dSm^{-1}) not more than	4
13	Pathogens	Nil

14	Heavy metal content (as $mgKg^{-1}$) Per cent by weight, Maximum	
	Arsenic (as As_2O_3)	10.00
	Cadmium (as Cd)	5.00
	Chromium (as Cr)	50.00
	Copper (as Cu)	300.00
	Mercury (as Hg)	0.15
	Nickel (as Ni)	50.00
	Lead (as Pb)	100.00
	Zinc (as Zn)	1000.00

2.4.1.16.2 Vermicompost

1	Moisture, per cent by weight	15.0 - 25.0
2	Colour	Dark brown to black
3	Odour	Absence of foul order
4	Particle size	Minimum 90% material should pass through 4.0mm IS Sieve
5	Bulk density (gcm^{-3})	0.7-0.9
6	Total Organic Carbon, Per cent by weight, Minimum	18.0
7	Total Nitrogen (as N) Per cent by weight, Minimum	1.0
8	Total Phosphates (as P_2O_5) Per cent by weight, Minimum	1.0
9	Total Potash (as K_2O) Per cent by weight, Minimum	1.0
10	Heavy metal content (as $mgKg^{-1}$) Per cent by weight, Maximum	
	Arsenic (as As_2O_3)	10.00
	Cadmium (as Cd)	5.00

Chromium (as Cr)	50.00
Mercury (as Hg)	0.15
Nickel (as Ni)	50.00
Lead (as Pb)	100.00

2.4.1.16.3 Pressmud

1	Moisture, percent by weight, Maximum	15
2	Total Nitrogen (as N) Per cent by weight, Minimum	1.8
3	Total Phosphorous (as P_2O_5) Per cent by weight, Minimum	2.0
4	C: N ratio	10:1
5	Total potassium, (as K_2O) per cent by weight, Minimum	1.4
6	pH	7.0 - 8.0
7	Heavy metal content (as $mgKg^{-1}$) Per cent by weight, Maximum	
	Arsenic (as As_2O_3)	10.00
	Cadmium (as Cd)	5.00
	Chromium (as Cr)	50.00
	Copper (as Cu)	300.00
	Mercury (as Hg)	0.15
	Nickel (as Ni)	50.00
	Lead (as Pb)	100.00
	Zinc (as Zn)	1000.00

The Part C of the Schedule specifies the procedure for drawing samples of organic fertilizer which is as per methodology mentioned in the schedule II, Part- A of the FCO, 1985.

According to Lee and Kim (1997), the government regulations to control the quality of organic fertilizers in Korea specify the maximum level of harmful substances as: Arsenic 50ppm, cadmium 5ppm, mercury 2 ppm, lead 150 ppm, chromium 300ppm and copper 500 ppm. It also stated that the HCl insoluble matter in organic fertilizers should be below 30 per cent. The organic matter to nitrogen ratio required for different types of compost varied with the type of raw materials used.

2.5 Effect of raw materials on organic manure quality

The selection of composting materials is important, since it has a direct influence on compost quality. Materials that have no nutrient value or which may be contaminated by heavy metals cannot be used for composting. There is little possibility of including harmful materials in composting rice straw, but the increasing use of livestock manure, and industrial and municipal wastes, is a concern. Needless to say, the purpose of compost is to improve soil quality and to produce high-quality crops. It is not a means of disposing of organic wastes. Therefore, the selection of good raw materials for composting is crucial in quality control (Um and Lee, 2001).

Agricultural by-products in general have a low nutrient content and hence are suitable only as bulking agents. Sawdust is not a good raw material for composting, because of its high C/N ratio and low nutrient content. Since it has a low bulk density and can hold moisture, it is often used as a bulking agent for wet materials. Livestock manure varies in its C/N ratio and nutrient content. It has a higher phosphate and potassium content than most other organic wastes. The heavy metal content is very low, compared to the levels found in industrial and municipal wastes. Sewage sludge has a relatively high nutrient content and can be used as an organic fertilizer without composting. However, it cannot be applied to edible crops, because of the high content of heavy metals, and the possibility of harmful microorganisms. Human sewage has high phosphate content. The heavy metal content is lower than in sewage sludge, which often includes industrial wastes. However, the lead content of human sewage may be high, and there are cases of very serious heavy metal contamination. Most food wastes have high salt content and so it is recommended to mix food wastes with livestock manure for composting, or use them in earthworm production.

It is necessary to analyze the chemical content of industrial wastes before they can be used for composting. Sludge from the dairy industry has a higher nitrogen content than other types of industrial sludge. Since it also has a relatively low level of harmful materials, it is often used as organic fertilizer for edible crops. Sludge from the oil industry has a high organic matter content and a low nitrogen content. It contains as high a level of heavy metals as sewage sludge, and there are some reports that it has a damaging effect on plant growth. Sludge from the oil industry is not recommended for crop production. Sludge from the paper industry has a high C/N ratio. It is sometimes contaminated with lead, which is used in printing. Paper sludge should be dried before being used as a bulking agent when composting livestock manure. Sludge from the alcohol industry has a low C/N ratio, but a high level of nitrogen, potassium and phosphorus. It has been used as an organic fertilizer for some time. However, it is necessary to check the chemicals used for processing and in wastewater treatment. Sludge from beverage production has characteristics similar to those of sludge from alcohol production. It can be recycled in agriculture if it is free of contamination (Um and Lee, 2001).

In a study conducted by Zmora-Nahum et al. (2007), thirty-seven commercial composts were collected from France, Greece and the Netherlands. When grouped by country of origin, significant differences were found in OM, C, N, dissolved organic carbon (DOC) concentration, electrical conductivity (EC) and NO_3 concentration. These differences may be attributable to source materials or local regulations and quality control measures. When the composts were classified into 7 groups by their source materials: wood, green, manure, grape marc (GM), oilcake, spent mushroom substrate and municipal solid waste-based composts, significant differences between groups were found in OM, C, N, DOC, pH, EC, NO_3 and soluble sugars. Cucumber plants grown on manure-based composts had greater fresh weight than those grown on other composts. Plants grown on oilcake and GM composts exhibited low fresh weight. The difference in characteristics of the oilcake and GM composts may be a result of their unique chemical composition which slows their degradation. It may also be related to their relatively low degree of maturity, which is a consequence of their slow degradation.

In a study to evaluate the suitability of fish farm wastes as manure, Salazar and Saldana (2007) reported that significant differences were observed between wastes collected from fish farms in sea and lake. Both manures had low total N contents with values of <0.9%, more than 75% of which was in the organic form.

Lake manure showed high contents of P (1.56%), Ca (3.89%), Fe (27,948 ppm), Mn (446 ppm), Al (31,789 ppm), As (5.13 ppm), Cd (1.04 ppm), Cr (18.8 ppm), Ni (12.3 ppm), Pb (3.5 ppm) and Zn (393 ppm). Sea manure had high contents of Mg (1.65%), K (0.63%), Na (11.8%) and Cu (89 ppm). Fish farm manure had low nutrients and heavy metal contents and a potential use in agricultural soils, which could reduce the risks of water pollution on water from fish farming.

Another input in organic farming is wood ash. The addition of wood ash, without concurrent addition of nitrogen, showed increased seed yield and economic returns of barley and field pea and alfalfa forage yield and protein content. The main yield benefit most likely resulted from improvement in availability of P and/or other nutrients from wood ash. Wood ash also has other potential benefits such as reduction in soil acidity (which may last for several years) improvement in soil tilth, increased microbial biomass and reduced weed infestation (Malhi et al., 2008).

A study conducted in Sri Lanka by Sangakkara et al. (2008) involved composts made from commonly available organic matter with different C/N ratios, and inoculums consisting of cattle manure slurry, Effective Microorganisms (EM) or a mixture of both. The mixture of cattle manure and EM increased N availability and reduced C/N ratios of composts than when applied individually. Legume green matter enhanced compost quality and crop yields. The nodulation and mycorrhizal populations of roots of beans were increased by a mixture of inoculums and using diverse materials in the compost.

A case study of content and sources of metals in compost manure in South Africa revealed that the main source of heavy metals in the composting materials was found to be sawdust. The level of heavy metals in all the compost materials were found in the following order: Fe > Mn > Cr > Ni > Zn > Cu > Co > Cd (Manungufala et al., 2008). In a study to evaluate the suitability of wood ash for composting, it was concluded that up to 16% ash admixture to organic wastes does not impair the composting process but is even able to improve the product quality. However, it has to be made sure that only bottom ashes of low heavy metal contents are being used and strict quality control is implemented (Kuba et al., 2008).

2.6 Long term effects of organic manure application in soil

Agricultural policy in Korea supported high applications of chemical fertilizers to maximize agricultural output from the 1960s. As a result, the soil organic matter content decreased, becoming a barrier to increased agricultural productivity. Also, massive inputs of chemical fertilizer caused salt accumulation and an imbalance of nutrients in soils. The deterioration in soil quality became an important issue (Um and Lee, 2001).

Generally, the amount of organic fertilizer applied to farms is based on the nitrogen requirement of crops and the rate of N mineralization. There is little regard for the supply status of phosphate in soils (Olsen and Barber, 1977). The percentage of phosphate absorbed by crops from compost annually is usually far lower than the percentage of nitrogen, while the mineralization of soil organic phosphorus (P) is strongly affected by the P fixing capacity of the soil. It is necessary to have a better understanding of the behavior of N and P in strongly acidic soils after composted livestock manure is applied, in order to develop a suitable management strategy.

The heavy application of manure or compost in excess of crop needs can cause a significant buildup of nitrogen, phosphorus and salt in soil. Applying enough manure or compost to meet the nitrogen requirements of corn may greatly increase the levels of P and other ions in the soil (Eghball and Power, 1999). The reason for this is probably because the N/P ratio in most livestock manure, even after composting, was lower than the N/P uptake ratio of most crops. Eghball and Power (1995) found that the phosphorus content (measured by Bray-1) increased by 81 mg/kg after a single application of manure based on nitrogen requirements, and by 114 mg/kg after a similar application of compost. A high level of phosphorus in the soil is an environmental concern. It may be washed into streams and lakes by runoff or soil erosion, and cause eutrophication (Sharpley et al., 1996).

Agricultural users might have concerns regarding potential levels of heavy metals and other possible contaminants in compost, particularly mixed municipal solid wastes. The potential for contamination becomes an important issue when compost is used on food crops. Heavy metals in sewage sludges (biosolids) may be found in the inorganic form or may be organically complexed, which could affect their chemical reactions in soil. These heavy metals may accumulate in soil with repeated fertilizer applications. Cadmium (Cd) is the heavy metal of most concern because it may affect human health. Other heavy metals of possible significance are arsenic (As), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and vanadium (V). Some countries have set tolerance limits on heavy-metal additions to soil because their long-term effects are unknown (Mortvedt, 1995). Long-term and/or heavy application of composts to agricultural soils has been found to result in salt, nutrient, or heavy metal accumulation and may adversely affect plant growth, soil organisms, water quality, and animal and human health. There have been reports of Mg deficiency being induced in crops by applying compost with low Mg content, Ca deficiency of cabbage grown in strongly acidic soil applied with compost, poor growth of tomato in soil with high EC value due to heavy application of animal compost and poor seed generation of cabbage in soil with salt accumulation due to heavy application of animal compost (Chen and Bejosano- Gloria, 2005).

In an experiment by Chen et al. (2001), three farming methods were evaluated which were: conventional with recommended chemical fertilizer and pesticides, intermediate (half chemical fertilizers were used, and half organic), organic (no chemical pesticides and only organic fertilizers were used). The results showed that the soil pH, the level of phosphorus in the soil, and the soil organic matter content all increased over time in the organic plot. In the chemical plot, they all decreased. The level of soil exchangeable potassium also rose slightly in both the organic and mixed plots and fell in the chemical plot. The plot with combined chemicals and organic inputs had the best ability to build up soil nitrogen and produced the highest crop yield. However, the nitrate content of the harvested crop was also high. Thus, it indicated that soil fertility will improve if organic methods are used. However, study of the soil from the organic farming plot showed that the levels of extractable zinc increased from 11.5 mg/kg at the beginning of the treatment to 27.8 mg/kg at the end. Similarly, copper increased from 10.0 to 29.1 mg/kg. With long-term compost applications, it is necessary to monitor the accumulation of toxic substances such as heavy metals.

Integrated plant nutrition system (IPNS) is a current approach of applying organic materials coupled with inorganic fertilizers. This helps to reduce the uncertainty of nutrient supply from the organic N pool for crop uptake. The basic requirements of optimizing N fertilization are to quantity N being available from organic amendments during a crop growth period, N removed by a crop and inorganic N previously optimized for a specific crop. To achieve these goals, research scientists have been involved in assessing the plant residue quality using biochemical compositions (lignin, polyphenol, dehydrogenase activity, etc.) of plant residues to predict decomposition characteristics (*k*) and nutrient release, whose determinations are too expensive and time consuming. Recently, new equations have also been proposed, termed as the organic material quality index (OMQI), which can predict *k*, net *N* mineralization and nitrification in upland soils having distinct physico-chemical properties. Only pH and C/N ratio of organic materials from either source can be used in the equations developed by others to calculate OMQI based on the coefficients of the relative contribution (CRC) of the input variables. The equation for OMQI is: [1/(a * pH + b * C/N)*100] where ‘a' and ‘b' are the CRC of the input variables. Those can be calculated using the F-values of the regression analyses and CRC is the value of the given factors/sum of F-values of these factors. The OMQI could be an advancement of IPNS to estimate *k* values and mineral N to be available for crop uptake. The prediction capabilities of such indices can be improved greatly by considering soil factors. Application of organic materials to agricultural fields following these indices would ensure the enrichment of soil C and N pool as well as minimize N loss, and thus, the improvement of soil and crop productivity (Khalil et al., 2006).

Crop yields did not benefit from low compost rates during the 3-year duration of a study with poultry litter-yard waste compost; however, improvements in some bulk density and porosity indicated that benefits of longer term, low compost rate additions may accrue over time (Evanylo et al., 2008).

A study was conducted by Jardé et al. (2007) to trace the fate of manure organic matter in the environment to assess whether manure disposal on the soils of catchments could affect the organic quality of rivers. The results showed that the organic matter fractions of the rivers were significantly influenced by the type of organic manures applied in the catchments and that the organic quality of rivers is modified in catchments where there is intense manure spreading on soils.

Elemental contaminants, also known as heavy metals, in fertilizers and manure pose a threat to human health and environment. Heavy metals occur naturally in soils. They can also be accumulated through conventional agricultural practices and are found in a variety of industrial by products, some of which are combined with fertilizers and soil conditioners. The highest arsenic (As) levels were sound in dehydrated poultry litter and rock phosphate. Conventional broiler production in USA uses arsenic as a parasiticide. It is a known impurity in many rock phosphate deposits. Rock phosphate also had the highest levels of cadmium (Cd). The highest level of lead (Pb) was found in compost made from municipal green waste. Hence it is suggested that organic farmers should be made aware of the long-term consequences of applying soil amendments that are contaminated with heavy metals and take precautions not to cause long term degradation (Baker and Tracy, 2008).

Long-term organic farming and the application of farmyard manure promoted soil quality, microbial biomass and fostered natural enemies and ecosystem engineers, suggesting enhanced nutrient cycling and pest control (Birkhofer et al., 2008).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

A detailed investigation was carried out at College of Agriculture, Vellayani to develop a protocol for the quality control of commercial organic manures in Kerala and to evaluate their efficiency using the test crop, amaranthus.

The study was carried out in five phases:

1. Identification and characterization of commercial organic manure products and raw materials and development of a protocol for quality standards of commercial organic manures.
2. Study of the changes in quality of organic manures during storage.
3. Comparison of quality of commercial organic manures samples collected from market outlets with their factory samples.
4. Incubation study to reveal the nutrient release pattern of selected commercial organic manure products
5. Evaluation of direct and residual effects of selected commercial organic manure products on the test crop, amaranthus.

The details on the laboratory analysis, incubation experiment, field experiment, observations recorded, analytical methods used and statistical procedures followed are presented in this chapter.

3.1 Characterization of commercial organic manure products and raw materials

3.1.1 Collection of various commercial organic manure products manufactured in Kerala

Samples (500g each) of different commercial organic manure (COM) products manufactured by various firms in Kerala were collected directly from the manufacturing site (factory). Forty four different products were procured in total. Information on the raw materials used and the proportion in which they are mixed to produce the COMs were collected. The details on commercial organic manure products, the proportion of their raw materials and the treatments numbers used for further studies are presented in Tables 1a, 1b and 1c. Samples of the raw materials of each product were also collected. The details of raw materials selected for further

Table 1a . Particulars of COMs with single ingredient

Serial No.	Treatment No.	Product Name	Raw material
1	SN 2	G.N.VERMICAKE	Groundnut
2	SN 4	NEEMCAKE	Neem seed
3	SN 6	FISH MEAL	Fish waste
4	SN 34	BIOMEAL	Pressmud
5	SN 35	BIOCARE	Pressmud
6	SN 44	FARM GOLD	Pressmud

Table 1b. Particulars of COMs which are mixtures of bone meal, leather meal and neem cake

Serial No.	Treatment No.	Product Name	Raw materials (%)		
			Bone meal	Leather meal	Neem cake
1	SN 7	Sterameal- N: 5-7% P: 9-10% K: 0	50	50	0
2	SN 8	Sterameal- N: 5-7% P: 9-10% K: 5%	50	50	0
3	SN 9	Sterameal- N: 3-5% P: 9-10% K: 10%	50	50	0
4	SN 12	Royal meal	40	40	20
5	SN 14	Super meal II	40	40	20
6	SN 18	Abtec Super meal	30	30	40
7	SN 22	Golden meal	55	30	15
8	SN 25	Excel meal (without MOP)	40	40	20
9	SN 33	Ecomeal	50	20	30
10	SN 36	Star meal	50	40	10
11	SN 39	P.L. Meal	40	40	20
12	SN 40	Raja meal	50	50	0

Table 1c. Particulars of COMs with miscellaneous ingredients.

Serial No.	Treatment No.	Product Name	Raw materials (%)							
			Bone meal	Leather meal	Neem cake	Press-mud	Castor cake	Ash	Fish waste	Miscellaneous
1	SN 1	Karshaka meal		20			20	20		Cowdung-40
2	SN 3	Orgameal			30		30	10	30	
3	SN 5	Vermicompost								Cowdung-25, Banana stem-50, Coconut leaf-25
4	SN 10	Sterameal Coconut Special	36.5	36.5			27			
5	SN 11	Fosmeal		20		50				Essence extracted coffee beans powder-30
6	SN 13	Super meal I	40	40	20					Calcium powder-2
7	SN 15	Greenrich			30-40			10-20		Spice wastes-30-40 Poultry wastes-30
8	SN 16	Abtec Organic Manure			10					Decomposed husk-40, Biocompost-40, Vermicompost-10
9	SN 17	Abtec Super Organic Plus			70	20				Decomposed coirpith-10
10	SN 19	Abtec Super Organic Manure			20					Decomposed husk-30, Biocompost-30, Vermicompost-20
11	SN 20	Haritha Super	25		35					Fermented compost-50

Table 1c. continued

12	SN 21	Haritha Gold	10		10					Fermented compost-80
13	SN 23	Pavizham Organic	20	30	15				35	
14	SN 24	Excel meal	40	40	15					MOP-5
15	SN 26	Karshaka Agromeal Grade I	50	35	5					MOP-10
16	SN 27	Karshaka Agromeal Grade II	50	30		3				MOP-17
17	SN 28	Karshaka Organic	15	10		15				Decomposed coirpith-40, Vermicompost-15, MOP-5
18	SN 29	Karshaka Organic Total	15		10	50				Decomposed coirpith-15, Vermicompost-5, MOP-5
19	SN 30	Sabarimeal	46	46						MOP-8
20	SN 31	Biomeal	50	40						MOP-8.4, Urea-1.6
21	SN 32	Greenmeal		20	20			20		Biocompost- 20, coirpith-20
22	SN 37	Kotharimeal	40	33	5					Biocompost-20, coirpith-2
23	SN 38	Jeevomeal	20		30	15		15		Ground nut seed shell-10, dolomite- 15
24	SN 41	Kalpameal	40	40	15					MOP-5
25	SN 42	Kanakam	10		10					Mushroom waste-50, Biocompost- 30
26	SN 43	Skymeal	30	40	15				15	

analysis and for preparation of organic meal mixtures are presented in Table 2. All the samples were stored in closed PET jars, labeled and kept away from direct sunlight for further studies.

3.1.2 Characterization of COMs

The physical, chemical and biochemical characteristics of the COMs were analysed and the analytical methods adopted for the study are given in Table 3.

3.1.3 Characterization of raw materials

The odour, colour, bulk density, moisture, organic carbon, nitrogen, phosphorus and potassium contents of the raw materials were analysed as per the methods presented in Table 3.

3.1.4 Effect of composition of raw materials on quality of organic meal mixtures (OMMs)

The effect of raw materials on the quality of commercial organic manure products was studied by preparing different organic meal mixtures by mixing the raw materials from different sources in specific ratios. The raw materials selected were: five types of bone meal (BM1 to BM5), five types of leather meal (LM1 to LM5) and five types of neem cake (NC1 to NC5). The details on the sources of each raw material are given in Appendix II. The raw materials were mixed in the proportions 40:40:20, 30:30:40 and 50:40:10 of BM, LM and NC respectively. The compositions of the organic meal mixtures are given in Table 4.

The physical and chemical characteristics of the organic meal mixtures viz., odour, colour, moisture content, bulk density, organic carbon content and nitrogen, phosphorus and potassium contents were analysed following the standard analytical methods as adopted for COMs given in Table 3.

3.1.5 Preparation and analysis of standard compost manures (SCMs)

Vermicompost, coir pith compost and city waste compost were prepared under standard conditions as recommended by KAU. The physical and chemical characteristics of the SCMs, viz., standard vermicompost (SVC), standard coirpith compost (SCC) and standard city waste compost (SCWC) were analysed as per methods given in Table 3.

Table.2. Particulars of raw materials selected for analysis and for preparation of OMMs

Serial No.	Code No.	Type of Raw Material
1	NC1	Neem cake powder
2	NC2	Neem cake
3	NC3	Neem cake
4	NC4	Neem cake
5	NC5	Neem powder
6	LM1	Leather waste powder
7	LM2	Leather meal
8	LM3	Leather meal
9	LM4	Leather meal
10	LM5	Leather meal
11	BM1	Bone meal
12	BM2	Bone meal
13	BM3	Bone meal
14	BM4	Bone meal
15	BM5	Bone meal
16	PM1	Pressmud
17	PM2	Pressmud (decomposed)
18	PM3	Pressmud
19	RM47	Ash
20	FM	Fish meal
21	RM7	Castor cake
22	RM56	Decomposed coir pith
23	RM48	Ground nut seed shell
24	RM5	Essence extracted coffee beans powder
25	RM13	ABTEC Biocompost
26	RM14	ABTEC vermicompost

Table.3. Analytical methods used for the physico-chemical characterization of COMs

Sl.No.	Estimated characters	Method	Reference
I.	**Physical parameters**		
1.	Moisture Content (%)	Gravimetric method	Fertilizer (Control) Amendment Order, 2006.Part D, p.75
2.	Odour		
3.	Colour	Visual description	
4.	Bulk Density ($Mg\ m^{-3}$)		Fertilizer (Control) Amendment Order, 2006.Part D, p.75
II	**Chemical parameters**		
1	Total ash (%)	Dry Combustion	Waggoner, 1974
2	Organic carbon (%)	Chromic acid wet digestion method	Walkley and Black (1934)
3.	Total Organic Carbon (%)	Dry Combustion TOC=(100-%ash)/1.8	Waggoner, 1974
4.	Acid Insoluble matter (%)	Digestion with hydrochloric acid	Jaiswal,2003
5.	Total nitrogen (%)	Microkjeldahl digestion using H_2SO_4 and distillation	Jackson (1973)
6.	Organic nitrogen (%)	Total N- (NH_4^+-N)	
7.	Inorganic nitrogen (%)	(NH_4^+-N) by the method of A.O.A.C.	A.O.A.C. (1970)
8.	Total Phosphorus (%)	Samples were digested using 5.5 ml of HNO_3 and 2ml of HCl in microwave digester model Multiwave 3000 by Anton Paar and P estimated by Volumetric Ammonium phospho molybdate method	A.O.A.C. (1960)

Table 3. continued

9.	Total potassium (%)	Samples were digested using 5.5 ml of HNO_3 and 2ml of HCl in microwave digester model Multiwave 3000 by Anton Paar and K estimated by flame photometry	Jackson (1973)
10.	Total Calcium and Magnesium (%)	Samples were digested using 5.5 ml of HNO_3 and 2ml of HCl in microwave digester model Multiwave 3000 by Anton Paar and Ca and Mg estimated using versenate titration with standard EDTA	Jackson (1973)
11	Trace elements	Iron, Manganese and Zinc (mg kg^{-1}): Samples were digested using 5.5 ml of HNO_3 and 2ml of HCl in microwave digester model Multiwave 3000 by Anton Paar and the extract was analysed by Atomic Absorption Spectrophotometer. Copper, Lead and Cadmium (mg kg^{-1}): Acid extract was analysed in Ion Trace analyzer model 797 VA Computrace by Metrohm.	Jackson (1973)
III.	**Biochemical parameters**		
1.	Lignin	Spectrophotometric method	Sadasivam and Manickam,1996
2.	Cellulose	Colorimetric method	Sadasivam and Manickam,1996
3.	Total Phenols	Colorimetric method	Bray and Thorpe, 1954
4.	Water soluble carbohydrates	Acid hydrolysis	Cheshire and Mundie, 1966
5.	Water soluble carbon	Hot water soluble carbon (1:10 manure and water)	McGill et al., 1986
6.	Biodegradability index	BI = 3.166+ 0.059TOC+ 0.832 WSC- 0.011 Days	Morel et al.,1979

Table 4. Composition of organic meal mixtures (OMMs)

Name of organic meal mixture		Proportion of raw materials	Type of raw materials used in the mixture		
			Bone meal	**Leather meal**	**Neem cake**
OMM_1	S_1	40:40:20	BM1	LM1	NC1
	S_2		BM2	LM2	NC2
	S_3		BM3	LM3	NC3
	S_4		BM4	LM4	NC4
	S_5		BM5	LM5	NC5
OMM_2	S_6	30:30:40	BM1	LM1	NC1
	S_7		BM2	LM2	NC2
	S_8		BM3	LM3	NC3
	S_9		BM4	LM4	NC4
	S_{10}		BM5	LM5	NC5
OMM_3	S_{11}	50:40:10	BM1	LM1	NC1
	S_{12}		BM2	LM2	NC2
	S_{13}		BM3	LM3	NC3
	S_{14}		BM4	LM4	NC4
	S_{15}		BM5	LM5	NC5

The COMs were considered as Group 1 and SCMs as Group 2 for the purpose of statistical analysis of the data obtained from the characterization of these manures in order to facilitate comparison between groups and within each group.

3.2 Development of protocol for quality standards of COMs

A mathematical model was developed to compute the quality standards of commercial organic manures prepared by mixing known organic manure ingredients in a specified ratio. The data obtained from the characterization of COMs, raw materials viz., bone meal, leather meal and neem cake and the OMMs were used for the development of the model. The model was developed according to the statistical methods followed in the case of “experiments with mixtures” (Cornell, 2002), which are used to study the performance of various mixtures formed by two or more ingredients the proportions of which in the combination add up to unity.

3.3 Storage study of COMs

In order to study the changes in quality of COMs during storage selected samples were stored under ambient conditions for one year. The storage study was started in January, 2007 and continued till December, 2007. The samples were drawn at quarterly intervals i.e., after the first quarter in March, 2007, after the second quarter in June, 2007, after the third quarter in September, 2007 and after the fourth quarter in December, 2007. The samples were analysed for physical and chemical characteristics by methods as given in Table 3. The samples kept for storage study were:

1. SN 1: Karshakameal
2. SN 8: Sterameal
3. SN 16: Abtec Organic Manure
4. SN 21: Haritha Gold
5. SN 28: Karshaka Organic
6. SN 33: Ecomeal
7. SN 36: Starmeal
8. SN 37: Kotharimeal
9. SVC

10. SCC

11. SCWC

3.4 Collection and analysis of market samples of selected COMs

The quality of the commercial organic manure product may undergo changes after its manufacture in the factory when it is transported to the market and stored till it is sold to the consumer. In order to compare the quality of the factory sample and market sample of the same product, samples of all the COMs available in the market at the time of study were collected from the market outlets and analysed for the physical and chemical characteristics viz., moisture content, bulk density, organic carbon, total nitrogen, total phosphorus and total potassium contents using the methods given in Table 3.

The COMs collected from the market outlets were:

M_1: Sample No.26 Karshaka Agromeal

M_2: Sample No.18. Abtec Super meal

M_3: Sample No.33. Ecomeal

M_4: Sample No. 25. Excelmeal

M_5: Sample No.22. Goldenmeal

M_6: Sample No.41. Kalpameal

M_7: : Sample No.37. Kotharimeal

M_8: Sample No.28. Karshaka Organic

M_9: Sample No. 29. Karshaka Organic Total

M_{10}: Sample No.39. PL meal

M_{11}: Sample No.43. Skymeal

M_{12}: Sample No. 36. Starmeal

M_{13}: Sample No.8. Sterameal

The data obtained from the analysis of the market samples were compared with those of the corresponding factory samples.

3.5 Incubation study on nutrient mineralization.

An incubation study was conducted during December, 2007 to March, 2008 to find out the pattern of release of plant nutrients from organic manures to soil. The COMs for the study were selected on the basis of high nitrogen content as well as the availability of the product in the market. One sample from each of the OMMs was also selected viz., S_1, S_6 and S_{11}. The three SCMs were also included in the incubation experiment.

The technical details of the incubation study are given below.

Design : CRD

Treatments : 13

Replications :03

Treatments :

T_1: SN 8. Sterameal

T_2: SN 41.Kalpameal

T_3: SN 25. Excelmeal

T_4: SN 26. Karshaka Agromeal

T_5 : SN 18. Abtec Supermeal

T_6 : SN 33. Ecomeal

T_7 : S_1

T_8 :S_6

T_9 :S_{11}

T_{10} : SCC

T_{11} : SCWC

T_{12} : SVC

T_{13} : Control (soil alone)

The study was carried out in plastic containers identical in all respects, for a period of three months. The soil for study belonging to the Vellayani series (Typic Kandiustult) was collected from the plot in the Instructional Farm attached to the College of Agriculture, Vellayani, where the field experiment was to be carried out. The collected samples were thoroughly mixed, air dried under shade and sieved through 2mm sieve and analysed for important physico chemical characters using the standard analytical procedures as given in Table 5.

The containers were filled with 2 kg each of this soil and the treatments were applied at room temperature. The manures were applied at the rate of 50 t ha^{-1} which was calculated to be 50g each of manure to be mixed with 2 kg of soil in each container. The manures were mixed thoroughly with the soil in each container. The water holding capacity (WHC) of the soil was determined initially and the moisture content of the soil in each container was maintained at 60 per cent of WHC throughout the period of incubation study by replenishing the water lost by evaporation. The incubation experiment is shown in Plate 4.

Soil samples were taken at fortnightly intervals and analysed for available N, P and K as per the standard analytical procedures given in Table 5.

3.6 Evaluation of selected COMs using the test crop amaranthus

In order to study the efficiency of selected COMs in improving the growth characters and yield of crops, a field experiment was conducted using amaranthus as the test crop. A second crop of amaranthus was raised to study the residual effect of the treatments applied to the first crop.

3.6.1. First Crop

3.6.1.1 Experimental site

The field experiment was conducted in the Area II (Palappoor) Instructional Farm, College of Agriculture, Vellayani. Geographically the area is 8° 5′ North latitude, 77° 1′ East longitude and at an altitude of 29m above MSL.

3.6.1.2 ***Design and layout of experiment***

The lay out of the experiment is presented in Figure 1.

The COMs and SCMs studied in the incubation experiment were included in the field experiment also. The three OMMs in the incubation experiment were replaced with three new COMs.

The technical details of the field experiment are given below.

Table 5. Analytical methods adopted for soil analysis.

Sl.No.	Estimated Character	Method	Reference
1.	Mechanical composition	International pipette method	Piper (1967)
2.	Particle Density	Pycnometer method	Black et al. (1965)
3.	Bulk Density	Core method	Black et al. (1965)
4.	Water holding capacity	Core method	Black et al. (1965)
5.	Soil reaction	Direct reading using pH pen (model Water proof pH testr 2, Eutech Instruments) in 1:2.5 soil- water suspension	Jackson (1973)
6.	Electrical conductivity	Direct reading using EC pen (model Water proof EC Testr, Eutech Instruments) in 1:2.5 soil- water suspension	Jackson (1973)
7.	Organic carbon	Chromic acid wet digestion method	Walkely and Black (1934)
8.	Available Nitrogen	Alkaline potassium permanganate method	Subbiah and Asija (1956)
9.	Available Phosphorus	Extraction with Bray No.1 extractant and estimation by spectrophotometry (stannous chloride method)	Jackson (1973)
10.	Available potassium	Extraction with neutral normal ammonium acetate and estimation by flame photometry	Jackson (1973)

I		II		III	
T5	T14	T12	T3	T6	T8
T2	T11	T9	T14	T9	T14
T8	T1	T11	T1	T10	T11
T6	T4	T8	T5	T4	T2
T9	T13	T6	T4	T3	T1
T10	T7	T10	T7	T5	T13
T12	T3	T13	T2	T7	T12

Figure 1. Lay out of Field Experiment

Design : RBD

Treatments : 14

Replications : 03

Spacing : 20 cm x 20 cm

Plot size : 1.5 m x 2.0 m

Treatments:

T_1: Sample No.8. Sterameal

T_2: Sample No.41. Kalpameal

T_3: Sample No.25. Excelmeal

T_4: Sample No.26. Karshaka Agromeal grade I

T_5 : Sample No.18. Abtec Super meal

T_6: Sample No.43. Skymeal

T_7: Sample No.22. Golden meal

T_8 : Sample No.33. Ecomeal

T_9 : Sample No.28. Karshaka Organic

T_{10} :SVC

T_{11} :SCC

T_{12}:SCWC

T_{13} :P.O.P

T_{14} : Absolute control (No fertilizers or manures)

An overview of the experimental site is presented in Plate 5.

3.6.1.3 ***Crop and variety***

Amaranthus variety Arun was grown as the test crop. The fertilizer recommendation as per the Package of Practices Recommendation of Kerala Agricultural University (KAU, 2002) for the crop is 50:50:50 kg N: P_2O_5: K_2O ha^{-1}.

3.6.1.4 ***Season***

The first crop was grown from November 2007 to January 2008. Weather parameters during the entire cropping season were recorded from the Meteorological Observatory attached to the College of Agriculture, Vellayani, and presented as weekly averages in Appendix III and graphically in Figure 2.

3.6.1.5 ***Planting material***

Seeds of red Amaranthus variety Arun were collected from the Instructional farm, Vellayani.

3.6.1.6 Manures and fertilizers

Urea (46 per cent N), mussooriephos (20 per cent P_2O_5) and muriate of potash (60 per cent K_2O) were used as sources of N, P and K respectively. The COMs selected for the field evaluation were applied as basal dressing in quantities on nitrogen equivalent basis of 50 tonnes ha^{-1} of FYM as per the Package of Practices Recommendation of Kerala Agricultural University (KAU, 2002).

Urea, mussooriephos and MOP were applied uniformly to all treatment plots except absolute control as per P.O.P recommendations of KAU (KAU, 2002). The COMs were applied as per treatment schedule.

Table 6. Quantities of fertilizers and manures applied to first crop

Input	Percentage of nutrient	Quantity required per hectare
Urea	46.0 (N)	108.68 kg
Mussooriephos	20.0 (P)	250.00 kg
MOP	60.0 (K)	83.33 kg
Sterameal	5.6 (N)	8.93 t
Kalpameal	7.0 (N)	7.14 t
Excelmeal (without MOP)	7.9 (N)	6.33 t
Karshaka Agromeal	7.7 (N)	6.49 t
Abtec Super meal	5.9 (N)	8.48 t
Skymeal	6.2 (N)	8.07 t
Goldenmeal	4.9 (N)	10.20 t
Ecomeal	4.9 (N)	10.20 t
Karshaka Organic	5.1 (N)	9.80 t
SVC	1.4 (N)	35.71 t
SCC	0.7 (N)	71.43 t
SCWC	2.1 (N)	23.81 t
FYM	1.0 (N)	50.0 t

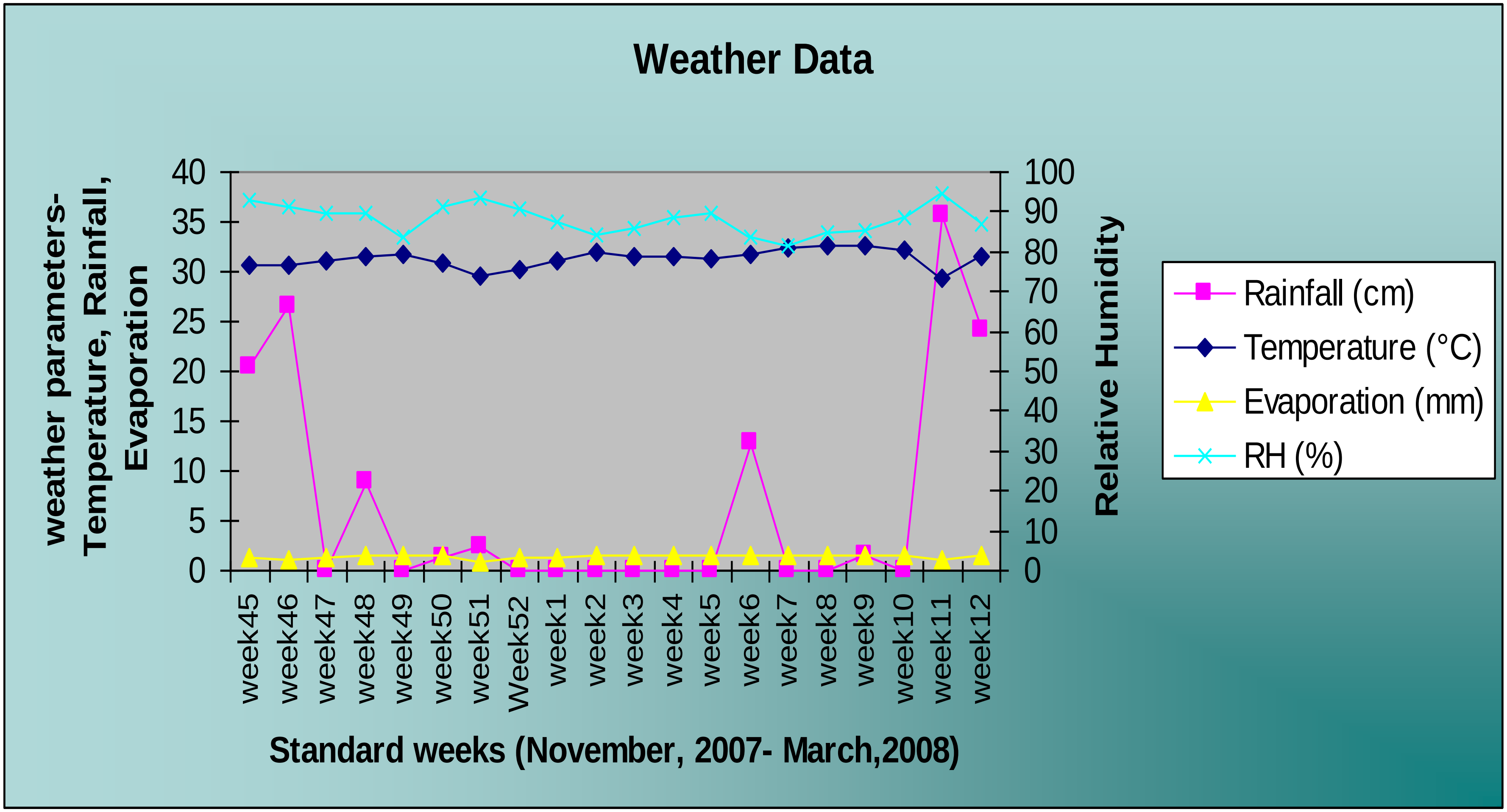


Figure 2. Weather parameters during cropping period

3.6.1.7 ***Details of cultivation***

3.6.1.7.1 ***Nursery***

Amaranthus seedlings were raised in well prepared elevated nursery beds of 1.2m and 15cm height with channels around to facilitate drainage of excess water. A basal dressing of FYM @ 1 kg m^{-2} was applied in nursery beds. The seeds were sown on November 21, 2007 for the first crop. The seedlings were irrigated daily. Hand weeding was done at weekly intervals.

3.6.1.7.2 ***Transplanting***

Fifteen days old robust seedlings were transplanted to main field on 4th December, 2007, @ 75 plants $plot^{-1}$ at a spacing of 20cm x20cm after the application of fertilizers and manures. The crop was irrigated thrice daily.

3.6.1.7.3 ***After cultivation***

Gap filling was done with healthy seedlings so as to maintain 75 plants $plot^{-1}$. Regular irrigation and weeding were carried out.

3.6.1.7.4 ***Plant protection***

There was no major pest or disease incidence and hence only mechanical control measures were adopted. The pest or diseased plant portion was removed and destroyed.

3.6.1.7.5 ***Harvesting***

The first harvest was done on January 1st, 2008, about 1 MAT and the second harvest was done after 2 weeks.

3.6.1.8 ***Growth characters observed***

The following growth characters were recorded from five randomly selected plants from each plot on the first harvest day.

3.6.1.8.1 ***Plant height***

The height of plant was measured from base to the growing tip (top most leaf bud) and the mean values were computed and expressed in cm.

3.6.1.8.2 ***Number of leaves***

The total number of leaves in each observational plant was counted and the average was recorded for each plot.

3.6.1.8.3 ***Stem girth***

The girth of the stem at a height of 5cm from the base was measured in each observational plant and was expressed in cm.

3.6.1.8.4 ***Number of branches***

The total number of branches on each observational plant was counted and the average was recorded for each plot.

3.6.1.8.5 ***Leaf: Stem ratio***

The separate dry weights of the leaves and stems of the observational plants from each plot were determined and the leaf: stem ratios were calculated.

3.6.1.9 ***Yield and yield attributes***

3.6.1.9.1 ***Yield per cutting***

Total weight of leaf and stem portion 10 cm above the ground leaving the woody portion were recorded for each plot and expressed in kg ha^{-1}.

3.6.1.9.2 ***Total Yield per plant***

The weight of the harvested portion of each observational plant in each plot was recorded for each cutting and the total yield was calculated and expressed in kg $plant^{-1}$.

3.6.1.9.3 ***Total Marketable Yield***

The weight of disease and pest free leaf and stem portion was taken as the marketable green yield and expressed in kg ha^{-1}. Plants which had flowered were also excluded.

3.6.1.9.4 ***Total Dry mater production***

Dry matter production (DMP) of whole plant was recorded at the time of harvest. Plants were cut at ground level, dried first in shade and then oven dried at 70°C till two constant weights were obtained. The mean weight was presented as kg ha^{-1}.

3.6.1.10 *Crop Quality Attributes*

The quality of the crop due to the effect of different treatments was determined based on the parameters viz., moisture content, crude fibre, protein, β – carotene and oxalate contents.

3.6.1.10.1 *Moisture content*

Plant samples of known fresh weight were first sun dried and then oven dried at 70°C to a constant weight. The moisture content was expressed as percentage of fresh weight.

3.6.1.10.2 *β -Carotene*

β -carotene content of the plant samples from each treatment was estimated by the method proposed by Srivastava and Kumar (1998) and expressed as μg per 100g of sample.

3.6.1.10.3 *Crude Protein*

The nitrogen contents of the plant samples from each treatment plot were multiplied by the factor 6.25 to obtain the crude protein content of plants and the values were expressed as percentage (Simpson et al., 1965).

3.6.1.10.4 *Crude fibre*

Fibre content of the plant samples was estimated by the method suggested by A.O.A.C (1984) and expressed as percentage.

3.6.1.10.5 *Ash content*

A known weight of dried and powdered plant sample from each plot was ignited to ash and the weight of the ash was expressed as percentage (Piper, 1967).

3.6.1.10.6 *Oxalate*

Oxalate is one of the antinutritional factors present in amaranthus and it interferes with the proper utilization of calcium present in the plant thereby reducing its food value. The quantity of oxalate present in the plant samples from each treatment was determined by the method proposed by A.O.A.C (1984).

3.6.1.11 Plant Analysis

The plant samples were chopped, and dried in an air oven at 70°C till constant weights were obtained. Samples were then ground in a Wiley mill to pass through 0.5mm mesh sieve. The samples were analysed for nitrogen, phosphorus, potassium and sodium at final harvest stage.

3.6.1.11.1 *Nitrogen content and N uptake*

The N content of the plants was estimated by modified microkjeldahl method (Jackson, 1973) and the uptake of N was calculated by multiplying the N content with the dry matter produced in the particular plot and expressed as kg ha^{-1}.

3.6.1.11.2 *Phosphorus content and P uptake*

The P content in plants was estimated by colorimetry (Jackson, 1973). The uptake of P by plants in each treatment was worked out from the P content and dry matter produced, and expressed in kg ha^{-1}.

3.6.1.11.3 *Potassium content and K uptake*

The K content of the plants was estimated by the flame photometric method (Jackson, 1973). The uptake of K by plants was calculated by multiplying the K content in percentage with DMP.

3.6.1.12 Soil Analysis

Soil samples were collected from the experimental site before and after the first crop. The initial soil samples as well as the soil samples collected after the harvest of first crop were processed and analysed as per the methods given in Table 5.

3.6.1.13. Incidence of Pests and Diseases

There was no major pest or disease incidence in the crop.

3.6.2 Second Crop

A second crop of amaranthus was raised for studying the residual effect of manures from February to March 2008. No fertilizers or manures were applied to the crop and all other cultivation practices were carried out in the same manner as for the first crop. Seeds of amaranthus variety Arun were sown in the nursery on January 28, 2008 and transplanting to the main field was done on 12.02.2008. The treatment plots of the first crop were maintained as such for the second crop also. Harvest was done on March 3rd, 2008. As the growth of plants was slow, only one cutting was taken. The observations on growth characters and yield and yield attributes were recorded in the same manner as done for first crop. Plant and soil samples were collected for analyses which were done as per the standard analytical methods given for the first crop.

3.6.3 Economics of cultivation

The economics of cultivation of amaranthus was worked out considering the total expenditure and total income from both first and second crops together and the benefit-cost ratio was calculated as follows:

Benefit: Cost ratio = Gross income/Cost of cultivation

The actual profit obtained for the crop was worked as:

Profit = Gross income- cost of cultivation

3.7 Statistical Analysis

Data generated from the investigations were analysed by applying the analysis of variance technique described by Cochran and Cox (1965) and the significance was tested by F test (Snedecor and Cochran, 1967). In the cases where the effects were found to be significant, CD values were calculated by using standard techniques.

RESULT

4. RESULTS

The data generated from various experiments were subjected to statistical analysis and the results are presented in this chapter.

4.1 CHARACTERIZATION OF ORGANIC MANURES AND RAW MATERIALS

4.1.1 Characterization of Commercial organic manure (COMs) products

The physical, chemical and biochemical characters of the 44 commercial organic manure products were analysed and the results are presented in Tables 7-13. The COMs and SCMs were categorized as group 1 and group 2 respectively, and the statistical analysis was done group-wise so as to facilitate comparison between the commercial organic manure products and standard compost manures.

4.1.1.1 Physical characters of COMs

The physical characters of COMs namely colour, odour, moisture content and bulk density are given in Table 7.

4.1.1.1.1 Colour

The colour of the COMs (Table 7) showed wide variation from light brown to dark brown, grey and black and also mixtures of various shades of brown, grey and black.

4.1.1.1.2. Odour

The odour of the COMs (Table 7) varied as no odour, earthy odour, fruity odour, slightly foul odour and pungent odour.

4.1.1.1.3 Moisture content

The moisture content of the COMs (Table 7) varied from 0.72 per cent in SN 9 (Sterameal) to 46.17 per cent (SN 16-Abtec organic manure). The moisture content of SN 16 was on par with that of SN 19, SN 44 and SN 5. The lowest moisture content recorded in SN 9 was on par with samples SN 23, SN 41, SN 26, SN 22, SN 38, SN 33, SN 8, SN 25, SN 36, SN 37, SN 13, SN 24, SN 39, SN 43, SN 12, SN 31, SN 2, SN 30, SN 27, SN 7, SN 40, SN 14 and SN 10.

Table 7.Physical characteristics of COMs and SCMs

Treatment No.	ODOUR	COLOUR	MOISTURE (%)	BULK DENSITY (Mg m^{-3})
Group 1				
SN 1	Smell of dried dung, no foul odour	Greyish black	30.79	0.40
SN 2	Smell of ground nut, no foul odour	Brown	03.15	0.72
SN 3	No foul odour	Mixture of brown, grey and black	14.01	0.55
SN 4	Odour of neem cake	Mixture of grey, black, brown and yellow	08.17	0.46
SN 5	No odour	Black	43.30	0.57
SN 6	No odour	Yellowish brown	08.88	0.51
SN 7	Slight foul odour	Mixture of white, black, grey and brown	02.81	0.73
SN 8	No foul odour	Mixture of white, black, grey and brown	05.18	0.60
SN 9	Slight foul odour	Mixture of white, black, grey and brown	00.72	0.72
SN 10	Slight foul odour	Mixture of white, black, grey and brown	02.41	0.78
SN 11	No foul odour	Greyish black	25.69	0.55
SN 12	Fermented, fruity smell	Mixture of black, brown, grey, and white	03.57	0.71
SN 13	Slight foul odour	Mixture of black, yellow, grey and brown	04.99	0.55
SN 14	Slight foul odour	Mixture of black, yellow, grey and brown	02.59	0.60
SN 15	Pungent smell	Mixture of dark brown, yellow and black	16.05	0.75
SN 16	Smell of dung	Black	46.12	0.47
SN 17	Pungent odour	Greyish black	24.67	0.58
SN 18	No foul odour	Grey	08.34	0.56
SN 19	Smell of dung	Black	44.36	0.46

Table 7. continued

SN 20	Fermented fruity smell	Mixture of black, grey and brown	11.08	0.53
SN 21	Fermented fruity smell	Greyish black	15.70	0.56
SN 22	Slight odour of neem cake	Mixture of brown, white, grey and black	06.00	0.63
SN 23	Slight foul odour	Black, brown and yellow	06.19	0.69
SN 24	Slight foul odour	Black, greyish brown and white	04.96	0.68
SN 25	No foul odour	Black, greyish brown and white	05.04	0.57
SN 26	Slight foul odour	Black, greyish brown and white	06.01	0.66
SN 27	Slight foul odour	Black, greyish brown and white	02.87	0.67
SN 28	Pungent odour	Black	30.62	0.47
SN 29	Pungent odour	Black	33.02	0.44
SN 30	Slight foul odour	Mixture of black, grey, white and red	03.06	0.83
SN 31	Pungent odour	Mixture of black, grey, white and red	03.52	0.63
SN 32	No foul odour	Grey and brown	09.94	0.57
SN 33	No foul odour	Grey, brown and white	05.63	0.66
SN 34	No foul odour	Grey and white	10.35	0.52
SN 35	Pungent odour	Black, grey	21.70	0.64
SN 36	Smell of bone meal	Mixture of black, grey and yellow	05.00	0.69
SN 37	No foul odour	Grey and brown	05.00	0.64
SN 38	Slight fruity smell	Mixture of black, brown, grey and white	05.97	0.46
SN 39	No foul odour	Mixture of brown, black, grey and yellow	04.44	0.62
SN 40	Pungent odour	Mixture of black, brown, and white	02.77	0.69

Table 7. continued

SN 41	Fermented fruity odour	Mixture of black, brown, yellow and grey	06.10	0.62
SN 42	Earthy smell	Greyish black	23.51	0.67
SN 43	No foul odour	Mixture of yellow, black, brown and grey	03.75	0.58
SN 44	No foul odour	Black, brown	43.31	0.47
Group 2				
SVC	No odour	Black	69.03	0.38
SCC	No odour	Dark brown	80.88	0.30
SCWC	No odour	Brown and black	04.93	0.78
SE	-	-	2.28	0.015
Mean				
Group 1			12.99	0.59
Group 2			51.62	0.49
CD				
Group 1	-	-	6.21	0.039
Group 2	-	-	1.62	0.010
Group 1 Vs. Group 2	-	-	S	S

S-Significant

4.1.1.1.4 Bulk density

The bulk density of the COMs (Table 7) varied from 0.40 Mg m^{-3} in SN1 (Karshakameal) to 0.83 Mg m^{-3}in SN 30 (Sabarimeal). The bulk density of SN 30 was significantly higher than that of all other COMs. It was followed by SN 10 and SN 15 which were on par with each other. The lowest bulk density recorded in SN 1 (0.40 Mg m^{-3}) was on par with SN 29 (0.44 Mg m^{-3}). The next higher value of bulk density was recorded in SN 38 (0.46 Mg m^{-3}) which was on par with SN 19, SN 4, SN 25, SN 44 and SN 16.

4.1.1.2 Chemical characters of COMs

The chemical characters of COMs, viz., ash, organic carbon, total organic carbon, acid insoluble matter, pH , EC, total nitrogen, ammoniacal nitrogen, organic nitrogen, water soluble nitrogen, C/N ratio, total organic carbon/total nitrogen ratio, total phosphorus, water soluble phosphorus, total potassium, water soluble potassium, calcium, magnesium sodium and trace metals are presented in Tables 8-11.

4.1.1.2.1 Ash content

The ash content of COMs (Table 8) varied from 27.45 per cent in SN 20 (Haritha Super) to 68.17 per cent in SN 5 (Vermicompost). SN 5 was not significantly different from SN6 (Fishmeal). SN 20 was on par with SN11 (Fosmeal), SN 3 (Orgameal) and SN 4 (Neem cake).

4.1.1.2.2 Organic carbon content

The organic carbon contents of the COMs are given in Table 8. The organic carbon content of the COMs was highest (31.72 per cent) in SN 20 (Haritha Super) and it was on par with SN 4 (Neem cake-30.23 per cent) and SN 2 (G.N. Vermicake-29.30 per cent). The lowest organic carbon percentage (6.02 per cent) was found in SN 6 (Fishmeal) which was on par with SN 5 which had 6.83 per cent carbon.

4.1.1.2.3 Total Organic carbon content (TOC)

The TOC content of COMs (Table 8) ranged from 17.68 per cent in SN 5(Vermicompost) to 40.30 per cent in SN 20 (Haritha Super). The TOC content of SN 20 was on par with TOC of SN 11 (39.43 per cent) SN 3 (Orgameal), and SN 4 (Neem cake). SN 5 was on par with SN 6 (Fishmeal).

Table 8. Chemical characteristics of COMs and SCMs

Treatment No.	Total Ash (%)	Organic carbon (%)	Total Organic Carbon (TOC) (%)	Acid Insoluble Matter (%)	pH	EC (dSm^{-1})
Group 1						
SN 1	33.70	20.02	36.83	16.42	9.07	7.70
SN 2	39.02	29.30	33.88	9.79	5.13	3.30
SN 3	29.62	20.92	39.10	12.75	6.40	12.13
SN 4	30.00	30.23	38.89	17.14	4.93	15.53
SN 5	68.17	06.83	17.68	56.97	6.67	1.53
SN 6	66.26	06.02	18.74	41.34	8.03	8.50
SN 7	36.54	26.45	35.25	13.66	7.13	6.10
SN 8	40.51	21.32	33.05	22.88	6.57	11.37
SN 9	39.79	22.49	33.45	19.55	7.17	20.03
SN 10	36.25	17.23	35.41	15.08	7.17	20.17
SN 11	29.02	20.02	39.43	10.85	6.63	8.90
SN 12	38.01	17.68	34.44	18.34	6.63	4.37
SN 13	37.47	28.86	34.74	16.49	6.57	4.87
SN 14	35.64	28.86	35.75	25.75	6.43	7.90
SN 15	56.79	16.45	24.00	33.99	7.67	19.87
SN 16	50.37	21.13	27.57	24.75	7.77	10.53
SN 17	51.56	19.18	26.91	16.11	7.87	7.33
SN 18	48.12	23.79	28.82	13.09	6.93	7.13
SN 19	45.84	20.99	30.09	21.85	7.27	8.07
SN 20	27.45	31.72	40.30	10.49	7.13	6.57
SN 21	33.41	24.57	36.99	21.19	7.93	8.73
SN 22	44.67	26.59	30.74	8.26	5.57	19.90
SN 23	42.67	22.62	31.85	19.62	6.03	7.47
SN 24	40.79	24.90	32.89	12.17	5.83	19.97
SN 25	42.45	23.73	31.97	26.21	6.63	5.37
SN 26	48.25	22.88	28.75	9.86	9.03	20.03
SN 27	42.24	23.60	32.09	19.94	9.27	20.00
SN 28	40.04	23.07	33.31	12.26	6.53	18.70
SN 29	45.86	25.55	30.08	13.53	7.60	11.23
SN 30	54.40	24.24	25.34	24.16	6.27	20.03
SN 31	50.17	22.36	27.69	11.35	8.37	10.70
SN 32	61.67	23.53	21.30	12.60	7.30	16.33
SN 33	53.85	21.54	25.63	10.22	6.20	14.47
SN 34	46.65	22.75	29.64	14.09	7.03	19.73
SN 35	47.04	17.23	29.42	22.11	7.77	16.57

Table 8. continued

SN 36	48.79	26.59	28.45	17.37	7.47	5.33
SN 37	40.49	16.31	33.06	27.12	7.87	8.43
SN 38	45.04	21.97	30.53	11.96	6.03	17.83
SN 39	47.07	22.10	29.41	21.45	5.93	10.47
SN 40	37.97	19.31	34.46	14.31	9.37	19.37
SN 41	38.66	26.33	34.08	16.65	6.07	3.27
SN 42	32.54	14.37	37.48	17.78	7.60	6.57
SN 43	43.89	26.20	31.17	17.12	6.80	7.53
SN 44	44.00	24.51	31.11	21.00	8.03	13.53
Group 2						
SVC	43.72	09.75	31.27	21.71	7.10	1.70
SCC	09.81	10.97	50.11	05.87	3.93	3.40
SCWC	42.13	13.29	32.15	20.93	6.57	0.33
SE	0.953	0.911	0.529	0.646	0.037	0.069
Mean						
Group 1	43.47	22.19	31.40	18.63	7.08	11.67
Group 2	31.89	11.33	37.84	16.17	5.87	1.81
CD						
Group 1	2.59	2.48	1.44	1.76	0.10	0.19
Group 2	0.68	0.65	0.38	0.46	0.03	0.05
Group 1 Vs. Group 2	S	S	S	S	S	S

4.1.1.2.4 Acid Insoluble Matter

The percentage of acid insoluble matter in COMs (Table 8) was found to vary from 8.26 per cent in SN 22 (Goldenmeal) to 56.97 per cent in SN 5. SN 5 contained significantly higher amount of acid insoluble matter than all other COMs and it was followed by SN 6 and SN 15 which were also significantly different from each other. SN 37, SN 25 and SN 14 were next in content of acid insoluble matter and were on par. The sample Goldenmeal (SN 22) contained the lowest amount of acid insoluble matter and it was on par with SN 2 and SN 26.

4.1.1.2.5 pH

The acidity/alkalinity of COMs was recorded using their water extracts and the results are presented in Table 8. The pH values ranged from 4.93 in SN 4 to 9.37 in SN 40 (Rajameal). The pH of SN 40 was not significantly different from the pH of SN 27. SN 4 was significantly more acidic than all other COMs, and SN 2, SN 22 and SN 24 also recorded high acidity.

4.1.1.2.6. Electrical conductivity

The EC of COMs (Table 8) was found to range from 1.53 in SN 5 (Vermicompost) to 20.17 dS m^{-1} in SN 10 (Sterameal).The EC was not significantly different among the SN10, SN 30, SN 9, SN 26 and SN 27. SN 5 had significantly lower EC compared to all other COMs.

4.1.1.2.7 Total Nitrogen content

The total nitrogen percentage of COMs given in Table 9 varied from 0.7 per cent to 7.87 per cent. The highest nitrogen content was observed in SN 25 (Excelmeal without MOP) which was on par with SN 26 (Karshaka Agromeal Grade I) and SN 27 (Karshaka Agromeal Grade II). The lowest nitrogen content was recorded in SN 4 (Neem cake) which was significantly less than the next higher nitrogen content of SN 11(1.4 per cent). SN11 was on par with SN 19, SN 44 and SN 42.

4.1.1.2.8 Ammoniacal Nitrogen content

The content of ammoniacal nitrogen (Table 9) was highest in SN 26 (0.53 per cent) followed by SN 2 (0.48 per cent) which was on par with SN 40, SN 28 and SN 7.The ammoniacal N content was lowest in SN 4 (0.01 per cent) and it was significantly lesser than all other COMs. The next higher value of ammoniacal N was

Table 9. Chemical characteristics of COMs and SCMs (continued)

Treatment No.	Total Nitrogen (TN) (%)	Ammoniacal Nitrogen (%)	Organic nitrogen (%)	Water soluble Nitrogen (%)	C/N	TOC/TN
Group 1						
SN 1	2.80	0.10	2.70	0.03	7.15	13.16
SN 2	6.07	0.48	5.58	1.03	4.85	5.59
SN 3	2.33	0.09	2.25	0.34	9.22	17.05
SN 4	0.70	0.01	0.69	0.02	43.18	55.56
SN 5	2.23	0.11	2.12	0.02	3.10	8.01
SN 6	2.10	0.11	1.99	0.02	2.86	8.92
SN 7	7.23	0.45	6.79	0.78	3.70	4.94
SN 8	5.63	0.20	5.43	0.53	3.79	5.87
SN 9	5.60	0.22	5.38	0.44	4.02	5.97
SN 10	3.53	0.07	3.46	0.29	4.88	10.02
SN 11	1.40	0.06	1.34	0.06	14.30	28.17
SN 12	4.87	0.11	4.76	0.35	3.68	7.20
SN 13	6.23	0.39	5.84	0.55	4.63	5.58
SN 14	5.60	0.19	5.41	0.76	5.15	6.39
SN 15	3.50	0.11	3.39	0.19	4.69	6.86
SN 16	2.13	0.08	2.05	0.03	9.90	12.93
SN 17	4.27	0.13	4.14	0.38	4.51	6.32
SN 18	5.93	0.10	5.84	0.55	4.03	4.87
SN 19	1.40	0.06	1.34	0.03	15.00	21.49
SN 20	2.80	0.10	2.70	0.03	11.33	14.39
SN 21	3.73	0.09	3.65	0.21	6.62	9.98
SN 22	4.87	0.19	4.68	0.38	5.46	6.32
SN 23	4.23	0.11	4.12	0.30	5.35	7.52
SN 24	6.30	0.26	6.04	0.56	3.95	5.22
SN 25	7.87	0.18	7.69	0.11	3.02	4.06
SN 26	7.67	0.53	7.14	1.48	2.99	3.75
SN 27	7.47	0.34	7.13	1.17	3.19	4.33
SN 28	5.13	0.46	4.67	1.01	4.51	6.62
SN 29	3.27	0.08	3.18	0.08	7.89	9.27
SN 30	5.13	0.19	4.94	0.48	4.73	4.96

Table 9. continued

SN 31	6.30	0.23	6.07	0.60	3.55	4.39
SN 32	3.97	0.19	3.77	0.24	5.96	5.41
SN 33	4.90	0.08	4.82	0.39	4.40	5.23
SN 34	3.03	0.13	2.90	0.28	7.95	10.35
SN 35	4.17	0.17	3.99	0.38	4.13	7.06
SN 36	4.93	0.23	4.70	0.23	5.39	5.77
SN 37	3.27	0.09	3.17	0.28	5.06	10.25
SN 38	2.80	0.13	2.67	0.11	7.85	10.90
SN 39	4.43	0.17	4.26	0.25	5.03	6.67
SN 40	5.83	0.47	5.37	0.45	3.32	5.92
SN 41	7.00	0.17	6.83	0.37	3.76	4.87
SN 42	1.87	0.10	1.76	0.03	7.97	20.78
SN 43	6.23	0.15	6.08	0.46	4.20	5.00
SN 44	1.63	0.10	1.53	0.04	15.65	19.84
Group 2						
SVC	1.40	0.05	1.35	0.01	6.96	22.33
SCC	0.70	0.05	0.65	0.01	15.66	71.58
SCWC	2.10	0.05	2.05	0.01	6.33	15.31
SE	0.202	0.014	0.202	0.004	0.559	0.034
Mean						
Group 1	4.37	0.18	4.19	0.37	6.73	3.82
Group 2	1.40	0.05	1.35	0.01	9.65	3.93
CD						
Group 1	0.55	0.038	0.55	0.01	1.52	1.23
Group 2	0.14	0.01	0.14	0.003	0.39	0.34
Group 1 Vs. Group 2	S	S	S	S	S	S

S-significant

registered in SN 19 (Abtec Super Organic Manure) and it was on par with SN 11, SN 10, SN 33, SN 16, SN 29, SN 21, SN 3 and SN 37.

4.1.1.2.9 Organic nitrogen content

The organic fraction of nitrogen (Table 9) present in COMs was found to vary from 0.69 per cent in SN 4 to 7.69 per cent in SN 25. SN 25 was on par with SN 26. SN 4 was significantly inferior with regard to organic nitrogen content than all other COMs. The next lowest organic nitrogen content was found in SN 11 (1.34 per cent) which was on par with SN 19, SN 44 and SN 42.

4.1.1.2.10 Water soluble nitrogen

The water soluble nitrogen fraction (Table 9) in COMs ranged from 0.017 per cent in SN 5 to 1.48 per cent in SN 26. SN 26 was significantly superior to all other COMs with respect to water soluble N content. It was followed by SN27 (1.17 per cent), SN 2 (1.03 per cent), SN 28 (1.01 per cent), SN 7 (0.78 per cent), and all were significantly different from each other.

4.1.1.2.11 Carbon / Nitrogen Ratio

The C/N ratio (Table 9) of COMs varied from 2.86 (SN 6) to 43.18 (SN 4). The C/N ratio of SN 4 was significantly higher than that of all other COMs. The second highest value of C/N ratio was recorded in SN 44 which was 15.65 and was on par with SN 19 and SN 11. The ratio was narrowest in SN 6 and it was on par with the ratios in SN 26, SN 25, SN 5, SN 27, SN 40, SN 31, SN 12, SN 7, SN 41, SN 8, SN 24, SN 9, SN 18, SN 35 and SN 43.

4.1.1.2.12 Total Organic Carbon/ Total Nitrogen Ratio (TOC/TN)

The TOC/TN ratios of COMs are given in Table 9.The TOC/TN ratio ranged from 3.75 in SN 26-Karshaka Agromeal grade I to 55.56 in SN 4-Neem cake from TIFFCO. There was significant difference among different COMs with regard to their TOC/TN ratios. SN 4 was significantly superior to all other COMs and it was followed by SN 11 and then by SN19, SN 42 and SN 44, the three of which were on par with each other. At the lower end SN 26 was on par with a large number of COMs.

4.1.1.2.13 Total Phosphorus

The total P content of COMs (Table 10) ranged from 0.12 per cent in SN 4 to 4.57 per cent in SN 25. The P content in SN 25 was on par with that of SN 26 (4.54 per cent). SN 5 recorded the second lowest P content (0.33 per cent) which was on par with SN 14 and SN 1.

4.1.1.2.14 Water Soluble Phosphorus

The water soluble fraction of P found in COMs (Table 10) was in trace quantities only. In some samples water soluble P could not be detected. The highest value was recorded in SN 26 (0.016 per cent) followed by 0.015 per cent in SN 25 and 36.

4.1.1.2.15 Total Potassium

The total K content of the COMs (Table 10) varied from 0.12 per cent to 7.87 per cent. The highest K content was recorded in SN 27-Karshaka Agromeal Grade II which was significantly higher than all other COMs. The next higher K content was found in SN 9 (7.44 per cent) which was on par with SN 10 and SN 24. The lowest K percentage was observed in SN 7 which was on par with SN 23, SN 25, SN43, SN 14, SN 13, SN 41, SN39, SN36, SN 12, SN 5 and SN3.

4.1.1.2.16 Water soluble potassium

The content of water soluble fraction of potassium in COMs (Table 10) was highest in SN 27 (6.18 per cent) followed by SN 24, SN 10, SN 9 and SN 30. All these were significantly different with regard to their water soluble K content. The lowest content of water soluble K was recorded in SN 7 (0.04 per cent) which was on par with SN: 36, 13, 43, 14 and 25.

4.1.1.2.17 Calcium

The content of calcium in COMs (Table 10) ranged from 0.76 per cent in SN 4 (Neem cake) to 10.10 per cent in SN 6 (Fishmeal). SN 6 had significantly higher amount of Ca than all other COMs while SN 4 was significantly inferior to all others in Ca content.

Table 10. Chemical characteristics of COMs and SCMs (continued)

Treatment No.	Total Phosphorus (%)	Water soluble P (%)	Total Potassium (%)	Water soluble K (%)	Calcium (%)	Magnesium (%)	Sodium (%)
Group 1							
SN 1	0.41	0.001	2.00	1.46	3.93	1.35	0.19
SN 2	0.50	0.001	0.78	0.58	1.02	0.09	0.19
SN 3	0.47	0.001	0.52	0.34	3.49	0.25	1.96
SN 4	0.12	0.000	0.80	0.62	0.76	0.28	4.21
SN 5	0.33	0.000	0.35	0.12	1.61	0.33	1.10
SN 6	1.25	0.002	1.06	0.77	10.10	0.07	0.80
SN 7	2.49	0.003	0.12	0.04	1.12	0.08	0.63
SN 8	2.20	0.011	2.39	1.74	1.87	0.13	0.56
SN 9	3.62	0.004	7.44	3.32	2.63	0.79	0.80
SN 10	1.77	0.001	7.30	4.96	1.57	1.06	0.47
SN 11	1.10	0.003	1.88	1.42	7.68	0.38	0.19
SN 12	3.25	0.003	0.29	0.21	5.59	0.74	0.61
SN 13	3.37	0.003	0.19	0.06	2.02	0.75	0.55
SN 14	0.35	0.000	0.19	0.08	2.43	0.88	0.90
SN 15	2.59	0.002	2.21	1.54	6.84	2.05	0.30
SN 16	2.94	0.002	1.84	1.38	7.16	1.87	0.90
SN 17	3.76	0.003	1.12	0.43	4.43	0.57	0.95
SN 18	4.37	0.010	0.94	0.45	3.21	0.94	1.00
SN 19	2.53	0.002	1.72	1.22	2.47	0.49	0.60
SN 20	2.54	0.002	1.69	1.37	4.70	2.16	0.90
SN 21	3.00	0.003	2.51	1.83	3.87	0.68	0.09
SN 22	2.77	0.002	6.00	1.53	3.55	1.22	1.03
SN 23	0.97	0.001	0.15	0.11	2.08	0.34	0.48
SN 24	3.82	0.003	7.03	5.98	1.80	0.44	0.84
SN 25	4.57	0.015	0.17	0.08	1.24	0.08	0.65
SN 26	4.54	0.016	3.18	1.48	2.61	1.04	0.65
SN 27	4.41	0.011	7.88	6.18	2.21	0.53	0.56
SN 28	3.10	0.007	3.31	1.92	3.41	1.00	0.47
SN 29	3.05	0.004	2.79	2.05	3.20	1.08	0.37
SN 30	3.00	0.003	4.09	3.00	4.22	0.57	0.56

Table 10. continued

SN 31	3.67	0.004	4.27	2.87	2.64	1.00	0.70
SN 32	0.57	0.001	1.88	1.03	1.35	1.53	2.00
SN 33	0.54	0.000	0.60	0.57	1.75	1.06	2.10
SN 34	0.83	0.002	2.58	1.84	2.75	0.53	1.49
SN 35	3.69	0.005	3.00	2.11	6.45	0.73	0.37
SN 36	1.30	0.015	0.26	0.05	3.24	0.95	0.80
SN 37	1.87	0.002	0.84	0.80	4.73	1.03	0.56
SN 38	3.31	0.004	0.56	0.50	4.04	1.02	2.80
SN 39	3.37	0.004	0.25	0.18	2.82	1.56	1.74
SN 40	2.77	0.002	3.17	1.47	2.23	0.58	0.37
SN 41	3.69	0.005	0.20	0.13	4.12	0.88	0.34
SN 42	1.65	0.002	1.43	0.88	3.97	1.28	0.20
SN 43	4.09	0.014	0.18	0.08	2.87	1.05	0.68
SN 44	1.99	0.004	3.16	1.52	3.42	1.79	0.37
Group 2							
SVC	0.47	0.00	0.43	0.15	0.23	0.09	0.10
SCC	0.05	0.00	0.20	0.11	0.32	0.13	0.25
SCWC	0.76	0.001	0.16	0.05	0.47	0.05	0.16
SE	0.049	0.396	0.151	0.020	0.029	0.022	0.011
Mean							
Group 1	2.42	0.005	2.14	1.37	3.39	0.85	0.86
Group 2	0.42	0.000	0.26	0.10	0.34	0.09	0.17
CD							
Group 1	0.13	0.65	0.41	0.06	0.08	0.06	0.03
Group 2	0.04	-	0.11	0.01	0.02	0.02	0.01
Group 1 Vs. Group 2	S	S	S	S	S	S	S

4.1.1.2.18 Magnesium

The Mg content of COMs (Table 10) varied significantly. The highest value was observed in SN 20 (2.16 per cent) followed by 2.05 per cent in SN 15 and 1.87 per cent in SN 16. The lowest value of Mg was in SN 6 (0.07 per cent) which was on par with SN 7, SN 25, SN 2 and SN 8.

4.1.1.2.19 Sodium

The total sodium contents of COMs presented in Table 10 showed variation from 0.09 per cent in SN 21 to 4.21 per cent in SN 4. The sample SN 4 was followed by SN 38, SN 33, SN 32, SN 3, SN 39, SN 34, SN 5 and SN 22 which were all significantly different from each other.

4.1.1.2.20 Trace Metals

The content of trace metals viz., iron, zinc, manganese and copper as well as that of heavy metals viz., lead and cadmium in COMs are given in Table 11.

4.1.1.2.20.1 Iron

The iron content (Table 11) of COMs ranged from 847.17 mg kg^{-1} in SN 2 to 9078.17 mg kg^{-1} in SN 42. SN 42 contained significantly higher quantity of Fe than other COMs and it was followed by 9013.50 mg kg^{-1} in SN 17 and 8823.00 mg kg^{-1} in SN 19. The lowest value of Fe in SN 2 was significantly less than the next higher iron content in SN 3 (901.00 mg kg^{-1}).

4.1.1.2.20.2 Zinc

The content of zinc (Table 11) in COMs ranged from non detectable level to 374.83 mg kg^{-1}. Zinc was undetectable in SN 22.The highest value was recorded in SN 20 (374.83 mg kg^{-1}) followed by SN 1 (308.83 mg kg^{-1}).

4.1.1.2.20.3 Manganese

The content of Mn (Table 11) in COMs varied from non-detectable level to 597.00 mg kg^{-1} in SN 15. The data involved mostly N.D (non- detectable) values and hence it was not subjected to statistical analysis.

Table 11. Chemical characteristics of COMs and SCMs-Trace elements

Treatment No.	Iron (mg kg^{-1})	Zinc (mg kg^{-1})	Manganese (mg kg^{-1})	Copper (mg kg^{-1})	Lead (mg kg^{-1})	Cadmium (mg kg^{-1})
Group 1						
SN 1	1178.17	308.83	N.D	N.D	N.D	N.D
SN 2	847.17	267.67	N.D	17.26	N.D	2.34
SN 3	901.00	254.50	N.D	3.42	N.D	4.11
SN 4	2423.33	215.50	438.33	10.56	N.D	1.41
SN 5	1801.67	254.17	N.D	14.34	14.45	3.72
SN 6	2865.50	176.17	N.D	14.26	13.12	1.46
SN 7	3463.33	172.33	N.D	N.D	14.51	N.D
SN 8	4317.83	178.50	N.D	N.D	25.24	N.D
SN 9	2223.00	185.17	N.D	N.D	N.D	N.D
SN 10	4386.67	144.83	201.33	90.34	16.99	2.04
SN 11	4779.17	115.83	N.D	194.74	42.40	N.D
SN 12	3791.50	109.83	N.D	73.41	77.34	1.19
SN 13	1725.83	267.00	N.D	N.D	3.81	N.D
SN 14	2171.83	212.33	N.D	263.93	13.99	2.50
SN 15	2715.50	285.67	597.00	0.686	12.02	N.D
SN 16	1097.57	258.00	552.17	287.30	39.22	3.78
SN 17	9013.50	221.33	387.00	244.49	N.D	N.D
SN 18	5014.33	220.33	519.17	N.D	N.D	N.D
SN 19	8823.00	213.17	N.D	32.23	15.84	1.65
SN 20	2551.71	374.83	N.D	22.53	62.79	6.82
SN 21	3988.33	115.80	N.D	43.89	82.41	N.D
SN 22	1046.67	N.D.	N.D	N.D	22.38	N.D
SN 23	2576.83	222.17	N.D	N.D	34.53	N.D
SN 24	2546.17	305.83	N.D	N.D	N.D	1.01
SN 25	2256.67	279.33	N.D	N.D	44.57	1.08
SN 26	1354.33	262.83	N.D	N.D	22.34	2.23
SN 27	1315.00	262.17	N.D	0.670	1.19	3.34
SN 28	2268.00	262.83	N.D	N.D	1.90	2.44
SN 29	6652.83	294.83	N.D	0.885	N.D	N.D
SN 30	2650.17	185.17	N.D	0.561	N.D	2.23

Table 11. continued

SN 31	3859.67	207.00	N.D	1.008	N.D	3.44
SN 32	3849.00	153.50	N.D	N.D	22.66	1.12
SN 33	2384.00	53.33	N.D	1.19	12.23	1.97
SN 34	8641.67	147.00	N.D	2.03	29.28	N.D
SN 35	8039.33	203.83	N.D	N.D	33.79	N.D
SN 36	1026.00	203.33	N.D	N.D	13.01	0.986
SN 37	5115.00	124.33	N.D	N.D	N.D	4.44
SN 38	1775.00	95.83	N.D	0.453	54.38	N.D
SN 39	4083.50	177.50	N.D	0.663	87.65	1.36
SN 40	3789.67	154.33	N.D	N.D	N.D	3.67
SN 41	3693.67	162.67	377.83	10.25	4.45	2.52
SN 42	9078.17	205.67	N.D	0.550	56.08	N.D
SN 43	1179.17	108.67	275.50	0.886	N.D	5.64
SN 44	3824.17	165.67	N.D	1.019	N.D	N.D
Group 2						
SVC	1114.98	266.17	253.17	N.D	N.D	N.D
SCC	1242.83	7.30	N.D	N.D	N.D	N.D
SCWC	2084.35	7.80	N.D	0.346	N.D	N.D
Mean						
Group 1	3479.19	199.76				
Group 2	1480.72	93.76	-	-	-	-

ND: Not Detectable

4.1.1.2.20.4 Copper

The copper contents (Table 11) of COMs ranged from non-detectable level in most of the samples to a highest value of 287.30 mg kg^{-1}in SN 16. The data being mostly made up of N.D values, no statistical analysis was done.

4.1.1.2.20.5 Lead

The lead content in COMs (Table 11) was mostly in trace quantities and hence undetectable. The highest lead content among COMs was recorded in SN 39 (87.65 mg kg^{-1}) followed by 82.41 mg kg^{-1} in SN 21. The data was not statistically analysed.

4.1.1.2.20.6 Cadmium

The Cd content of COMs (Table 11) varied from traces to 6.82 mg kg^{-1} in SN 20 followed by 5.64 mg kg^{-1} in SN 43. The data was not statistically analysed.

4.1.1.3 Biochemical characters of COMs

The biochemical characters of the COMs viz., lignin, cellulose, lignin/cellulose, total phenols, water soluble carbohydrates, water soluble organic carbon and biodegradability index are given in Tables 12 and 13.

4.1.1.3.1 Lignin

The lignin content of the COMs (Table 12) varied from zero to 64.58 per cent (SN 34). Lignin was absent in COMs: SN 6, SN 7, SN 8, SN 9, SN 30, SN 31 and SN 40. Comparatively high content of lignin was found in samples in the order: SN 34, SN 19, SN 35, SN 37, SN 29, SN 5, SN 4, and SN 17, and all were significantly different in their lignin contents.

4.1.1.3.2 Cellulose

The cellulose content in COMs (Table 12) varied from zero to 15.09 per cent in SN 35. The COMs with cellulose absent in them were: SN 6, SN 7, SN 8, SN 9, SN 30, SN 31 and SN 40. The highest cellulose content in SN 35 was significantly higher than the next value, 11.7 per cent recorded in SN 34.Among those which registered low content of cellulose SN 10 had 0.62 per cent, followed by SN 24 with 0.65 per cent.

Table 12. Biochemical characteristics of COMs and SCMs

Treatment No.	Lignin (%)	Cellulose (%)	Lignin/Cellulose	Total phenols (mg 100g^{-1})
Group 1				
SN 1	2.15(1.47)	1.07	2.01	46.86
SN 2	8.44(2.91)	2.12	3.98	32.63
SN 3	5.50(2.35)	0.98	5.63	38.17
SN 4	34.18(5.85)	5.51	6.22	31.51
SN 5	39.38(6.28)	8.73	4.51	54.12
SN 6	0.00	0.00	0.00	45.71
SN 7	0.00	0.00	0.00	58.05
SN 8	0.00	0.00	0.00	61.14
SN 9	0.00	0.00	0.00	58.22
SN 10	1.19(1.09)	0.62	1.93	65.63
SN 11	9.99(3.16)	5.16	1.94	48.49
SN 12	2.54(1.59)	0 .89	2.85	58.06
SN 13	3.49(1.87)	1.23	2.83	63.39
SN 14	7.49(2.74)	1.06	7.10	55.78
SN 15	8.27(2.88)	2.11	3.91	38.59
SN 16	23.41(4.84)	5.92	3.96	57.86
SN 17	29.94(5.47)	6.03	4.96	88.68
SN 18	9.10(3.02)	1.09	8.38	74.30
SN 19	60.54(7.78)	7.35	8.24	93.27
SN 20	12.82(3.58)	4.23	3.03	43.05
SN 21	4.23(2.06)	2.96	1.46	37.84
SN 22	2.93(1.71)	0.86	3.41	63.75
SN 23	5.33(2.31)	0.78	6.89	50.63
SN 24	3.47(1.86)	0.65	5.32	59.41
SN 25	3.50(1.87)	0.73	4.79	68.92
SN 26	5.47(2.34)	1.23	4.44	88.71
SN 27	12.14(3.49)	1.53	7.96	82.27
SN 28	24.42(4.94)	3.45	7.09	86.88
SN 29	45.73(6.77)	4.22	10.83	92.08
SN 30	0.00	0.00	0.00	45.61

Table 12. continued

SN 31	0.00	0.00	0.00	36.25
SN 32	24.76(4.98)	5.16	4.79	94.80
SN 33	18.42(4.29)	2.12	8.71	83.67
SN 34	64.58(8.04)	11.7	5.52	71.34
SN 35	59.13(7.69)	15.09	3.92	64.64
SN 36	10.29(3.21)	1.26	8.19	55.92
SN 37	53.14(7.29)	6.02	8.83	75.52
SN 38	9.65(3.11)	6.26	1.54	51.35
SN 39	19.52(4.42)	2.08	9.37	65.62
SN 40	0.00	0.00	0.00	48.12
SN 41	18.60(4.31)	2.82	6.61	113.10
SN 42	24.76(4.98)	7.16	3.46	80.71
SN 43	3.87(1.97)	0.87	4.45	63.01
SN 44	22.48(4.74)	10.8	2.08	49.34
SVC	65.56(8.09)	7.55	8.69	73.95
SCC	46.23(6.79)	16.61	2.78	94.91
SCWC	54.16(7.36)	7.74	7.00	100.42
SE	0.027	0.079	0.123	1.752
CD	0.08	0.22	0.35	4.93

*Square root transformed data within parentheses.

4.1.1.3.3 Lignin/ Cellulose Ratio

The ratio between lignin and cellulose contents of COMs (Table 12) was worked out and subjected to statistical analysis. The result showed that the lignin/cellulose ratio ranged from zero in SN 6, SN 7, SN 8, SN 9, SN 30, SN 31 and SN 40, which contained no lignin and cellulose, to 10.83 in SN 29. Among the COMs which contained lignin and cellulose, the lowest value was 1.46 in SN 21. There was significant difference among COMs with regard to the ratio.

4.1.1.3.4 Total Phenols

The total phenol content of COMs (Table 12) ranged from 31.51 mg $100g^{-1}$ in SN 4 to 113.10 mg $100g^{-1}$ found in SN 41. SN 41 contained significantly higher amount of phenols than all other COMs and it was followed by SN: 32, 19 and 29 which were on par. The lowest content of phenols recorded in SN 4 was on par with that in SN 2 and SN 31.

4.1.1.3.5 Water Soluble Carbohydrates (WSC)

The WSC percentages of the COMs (Table 13) showed variation from 0.237 per cent (SN 22) to 1.363 per cent (SN 32). The highest WSC content recorded in SN 32 (Greenmeal) was significantly higher than all others. The next higher WSC content was observed in SN 31 (Biomeal) which was 1.017 per cent. The lowest WSC content was found in SN 22 (Goldenmeal) which was on par with SN 1, SN 18 and SN 10.

4.1.1.3.6 Water Soluble Organic Carbon (WSOC)

The WSOC content of COMs (Table 13) ranged from 0.131 per cent in SN 25 to 0.462 per cent in SN 27. The WSOC content of SN 27 was significantly superior to all other COMs. It was followed by 0.421 per cent in SN 44, which was on par with SN 34 (0.413 per cent). The lowest value of WSOC in SN 25 was significantly different from the next higher value of WSOC in SN 18 (0.147 per cent). SN 18 was on par with SN 33 and SN 23.

4.1.1.3.7 Biodegradability Index (BI)

The biodegradability index of the COMs ranged from 3.15 in SN 5 to 4.21 in SN 4. There was significant difference among the COMs with regard to their BI. The BI of SN 4 was on par with that of SN 32 and SN 20. SN 5 was on par with SN 6.

Table 13. Biochemical characteristics of COMs and SCMs (continued)

Treatment No.	Water soluble carbohydrates (%)	Water soluble organic carbon (%)	Biodegradability Index
Group 1			
SN 1	0.287	0.201	3.85
SN 2	0.573	0.385	3.97
SN 3	0.450	0.334	4.08
SN 4	0.627	0.302	4.21
SN 5	0.337	0.215	3.15
SN 6	0.390	0.256	3.23
SN 7	0.317	0.327	3.82
SN 8	0.377	0.267	3.78
SN 9	0.347	0.273	3.77
SN 10	0.313	0.293	3.82
SN 11	0.317	0.179	3.98
SN 12	0.560	0.168	3.99
SN 13	0.413	0.208	3.87
SN 14	0.493	0.197	3.98
SN 15	0.367	0.223	3.42
SN 16	0.430	0.381	3.61
SN 17	0.483	0.158	3.63
SN 18	0.287	0.147	3.54
SN 19	0.360	0.208	3.65
SN 20	0.460	0.277	4.13
SN 21	0.353	0.312	3.92
SN 22	0.237	0.190	3.57
SN 23	0.320	0.152	3.68
SN 24	0.370	0.289	3.77
SN 25	0.353	0.131	3.72
SN 26	0.417	0.169	3.64
SN 27	0.533	0.462	3.87
SN 28	0.393	0.247	3.80
SN 29	0.633	0.300	3.88
SN 30	0.537	0.324	3.61

Table 13. continued

SN 31	1.017	0.313	4.10
SN 32	1.363	0.387	4.14
SN 33	0.913	0.148	3.94
SN 34	0.863	0.413	4.05
SN 35	0.417	0.177	3.67
SN 36	0.700	0.228	3.87
SN 37	0.620	0.192	3.98
SN 38	0.580	0.389	3.85
SN 39	0.657	0.243	3.87
SN 40	0.623	0.206	4.04
SN 41	0.343	0.189	3.79
SN 42	0.380	0.254	3.95
SN 43	0.670	0.378	3.95
SN 44	0.570	0.421	3.86
Group 2			
SVC	0.283	0.189	3.63
SCC	0.387	0.233	4.45
SCWC	0.343	0.201	3.72
SE	0.029	0.003	0.034
Mean			
Group 1	0.50	0.26	3.82
Group 2	0.34	0.21	3.93
CD			
Group 1	0.079	0.008	0.037
Group 2	0.021	0.002	0.009
Group 1 Vs. Group 2	S	S	S

S- Significant

4.1.2 Characterization of Standard Compost Manures (SCMs)

The standard compost manures viz., standard vermicompost (SVC), standard coir pith compost (SCC) and standard city waste compost (SCWC) were analysed for their physical, chemical and biochemical characters and the results are presented in Tables 7-13.

4.1.2.1 Physical characters

The physical characters of the SCMs are presented in Table 7.

4.1.2.1.1 Colour

The colour of the three SCMs were black for SVC, dark brown for SCC and a mixture of brown and black for SCWC.

4.1.2.1.2 Odour

The three SCMs had no odour.

4.1.2.1.3 Moisture content

The moisture contents of the three SCMs were significantly different from each other. The highest moisture content was recorded in SCC (80.88 per cent) followed by SVC (69.03 per cent) and SCWC (4.93 per cent).

4.1.2.1.4 Bulk density

The bulk density of SCWC (0.78 Mg m^{-3}) was highest, followed by SVC (0.38 Mg m^{-3}) and SCC (0.30 Mg m^{-3}). The values were significantly different from one another.

4.1.2.2 Chemical characters of SCMs

The chemical characters of the SCMs are given in Tables 8-11.

4.1.2.2.1 Ash content

The total ash content (Table 8) of the SCMs were 43.72 per cent in SVC, 42.13 in SCWC and 9.81 in SCC. The composts were significantly different in their ash contents.

4.1.2.2.2 Organic carbon content (Table 8)

The organic carbon content (Table 8) was highest in SCWC (13.29 per cent) followed by SCC (10.97per cent) and SVC (9.75 per cent). The carbon contents of SCMs were significantly different from each other.

4.1.2.2.3 Total Organic carbon content (TOC)

The total organic carbon contents of SCMs are given in Table 8 and the values were 50.11 per cent in SCC, 32.15 per cent in SCWC and 31.27 per cent in SVC. The TOC contents of SCMs were significantly different from each other.

4.1.2.2.4 Acid Insoluble Matter

The content of acid insoluble matter (Table 8) in the SCMs varied from 5.87 per cent in SCC to 21.71 per cent in SVC. SCWC registered a value of 20.93 per cent. All three SCMs were significantly different from each other with regard to their acid insoluble matter content.

4.1.2.2.5 pH

The pH values of SCMs (Table 8) were 7.10 in SVC, 6.57 in SCWC and 3.93 in SCC. All were significantly different from each other.

4.1.2.2.6. Electrical conductivity

The EC of SCMs (Table 8) ranged from 0.33 dS m^{-1} to 3.40 dS m^{-1}. The highest value was found in SCC, followed by 1.70 dS m^{-1} in SVC and the lowest EC was observed in SCWC.

4.1.2.2.7 Total Nitrogen

The content of total nitrogen (Table 9) was highest in SCWC (2.10 per cent) followed by SVC (1.40 per cent) and SCC (0.70 per cent). The three SCMs were significantly different with respect to their nitrogen contents.

4.1.2.2.8 Ammoniacal Nitrogen

The ammoniacal nitrogen fraction in SCMs (Table 9) was uniformly 0.05 per cent in SVC, SCC and SCWC.

4.1.2.2.9 Organic Nitrogen

The fraction of total nitrogen in organic form was significantly different in all three SCMs. The organic nitrogen content (Table 9) of SVC was 1.35 per cent, that of SCC was 0.65 per cent and 2.05 per cent for SCWC.

4.1.2.2.10 Water soluble nitrogen

The water soluble fraction of the total nitrogen (Table 9) in all the three SCMs was uniformly 0.01 per cent.

4.1.2.2.11 Carbon / Nitrogen Ratio (C/N)

The C/N ratios of SCMs (Table 9) were in the range of 6.33 to 15.66. SVC had a C/N ratio of 6.96, SCC had 15.66 and SCWC had a ratio of 6.33. The ratios were significantly different from one another.

4.1.2.2.12 Total Organic Carbon/Total Nitrogen Ratio (TOC/TN)

The TOC/TN ratios of SCMs are given in Table 9.The values were: 71.58 in SCC followed by 22.33 in SVC and the lowest was in SCWC i.e., 15.31. All the three ratios were significantly different from one another.

4.1.2.2.13 Total Phosphorus

The total P contents (Table 10) of SCMs were 0.76 per cent in SCWC, 0.47 per cent in SVC and 0.05 per cent in SCC. All the three values were significantly different from each other.

4.1.2.2.14 Water soluble Phosphorus

The water soluble P content (Table 10) of SVC and SCC was zero and SCWC contained 0.001 per cent water soluble P.

4.1.2.2.15 Total potassium

The total potassium contents (Table 10) of the SCMs were 0.43 per cent in SVC, 0.20 per cent in SCC and 0.16 per cent in SCWC. SCC and SCWC were on par with each other.

4.1.2.2.16 Water soluble potassium

The water soluble K fractions (Table 10) of SCMs were: 0.15 per cent in SVC, 0.11 per cent in SCC and 0.05 per cent in SCWC. The values were significantly different from each other.

4.1.2.2.17 Calcium

The calcium content of SCMs (Table 10) varied between 0.23 per cent and 0.47 per cent and all were significantly different from each other. The highest value was recorded by SCWC and the lowest by SVC. SCC had a calcium content of 0.32 per cent.

4.1.2.2.18 Magnesium

The Mg content (Table 10) of SCMs were 0.13 per cent in SCC, 0.09 per cent in SVC and 0.05 per cent in SCWC. The three SCMs were significantly different from each other with regard to their Mg contents.

4.1.2.2.19 Sodium

The total sodium content (Table 10) of SCMs were 0.25 per cent in SCC, 0.16 per cent in SCWC and 0.10 per cent in SVC. The three standard composts were significantly different with regard to their sodium contents.

4.1.2.2.20 Trace metals

4.1.2.2.20.1 Iron

The iron contents of SCMs (Table 11) were 1114.98 mg kg^{-1} in SVC, 1242.83 mg kg^{-1} in SCC and 2084.35 mg kg^{-1} in SCWC. The values were all significantly different from each other.

4.1.2.2.20.2 Zinc

The Zn contents of SCMs (Table 11) were 7.30 mg kg^{-1} in SCC, 7.80 mg kg^{-1} in SCWC and 266.17 mg kg^{-1} in SVC. SVC was significantly superior to SCC and SCWC with regard to its Zn content, while SCC and SCWC were on par with each other.

4.1.2.2.20.3 Manganese

The Mn content (Table 11) in SVC was 253.17 mg kg^{-1} and both SCC and SCWC contained only traces of the metal which could not be detected by instrumental analysis.

4.1.2.2 .20.4 Copper

Copper (Table 11) could be detected only in SCWC which was 0.346 mg kg^{-1}. In the other two SCMs copper was present only in traces or absent.

4.1.2.2.20.5 Lead

In all the three SCMs, the presence of lead could not be detected (Table 11).

4.1.2.2.20.6 Cadmium

The presence of Cd (Table 11) could not be detected in all three SCMs.

4.1.2.3 Biochemical characters of SCMs

The biochemical characters of SCMs are given in Tables 12 and 13.

4.1.2.3.1 Lignin

The lignin contents (Table 12) of the SCMs were 65.56 per cent in SVC, 54.16 per cent in SCWC and 46.23 per cent in SCC. The values showed significant difference among them. SVC was significantly superior with regard to lignin content.

4.1.2.3.2 Cellulose

The cellulose contents (Table 12) of SCMs were 7.74 per cent in SCWC, 7.55 per cent in SVC and 16.61 per cent in SCC. SVC and SCWC were on par.

4.1.2.3.3 Lignin/ Cellulose Ratio

The lignin/cellulose ratio of SCMs varied from 2.78 to 8.69. SVC had a ratio of 8.69; SCC showed a value of 2.78 and SCWC had a ratio of 7.00. All the values were significantly different from each other.

4.1.2.3.4 Total Phenols

The total phenol contents (Table 12) of the SCMs were recorded as 73.95 mg $100g^{-1}$ in SVC, 94.91 mg $100g^{-1}$ in SCC and 100.42 mg $100g^{-1}$ in SCWC. The phenol contents of the SCMs were significantly different from each other.

4.1.2.3.5 Water Soluble Carbohydrates

The water soluble carbohydrate contents (Table 13) of the SCMs were: 0.387 per cent in SCC, 0.343 per cent in SCWC and 0.283 per cent in SVC. The values were significantly different from one another. SCC was significantly superior with regard to WSC content.

4.1.2.3.6 Water Soluble Organic Carbon

The water soluble carbon contents (Table 13) of SCMs were 0.233 per cent in SCC followed by 0.201 per cent in SCWC and 0.189 per cent in SVC. All three were significantly different from each other and SCC was significantly superior to the other two composts.

4.1.2.3.7 Biodegradability Index

The biodegradability index of the SCMs (Table 13) varied significantly among the three standard composts and it ranged between 3.63 in SVC to 4.45 in SCC. SCWC recorded a value of 3.72 for BI. The BI of SCC was significantly higher than that of SVC and SCWC.

4.1.3. Characterization of raw materials

The raw material used for the preparation of the COMs were analysed of their physical and chemical properties and the results are presented in Tables 14 and 15.

4.1.3.1 Physical characters of raw materials

The physical characters of raw materials viz., colour, odour, moisture content and bulk density are given in Table 14.

4.1.3.1.1 Colour

The colour of raw materials (Table 14) showed a distinct variation within the same category. In bone meal, the colour varied as yellowish brown, brown, greyish brown and dark brown. In leather meal the colour was black, greyish black or ash grey. For neem cake, the colour was dark brown or a mixture of brown, dark brown and yellow. The colour of one sample of pressmud was brownish grey and the other two were greyish black. The colour of castor cake (RM 7) was a mixture of black, grey and brown. The colour of decomposed coir pith (RM 56) was brown and ground nut seed shell (RM 48) was yellowish brown. Fish meal (RM 38) showed light brown

Table 14. Physical characters of raw materials.

Raw material No.	Colour	Odour	Moisture content (%)		Bulk density (Mg m^{-3})	
			Mean	Group mean	Mean	Group mean
BM1	Yellowish brown	Slight foul odour	5.01		0.63	
BM2	Brown	Foul odour	9.57		0.56	
BM3	Light brown	Fruity odour	11.56	9.79	0.54	0.57
BM4	Greyish brown	Slightly pungent	8.69		0.53	
BM5	Dark brown	Pungent odour	14.13		0.57	
LM1	Black	No odour	6.04		0.59	
LM2	Black	No odour	8.08		0.54	
LM3	Greyish black	No odour	6.90		0.56	
LM4	Greyish black	No odour	4.18	6.46	0.62	0.59
LM5	Ash grey	No odour	7.11		0.63	
NC1	Mixture of dark brown, brown and yellow.	Fruity odour	11.63		0.48	
NC2	Greyish brown	Fruity odour	24.23	15.83	0.42	0.49
NC3	Mixture of brown, dark brown and yellow	Fruity odour	17.03		0.46	
NC4	Dark brown	Fruity odour	19.14		0.47	
NC5	Dark brown	Earthy odour	7.13		0.59	
PM1	Brownish grey	No odour	19.39		0.59	
PM2	Greyish black	No odour	15.38	13.65	0.44	0.49
PM3	Greyish black	No odour	6.19		0.43	
RM5	Brownish black	No odour	3.99		0.42	
RM7	Mixture of black, grey and brown	No odour	1.06		0.61	
RM13	Black	No odour	30.21		0.53	
RM14	Black	No odour	50.04		0.55	
RM48	Yellowish brown	No odour	4.05		0.22	
RM56	Brown	No foul odour	87.66		0.39	
FM	Light brown	Pungent	4.76		0.42	
Ash	Black	No odour	4.01		0.17	
SE	-	-	0.369		0.010	
CD	-	-	1.05		0.03	

colour, ash was black, essence extracted coffee beans powder (RM 5) was brownish black, Abtec biocompost (RM 13) and Abtec vermicompost (RM 14) were black in colour.

4.1.3.1.2 Odour

The odour (Table 14) of different types of bone meal varied as fermented fruity odour in BM3, slightly foul odour in BM1, foul odour in BM2 slightly pungent in BM4 and pungent odour in BM5. The leather meal samples had no odour. All neem cake samples except NC5 had fruity odour, while NC5 had an earthy smell. Pressmud, castor cake, essence extracted coffee beans powder, Abtec biocompost (RM 13) and Abtec vermicompost (RM 14), ash and ground nut seed shell (RM 48) had no recognizable odour. The decomposed coir pith (RM 56) had no foul odour while fishmeal had a pungent odour.

4.1.3.1.3 Moisture content

The moisture content of various raw materials (Table 14) showed significant variation. The highest moisture content was recorded in RM 56 which was 87.66 per cent. The lowest moisture content (1.06 per cent) was found in RM 7. The moisture content in RM 56 was significantly higher than that of all other raw materials analysed. It was followed by RM 14 with 50.04 per cent moisture content.

Among the five samples of bone meal, the highest moisture content was found in BM5 with 14.13 per cent and the lowest was in BM1 with 5.01 per cent moisture. BM2 (9.57 per cent) was on par with BM4 (8.69 per cent). The average moisture content of bone meal was 9.79 per cent. Among leather meal samples, the highest moisture percentage was recorded in LM2 (8.08 per cent) and the lowest was in LM4 (4.18 per cent) with a mean moisture content of 6.46 per cent. LM4 was significantly inferior to the other leather meal samples with regard to moisture content. In the group of neem cake, NC2 contained the highest moisture percentage (24.23 per cent) and the driest sample was NC5 with only 7.13 per cent moisture. The overall mean for neem cake was 15.83 per cent and all the neem cake samples were significantly different from each other with regard to moisture content. Among the three pressmud samples, PM1 had 19.39 per cent moisture while PM3 had only 6.19 per cent and the average was 13.65 per cent. All the three pressmud samples were significantly different from each other in moisture content. Among the group of miscellaneous raw materials, the highest moisture content was found in RM56 (87.66 per cent), followed by RM14 (50.04 percent) and RM13 (30.21 per cent), while RM7 was the driest (1.06 per cent). The group mean for miscellaneous raw materials was not considered because of the highly heterogeneous nature of its components. The raw materials viz., FM, RM48, ash and RM5 were on par with each other.

4.1.3.1.4 Bulk density

The highest value for the bulk density (Table 14) of the raw materials (0.63 Mg m^{-3}) was recorded in BM1 and LM 5. It was followed by 0.62 Mg m^{-3} in LM4, and 0.61 Mg m^{-3} in RM 7. All these were on par. The lowest bulk density among the raw materials was noted in ash (0.17 Mg m^{-3}) followed by 0.22 Mg m^{-3} in RM 48.

Among the five types of bone meal, the highest bulk density was recorded in BM1 (0.63 Mg m^{-3}) followed by BM5 with 0.57 Mg m^{-3}. BM1 was significantly superior to all other types of bone meal samples with regard to bulk density. The lowest bulk density was in BM4 (0.53 Mg m^{-3}) and the overall mean was 0.57 Mg m^{-3}. In leather meal group, the highest bulk density ranged from 0.54 Mg m^{-3}in LM2 to 0.63 Mg m^{-3} in LM5. But all the leather meal samples were on par with regard to bulk density and the group mean was 0.59 Mg m^{-3}.Among the neem cake samples, the highest bulk density was registered as 0.59 Mg m^{-3}in NC5, which was significantly superior to all others, and the lowest was in NC2 (0.42 Mg m^{-3}), which was significantly inferior to all others. NC1, NC3 and NC4 were on par. The group mean was 0.49 Mg m^{-3}. For the pressmud category, the highest bulk density was 0.59 Mg m^{-3} in PM1 and the lowest was 0.43 Mg m^{-3} in PM3 and the mean was 0.49 Mg m^{-3}. PM1 registered significantly higher bulk density while PM2 and PM3 were on par. In the miscellaneous group of raw materials, the lowest bulk density was recorded in ash (0.17 Mg m^{-3}) and the highest was 0.61 Mg m^{-3} in RM7. Since the group consisted of widely varying materials the group mean was not considered relevant. RM7 recorded significantly higher bulk density compared to all other raw materials in the group. RM13 and RM14 were on par with each other, while RM5, RM56 and FM were also on par.

4.1.3.2 Chemical characters of raw materials

The chemical characters of the raw materials are presented in Table 15.

4.1.3.2.1 Nitrogen

The highest nitrogen content (Table 15) among raw materials (9.03 per cent) was recorded in LM2 followed by 7.10 per cent in RM7 and 6.53 per cent in LM3. The raw materials were significantly different with regard to their nitrogen contents. The lowest nitrogen content was 0.40 per cent in ash, followed by 0.77 in FM.

Among the various types of bone meal, the highest nitrogen content was recorded in BM1 with 4.23 per cent and the lowest was in BM2 with 3.10 per cent. The group mean value was 3.73 per cent. BM1 was on par with BM3 which was on par with BM5. BM2 and BM4 were also on par with each other. The leather meal group recorded highest value of 9.03 per cent N in LM2 and a lowest value of 2.47 per cent in LM4 and the group mean value was 5.75 per cent. LM1 and LM5 were on par. In neem cake group, the N content varied from 1.53 per cent in NC1 to 2.00 per cent in NC3 and the group mean was 1.78 per cent. The neem cake samples were on par with each other with regard to nitrogen content. In pressmud, the N content varied from 1.47 per cent in PM3 to 1.77 per cent in PM1, but all the three samples were on par. The mean N content was 1.59 per cent for pressmud. In the miscellaneous group of raw materials, the highest N content was found in RM7 with 7.10 per cent and the lowest was in ash with only 0.40 per cent. Since the group consisted of highly heterogeneous materials the group mean was not relevant. RM7 was significantly superior to all other raw materials in the group while ash was significantly inferior to all others. RM5, RM13, RM14 and RM48 were on par with each other wit regard to their N contents.

4.1.3.2.2 Phosphorus

The phosphorus content (Table 15) of the raw materials ranged from 0.12 per cent in ash to 10.36 per cent in BM3. The raw materials showed significant difference with regard to their P contents. BM3 was significantly superior to all other raw materials and it was followed by BM4 with 9.77 per cent P and BM1 with 9.36 per cent. The P content in ash was on par with that in RM48 (0.23 per cent).

Among the five types of bone meal, the highest P content was found in BM3 (10.36 per cent) and the lowest was in BM2 (6.18 per cent) the average P content of

Table 15. Chemical characters of raw materials

Raw material type	Raw material No.	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sodium (%)		Organic carbon (%)	
		Mean	Group mean	Mean	Group mean	Mean	Group mean	Mean	Group mean	Mean	Group mean
Bone meal	BM1	4.23	3.73	9.36	8.83	0.25	0.36	0.55	0.59	12.65	10.04
	BM2	3.10		6.18		0.72		0.42		9.91	
	BM3	4.07		10.36		0.25		0.62		5.66	
	BM4	3.40		9.77		0.25		0.64		11.63	
	BM5	3.83		8.45		0.31		0.73		10.34	
Leather meal	LM1	5.47	5.75	0.32	0.37	0.02	0.02	0.46	0.51	12.49	14.49
	LM2	9.03		0.36		0.01		0.74		17.73	
	LM3	6.53		0.39		0.03		0.83		19.33	
	LM4	2.47		0.38		0.02		0.28		9.28	
	LM5	5.27		0.38		0.02		0.23		13.59	
Neem cake	NC1	1.53	1.78	0.45	0.42	1.30	1.11	0.19	1.08	23.96	20.58
	NC2	1.77		0.36		0.95		1.68		18.56	
	NC3	2.00		0.52		1.05		0.92		29.39	
	NC4	1.63		0.42		1.26		1.16		19.35	
	NC5	1.97		0.35		0.99		1.46		11.64	
Pressmud	PM1	1.77	1.59	2.24	2.33	2.76	2.33	0.11	0.14	15.13	14.19
	PM2	1.53		2.33		2.76		0.17		15.57	
	PM3	1.47		2.43		1.47		0.14		11.88	
Miscellaneous	RM5	1.43		0.46		0.30		0.13		32.87	
	RM7	7.10		1.85		0.78		0.24		27.89	
	RM13	1.37		2.07		2.86		0.28		18.80	
	RM14	1.40		1.85		0.21		0.15		9.56	
	RM48	1.40		0.23		0.56		0.13		22.03	
	RM56	2.10		0.39		0.07		0.18		25.22	
	FM	0.77		1.02		0.08		0.46		5.69	
	Ash	0.40		0.12		0.97		0.19		6.52	
SE		0.126		0.064		0.036		0.024		1.14	
CD		0.36	S	0.18	S	0.103	S	0.069	S	3.25	S

S-significant

bone meal was 8.83 per cent. The five types of bone meal samples were significantly different from each other with regard to P content. In leather meal, the highest P was found in LM3 (0.39 per cent) and the lowest was 0.32 per cent found in LM1, but all the leather meal samples were on par with each other. The average P content of leather meal was 0.37 per cent. For neem cake, the P content varied from 0.35 in NC5 to 0.52 in NC3 with a mean of 0.42 per cent and all the neem cake samples were on par with each other. For pressmud, the mean P content was 2.33 per cent with a maximum of 2.43 per cent and a minimum of 2.24 per cent, and all the pressmud samples were on par. Among the miscellaneous group of raw materials, the highest content was found in RM13 (2.07 per cent) and the lowest was 0.12 per cent in ash. Since the group consisted of highly heterogeneous materials the group mean was not relevant. RM13 was significantly superior to all others with regard to P content while ash was on par with RM48. RM7 and RM14 were also on par, as was RM5 and RM56.

4.1.3.2.3 Potassium

The K content (Table 15) of raw materials ranged from 0.01 per cent in LM2 to 2.86 per cent in RM13 (Abtec biocompost). The raw materials were significantly different with regard to their K contents. RM13 was on par with PM1 and PM2 with regard to their K contents. The lowest K content recorded in LM2 was followed by 0.02 per cent K in LM1, LM4 and LM5.

In the group of bone meal, the highest K content was found in BM2 with 0.72 per cent and the lowest was 0.25 per cent in BM1, BM3 and BM4. The group mean K content was 0.36 per cent. BM1, BM3, BM4 and BM5 were on par. Among five types of leather meal, the K content varied from 0.01 per cent in LM2 to 0.03 per cent in LM3 with an average K content of 0.02 per cent, and all the leather meal samples were on par. For neem cake the K content ranged from 0.95 per cent in NC2 to 1.30 per cent in NC1 and the mean K content was 1.11 per cent. NC1 and NC4 were on par while NC2, NC3 and NC5 were on par with each other. The pressmud group had a mean K content of 2.33 per cent with a maximum of 2.76 per cent in PM1 and a minimum of 1.47 per cent in PM3. PM1 and PM2 were on par. In the group of miscellaneous raw materials, the highest K content was recorded as 2.86 per cent (RM13) and the lowest value was observed in RM56 (0.07 per cent). Since the group consisted of highly heterogeneous materials the group mean was not relevant. RM13 was significantly superior to all other raw materials in the group and it was followed by ash (0.97 percent), RM7 (0.78 per cent) and RM48 (9.56 per cent) which were all significantly different for each other. RM5 and RM14 were on par while FM and RM56 were also on par with each other.

4.1.3.2.4 Sodium

The sodium content of raw materials (Table 15) ranged from 0.11 per cent in PM1 to 1.68 per cent in NC2. The raw materials showed significant difference with regard to their Na contents. NC2 was significantly superior to all other raw materials in Na content. It was followed by NC5, NC4, NC3 and LM3 which were significantly different from each other. PM1 was on par with PM2, PM3, RM5, RM14, RM48 and RM56.

In the group of bone meal, the highest sodium content was recorded in BM5 (0.73 per cent) and the lowest value was found in BM2 (0.42 per cent). BM5 contained significantly higher amount of sodium compared to all other types of bone meal, while BM2 was significantly inferior with regard to Na content. BM1, BM3 and BM4 were on par with each other. The group mean Na content was 0.59 per cent. In leather meal category, the highest sodium content was found in LM3 (0.83 per cent) and the lowest was in LM5 (0.23 per cent). LM3 was significantly superior with regard to Na content while LM5 was on par with LM4 (0.28 per cent Na).The group mean sodium content of leather meal was 0.51 per cent. In the group of neem cake, the highest Na content was observed in NC2 with 1.68 per cent and the lowest value was found in NC1 (0.19 per cent). All the five types of neem cake were significantly different from each other with regard to their Na contents with a group mean value of 1.08 per cent. Among different types of pressmud, the sodium content varied between 0.11 per cent and 0.17 per cent and all the three pressmud samples were on par with each other with a group mean of 0.14 per cent. In the miscellaneous group of raw materials, the highest Na content was found in FM with 0.46 per cent and the lowest was in RM5 and RM48 (0.13 per cent). FM was significantly superior to all other raw materials in the group. Since the group consisted of highly heterogeneous materials the group mean was not relevant.

4.1.3.2.5 Organic carbon

The organic carbon content of raw materials (Table 15) varied between 5.66 per cent and 32.87 per cent. The highest organic carbon content was recorded in RM5 (essence extracted coffee beans powder) and it was significantly higher than all other raw materials analysed. It was followed by NC3 with 29.39 per cent and RM 7 with 27.89 per cent organic carbon. The lowest organic carbon content was found in BM3 (5.66 per cent).It was on par with FM and ash. The group mean value for organic carbon was lowest for bone meal.

Among the different types of bone meal samples, the highest organic carbon content was found in BM1 with 12.65 per cent and the lowest was in BM3 with 5.66 per cent. The five types of bone meal had a mean organic carbon content of 10.04 per cent. BM1, BM2, BM4 and BM5 were on par. In the category of leather meal, the highest organic carbon content was observed in LM3 with 19.33 per cent and the lowest was in LM4 with 9.28 per cent with a group mean value of 14.49 per cent. LM3 was on par with LM2 while LM1, LM4 and LM5 were on par. In neem cake, the highest value for organic carbon was found in NC3 with 29.39 per cent while the lowest was 11.64 per cent in NC5 and the mean value was 20.58 per cent. For pressmud, the mean organic carbon content was 14.19 per cent with range of 11.88 per cent to 15.57 per cent. All the pressmud samples were on a par with regard to their organic carbon contents. Among the miscellaneous group of raw materials, the highest organic carbon content was in RM5 (32.87 per cent) and the lowest was 5.69 per cent in fishmeal (FM). Since the group consisted of highly heterogeneous materials the group mean was not relevant. RM5 was significantly superior to all others with regard to organic carbon content.

4.1.4 Effect of Composition of Raw Materials on Quality of Organic Meal Mixtures (OMMs)

The fifteen organic meal mixtures belonging to three groups of OMMs were analysed to estimate their physical and chemical properties. The results of analyses are presented in Tables 16 and 17.

4.1.4.1 Physical Properties

The data on the physical characters of OMMs are presented in Table 16.

Table 16. Physical characters of prepared organic meal mixtures (OMMs)

OMM group	OMM No.	Colour	Odour	Moisture content (%)		Bulk density (Mg m^{-3})	
				Mean	Group mean	Mean	Group mean
OMM1	S_1	Mixture of brown, white, yellow and grey	Slight fruity odour	8.19	7.32	0.66	0.618
	S_2	Mixture of black, grey, white and red	"	7.59		0.58	
	S_3	Mixture of black , grey and white	No foul odour	7.04		0.60	
	S_4	"	"	7.86		0.64	
	S_5	Mixture of brown and black	Slight foul odour	5.93		0.61	
OMM2	S_6	Mixture of brown, white and grey	Slight fruity odour	6.77	7.58	0.56	0.566
	S_7	Mixture of light grey, dark brown, black and red.	"	8.22		0.56	
	S_8	Mixture of grey, dark brown, black and white	Smell of neem cake	7.57		0.55	
	S_9	Mixture of black, grey, brown and white	Slight foul odour	8.42		0.56	
	S_{10}	Mixture of brown, grey, and black	Slight pungent odour	6.93		0.60	
OMM3	S_{11}	Mixture of brown, white and grey	Slight fruity odour	7.45	7.37	0.63	0.595
	S_{12}	Mixture of light brown, off white, dark brown and black	"	7.58		0.56	
	S_{13}	Mixture of black, grey , brown and white	No foul odour	7.24		0.59	
	S_{14}	Mixture of black, brown and grey	Slight foul odour	6.94		0.62	
	S_{15}	Mixture of dark brown, light brown, grey, black and yellow.	Pungent odour	7.63		0.58	
SE				0.884		0.021	
CD				NS	NS	0.060	S

S- Significant NS- Not significant

4.1.4.1.1 Colour of OMMs

The colours of OMMs (Table 16) were various mixtures of brown, black, white, yellow and red, and thus gave a mottled appearance.

4.1.4.1.2 Odour of OMMs

The odour of OMMs (Table 16) varied as fruity odour, no foul odour, slight foul odour and pungent odour.

4.1.4.1.3 Moisture content of OMMs

The moisture contents of OMMs (Table 16) did not vary significantly. The highest moisture content was 8.42 per cent and it was recorded in S_9. It was followed by 8.22 per cent in S_7. The lowest moisture content was found in S_5 which was 5.93 per cent followed by 6.77 per cent in S_6.

4.1.4.1.4 Bulk Density of OMMs

There was no significant difference among OMMs when their bulk densities were compared (Table 16). The highest bulk density was recorded in S_1 (0.66 Mg m^{-3}) followed by S_4 and S_{11}. The lowest bulk density was observed in S_8 (0.55 Mg m^{-3}) followed by S_7 and S_{12}.

4.1.4.2 Chemical Properties

The chemical characters of the OMMs are presented in Table 17.

4.1.4.2.1 Organic Carbon

The organic carbon content (Table 17) of the various organic meal mixtures was estimated and the results were statistically analysed. The highest value of organic carbon among the OMMs was recorded in S_7 (22.80 per cent) which was on par with S_6 (19.85 per cent). The lowest value was recorded in S_{10} (9.94 per cent) and it was on par with S_2, S_4, S_{14} and S_{15}.

The three groups of OMMs were compared and the highest mean content of organic carbon (16.74 per cent) was found in the group OMM_2 which includes organic meal mixtures from S_6 to S_{10} and it was significantly different from the mean organic carbon percentages of the other two groups.

Within the group OMM_1, the effect of raw materials from different sources was compared and the highest organic carbon per cent was observed in S_1 (16.47 per cent) followed by S_5 and S_3, and all were on par with each other. The lowest value of organic carbon was noted in S_4 (10.19 per cent) which was significantly lower than all others.

Within the second group OMM_2, the raw materials used to prepare S_7 were found to contribute significantly higher amount of organic carbon (22.80 per cent) than all other products in the group. S_8 and S_9 were on par with each other and the lowest amount of organic carbon was recorded in S_{10} (9.94 per cent).

Within the group OMM_3, the highest organic carbon per cent was in S_{11} (16.49 per cent) which was on par with S_{13} (15.96 per cent). The lowest quantity of organic carbon was in S_{15} (10.86 per cent) which was on par with S_{14} (11.43 per cent).

4.1.4.2.2 Nitrogen

The nitrogen content (Table 17) present in OMMs varied from 3.53 per cent in S_7 to 5.60 per cent in S_{15}. There was significant difference between different organic meal mixtures with regard to their N content. S_{15} was on par with S_{11}, S_{13}, S_{12}, S_1, S_6 and S_{14}. The low content of N in S_7 was on par with the N content in S_{10} and S_5.

The three groups of OMMs were significantly different from each other in their N content. The highest mean N content of 5.33 per cent was observed in the group OMM_3 and it was significantly higher than the other two groups. It was followed by OMM_1 with 4.46 per cent, and it was on par with OMM_2 with 4.27 per cent.

Within the group OMM_1, the nitrogen content varied from 4.07 per cent in S_4 and S_5 to 5.13 per cent in S_1. S_3 had a nitrogen content of 4.70 per cent and it was on par with S_2. Also S_2, S_4 and S_5 were on par.

Within OMM_2, the lowest nitrogen content was found in S_7 (3.53 per cent) which was on par with S_{10} (3.60 per cent). The highest N content was observed in S_6 (4.97 per cent) and it was on par with S_9 and S_8.

Within OMM_3, the highest N content was in S_{15} (5.60 per cent) which was on par with S_{13}, S_{11} and S_{12}. The lowest N content was found in S_{14} (4.97 per cent) and it was on par with S_{12}.

Table 17. Chemical characters of prepared organic meal mixtures (OMMs)

OMM group	OMM No.	Organic Carbon%		Total Nitrogen (%)		Total phosphorus (%)		Total Potassium %	
		Mean	Group mean	Mean	Group mean	Mean	Group mean	Mean	Group mean
OMM_1	S_1	16.47	13.87	5.13	4.46	3.49	3.32	0.21	0.19
	S_2	12.70		4.33		2.65		0.20	
	S_3	14.80		4.70		3.74		0.16	
	S_4	10.19		4.07		3.39		0.28	
	S_5	15.17		4.07		3.34		0.10	
OMM_2	S_6	19.85	16.74	4.97	4.27	2.63	2.58	0.33	0.23
	S_7	22.80		3.53		3.21		0.27	
	S_8	16.13		4.57		2.44		0.26	
	S_9	14.96		4.67		2.14		0.11	
	S_{10}	9.94		3.60		2.49		0.18	
OMM_3	S_{11}	16.49	13.81	5.37	5.33	4.56	4.59	0.16	0.28
	S_{12}	14.31		5.33		3.40		0.23	
	S_{13}	15.96		5.37		5.63		0.17	
	S_{14}	11.43		4.97		4.75		0.20	
	S_{15}	10.86		5.60		4.61		0.63	
SE		1.25		0.243		0.226		0.032	
CD		3.59	1.61	0.701	0.313	0.653	0.292	0.091	0.041

4.1.4.2.3 Phosphorus

The P content (Table 17) of OMMs varied from 2.14 per cent to 5.63 per cent. The lowest value was noted in S_9 and the highest value in S_{13}. There was significant difference among OMMs with respect to their P content. S_{13} was followed by S_{14}, S_{15} and S_{11}which were all on par with each other. The lowest P content in S_9 was on par with S_8, S_{10} and S_6.

Among the three groups, OMM_3 had the highest mean P content of 4.59 per cent and it was significantly superior to OMM_2 and OMM_1. OMM_1 had a mean P content of 3.32 per cent and the lowest P content was in OMM2 with 2.58 per cent.

Within OMM_1, the lowest P content was recorded in S_2 (2.65 per cent) and the highest P content was in S_3 (3.74 per cent).There was significant difference among the organic meal mixtures within OMM_1 with regard to their P content. S_3 was on par with S_1 and S_4. S_2 was significantly inferior with regard to P content. S_4 and S_5 were on par.

Within OMM_2, S_7 was significantly superior in P content (3.21 per cent). The lowest P content was in S_9 (2.14 per cent). S_6, S_{10} and S_8 were on par. S_9 was on par with S_8.

In OMM_3, the highest P content was in S_{13} (5.63 per cent) and the lowest was S_{12} (3.40 per cent). S_{14}, S_{15} and S_{11} were on par regarding their P content.

4.1.4.2.4 Potassium

The potassium content (Table 17) of OMMs showed significant variation among different combination of raw materials. The highest K content was observed in S15 (0.63 per cent) and the lowest was in S_5 (0.10 per cent). S15 was significantly superior in K content and it was followed by S_6 which was on par with S_4, S_7 and S_8. S_5 was on par with S_9, S_3, S_{11} and S_{13}.

Among the three groups, the highest mean K content was recorded in OMM3 with 0.28 per cent. It was followed by OMM_2 with 0.23 per cent and the lowest was in OMM_1 (0.19 per cent). OMM1 and OMM_2 were on par regarding their K content.

In the group OMM_1, the highest K content was found in S_4 with 0.28 per cent. The lowest K content was in S_5 (0.10 per cent). S_1, S_2 and S_3 were on par with each other.

Within OMM_2, the highest K content was in S_6 (0.33 per cent) followed by S_7 and S_8 which were on par. The lowest K content (0.11 per cent) was found in S_9.

In OMM_3, the highest K content was found in S_{15} (0.63 per cent) followed by S_{12} and S_{14} which were on par. The lowest K content was in S_{11} (0.16 per cent) and it was on par with S_{13} and S_{14}.

4.2 DEVELOPMENT OF PROTOCOL FOR QUALITY STANDARDS OF COMs

4.2.1 Development of mathematical model

A mathematical model was developed for predicting the quality standards viz., nitrogen, phosphorus and potassium contents of COMs prepared by mixing different proportions of bone meal, leather meal and neem cake. The data used for the development of mathematical model are given in Table 18. The model parameters or partial regression coefficients are presented in Table 19a. Based on these, the equations for estimating N, P and K are:

N estimated= 3.62088 BM+ 6.58962 LM+ 1.74407 NC+ 4.74391 (BM)x(LM) + 7.8398 (BM) x (NC) – 9.87862 (LM)x(NC), where BM is the proportion of bone meal in the mixture, LM is the proportion of leather meal in the manure and NC is the proportion of neem cake in the mixture.

P estimated= 8.41214 BM+ 0.37157 LM+ 0.41953 NC- 2.73548 (BM) x (LM) + 10.15749 (BM) x (NC) – 8.72905 (LM) x (NC)

K estimated= 0.38543 BM+ 0.01872 LM+ 1.19747 NC+ -0.04393 (BM) x (LM) + 2.98573 (BM) x (NC) – 5.64704 (LM) x (NC)

4.2.2 Prediction of quality standards of COMs

Based on the model the theoretical values of important quality parameters of COMs viz., nitrogen, phosphorus and potassium contents were estimated for various combinations of raw materials. The estimated values are given in Table 19b. Various combinations of raw materials to obtain different levels of nitrogen, phosphorus and potassium were arrived at using the model.

Table 18. Data used for the development of mathematical model

Serial No.	Proportion of raw materials			Moisture content (%)	Bulk density (dS m^{-1})	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Organic carbon (%)
	Bone meal	Leather meal	Neem cake						
1	1	0	0	5.01	0.63	4.23	9.36	0.25	12.65
2	1	0	0	9.57	0.56	3.10	6.18	0.72	9.91
3	1	0	0	8.69	0.53	3.40	9.77	0.25	11.63
4	0	1	0	6.04	0.59	5.47	0.32	0.02	12.49
5	0	1	0	6.90	0.56	6.53	0.40	0.03	19.33
6	0	1	0	7.11	0.63	5.27	0.38	0.02	13.59
7	0	0	1	11.63	0.48	1.53	0.45	1.30	23.96
8	0	0	1	19.14	0.47	1.63	0.42	1.26	19.35
9	0.4	0.4	0.2	8.19	0.66	5.13	3.49	0.21	16.47
10	0.4	0.4	0.2	7.59	0.58	4.33	2.65	0.20	12.70
11	0.4	0.4	0.2	7.04	0.60	4.70	3.74	0.16	14.80
12	0.4	0.4	0.2	7.86	0.64	4.07	3.39	0.28	10.19
13	0.4	0.4	0.2	5.04	0.57	7.87	4.57	0.17	23.73
14	0.4	0.4	0.2	4.44	0.62	4.43	3.37	0.25	22.10
15	0.3	0.3	0.4	6.77	0.56	4.97	2.63	0.33	19.85
16	0.3	0.3	0.4	8.22	0.56	3.53	3.21	0.27	20.80
17	0.3	0.3	0.4	7.57	0.55	4.57	2.44	0.11	16.13
18	0.3	0.3	0.4	6.93	0.60	3.60	2.49	0.18	9.94
19	0.5	0.4	0.1	7.45	0.63	5.37	4.56	0.16	16.49
20	0.5	0.4	0.1	7.58	0.56	5.33	3.40	0.23	14.31
21	0.5	0.4	0.1	7.24	0.59	5.37	5.63	0.17	15.96
22	0.5	0.4	0.1	6.94	0.62	4.97	4.75	0.20	11.43
23	0.55	0.3	0.15	6.00	0.63	4.87	2.77	0.60	26.59
24	0.5	0.2	0.3	5.63	0.66	4.90	0.54	0.60	21.54
25	0.5	0.5	0	6.21	0.73	7.23	2.49	0.12	26.45

Table 19a. Model parameters (Partial regression coefficients) for various proportions of raw materials.

Serial No.	Raw material	Model parameters		
		N	P	K
1	BM	3.6208	8.4121 **	0.3854**
2	LM	6.5896	0.3716	0.0187
3	NC	1.7441	0.4195	1.1975**
4	BM x LM	4.7439	-2.7355	-0.0439
5	BM x NC	7.8398	10.1575	2.9857*
6	LM x NC	-9.8786	-8.7291	-5.6470
Stationary point		4.739	4.263	0.2069
R^2		0.961	0.952	0.939

Table 19b. Estimated values of N, P and K for different combinations of bone meal, leather meal and neem cake.

Serial No.	Proportion of raw materials			Estimated values		
	BM	LM	NC	N (%)	P (%)	K (%)
1	0.7	0.2	0.1	5.04	6.16	0.48
2	0.7	0.1	0.2	4.77	7.07	0.81
3	0.7	0.0	0.3	4.70	8.15	1.26
4	0.7	0.3	0.0	5.51	5.42	0.27
5	0.6	0.3	0.1	5.35	5.06	0.36
6	0.6	0.2	0.2	4.95	5.75	0.60
7	0.6	0.1	0.3	4.75	6.61	0.96
8	0.6	0.0	0.4	4.75	7.65	1.43
9	0.5	0.3	0.2	5.04	4.48	0.39
10	0.5	0.2	0.3	4.71	5.13	0.66
11	0.5	0.1	0.4	4.58	5.96	1.04
12	0.5	0.0	0.5	4.64	6.96	1.54
13	0.5	0.5	0.0	6.29	3.71	0.19
14	0.4	0.3	0.3	4.57	3.71	0.36
15	0.4	0.5	0.1	5.69	3.02	0.11
16	0.4	0.6	0.0	6.54	2.93	0.16
17	0.4	0.2	0.4	4.31	4.32	0.66
18	0.4	0.1	0.5	4.24	5.09	1.07
19	0.3	0.7	0.0	6.69	2.21	0.12
20	0.2	0.8	0.0	6.76	1.54	0.68

4.3 STORAGE STUDY

The change in quality parameters of the organic manures during long term storage was studied by keeping the selected COMs and SCMs for one year and analysing the physical and chemical characters at quarterly intervals. The statistically analysed results from the storage study are presented in Tables 20-27.

4.3.1Changes in Physical Properties

The changes in physical properties of the stored organic manures are presented in Tables 20 -22.

4.3.1.1 *Colour*

The original colours of the organic manures kept in storage study are presented in Table 7. There was no change in the colour of the COMs and SCMs under storage study from their original colours during the period of one year.

4.3.1.2 *Odour*

The changes in the odour of the manure samples kept in storage are given in Table 20.The samples SN8, SN16, SN37 and the SCMs viz., SCC, SVC and SCWC did not have any foul odour from the beginning to the end of storage study. SN28 had pungent odour from the beginning till end. SN36 maintained slightly foul odour throughout the duration of the storage study. SN1 did not have any foul odour at the beginning of the study period but as the manure was stored for more than 6 months it developed the pungent odour of volatile ammonia.SN21 had a pleasant fruity odour at the start of the storage period. But as months elapsed, the odour changed to slightly foul odour and then distinctly foul odour. SN33 had no particular odour initially and at the end of storage for one year, it gave a fruity odour. The SCMs did not have any detectable odour during the entire period of storage study.

4.3.1.3 Moisture Content

The moisture content of the COMs showed a highly varying behaviour (Table 21). In SN1 the moisture content was increasing throughout the period of storage study. The moisture content at the end of first quarter (March, 2007) was 30.90 per cent, which reached a value of 39.82 per cent at the end of fourth quarter (December, 2007). In SN8, the moisture content at the end of first quarter was 5.17 per cent which decreased to 4.12 per cent after the second quarter. It increased to 8.12 per cent after

Table 20. Changes in odour of stored organic manure samples

Treatment No.	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter
SN 1	No foul odour	No foul odour	Pungent odour	Pungent odour
SN 8	No foul odour	No foul odour	No foul odour	No foul odour
SN 16	No foul odour	No foul odour	No foul odour	No foul odour
SN 21	Fruity odour	Fruity odour	Slight foul odour	Foul odour
SN 28	Pungent odour	Pungent odour	Pungent odour	Pungent odour
SN 33	No foul odour	No foul odour	No foul odour	Slight fruity odour
SN 36	Slight foul odour	Slight foul odour	Slight foul odour	Slight foul odour
SN 37	No foul odour	No foul odour	No foul odour	No foul odour
SCC	No foul odour	No foul odour	No foul odour	No foul odour
SVC	No foul odour	No foul odour	No foul odour	No foul odour
SCWC	No foul odour	No foul odour	No foul odour	No foul odour

Table 21. Change in moisture content of stored organic manures

Treatment No.	Moisture content (%)				
	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter	Grand Mean
Group 1					
SN 1	30.80	33.23	37.95	39.82	35.45
SN 8	5.17	4.12	8.12	6.74	6.04
SN 16	46.15	46.63	50.61	48.31	47.93
SN 21	15.79	13.51	19.62	18.83	16.94
SN 28	30.61	34.36	41.81	41.20	36.99
SN 33	5.68	2.83	8.35	7.72	6.14
SN 36	5.11	2.23	5.38	4.93	4.41
SN 37	5.05	3.67	5.94	8.78	5.86
Group 2					
SCC	81.50	80.78	80.56	81.52	81.09
SVC	73.39	69.16	50.64	64.63	64.45
SCWC	4.89	4.94	4.48	4.48	4.53
Mean					
Group 1	18.05	17.57	22.22	22.04	
Group 2	53.26	51.62	45.00	50.21	
SE	0.101	0.118	0.244	0.363	
CD					
Treatments	0.29	0.35	0.71	1.07	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	27.65	26.86	28.43	29.72	
CD					
Time period	0.19				
Treatments	0.38				
Time Vs. Treatments	0.63				

third quarter and again declined to 6.74 per cent after fourth quarter. The moisture contents recorded at different stages of storage study were significantly different from each other. In SN16 the moisture content did not change significantly during the first and second quarters. In the third quarter it increased to 50.61 per cent and then decreased to 48.31 per cent after the fourth quarter. For SN21, the moisture content recorded an undulating pattern. The moisture content after the first quarter was 15.79 per cent which decreased to 13.51per cent after second quarter, then increased to 19.62 per cent after third quarter and finally it decreased to 18.83 per cent. In SN28, the moisture content after the first quarter was 30.61 per cent, which increased to 34.36 after the second quarter and there was no significant change in moisture content after the third and fourth quarters of storage. In the case of SN33 there was significant difference between the moisture content values recorded at the four sampling stages of the study. The change in moisture content showed an undulating pattern. The moisture content after the first quarter was 5.68 per cent which declined to 2.83 per cent after the second quarter, then increased to 8.35 per cent after third quarter and again decreased to 7.72 per cent after the fourth quarter. In SN36, the moisture cont4et decreased from 5.11 at the end of first quarter to 2.23 at the end of second quarter, and it again increased to 5.38 after the third quarter and there was no significant change in moisture content after fourth quarter. In SN37 there was significant difference between the moisture content at various stages of study. The moisture content after the first quarter was 5.05 per cent which decreased to 3.67 per cent at the end of 2^{nd} quarter, then increased to 5.94 after third quarter and to 8.78 per cent after fourth quarter.

The moisture content in SCC decreased slightly at first, from 81.50 per cent at the end of first quarter to 80.78 per cent at the end of second quarter. There was no significant change during the third quarter and after the fourth quarter it again increased to 81.52 per cent. In SVC, the moisture content decreased during the first three quarters (from 73.39 per cent to 50.64 per cent), and then increased to 64.63 per cent at the end of the storage period. In SCWC, the moisture content did not change significantly during the entire period of storage study.

At all stages of the storage study, the highest moisture content was observed in SCC, followed by SVC and SN16. SCC contained significantly higher moisture content than all other organic manures under storage. At the end of first quarter, the lowest moisture content (4.89 per cent) was recorded in SCWC and it was on par with SN8, SN36 and SN37. During the sampling in June after second quarter, the lowest moisture content was recorded in SN36 (2.23 per cent). At later stages of sampling, again SCWC registered the lowest moisture content (4.48 per cent).

4.3.1.4 Bulk Density

The changes in bulk densities of the stored manures showed varying patterns (Table 22). The bulk density of SN1 showed a slight increase at first from 0.40 Mg m^{-3} to 0.44 Mg m^{-3} which was on par with the value recorded after third quarter (0.45 Mg m^{-3}) and again increased to 0.49 Mg m^{-3}.In SN8, the change in bulk density followed a similar pattern as that of SN1. It increased at first from 0.60 Mg m^{-3} to 0.67 Mg m^{-3}, then there was no significant change during third quarter and then decreased to 0.61 Mg m^{-3}. For SN16, the changes in bulk density during storage were not significant. In the case of SN21, the bulk density decreased at first from 0.56 to 0.53 Mg m^{-3}, remained unchanged during third quarter, and then increased to 0.56 Mg m^{-3}. For SN28 there were no significant changes in bulk density during the first three quarters, and it decreased to 0.44 Mg m^{-3} from an initial value of 0.47 Mg m^{-3}. In SN33 there was increase in bulk density from 0.66 Mg m^{-3} to 0.70 Mg m^{-3}, which remained without significant change during the third quarter, and increased to 0.74 Mg m^{-3} after the fourth quarter. In SN36 there was o significant change in bulk density during the first two quarters, and then the value decreased from 0.68 Mg m^{-3} to 0.61 Mg m^{-3} and finally increased to 0.72 Mg m^{-3} after fourth quarter. In SN37 there were significant changes in bulk density during storage period. The bulk density increased from 0.64 Mg m^{-3} to 0.69 Mg m^{-3}, declined to 0.63 Mg m^{-3} and to 0.52 Mg m^{-3} after one year of storage.

At all the stages of the storage study, the highest bulk density was recorded in SCWC. The lowest bulk density was always found in SCC. At the end of first quarter, the bulk densities of SN16 and SN28 were on par with each other. At the end of second quarter in June, SN8, SN36 and SN37 were on par. SN36 and SN37 were on par at the end of third quarter (September, 2007) also. And in December, after the fourth quarter, the bulk densities of SN33 and SN36 were on par.

4.3.2 Changes in chemical properties

The changes in the chemical properties of the stored organic manures are given in Tables 23-27.

Table 22. Change in bulk density of stored organic manure samples.

Treatment No.	Bulk density (Mg m^{-3})				
	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter	Grand Mean
Group 1					
SN 1	0.40	0.44	0.45	0.49	0.45
SN 8	0.60	0.67	0.66	0.61	0.64
SN 16	0.47	0.49	0.49	0.48	0.48
SN 21	0.56	0.53	0.53	0.56	0.55
SN 28	0.47	0.48	0.48	0.44	0.47
SN 33	0.66	0.70	0.69	0.74	0.69
SN 36	0.69	0.68	0.61	0.72	0.67
SN 37	0.64	0.69	0.63	0.52	0.62
Group 2					
SCC	0.30	0.30	0.31	0.26	0.29
SVC	0.38	0.39	0.39	0.46	0.41
SCWC	0.78	0.79	0.82	0.79	0.79
Mean					
Group 1	0.56	0.59	0.57	0.57	
Group 2	0.49	0.49	0.50	0.50	
SE	0.004	0.004	0.006	0.007	
CD					
Treatments	0.01	0.01	0.02	0.02	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	0.54	0.56	0.55	0.55	
CD					
Time period	0.01				
Treatments	0.01				
Time Vs. Treatments	0.02				

4.3.2.1 Organic Carbon

The organic carbon content of organic manures stored for one year showed a decreasing trend (Table 23). For all the stored COMs, the decrease was fast during the initial quarter and then the organic carbon content reached almost constant level. At the beginning of the storage experiment, the lowest organic carbon content among COMs was registered in SN37 (16.31per cent) and it recorded the lowest organic carbon percentage at the end of the experiment also (9.53 per cent). At the beginning of the experiment the highest organic carbon content was found in SN36 (26.59 per cent). It was on par with SN21 (24.57 per cent) and was followed by 23.07 per cent in SN28. At the end of the experiment the highest value of organic carbon was noted in SN21 (15.48 per cent) followed by SN8 (14.75 per cent) and SN28 (14.45 per cent). For SCC and SVC the decrease in organic carbon was much less compared to the COMs.

In SN1 the organic carbon content decreased initially from 20.02 per cent to 11.02 per cent and then there was no significant change in organic carbon content during the last two quarters. The same trend was observed in SN8, SN16, SN21 and SN28. In SN8 the initial organic carbon content of 21.32 per cent decreased to 14.75 per cent after the storage period. In SN16 the decrease in carbon content was from 21.13 per cent to 11.08 per cent. In SN21, the initial organic carbon content of 24.57 per cent declined to 15.48 per cent. In SN28 the organic carbon content was 23.07 at the end of first quarter which decreased to 14.45 per cent at the end of fourth quarter. In the case of SN33 the carbon content decreased from 21.54 per cent to 9.84 per cent at the end of third quarter and thereafter there was no significant change. In SN36 and SN37 also the trend of change in organic carbon content was the same as that of SN33. For SN36 the carbon content decreased from 26.59 per cent 13.18 per cent at the end of third quarter and the change was not significant during the fourth quarter. For SN37 the decrease in carbon content was from 16.31 per cent to 9.53 per cent at the end of storage period.

For SVC there was no significant change in organic carbon content during the entire period of storage study. The initial organic carbon content was 9.75 per cent and the final value was 8.68 per cent. SCC also recorded no significant change in carbon content during storage. For SCWC, there was drastic decrease in organic

Table 23. Change in organic carbon content of stored organic manure samples

Treatment No.	Organic carbon (%)				
	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter	Grand Mean
Group 1					
SN 1	20.02	11.02	11.77	11.81	13.66
SN 8	21.32	16.13	14.88	14.75	16.77
SN 16	21.13	11.77	11.12	11.08	13.78
SN 21	24.57	15.82	15.74	15.48	17.90
SN 28	23.07	15.38	14.48	14.45	16.85
SN 33	21.54	11.77	9.84	9.74	13.22
SN 36	26.59	19.60	13.18	13.10	18.12
SN 37	16.31	12.65	10.52	9.53	12.25
Group 2					
SVC	9.75	9.72	9.04	8.68	9.29
SCC	10.97	9.61	9.74	9.46	9.95
SCWC	13.29	3.21	2.87	2.56	5.48
Mean					
Group1	21.82	14.27	12.69	12.49	
Group 2	11.33	7.51	7.22	6.90	
SE	0.834	0.74	0.689	0.047	
CD					
Treatments	2.45	2.17	2.02	0.14	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	18.96	12.43	11.19	10.97	
CD					
Time period	0.53				
Treatments	1.11				
Time Vs. Treatments	1.75				

carbon content from 13.29 per cent to 3.21 per cent after the second quarter and thereafter there was no significant change.

At the end of first and second quarters, the highest organic carbon content was found in SN36 (26.59 per cent and 19.60 per cent respectively).After the first quarter in March, the lowest organic carbon content was in SVC (9.75 per cent) and it was on par with SCC. SN36 was on par with SN21 and SN28. SN1, SN8, SN16 and SN33 were also on par. SCC, SVC and SCWC were on par with regard to their organic carbon contents. At the end of second quarter (June, 2007), the organic carbon contents of SN8, SN21 and SN28 were on par as was SN 33, SN37, SN16, SN1, SCC and SVC. The lowest organic carbon content was in SCWC at the end of second, third and fourth quarters. In September (end of third quarter), the highest organic carbon content was recorded in SN21 (15.74per cent and 15.48 per cent respectively). SN 21 was on par with all other organic manures with regard to the organic carbon content except for SCWC. At the end of fourth quarter, SN21 was significantly superior to all other manures with respect to its organic carbon content. SN37 and SCC were on par.

4.3.2.2 Nitrogen

The changes in nitrogen content of organic manures showed varying patterns during storage (Table 24). In SN1 the nitrogen content decreased from 2.80 per cent to 1.17 per cent at the end of the second quarter and then increased to 2.17 per cent at the end of third quarter. Thereafter the change was not significant. In SN8 the changes in nitrogen content over the different sampling stages were significant. The initial value of 5.63 per cent increased to 6.53 per cent at the end of second quarter and then declined to 3.16 per cent and again increased to reach a value of 4.77 per cent after the fourth quarter. In the case of SN16 there was no significant change in nitrogen content till the end of second quarter (June, 2007). After the third quarter there was a significant increase in nitrogen content from 1.73 per cent to 2.47 per cent. At the end of fourth quarter a significant decline in nitrogen content of SN16 was observed and the value reached 1.40 per cent. In SN21 the nitrogen content of 3.73 per cent recorded at the end of first quarter decreased to 2.57 per cent at the end of second quarter and there was no significant change afterwards. In SN28 the nitrogen content decreased from 5.13 per cent to 2.80 per cent at the end of second quarter and there was no significant change during the last two quarters. In SN33 there was decrease in the nitrogen content from 4.90 per cent to 2.82 per cent at the end of the third quarter

Table 24. Change in total N content of stored organic manure samples

Treatment No.	Total Nitrogen (%)				
	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter	Grand Mean
Group 1					
SN 1	2.80	1.17	2.17	2.07	2.05
SN 8	5.63	6.53	3.16	4.77	5.02
SN 16	2.13	1.73	2.47	1.40	1.94
SN 21	3.73	2.57	2.77	2.81	2.97
SN 28	5.13	2.80	2.42	2.04	3.09
SN 33	4.90	4.37	2.82	2.79	3.72
SN 36	4.93	1.87	3.12	3.23	3.29
SN 37	3.27	4.43	2.94	2.76	3.35
Group 2					
SVC	1.40	0.57	1.37	0.71	1.01
SCC	0.70	0.90	2.06	0.72	1.09
SCWC	2.10	1.30	1.03	0.93	1.34
Mean					
Group1	4.07	3.18	2.73	2.73	
Group 2	1.40	0.92	1.49	0.79	
SE	0.173	0.303	0.034	0.037	
CD					
Treatments	0.51	0.89	0.09	0.11	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	3.34	2.57	2.39	2.20	
CD					
Time period	0.15				
Treatments	0.25				
Time Vs. Treatments	0.50				

and the nitrogen content remained stable afterwards. In SN36 also the trend of change in nitrogen content was the same as that of SN33.The nitrogen content of SN36 decreased from 4.93 per cent to 1.87 per cent at the end of second quarter and then increased to 3.12 per cent which remained without significant change during the next quarter. In SN37 the nitrogen content showed a rise from 3.27 per cent to 4.43 per cent at the end of second quarter which decreased to 2.94 per cent after the third quarter and then remained stable.

In SVC there was significant change in nitrogen content throughout the storage period. The initial nitrogen content of 1.40 per cent decreased to 0.57 per cent at the end of second quarter, then increased to 1.37 per cent at the end of third quarter and again decreased to 0.71 per cent after the fourth quarter. In SCC there was no significant change in nitrogen content during the first two quarters (0.70 per cent and 0.90 per cent). Then it increased to 2.06 per cent at the end of third quarter and then declined to 0.72 per cent at the end of one year. In SCWC the nitrogen content declined from an initial value of 2.10 per cent to 1.30 per cent at the end of second quarter and thereafter the changes were not significant.

At all stages of sampling in the storage study the highest N content was recorded in SN8 (5.63, 6.53, 3.16 and 4.77 per cent N). It was followed by SN28 after the first quarter, and the two were on par with each other. At the end of second quarter, SN8 was significantly superior to all other manures with regard to nitrogen content. It was followed by SN37 and SN33 which were on par. The lowest N content was in SN1 and it was significantly inferior to all other manures at the end of second and third quarters. SN16, SN21, SN28 and SN36 were on par. At the end of third quarter (in September), SN8 was on par with SN36. After the fourth quarter (in December), SN8 had significantly higher content of N than all other manures. SN21, SN33 and SN38 were on par, as well as SN1 and SN28.

4.3.2.3 Phosphorus

The changes in phosphorus contents of various organic manures in the storage study showed varying patterns (Table 25). In SN1 the P content remained stable during ht first two quarters (0.41 per cent and 0.49 per cent). Then it increased to 0.71 per cent at the end of third quarter and remained stable thereafter. In SN8 the P content increased from 2.19 per cent to 4.17 per cent at the end of second quarter and

Table 25. Changes in total P content of stored organic manure samples

Treatment No.	Total Phosphorus %				
	End of 1st quarter	**End of 2nd quarter**	**End of 3rd quarter**	**End of 4th quarter**	**Grand Mean**
Group 1					
SN 1	0.41	0.49	0.71	0.83	0.61
SN 8	2.19	4.17	3.09	2.92	3.09
SN 16	2.94	2.76	2.67	4.17	3.13
SN 21	3.00	2.49	2.56	2.32	2.59
SN 28	3.09	3.02	3.29	4.09	3.38
SN 33	0.54	4.16	2.09	1.27	2.02
SN 36	1.30	1.34	1.42	1.58	1.41
SN 37	1.87	1.96	1.84	2.35	2.00
Group 2					
SVC	0.47	0.16	0.10	0.44	0.29
SCC	0.05	0.58	0.39	0.77	0.45
SCWC	0.76	0.98	0.56	0.53	0.71
Mean					
Group1	2.55	2.21	2.44	1.72	
Group 2	0.57	0.35	0.58	0.26	
SE	0.092	0.066	0.032	0.046	
CD					
Treatments	0.27	0.19	0.09	0.13	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	1.51	2.01	1.70	1.93	
CD					
Time period	0.06				
Treatments	0.09				
Time Vs. Treatments	0.19				

then decreased to 3.09 per cent at the end of third quarter. There was no significant change in P content of SN8 during the fourth quarter. In SN16 the P content showed no significant change during the first two quarters (2.94 per cent and 2.76 per cent). It decreased to 2.67 per cent at the end of third quarter and then increased to 4.17 per cent after the fourth quarter. In SN21 the initial P content of 3.00 per cent decreased to 2.49 per cent at the end of second quarter and remained stable for the next quarter (2.56 per cent). Then it decreased to reach 2.32 per cent at the end of storage period. In SN28, the P content remained stable during the first two quarters (3.09 per cent and 3.02 per cent) and then increased to 3.29 per cent and 4.09 per cent after the third and fourth quarters respectively. In SN33 the changes in P content during the storage period of one year were significant. The initial value of 0.54 per cent increased to 4.16 per cent at the end of second quarter and then it declined to 2.09 and 1.27per cent during the next two quarters. In SN36 the changes in P content during storage period were not significant. In SN37 the P content remained stable during the first three quarters (1.87 per cent, 1.96 per cent and 1.84 per cent) and then increased to reach a value of 2.35 per cent.

In SVC the initial P content changed from 0.47 per cent to 0.16 per cent at the end of second quarter and remained stable for the next quarter. It then increased to 0.44 per cent at the end of fourth quarter. In SCC the P content of 0.05 per cent increased to 0.58 per cent at the end of second quarter and remained stable for the third quarter. Then it increased to 0.77 per cent at the end of one year. In SCWC the P content increased from 0.76 per cent to 0.98 per cent at the end of second quarter and then decreased to 0.56 per cent after third quarter, and remained stable thereafter.

During the sampling done after first quarter of storage period in March, the highest P content was recorded in SN28 (3.09 per cent) followed by SN21 (3.0) and SN16 (2.94 per cent). These three manures were on par with regard to their P content in March. The lowest P content was recorded in SVC (0.05 per cent), which was significantly inferior to all other manures. At the end of second quarter in June, the highest P content was found in SN8 (4.17 per cent) which was on par with SN33 (4.16 per cent). SN16, SN21 and SN28 were also on par with each other. The lowest P content was found in SCC (0.16 per cent) and it was significantly less than all other manures. SN1 and SVC were on par. After three quarters of storage period, the sample analysis indicated the highest P content in SN28 (3.29 per cent) and the lowest

P content in SCC (0.10 per cent). SN28 was on par with SN8. At the end of storage period, the P content was highest in SN16 (4.17 per cent) and was the lowest in SCC (0.44 percent). SN16 was on par with SN28 (4.09 per cent). SCC was on par with SCWC (0.53 per cent).

4.3.2.4 Potassium

The variations in potassium contents of the stored organic manures showed different patterns (Table 26). In SN1 the K content remained stable for the first two quarters (2.00 per cent and 1.93 per cent) and then it went on decreasing for the next two quarters to reach a value of 1.83 per cent at the end of one year. For SN8 the change in K content showed an undulating pattern. The K content decreased at first from 2.39 per cent to 0.79per cent and then increased to 2.62 per cent and finally decreased to 1.54 per cent at the end of storage period. In SN16 also the changes recorded during the sampling stages were significant. The K content decreased from 1.84 per cent to 1.34 per cent at first, then increased to 1.87 per cent and finally reached a value of 0.73 per cent. In SN21 the K content decreased a first from a value of 2.51 per cent to 2.23 per cent at the end of second quarter. Then it increased to 2.47 per cent at the end of third quarter and remained stable for the rest of the storage period. For SN28 the changes in K content were significant at all stages of the storage study. The K content increased from 3.31 per cent to 3.53 per cent at the end of second quarter and to 4.34 per cent at the end of third quarter. Then it declined to 2.97 per cent at the end of fourth quarter in December, 2007. In SN33 there was no significant change in K content during the first two quarters (0.60 per cent and 0.55 per cent). It increased to 0.87 per cent at the end of third quarter in September, 2007 and then decreased to 0.37 per cent after the fourth quarter. In SN36 the K content increased from 0.26 percent to 0.69 per cent at the end of second quarter, then declined to 0. 37 per cent at the end of third quarter, and remained stable afterwards (0.22 per cent). In SN37 the initial value of K content was 0.84 per cent which decreased to 0.13 per cent at the end of second quarter. It increased to 0.99 per cent after the third quarter, and again decreased to 0.76 per cent.

In SVC the changes in K content were significant at all the stages of storage study. The initial value of 0.43 per cent decreased to 0.19 per cent at first and then increased to 0.73 per cent and again decreased to 0.22 per cent at the end of one year. In SCC the K content increased till the end of third quarter (from 0.20 per cent to 0.63

Table 26. Change in total K content of stored organic manure samples

Treatment No.	**Total Potassium %**				
	End of 1st quarter	**End of 2nd quarter**	**End of 3rd quarter**	**End of 4th quarter**	**Grand Mean**
Group 1					
SN 1	2.00	1.93	2.11	1.83	1.97
SN 8	2.39	0.79	2.62	1.54	1.83
SN 16	1.84	1.34	1.87	0.73	1.44
SN 21	2.51	2.23	2.47	2.48	2.42
SN 28	3.31	3.53	4.34	2.97	3.54
SN 33	0.60	0.55	0.87	0.37	0.59
SN 36	0.26	0.69	0.37	0.22	0.38
SN 37	0.84	0.13	0.99	0.76	0.68
Group 2					
SVC	0.43	0.19	0.73	0.22	0.39
SCC	0.20	0.45	0.63	0.36	0.41
SCWC	0.16	0.15	0.27	0.17	0.19
Mean					
Group1	1.72	1.39	1.95	1.36	
Group 2	0.26	0.26	0.55	0.25	
SE	0.46	0.079	0.035	0.031	
CD					
Treatments	0.13	0.23	0.10	0.09	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	1.32	1.09	1.57	1.06	
CD					
Time period	0.04				
Treatments	0.08				
Time Vs. Treatments	0.15				

per cent) and then decreased to 0.36 per cent at the end of one year. In SCWC the K content did not register any significant change during the period of storage study.

The highest potassium content among the stored organic manures was recorded in SN28 at all the stages of storage study. It contained 3.31 per cent, 3.53 per cent, 4.34 per cent and 2.97 per cent potassium at the end of first, second, third and fourth quarters respectively. After the first quarter in March, the lowest K content was founding SCWC (0.16 per cent) and it was on par with SVC and SN36. SN8 and SN21 were also on par in March. At the end of second quarter in June, the lowest K content was in SN37 and it was not significantly different from SCWC and SCC. SN8, 33 and 36 were also on par in June. After the second quarter in September, the lowest K content was again in SCWC on par with SN36. At the end of fourth quarter in December, SN16 and SN37 were on par, SN33 and SVC were on par and the lowest K content present in SCWC was on par with SCC and SN36.

4.3.2.5 Sodium

The changes in the sodium content of various organic manures under storage conditions for one year varied in their patterns (Table 27). In SN1, SN8 and SN16 the Na contents did not show any significant change during the first two quarters. In SN1 the Na content of 0.19 per cent changed to 0.22 per cent at the end of second quarter and both values were on par. It increased to 0.34 per cent at the end of third quarter and then decreased to 0.27 per cent after fourth quarter. In SN8 the initial Na content of 0.56 per cent decreased to reach 0.26 per cent at the end of fourth quarter. In SN16 the Na content of 0.90 per cent decreased during the last two quarters to reach a value of 0.41 per cent. In SN21 the initial Na content of 0.09 per cent did not show significant change during the storage period. In SN28 also the change in Na content was not significant during the first three quarters and then it increased to 0.54 per cent from the initial value of 0.47 per cent. In SN33 the Na content continuously decreased during the storage period. The initial Na content of 2.09 per cent decreased to 1.87 per cent at the end of second quarter,1.44 per cent after third quarter and finally to 1.22 per cent. In SN36 also the Na content showed decreasing trend and the value declined from 0.79 per cent to 0.69 per cent after the second quarter and to 0.56 per cent after the third quarter. Later there was no significant change. In SN37 the Na content decreased from 0.56 per cent to 0.48 per cent at the end of second quarter and remained stable thereafter.

Table 27. Change in total Na content of stored organic manure samples

Treatment No.	Total Potassium %				
	End of 1st quarter	End of 2nd quarter	End of 3rd quarter	End of 4th quarter	Grand Mean
Group 1					
SN 1	0.19	0.22	0.34	0.27	0.26
SN 8	0.56	0.57	0.45	0.26	0.46
SN 16	0.90	0.87	0.66	0.41	0.71
SN 21	0.09	0.11	0.13	0.12	0.11
SN 28	0.47	0.45	0.43	0.54	0.47
SN 33	2.09	1.87	1.44	1.22	1.66
SN 36	0.79	0.69	0.56	0.53	0.65
SN 37	0.56	0.48	0.44	0.41	0.47
Group 2					
SVC	0.10	0.33	0.65	0.26	0.34
SCC	0.25	0.12	0.12	0.09	0.15
SCWC	0.16	0.18	0.18	0.23	0.19
Mean					
Group1	0.71	0.66	0.56	0.47	
Group 2	0.17	0.21	0.32	0.19	
SE	0.008	0.025	0.016	0.018	
CD					
Treatments	0.02	0.07	0.05	0.05	
Group1 Vs. Group 2	S	S	S	S	
Pooled analysis					
Pooled mean	0.56	0.54	0.49	0.39	
CD					
Time period	0.02				
Treatments	0.03				
Time Vs. Treatments	0.05				

In SVC the Na content of 0.10 per cent increased to 0.65 per cent at the end of third quarter and then decreased to 0.26 per cent after the fourth quarter. In SCC the initial sodium content of 0.25 per cent decreased to 0.12 per cent and then remained stable for the rest of the storage period. In SCWC the changes in sodium content during storage period were not significant.

The highest content of sodium among all the stored manures was recorded in SN33 at all the stages of storage study. It registered a sodium content of 2.09 per cent, 1.87 per cent, 1.44 per cent and 1.22 per cent at the end of first, second, third and fourth quarters respectively. This manure was found to be significantly superior to all others in view of its Na content. The lowest Na contents at the end of both first and second quarters were recorded in SN21 (0.09 per cent and 0.11 per cent respectively). After first quarter, SN21 was on par with SCC and in June after the second quarter, it was on par with SN1, SCWC and SVC. After the third quarter in September, the lowest Na content was found in SVC which was on par with SN21 and SCWC. After the fourth quarter in December the lowest Na was again found in SVC on par with SN21.

4.4 QUALITY OF MARKET SAMPLES OF COMs

The market samples of selected COMs were analysed for their physical and chemical characters to detect any change in quality from their corresponding factory samples, and the statistically analysed data are presented in Tables 28-30.

4.4.1 Physical Properties

The data on the physical properties of the market samples along with that of their corresponding factory samples are presented in Tables 28 and 29.

4.4.1.1 Colour

The colour of market samples (Table 28) of the selected COMs were compared with their corresponding samples collected initially from the manufacturing sites (factory).The colour of market sample did not vary much from the colour of its factory sample.

Table 28. Physical characters of market samples of COMs

Treatment No.	Sample Name.	Colour	Odour
M_1	Karshaka Agromeal	Mixture of brown, black and yellow	No foul odour
M_2	Abtec Super meal	Mixture of black, grey and yellow	Pungent odour
M_3	Ecomeal	Mixture of grey, black and yellow	Fruity odour
M_4	Excelmeal	Mixture of black, greyish brown and white	No foul odour
M_5	Goldenmeal	Mixture of grey, black and white	No foul odour
M_6	Kalpameal	Mixture of black, brown, yellow and grey	No foul odour
M_7	Kotharimeal	Mixture of black and white	Pungent odour
M_8	Karshaka Organic	Mixture of black and brown	Fruity odour
M_9	Karshaka Organic Total	Mixture of black , grey and brown	Slightly pungent odour
M_{10}	PL meal	Mixture of brown, grey, black and yellow	No foul odour
M_{11}	Skymeal	Mixture of brown, black and yellow	No foul odour
M_{12}	Starmeal	Mixture of black, grey and yellow	Slight foul odour
M_{13}	Sterameal	Mixture of white, black, grey and brown	No foul odour

4.4.1.2 Odour

The market sample of Karshaka Agromeal (M_1) had no foul odour, while its factory sample had slight foul odour (Table 28). The odour of Abtec super meal (M_2) was pungent while its factory sample had no foul odour. The market sample of Kotharimeal (M_7) had pungent odour while its factory sample registered no foul odour. The odour of M_8 as well as M_9 also showed slight variation from their factory samples. For the other COMs, the market samples did not differ much from their corresponding factory samples with regard to their odour.

4.4.1.3 Moisture Content

Moisture content (Table 29) of the market samples were in general, less than their factory samples. The exceptions were M_5 (Goldenmeal), M_7 (Kotharimeal) and M_{11} (Skymeal).But the difference in moisture contents of market and factory samples of the same COM was significant only for M_9 (Karshaka Organic Total).

4.4.1.4 Bulk Density

There was no significant difference between the bulk densities (Table 29) of market sample and the corresponding factory sample of COMs except in the case of M_2 (Abtec Super meal), M_4 (Excelmeal), M_6 (Kalpameal) and M_{11} (Skymeal). For M_2 the bulk density of market sample (0.50 Mg m^{-3})was significantly less than its factory sample (0.56 Mg m^{-3}), while in the case of others, the market samples had significantly higher bulk densities than their factory samples.

4.4.2 Chemical Properties

The chemical properties of the market samples along with that of their corresponding factory samples are given in Tables 29-30.

4.4.2.1 Organic Carbon

The organic carbon contents (Table 29) of all the market samples were significantly less than their corresponding factory samples. The highest organic carbon content among the factory samples was recorded in M_5 and M_{12} (26.58 per cent). Among market samples the highest organic carbon content was found in M_3 (18.91 per cent) followed by 17.87 per cent in M_1.The lowest organic carbon content among factory samples was observed in M_7 (16.31 per cent0 while that in market samples was recorded in M_{13} (5.27 per cent).

Table 29. Comparison of quality of market samples of COMs with factory samples

Treatment No.	Moisture content (%)		Bulk density (Mg m^{-3})		Organic carbon (%)	
	Factory	Market	Factory	Market	Factory	Market
M_1	6.01	3.36	0.66	0.63	22.88	17.87
M_2	8.34	5.03	0.56	0.50	23.79	17.19
M_3	5.63	4.68	0.66	0.64	21.54	18.91
M_4	5.04	1.83	0.57	0.79	23.73	9.63
M_5	6.00	6.40	0.63	0.64	26.58	15.54
M_6	6.10	2.12	0.62	0.77	26.33	12.77
M_7	5.00	11.54	0.64	0.63	16.31	8.70
M_8	30.62	28.38	0.47	0.47	23.07	17.25
M_9	33.02	23.50	0.44	0.45	25.55	14.26
M_{10}	4.44	4.25	0.62	0.64	22.10	9.21
M_{11}	3.75	5.73	0.58	0.80	26.20	12.17
M_{12}	5.00	4.82	0.69	0.66	26.58	9.91
M_{13}	5.18	3.48	0.60	0.58	21.32	5.27
Mean	9.55	8.09	0.59	0.63	23.54	12.98
CD						
Source	7.55		0.03		2.39	
Source Vs. Treatment	NS		S		S	

Table 30. Comparison of quality of market samples of COMs with factory samples- continued

Treatment No.	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sodium (%)	
	Factory	Market	Factory	Market	Factory	Market	Factory	Market
M_1	7.67	4.83	4.54	3.65	3.18	1.52	0.65	0.55
M_2	5.93	4.13	4.37	3.60	0.94	1.23	1.00	0.70
M_3	4.90	4.20	0.54	6.62	0.60	0.78	2.09	1.19
M_4	7.87	2.77	4.57	2.07	0.17	0.79	0.65	0.39
M_5	4.87	2.80	2.77	4.21	6.00	0.38	1.03	0.87
M_6	7.00	2.87	3.69	0.99	0.19	0.57	0.34	0.16
M_7	3.27	1.77	1.87	1.75	0.84	0.38	0.56	0.42
M_8	5.13	4.33	3.09	2.87	3.31	2.15	0.47	0.42
M_9	3.27	2.80	3.05	3.19	2.79	4.08	0.37	0.34
M_{10}	4.43	3.40	3.37	3.16	0.24	0.19	1.74	1.07
M_{11}	6.23	2.90	4.09	2.36	0.18	0.40	0.68	0.45
M_{12}	4.93	3.40	1.30	1.63	0.26	0.21	0.79	0.49
M_{13}	5.63	2.83	2.19	4.80	2.39	1.71	0.56	0.29
Mean	5.47	3.31	3.04	2.685	1.623	1.107	0.84	0.57
CD								
Source	0.47		0.24		0.31		0.06	
Source Vs. Treatment	S		S		S		S	

4.4.2.2. Nitrogen

The nitrogen contents (Table 30) of all the market samples were significantly less than their corresponding factory samples. The highest nitrogen content among factory samples was found in M_4 (7.87 per cent) while M_1 recorded the highest N content (4.83 per cent) among market samples. The lowest N content was 3.27 per cent recorded in M_7 and M_9 in the factory samples, while in the market samples the lowest N content was in M_7 (1.77 per cent).

4.4.2.3 Phosphorus

The P contents (Table 30) of M_1, M_2, M_4, M_6 and M_{11} were significantly less than their corresponding factory samples. M_5, M_{12} and M_{13} contained significantly higher contents of P than their factory samples. M_3, M_7, M_8, M_9 and M_{10} were on par with their factory samples with regard to their P contents. The highest P content was recorded in M_4 (4.57 per cent) among factory samples and in M_3 (6.62 per cent) in market samples. The lowest P content was recorded in M_3 (0.54per cent) in factory samples and in M_6 (0.99 per cent) in market samples.

4.4.2.4 Potassium

The potassium contents (Table 30) of M_1, M_5, M_7, M_8 and M_{13} were significantly less than their factory samples. M_2, M_3, M_{10}, M_{11} and M_{12} were on par with their corresponding factory samples with regard to P content. M_4, M_6 and M_9 had significantly higher contents of K than their factory samples. The highest K content among factory samples was found in M_5 (6.00 per cent) and in M_9 (4.08 per cent) among market samples. Among factory samples the lowest K content was found in M_4 (0.17 per cent) while among market samples it was in M_{10} (0.19 per cent).

4.4.2.5 Sodium

The sodium contents of all the market samples (Table 30) except M_8 and M_9 were significantly less than their corresponding factory samples. In the case of M_8 and M_9, the sodium contents of market samples were on par with that of the corresponding factory samples. The highest sodium content among factory samples was recorded in M_3 (2.09 per cent) and the lowest was in M_6 (0.34 per cent).Among the market samples the highest Na content was found in M_3 (1.19 per cent) and the lowest Na content was in M_6 (0.16 per cent).

4.5 INCUBATION EXPERIMENT

An incubation experiment was conducted to study the mineralization pattern of nitrogen, phosphorus and potassium from the selected COMs, OMMs and SCMs. The results after statistical analysis are presented in Tables 31-33.

4.5.1 Mineralization Pattern of Nitrogen

The mineralization of nitrogen (Table 31) from different organic manures showed varying patterns. In T_1 the nitrogen content was 924.79 kg ha^{-1} at zero day after incubation (DAI) which increased upto 45DAI and reached a value of 1211.2 kg ha^{-1}. Thereafter it decreased till 105^{th} DAI to a value of 447.89 kg ha^{-1}. All the changes in available N content of soil during incubation study were significant.

In T_2, the available nitrogen content in the soil was continuously decreasing throughout the incubation period except at 30 DAI and 45 DAI when the values were on par with each other, and from the initial value of 2213.67 kg ha^{-1} it reached 1377.46 kg ha^{-1}on 105 DAI.

The nitrogen content of soil in T_3 showed a slight decrease at first. The initial value of 1014.33 kg ha^{-1} reached 974.12 kg ha^{-1} on 15 DAI. Thereafter it increased upto 45 DAI and reached a value of 1340.33 kg ha^{-1}. Again the nitrogen content decreased to a value of 982.06 kg ha^{-1} at 105 DAI. All the changes in available N content of soil during incubation study were significant.

In T_4 also there was an initial decrease in available nitrogen content in the soil from 1680.43 kg ha^{-1} to 1536.50 kg ha^{-1} at 15 DAI. Then it increased to 1816.09 kg ha^{-1} till 45 DAI. The nitrogen content again decreased and reached a value of 1414.16 kg ha^{-1} on 90 DAI and remained stable afterwards.

T_5 showed a continuous decrease in available nitrogen content in soil from the initial value of 924.99 kg ha^{-1} to 352.27 kg ha^{-1} at 105 DAI. The available N content at 45 DAI and 60 DAI were on par with each other.

T_6 showed an initial increase of nitrogen content from 1315.69 kg ha^{-1} to 1706.63 kg ha^{-1} on 30 DAI. Then it decreased to 984.29 kg ha^{-1} on 105 DAI.

In T_7 there was no significant change in N mineralization from zero day upto 30 DAI. The initial N content was 1176.96 kg ha^{-1} and at 30 DAI it as 1202.26 kg ha^{-}

Table 31. Incubation study-Mineralization pattern of nitrogen from organic manures

Treatment	Available N (kg ha^{-1})								
	0 DAI	15 DAI	30 DAI	45 DAI	60 DAI	75 DAI	90 DAI	105 DAI	Grand Mean
T_1	924.79 (30.41)	982.79 (31.35)	1032.33 (32.13)	1211.19 (34.8)	962.78 (31.03)	518.33 (22.77)	493.62 (22.22)	447.89 (21.16)	796.93 (28.23)
T_2	2213.67 (47.05)	2181.59 (46.71)	2013.39 (44.87)	2000.93 (44.73)	1875.00 (43.3)	1410.93 (37.56)	1376.43 (37.1)	1317.46 (36.3)	1780.84 (42.2)
T_3	1014.33 (31.85)	974.12 (31.21)	1141.03 (33.78)	1340.33 (36.61)	1216.33 (34.88)	1122.29 (33.5)	1085.00 (32.94)	982.06 (31.34)	1106.23 (33.26)
T_4	1680.43 (40.99)	1536.49 (39.2)	1780.87 (42.2)	1816.09 (42.62)	1644.03 (40.55)	1454.89 (38.14)	1414.16 (37.61)	1402.93 (37.46)	1588.02 (39.85)
T_5	924.99 (30.41)	813.76 (28.53)	448.76 (21.18)	481.12 (21.93)	473.26 (21.75)	365.65 (19.12)	347.78 (18.65)	352.27 (18.77)	508.05 (22.54)
T_6	1315.69 (36.27)	1372.96 (37.05)	1706.63 (41.31)	1617.9 (40.22)	1445.26 (38.02)	1232.93 (35.11)	1133.59 (33.67)	984.29 (31.37)	1341.76 (36.63)
T_7	1176.96 (34.31)	1190.16 (34.5)	1202.26 (34.67)	1288.19 (35.89)	981.06 (31.32)	867.86 (29.46)	875.42 (29.59)	896.56 (29.94)	1053.65 (32.46)
T_8	1026.83 (32.04)	994.96 (31.54)	1370.27 (37.02)	1005.59 (31.71)	686.79 (26.21)	714.63 (26.73)	718.49 (26.8)	703.02 (26.51)	889.23 (29.82)
T_9	587.72 (24.24)	961.06 (31)	1510.30 (38.86)	1236.49 (35.16)	643.42 (25.37)	896.49 (29.94)	874.09 (29.57)	811.96 (28.49)	919.91 (30.33)
T_{10}	392.98 (19.82)	257.13 (16.04)	334.66 (18.29)	274.96 (16.58)	227.91 (15.1)	393.59 (19.84)	392.16 (19.8)	389.79 (19.74)	329.42 (18.15)
T_{11}	587.59 (24.24)	564.06 (23.75)	533.66 (23.1)	574.79 (23.97)	362.35 (19.04)	351.24 (18.74)	377.32 (19.42)	291.86 (17.08)	448.17 (21.17)
T_{12}	447.59 (21.16)	513.42 (22.66)	606.36 (24.62)	556.59 (23.59)	504.02 (22.45)	392.05 (19.8)	374.32 (19.35)	348.93 (18.68)	463.97 (21.54)
T_{13}	338.62 (18.4)	376.72 (19.41)	506.89 (22.51)	406.56 (20.16)	351.33 (18.74)	434.92 (20.85)	402.59 (20.06)	387.09 (19.67)	399.20 (19.98)
Mean	905.41 (30.09)	913.85 (30.23)	1016.9 (31.89)	984.70 (31.38)	800.32 (28.29)	731.16 (27.04)	711.82 (26.68)	670.29 (25.89)	CD=0.14
CD	0.25								

(Square root transformed values within parentheses)

$^{-1}$.It increased to 1288.19 kg ha^{-1} on 45 DAI. Then it decreased to 896.56 kg ha^{-1} on 105 DAI.

T_8 indicated another pattern in N mineralization. The N content inT8 decreased at first from 1026.83 kg ha^{-1} to 994.96 kg ha^{-1} upto 15 DAI. Then it increased to 1370.27 kg ha^{-1} on 30 DAI. It was again decreasing to 1005.60 kg ha^{-1} on 45 DAI, remained stable at 75 DAI and 90 DAI, and decreased again to reach a final value of 703.02 kg ha^{-1} on 105 DAI.

In T_9, the available N content increased from the initial value of 587.72 kg ha^{-1} on 0DAI to 1236.49 kg ha^{-1} on 45 DAI. Then it decreased to 643.42 kg ha^{-1} on 60 DAI. Again there was increase in N content upto 896.49 kg ha^{-1} on 75 DAI. The N content decreased again to 811.96 kg ha^{-1} on 105 DAI. All the changes recorded for available N content during incubation period were significant.

In T_{10} the available nitrogen content decreased from 392.98 kg ha^{-1} to 257.13 kg ha^{-1} at 15 DAI, then increased to 334.66 kg ha^{-1} at 30 DAI, decreased to 227.91 kg ha^{-1} at 60 DAI, increased to 393.59 kg ha^{-1} at 75 DAI and remained stable thereafter. The final value of available N content in soil at 105 DAI was 389.79 kg ha^{-1}.

T_{11} showed decline from the initial available N content of 587.59 kg ha^{-1} to 564.06 kg ha^{-1} at 30 DAI. There was a slight increase at 45 DAI and again it dropped to 291.86 kg ha^{-1} at 105 DAI. All the changes in N content during the incubation period were significant.

T_{12} showed increase in available N content upto 30 DAI (606.36 kg ha^{-1}) and then it decreased till 105 DAI (348.93 kg ha^{-1}). All the changes in N content were significant.

T_{13} also showed an initial rise in available N upto 30 DAI (338.62 kg ha^{-1} to 506.89 kg ha^{-1}), then it decreased till 60 DAI (351.33 kg ha^{-1}), increased to 434.92 kg ha^{-1} on 75 DAI, remained stable during 90 DAI and again it decreased till 105 DAI to reach a value of 387.09 kg ha^{-1}.

Among the different treatments the highest nitrogen content (2213.67 kg ha^{-1}) was observed in T_2 at zero DAI. It was followed by T_4, T_6 and T_7 in that order. The treatments were significantly different from each other in their available nitrogen content of soil. The lowest available N content was in T_{13} (control) which contained 338.62 kg N ha^{-1}.T_5 and T_1 were on par with each other as was T_9 and T_{11}.

At 15th day of incubation also the highest available N content (2181.59 kg ha^{-1}) was found in T_2 followed by T_4, T_6 and T_7, all of which were significantly different from one another. The lowest N content was inT_{10} (257.13 kg ha^{-1}) followed by T_{13} (376.72 kg ha^{-1}). At 30 DAI, 45 DAI and 60 DAI, the highest N content was recorded in T_2 and the lowest was found in T_{10}.At 30 DAI, T_2 had 2013.39 kg N ha^{-1}, at 45 DAI 2000.93 kg ha^{-1} and at 60 DAI it recorded 1875.0 kg N ha^{-1}. T_{10} had values of 334.66 kg N ha^{-1}, 274.96 kg N ha^{-1} and 227.91 kg N ha^{-1} on 30 DAI, 45 DAI and 60 DAI respectively. From 75 DAI onwards, T_4 registered the highest available N content among the thirteen treatments and was significantly superior to all other treatments. T_2 was next in value to T_4 on all occasions. At 75 DAI, T_4 had 1454.89 kg N ha^{-1} and the lowest N content was found in T_{11} with 351.24 kg N ha^{-1}. At 90th day after incubation, T_4 had 1414.16 kg ha^{-1} while the lowest available N was observed in T_5 with 3447.78 kg N ha^{-1}. At 105 DAI, the N content in T_4 was1402.93 kg N ha^{-1} and the lowest N content was recorded in T_{11} with 291.86 kg N ha^{-1}.

4.5.2 ***Mineralization Pattern of Phosphorus***

The phosphorus release from different organic manures (Table 32) followed widely varying patterns. In T_1, the available P_2O_5 content (276.38 kg ha^{-1}) was found to remain stable at first till 15 DAI and then increased to 17.69 kg ha^{-1} at 30 DAI. There was no significant change at 45 DAI, but it was found to increase later throughout the period of the incubation experiment to reach a final value of 578.26 kg ha^{-1}.

In T_2, the available content (202.28 kg ha^{-1}) increased till 15 DAI (221.29 kg ha^{-1}), remained stable till 45 DAI, and then it was found to be decreasing till D90 (128.49 kg ha^{-1}) and there was a slight increase in P content of soil at 105 DAI (142.48 kg ha^{-1}).

In T_3, the P content increased at first from the value on zero day of incubation (226.99 kg ha^{-1}) to 287.64 kg ha^{-1} on 15 DAI and there was no significant change on 30 DAI. It increased to 314.31 kg ha^{-1} on 45 DAI and 339.11 kg ha^{-1} at 60 DAI. It again was stable on 75 DAI (328.98 kg ha^{-1}) and then increased to 384.87 kg ha^{-1} on 90 DAI and decreased to 324.32 kg ha^{-1} on 105 DAI.

In T_4, the available P content of soil increased from the initial value till 45DAI (293.84 kg ha^{-1} to 381.49 kg ha^{-1}). It decreased to 345.72 kg ha^{-1} on 60 DAI and

Table 32. Incubation study- Mineralization pattern of phosphorus from organic manures

Treatment	Available P_2O_5 (kg ha^{-1})								
	0 DAI	**15 DAI**	**30 DAI**	**45 DAI**	**60 DAI**	**75 DAI**	**90 DAI**	**105 DAI**	**Mean**
T_1	276.38 (16.62)	273.55 (16.54)	312.82 (17.69)	322.39 (17.96)	334.58 (18.29)	365.79 (19.13)	554.32 (23.54)	578.26 (24.05)	369.79 (19.23)
T_2	202.28 (14.22)	221.29 (14.88)	231.13 (15.2)	232.34 (15.24)	202.79 (14.24)	167.22 (12.93)	128.49 (11.34)	142.48 (11.94)	189.06 (13.75)
T_3	226.99 (15.07)	287.64 (16.96)	275.52 (16.6)	314.31 (17.73)	339.11 (18.42)	328.98 (18.14)	384.87 (19.62)	324.32 (18.01)	308.70 (17.57)
T_4	293.84 (17.14)	334.91 (18.3)	363.42 (19.06)	381.49 (19.53)	345.72 (18.59)	304.35 (17.45)	307.05 (17.52)	415.95 (20.39)	342.25 (18.5)
T_5	229.99 (15.17)	282.75 (16.82)	318.15 (17.84)	341.78 (18.49)	357.34 (18.9)	386.89 (19.67)	342.63 (18.51)	368.55 (19.2)	(326.52 18.07)
T_6	278.28 (16.68)	326.08 (18.06)	352.38 (18.77)	423.59 (20.58)	462.06 (21.5)	664.38 (25.78)	696.68 (26.39)	517.88 (22.76)	454.12 (21.31)
T_7	299.21 (17.3)	329.69 (18.16)	368.00 (19.18)	455.71 (21.35)	557.99 (23.62)	617.16 (24.84)	681.92 (26.11)	919.06 (30.32)	511.21 (22.61)
T_8	233.98 (15.3)	284.38 (16.86)	255.62 (15.99)	248.11 (15.75)	205.52 (14.34)	117.61 (10.84)	141.02 (11.88)	135.01 (11.62)	197.96 (14.07)
T_9	271.84 (16.49)	228.47 (15.12)	234.89 (15.33)	272.22 (16.5)	286.34 (16.92)	156.04 (12.49)	306.70 (17.51)	834.83 (28.89)	303.11 (17.41)
T_{10}	127.76 (11.3)	132.09 (11.49)	143.34 (11.97)	150.61 (12.27)	138.39 (11.76)	104.92 (10.24)	124.43 (11.15)	202.43 (14.23)	139.24 (11.8)
T_{11}	166.02 (12.89)	134.66 (11.6)	175.79 (13.26)	184.31 (13.58)	205.14 (14.32)	216.11 (14.7)	351.87 (18.76)	384.98 (19.62)	220.23 (14.84)
T_{12}	207.12 (14.39)	288.17 (16.98)	304.16 (17.44)	297.98 (17.26)	276.99 (16.64)	246.35 (15.7)	127.99 (11.31)	153.02 (12.37)	232.87 (15.26)
T_{13}	191.59 (13.84)	198.02 (14.07)	166.56 (12.91)	178.68 (13.37)	162.09 (12.73)	148.97 (12.21)	124.19 (11.14)	88.89 (9.43)	155.25 (12.46)
Mean	228.31 (15.11)	250.59 (15.83)	264.06 (16.25)	285.27 (16.89)	287.30 (16.95)	271.26 (16.47)	298.94 (17.29)	348.94 (18.68)	CD=0.29
CD	0.39								

(Square root transformed values within parentheses)

304.35 kg ha^{-1} on 75 DAI and remained stable on 90 DAI. It again increased at 105 DAI to reach 415.95 kg ha^{-1}.

In T_5, the available P content of soil increased till 75 DAI (from 229.99 kg ha^{-1} to 386.89 kg ha^{-1}), then it was decreasing till 90 DAI and again increased till 105 DAI. The final content was 368.55 kg ha^{-1}. All the changes recorded in available P content during incubation were significant.

In T_6 the P content increased till 90 DAI (from 278.28 kg ha^{-1} to 696.68 kg ha^{-1}) and then it decreased till 105 DAI (517.88 kg ha^{-1}). All the changes recorded in available P content during incubation were significant.

In T_7, the P release showed continuous and significant increase throughout the period of incubation. The P content increased from 299.21 kg ha^{-1} to 919.06 kg ha^{-1}.

In T_8, there was a rise in available P_2O_5 content till 15 DAI (233.98 kg ha^{-1} to 284.38 kg ha^{-1}) and then it decreased to 255.62 kg ha^{-1} on 30 DAI which remained stable on 45 DAI, and then it declined to 117.61 kg ha^{-1} at 75 DAI. The P content increased again to 141.02 kg ha^{-1}at 90 DAI and again dropped to reach 135.01 kg ha^{-1} on 105 DAI.

In T_9, there was a decline in available P_2O_5 content at 15 DAI. From the initial value of 271.84 kg ha^{-1} it reached 228.47 kg ha^{-1}.It remained without significant change on 30 DAI. Then it increased till 60 DAI (286.34 kg ha^{-1}). There was a decline in content at 75 DAI (156.04 kg ha^{-1}) and again it increased at D105 (834.83 kg ha^{-1}).

In T_{10}, the available P_2O_5 content in soil did not show any significant change till 15 DAI. Then it increased on 30 DAI (143.34 kg ha^{-1}) and again remained stable on 45 DAI. Then it decreased till 75 DAI (104.92 kg ha^{-1}) and again increased to reach 202.43 kg ha^{-1} at 105 DAI.

In T_{11}, the P content was decreasing at first till 15 DAI (166.02 kg ha^{-1} to 134.66 kg ha^{-1}) .Then it increased to 175.79 kg ha^{-1} on 30 DAI and remained without significant change on 45 DAI also. Again it increased to 205.14 kg ha^{-1} on 60 DAI and was stable on 75 DAI. Thereafter it kept on increasing 384.98 kg ha^{-1} at 105 DAI.

In T_{12}, there was increase in available P_2O_5 content till 30 DAI (207.12 kg ha^{-1} to 304.16 kg ha^{-1}).It remained stable on 45 DAI and declined to 127.99 kg ha^{-1} at 90 DAI and increased to 153.02 kg ha^{-1} at 105 DAI.

In T_{13} there was no significant change in available P_2O_5 content till 15 DAI (191.59 kg ha^{-1} and 198.02 kg ha^{-1}), then it decreased till 30 DAI (166.56 kg ha^{-1}) and again increased to 178.68 kg ha^{-1} at 45 DAI. Then again it decreased to 88.89 kg ha^{-1} at 105 DAI.

At day zero of the incubation study, the highest P_2O_5 content in soil was detected in T_7 (299.21 kg ha^{-1}) and it was on par with T_4 (293.84 kg ha^{-1}).The lowest content was found in T_{10} (127.76 kg ha^{-1}).After a fortnight, the highest content of available P_2O_5 was recorded inT_4 (334.91 kg ha^{-1}) which was on par with T_7 and T_6, and the lowest P_2O_5 was found in T_{10} (132.09 kg ha^{-1})which was on par with T_{11}. At 30 DAI, 45 DAI and 60 DAI, the highest P_2O_5 content was recorded in T_7 (368.00 kg ha^{-1}, 455.71 kg ha^{-1} and 557.99 kg ha^{-1} respectively) and the lowest P_2O_5 content was in T_{10} which were 143.34 kg ha^{-1}, 150.61 kg ha^{-1} and 138.39 kg ha^{-1}respectively. At 30 DAI, T_7 was on par with T_4 and T_6.T_5 was on par with T_1 and T_{12}, and T_9 and T_2 were also on par with each other. At 45 DAI, T_1 and T_3 as well as T_{11} and T_{13} were on par. At 60 DAI T_1, T_3, T_4 and T_5 were on par, with regard to their P content. At 75 DAI, T_6 registered the highest content (664.38 kg ha^{-1}) which was significantly superior to T_7 (617.16 kg ha^{-1}). The lowest content was in T_{10} (104.92 kg ha^{-1}) and it was significantly inferior to all other treatments. T_9 was on par with T_{13}. At day 90 DAI, the highest P_2O_5 content was found in T_6 (696.68 kg ha^{-1}) which was on par with T_7, while the lowest P_2O_5 was in T_{13} (124.19 kg ha^{-1}) which was on par with T_2, T_{10} and T_{12}. T_4 was on par with T_9. At 105th day after incubation, the highest P_2O_5 content was in T_7 (919.06 kg ha^{-}1) and the lowest P_2O_5 (88.90 kg ha^{-1}) content was in T_{13}.T_2 and T_8 were on par with each other. T_7 was significantly superior to all other treatments with regard to available P_2O_5 content.

4.5.3 *Mineralization pattern of Potassium*

The mineralization pattern of potassium (Table 33) also followed a widely varying behaviour in different treatments in incubation experiment. In T_1 the available K_2O content was found to increase till 30 DAI. From the initial value of 3222.12 kg ha^{-1} it reached 3562.99 kg ha^{-1} and then decreased till 60 DAI to 2249.69 kg ha^{-1}. Thereafter it increased till 105 DAI (5339.46 kg ha^{-1}) In T_2, there was an initial decrease in available K_2O content from 2515.65 kg ha^{-1} to 1440.98 kg ha^{-1}. Then it increased to 1570.22 kg ha^{-1} at 30 DAI and declined to 1202.69 kg ha^{-1} at 45 DAI. Again it increased to 3867.93 kg ha^{-1} at 105 DAI.

Table 33. Incubation study- Mineralization pattern of potassium from organic manures

Treatment	Available K_2O (kg ha^{-1})								
	Day 0	**Day 15**	**Day 30**	**Day 45**	**Day 60**	**Day 75**	**Day 90**	**Day 105**	**Mean**
T_1	3222.12 (56.76)	3478.99 (58.98)	3562.99 (59.69)	2521.72 (50.22)	2249.69 (47.43)	3446.09 (58.7)	4198.13 (64.79)	5339.46 (73.07)	3446.8 (58.71)
T_2	2515.65 (50.16)	1440.98 (37.96)	1570.22 (39.63)	1202.69 (34.68)	1291.13 (35.93)	3480.72 (59)	3745.43 (61.2)	3867.93 (62.19)	2264.8 (47.59)
T_3	1431.06 (37.83)	1045.72 (32.34)	846.72 (29.1)	1010.43 (31.79)	840.92 (29)	1140.19 (33.77)	3182.16 (56.41)	2702.09 (51.98)	1427.3 (37.78)
T_4	4844.77 (69.6)	3381.89 (58.15)	2764.39 (52.58)	3244.06 (56.96)	1951.22 (44.17)	4202.39 (64.83)	4204.53 (64.84)	5580.99 (74.71)	3688.1 (60.73)
T_5	1921.31 (43.83)	1310.52 (36.2)	1165.89 (34.15)	1056.23 (32.5)	1201.4 (34.66)	1979.93 (44.5)	3180.13 (56.39)	1382.09 (37.18)	1594.4 (39.93)
T_6	1019.49 (31.93)	1059.68 (32.55)	850.96 (29.17)	842.51 (29.03)	631.59 (25.13)	660.56 (25.7)	1799.39 (42.42)	1378.23 (37.12)	1000.5 (31.63)
T_7	339.21 (18.42)	306.64 (17.51)	371.96 (19.29)	251.72 (15.87)	179.48 (13.4)	303.51 (17.42)	326.52 (18.07)	348.68 (18.67)	300.3 (17.33)
T_8	401.88 (20.05)	417.28 (20.43)	359.99 (18.97)	398.21 (19.96)	303.37 (17.42)	649.85 (25.49)	839.06 (28.97)	774.66 (27.83)	501.3 (22.39)
T_9	161.27 (12.7)	156.89 (12.53)	175.52 (13.25)	169.88 (13.03)	120.59 (10.98)	124.66 (11.17)	421.59 (20.53)	121.56 (11.03)	172.9 (13.15)
T_{10}	199.12 (14.11)	193.44 (13.91)	169.61 (13.02)	192.21 (13.86)	149.55 (12.23)	540.70 (23.25)	505.01 (22.47)	480.89 (21.93)	283.9 (16.85)
T_{11}	369.73 (19.23)	372.32 (19.3)	348.79 (18.68)	312.58 (17.68)	212.14 (14.57)	371.23 (19.27)	422.05 (20.54)	480.79 (21.93)	357.2 (18.9)
T_{12}	261.55 (16.17)	348.76 (18.68)	260.65 (16.14)	316.05 (17.78)	211.22 (14.53)	540.84 (23.26)	342.22 (18.5)	468.49 (21.64)	(336.4 18.34)
T_{13}	127.00 (11.27)	122.81 (11.08)	90.21 (9.5)	86.62 (9.31)	59.74 (7.73)	76.10 (8.72)	181.43 (13.47)	180.88 (13.45)	111.7 (10.57)
Mean	956.7 (30.93)	808.3 (28.43)	738.2 (27.17)	694.8 (26.36)	558.4 (23.63)	985.3 (31.93)	1413.0 (37.59)	1322.1 (36.36)	CD=0.15
CD	0.33								

(Square root transformed values within parentheses)

In T_3, also there was an initial drop in available K_2O content from 1431.06 kg ha^{-1} to 846.72 kg ha^{-1}. Then it increased to 1010.43 kg ha^{-1} at 45 DAI, again to decrease at 60 DAI to a value of 840.92 kg ha^{-1}. It again increased at 90 DAI (3182.16 kg ha^{-1}) and declined at 105 DAI (2702.09 kg ha^{-1}). In T_4, the available K_2O content in soil decreased till 30 DAI (from 4844.77 kg ha^{-1} to 2764.39 kg ha^{-1}) and increased to 3244.06 kg ha^{-1} at 45 DAI. The K content remained without significant change on 75 DAI and 90 DAI, and finally the K content of soil was 5580.99 kg ha^{-1}.

In T_5, the K content decreased till 45DAI (1921.31 kg ha^{-1} to 1056.23 kg ha^{-1}) and then increased till 90 DAI (3180.13 kg ha^{-1}) to decrease again to 1382.09 kg ha^{-1} at 105 DAI. In T_6, the K content increased till 15 DAI from 1019.49 kg ha^{-1} to 1059.68 kg ha^{-1}. Then it remained without significant change on 30 DAI and 45 DAI. It then showed an undulating pattern of increase and decrease to reach a value of 1378.23 kg ha^{-1} at 105 DAI. In T_7 also the available K content showed an undulating pattern and the value at day zero (339.21 kg ha^{-1}) changed to 348.68 kg ha^{-1} at 105 DAI. In T_8, the pattern was the same and it changed from 401.88 kg ha^{-1} at day zero to 774.66 kg ha^{-1} at 105 DAI.

In T_9, the change in available K content was from 161.27 kg ha^{-1} at day zero to 121.56 kg ha^{-1}at 105 DAI. The peak content of available K was at 90 DAI which was 421.59 kg ha^{-1}.The values recorded at zero day and 15 DAI were on par with each other. The K content at 30 DAI was on par with that on 45 DAI as well as the K content registerd on 60 DAI was on par with that on 75 DAI.

In T_{10}, The value of available K_2O in soil changed from 199.12 kg ha^{-1} on day zero to 480.89 kg ha^{-1} at 105 DAI with a peak value of 540.70 kg ha^{-1} at 75 DAI. There was no significant change in available K content during the first fortnight. Thereafter it showed an undulating pattern of increase and decrease in K content of soil.

In T_{11}, there was no significant change in available K_2O (369.73 kg ha^{-1} and 372.32 kg ha^{-1}) during the first fortnight. Then it declined to 212.14 kg ha^{-1} at 60 DAI and again increased to 480.79 kg ha^{-1} at 105 DAI. In T_{12}, the available K_2O in soil showed alternate increase and decrease at the progressive sampling stages and the value at day zero which was 261.55 kg ha^{-1}, reached 468.49 kg ha^{-1} at the end of incubation period, at 105 DAI. In T_{13}, at day zero the content was 127.00 kg ha^{-1}

which remained without significant change during the first fortnight. Then it decreased to 90.21 kg ha^{-1} on 30 DAI which was stable on 45 DAI, and then decreased till 60 DAI (59.74 kg ha^{-1}). It then increased to reach a value of 181.43 kg ha^{-1} on 90 DAI which remained stable thereafter.

At day zero, the highest content was recorded in T_4 (4844.77 kg ha^{-1}) followed by T_1 (3222.12 kg ha^{-1}), and the lowest was in T_{13} (127.00 kg ha^{-1}). All the treatments were significantly different from each other in their K contents. At 15 DAI the highest content was observed in T_1 (3478.99 kg ha^{-1}) followed by T_4 (3389.89 kg ha^{-1}) and the lowest was in T_{13} (122.81 kg ha^{-1}). At 30 DAI, the highest content of 3562.99 kg $ha^{-1}$was noticed in T_1, followed by 2764.39 kg ha^{-1} in T_4, and the lowest (90.21 kg ha^{-1}) was recorded in T_{13}. At 45 DAI, the highest content was recorded in T_4 (3244.06 kg ha^{-1}) followed by T_1 (2521.72 kg ha^{-1}) and the lowest value of 86.62 kg ha^{-1} was found in T_{13}. At 60 DAI, the highest content was in T_1 (2249.69 kg ha^{-1}) and the lowest was in T_{13} (59.74 kg ha^{-1}). At 75 DAI and 90 DAI the highest content was observed in T_4 (4202.39 kg ha^{-1} and 4204.53 kg ha^{-1} respectively) and the lowest values were in T_{13} (76.10 kg ha^{-1} and 181.43 kg ha^{-1} respectively). At 75 DAI, T_1 and T_2 were on par. Also T_6 and T_8 were on par as well as T_{12} and T_{10}. At 90 DAI T_4 and T_1 were on par as well as T_3 and T_5, and T_9 and T_{11}. At 105 DAI, the highest content was found in T_4 (5580.99 kg ha^{-1}) and the lowest content was in T_9 (121.56 kg ha^{-1}).T_5 and T_6 were on par as well as T_{10}, T_{11} and T_{12}.

4.6 FIELD EXPERIMENT

A test crop of amaranthus variety Arun was raised to evaluate the efficiency of selected COMs and SCMs. A second crop was raised to study the residual effects of the organic manures. The data obtained from the experiment were statistically analysed and the results are presented below.

4.6.1 First crop

4.6.1.1 Growth characters

The data regarding growth characters of the crop viz., plant height, number of leaves per plant, number of branches per plant, stem girth and leaf: stem ratio are presented in Table 34.

Table 34. Growth characters of first crop

Treatment	Plant height (cm)	Number of leaves plant^{-1}	Stem girth (cm)	Number of branches plant^{-1}	Leaf: Stem
T_1	41.10	42.47	4.29	3.40	0.253
T_2	36.03	35.20	2.96	3.47	0.433
T_3	35.73	39.13	3.45	4.13	0.687
T_4	36.70	36.73	3.45	4.00	0.493
T_5	35.50	35.60	3.73	3.80	0.577
T_6	32.30	32.80	3.17	2.93	0.697
T_7	33.83	34.60	2.99	3.13	0.490
T_8	36.13	41.07	3.49	4.00	0.450
T_9	37.63	37.53	3.41	3.53	0.343
T_{10}	34.30	35.33	3.22	3.60	0.693
T_{11}	37.17	40.53	3.41	3.80	0.483
T_{12}	38.77	53.67	3.25	3.20	0.410
T_{13}	36.37	35.47	3.11	3.13	0.430
T_{14}	35.37	35.93	3.11	3.27	0.397
SE	2.04	7.12	0.245	0.711	0.058
CD	NS	NS	NS	NS	0.1699

Table 35. Yield and yield attributes of first crop

Treatment	Yield of 1st cutting (t ha^{-1})	Yield of 2nd cutting (t ha^{-1})	Total yield per plant (g plant^{-1})	Total marketable yield (t ha^{-1})	Total dry matter production (Kg ha^{-1})
T_1	9.22	7.78	34.60	16.21	1973.1
T_2	10.56	8.72	39.96	18.17	2164.4
T_3	9.66	8.44	35.95	17.18	1839.8
T_4	13.16	9.33	50.21	21.23	2523.3
T_5	9.00	7.11	33.21	15.06	1874.9
T_6	8.94	7.78	34.11	15.79	2007.7
T_7	7.78	7.11	29.26	13.74	1539.5
T_8	9.89	8.56	37.41	17.56	1995.1
T_9	8.33	7.72	31.27	15.31	1764.7
T_{10}	7.67	7.00	28.7	13.98	1717.1
T_{11}	7.33	5.55	27.15	12.15	1448.6
T_{12}	7.67	6.22	28.73	13.22	1514.0
T_{13}	7.61	6.05	28.99	12.67	1456.8
T_{14}	7.22	5.11	27.35	10.77	1320.3
SE	0.611	0.601	2.38	0.837	187.84
CD	1.7764	1.7459	6.915	2.434	546.16

4.6.1.1.1 Plant height

There was no significant difference in the height of plants (Table 34) due to different treatments. The height of plants was highest in T_1 (41.10cm) and lowest height was recorded in T_6 (32.30 cm).

4.6.1.1.2 Number of leaves per plant

There was found to be no significant difference in the number of leaves per plant (Table 34) in different treatments. The highest number of leaves was observed in T_{12} (53.67) and the lowest was 32.80 leaves per plant recorded in T_6.

4.6.1.1.3 Stem girth

The stem girth (Table 34) of the plants ranged from 2.96 cm in T_2 to 4.29 cm in T_1. All the treatments were on par with each other with regard to stem girth of plants.

4.6.1.1.4 Number of branches per plant

The number of branches per plant (Table 34) was highest in T_3 (4.13) while it was lowest in T_6 (2.93) and the different treatments showed no significant effect on this growth character of the crop.

4.6.1.1.5 Leaf: Stem ratio

The ratio of leaf: stem (Table 34) is an important indicator of growth of amaranthus. The ratio was highest in the treatment T_6 (0.697) which was on par with T_{10}, T_3 and T_5. The lowest value of leaf: stem ratio was observed in T_1 (0.253) which was on par with T_{12}, T_{14} and T_9.

4.6.1.2 Yield and Yield Attributes

The data on the yield and yield attributes of the first crop of amaranthus are given in Table 35.

4.6.1.2.1 Yield at first cutting

The highest yield (Table 35) of 13.16 t ha^{-1} was recorded in T_4 which was significantly higher than the yields of all other treatments. It was followed by T_2 with 10.56 t ha^{-1} and it was on par with T_3, T_1, T_6, T_5 and T_8. The lowest yield of 7.22 t ha^{-1} was obtained from the control treatment (T_{14}) and was on par with the treatments T_7, T_9, T_{10}, T_{11}, T_{12} and T_{13}.

4.6.1.2.2 Yield at second cutting

Yield of amaranthus crop at the second harvest (Table 35) was highest in the treatment T_4 (9.33 t ha^{-1}) which was on par with T_1, T_2, T_3, T_6, T_8 and T_9. The lowest yield was obtained from T_{14} (5.11 t ha^{-1}) and was on par with T_{11} and T_{13}.

4.6.1.2.3 Total yield per plant

The yield obtained per plant (Table 35) was highest in the treatment T_4 (50.21 g $plant^{-1}$) which was significantly different from all other treatments. The second highest yield per plant was recorded in T_2 (39.96 g $plant^{-1}$) which was on par with T_8, T_3, T_1, T_6 and T_5. The yield was lowest in T_{11} (27.15 g $plant^{-1}$) which was on par with T_{14}, T_{10}, T_{12}, T_{13}, T7, T_9 and T_5.

4.6.1.2.4 Total marketable yield

The total marketable yield (Table 35) from first crop varied from 10.77 t ha^{-1}in T_{14} to 21.23 t ha^{-1} in T_4. T_4 was significantly superior compared to all other treatments. T_2 was next to T_4 and was on par with T_8, T_3, T_1 and T_6. T_{14} was on par with T_{11}.

4.6.1.2.5 Total Dry Matter Production

The total dry matter production (DMP) of first crop (Table 35) varied from 1320.3 kg ha^{-1} in T_{14} to 2523.3 kg ha^{-1} in T_4. T_4 was on par with T_2, T_6 and T_8. T_{14} was on par with T_{11} and T_{13}.

4.6.1.2.6 Uptake of nutrients by first crop

The uptake of nitrogen, phosphorus, potassium and sodium by the crop are given in Table 36.

4.6.1.2.6.1 Nitrogen uptake

The crop removal of nitrogen (Table 36) from the soil was highest in T_4 which was 88.29 kg ha^{-1}. It was on par with T_5, T_9, T_7, T_{10}, T_8, T_2, T_6 and T_1. The lowest N uptake was recorded in the control plot (T_{14}) which was 38.40 kg ha^{-1} and was on par with T_3.

4.6.1.2.6.2 Phosphorus uptake

The uptake of phosphorus (Table 36) was highest in the plot which received the treatment T_6.The plants in this plot removed from the soil a quantity of 11.17 kg

Table 36. Uptake of plant nutrients by first crop

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sodium (kg ha^{-1})
T_1	67.03	8.53	109.90	7.68
T_2	70.40	6.96	77.33	5.41
T_3	54.80	6.90	113.07	9.20
T_4	88.29	6.27	160.43	12.62
T_5	83.03	3.93	80.83	6.80
T_6	67.87	11.17	87.47	5.02
T_7	75.40	6.77	72.87	6.48
T_8	73.23	10.63	94.47	8.26
T_9	75.73	7.73	87.43	5.50
T_{10}	74.47	6.30	102.97	8.86
T_{11}	59.73	4.17	62.67	7.29
T_{12}	59.90	6.03	65.10	7.27
T_{13}	63.83	5.50	64.60	4.21
T_{14}	38.40	3.07	49.20	3.30
SE	7.74	0.933	11.12	1.12
CD	22.514	2.714	32.33	3.249

Table 37. Quality parameters of first crop

Treatment	Moisture (%)	Crude fibre (%)	Crude Protein (%)	β-carotene (μg 100g^{-1})	Oxalate (%)	Ash (%)
T_1	88.39	11.67	21.25	1254.67	1.63	17.00
T_2	88.77	12.33	20.42	1258.30	1.59	16.00
T_3	89.96	13.00	18.96	1262.33	1.59	17.00
T_4	88.86	11.00	21.88	1255.10	1.44	19.33
T_5	88.38	11.33	27.71	1266.83	1.36	17.50
T_6	88.03	11.50	21.25	1257.30	1.46	17.17
T_7	89.62	12.33	30.63	1257.43	1.56	19.50
T_8	89.16	11.50	22.92	1265.77	1.78	17.67
T_9	89.01	13.33	26.96	1250.10	1.81	19.33
T_{10}	88.29	13.17	27.29	1251.10	1.98	18.67
T_{11}	88.76	12.33	25.42	1250.17	2.00	15.33
T_{12}	89.21	11.83	24.38	1252.50	1.99	18.00
T_{13}	89.41	12.67	26.88	1251.80	2.05	18.33
T_{14}	89.36	13.50	18.33	1248.47	2.31	16.17
SE	0.693	0.452	1.59	0.226	0.014	1.19
CD	NS	1.315	4.626	0.658	0.039	NS

ha^{-1} of P. The P uptake in T_6 was on par with that from T_8 and T_1. The lowest amount of P uptake was recorded in T_{14} which was only 3.07 kg ha^{-1}and was on par with T_5 (3.93 kg ha^{-1}).

4.6.1.2.6.3 Potassium uptake

The uptake of K (Table 36) by the crop was highest in the treatment T_4 and lowest in T_{14}. The uptake of K in T_4 was 160.43 kg ha^{-1} which was significantly superior to all other treatments. The second highest value was recorded in T_3 (113.07 kg ha^{-1}) and it was on par with T_1, T_{10}, T_8, T_6, T_9, and T_5.The lowest K uptake (49.20 kg ha^{-1}) was found in T_{14} which was on par with T_{11}, T_{13}, T_{12}, T_7, T_2 and T_5.

4.6.1.2.6.4 Sodium uptake

The crop uptake of sodium (Table 36) was highest in T_4 which was 12.62 kg ha^{-1} and it was significantly higher than all other treatments. The lowest Na uptake (3.30kg ha^{-1}) was observed in T_{14} and it was on par with T_{13}, T_6, T_2, T_9 and T_7.

4.6.1.3 Plant Analysis

4.6.1.3.1 Quality Parameters

The characters which determine the quality of the crop as a vegetable were analysed and the results are presented in Table 37.

4.6.1.3.1.1 Moisture content

The moisture contents (Table 37) of plants from different treatments were not significantly different from each other. The moisture content varied from 88.03 per cent in T_6 89.96 per cent in T_3.

4.6.1.3.1.2 Crude fibre content

The crude fibre content (Table 37) in plants was highest in T_{14} (13.50 per cent) followed by 13.33 per cent in T_9. The treatments T_2, T_3, T_7, T_9, T_{10}, T_{11}, T_{13} and T_{14} were all on par with each other with regard to crude fibre content. The lowest crude fibre content (11.00 per cent) was found in T_4 and it was on par with T_5, T_6, T_8, T_1 and T_{12}.

4.6.1.3.1.3 Crude Protein content

The crude protein content (Table 37) of plants was significantly influenced by the treatments. The highest protein content was recorded in T_7 (30.63 per cent) which was on par with T_5, T_{10}, T_9 and T_{13}. The lowest protein content was observed in T_{14} (18.33 per cent) and it was on par with T_1, T_2, T_3, T_4, T_6 and T_8.

4.6.1.3.1.4 β –carotene content

The β -carotene content (Table 37) varied from 1248.47 µg $100g^{-1}$ in T_{14} to 1266.83 µg $100g^{-1}$in T_5. The highest value registered in T_5 was followed by T_8 (1265.77 µg $100g^{-1}$), T_3 (1262.33 µg $100g^{-1}$) and T_2 (1258.30 µg $100g^{-1}$), and all the treatments were significantly different from each other with regard to their β -carotene content. T_{14} was significantly inferior to all other treatments.

4.6.1.3.1.5 Oxalate content

The antinutritional factor in amaranthus viz., oxalate content (Table 37) ranged from 1.36 per cent in T_5 to 2.31per cent in T_{14}. The highest value of oxalate recorded in T_{14} was significantly higher than all other treatments. It was followed by T_{13}, T_{11} which were also significantly different from each other. T_5 recorded a significantly lower (1.36 per cent) oxalate content compared to all other treatments. The next higher value was in T_4 which was on par with T_6.

4.6.1.3.1.6 Ash Content

The ash contents (Table 37) of the plants in different treatments were not significantly different from each other. The highest value was 19.50 per cent in T_7 and the lowest value of ash content was 15.33 per cent in T_{11}.

4.6.1.3.2 Nutrient content of plants

The plant samples collected from each treatment plot were analysed for their contents of nitrogen, phosphorus, potassium and sodium. The results obtained are given in Table 38.

4.6.1.3.2.1 Nitrogen

The nitrogen content (Table 38) in plants was found to range from 2.93 per cent to 4.90 per cent. The lowest N content was found in T_{14} which was on par with T_1, T_2, T_3, T_4, T_6 and T_8. The highest N content in T_7 was on par with that of T_5, T_9, T_{10} and T_{13}.

Table 38. Nutrient content in plants of first crop

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sodium (%)
T_1	3.40	0.428	5.58	0.400
T_2	3.27	0.321	3.58	0.250
T_3	3.03	0.379	6.17	0.500
T_4	3.50	0.242	6.33	0.500
T_5	4.43	0.212	4.33	0.367
T_6	3.40	0.548	4.33	0.250
T_7	4.90	0.435	4.75	0.417
T_8	3.67	0.532	4.75	0.417
T_9	4.30	0.440	4.92	0.317
T_{10}	4.37	0.369	6.00	0.517
T_{11}	4.07	0.287	4.33	0.500
T_{12}	3.90	0.399	4.22	0.483
T_{13}	4.30	0.381	4.42	0.283
T_{14}	2.93	0.234	3.75	0.250
SE	0.255	0.026	0.222	0.047
CD	0.7410	0.0752	0.6443	0.1374

Table 39. Physico-chemical properties of initial soil

Sl. No.	Character	Quantity
1	Mechanical analysis: Coarse sand (%)	13.5
	Fine sand (%)	35.2
	Silt (%)	26.9
	Clay (%)	24.1
	Texture	Sandy clay loam
2.	pH	4.5
3.	Electrical conductivity(dSm^{-1})	0.10
4	Bulk density (Mg m^{-3})	1.24
5.	Particle density (Mg m^{-3})	2.50
6.	Water holding capacity (%)	26.86
7.	Available nitrogen (kg ha^{-1})	357.0
8.	Available P_2O_5(kg ha^{-1})	197.6
9.	Available K_2O(kg ha^{-1})	126.7
10.	Organic carbon (%)	1.05

4.6.1.3.2.2 Phosphorus

The P content (Table 38) of plants was found to vary from 0.212 per cent in T_5 to 0.548 per cent in T_6. The effect of treatments on P content of plants was significant. T_6, which recorded the highest P content (0.548 per cent) was on par with T_8. The lowest P content of T_5 (0.212 per cent) was on par with T_4, T_{11} and T_{14}.

4.6.1.3.2.3 Potassium

The K content (Table 38) of plants was significantly influenced by the treatments. The highest K content was recorded in T_4 (6.33 per cent) which was on par with T_3 and T_{10}. The lowest K content was in T_2 (3.58 per cent) and it was on par with T_{14}.

4.6.1.3.2.4 Sodium

The highest content of sodium in plants (Table 38) was recorded in T_{10} (0.517 per cent) which was as per with T_3, T_4, T_{11}, T_{12}, T_7, T_8 and T_1. The lowest Na content was in plants grown in T_{14} (0.250 per cent) and it was on par with T_{13}, T_6 and T_2.

4.6.1.4 Soil Analysis

The soil samples taken from the experimental site were analysed prior to the cultivation of the crop and the results of initial soil analysis are presented in Table 39. The soil was sandy clay loam with a pH of 4.5 and medium status of available nitrogen, high status of available P, medium status of available K and high status of organic carbon. The soil from each treatment plot was analysed for the important soil properties after harvest of the first crop. The results are given in Table 40.

4.6.1.4.1 Organic Carbon

The organic carbon content (Table 40) of the soil in treatment plots after harvest of the first crop was analysed. The result of statistical analysis showed that the organic carbon content of the treatment T_{11} (1.80 per cent) was significantly superior compared to all other treatments. It was followed by 1.54 per cent in T_8 which was on par with T_2, T_{10}, T_{12} and T_7. The treatments showed an increase in organic carbon content from the initial value of 1.05 per cent. The lowest content of soil organic carbon was recorded in T_{14} (1.02 per cent) which was on par with T_5.

Table 40. Soil properties after first crop

Treatment	Organic carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available Na (kg ha^{-1})	pH	EC (dSm^{-1})
T_1	1.31	327.33	171.13	372.0	103.00	3.77	0.97
T_2	1.54	527.00	228.43	392.0	96.67	4.57	0.80
T_3	1.22	308.33	177.80	530.0	149.33	3.87	0.97
T_4	1.27	183.67	152.70	208.0	117.67	3.47	0.67
T_5	1.10	273.67	199.93	294.0	82.67	3.87	0.89
T_6	1.37	440.33	106.93	508.0	129.00	4.73	0.47
T_7	1.43	322.67	288.80	370.0	149.00	4.67	1.03
T_8	1.54	321.33	263.73	312.0	170.67	4.03	0.83
T_9	1.34	407.67	204.30	864.0	129.00	4.07	1.20
T_{10}	1.47	671.33	251.63	1140.0	194.33	4.27	1.13
T_{11}	1.80	293.33	223.87	442.0	102.33	4.43	1.07
T_{12}	1.45	358.67	239.27	422.0	145.67	4.10	1.17
T_{13}	1.26	379.00	161.47	322.0	123.33	3.63	0.83
T_{14}	1.02	279.00	157.23	206.0	99.33	3.67	0.57
SE	0.046	8.08	1.97	11.63	3.66	0.043	0.052
CD	0.135	23.493	5.738	33.825	10.634	0.125	0.152

4.6.1.4.2 Available Nitrogen

The data on available N content in soil after harvest of first crop was statistically analysed and the treatment effects were found to be significant (Table 40). The highest content of available N was recorded in T_{10} (671.33 kg ha^{-1}). The lowest available N content was observed in T_4 (183.67 kg ha^{-1}) which was significantly less than all other treatments. T_{13} (379.00 kg ha^{-1}) was on par with T_{12}, while T_1, T_7, T_8 and T_3 were on par.T_{14}, T_{11} and T_5 were also on par with each other.

4.6.1.4.3 Available Phosphorus

The available P in soil after harvest of the first crop (Table 40) was estimated as P_2O_5 kg ha^{-1}. The available phosphorus content was highest in T_7 (288.80 kg P_2O_5 ha^{-1}) which was significantly higher than all other treatments. It was followed by T_8 (263.73 kg ha^{-1}), T_{10} (251.63 kg ha^{-1}) and T_{12} (239.27 kg ha^{-1}) and all there were significantly different from each other. The lowest value of available P_2O_5 was observed in T_6 (106.93 kg ha^{-1}). The next higher value was found in T_4 (152.70 kg ha^{-1}) which was on par with T_{14} (157.23 kg ha^{-1}).

4.6.1.4.4 Available Potassium

The available potassium content (Table 40) in soil samples from each treatment plot was estimated and expressed as K_2O in kg ha^{-1}. The available potassium content was highest in T_{10} (1140.00 kg K_2O ha^{-1}) which was significantly higher than all other treatments. It was followed by T_9 (864.00 kg K_2O ha^{-1}). The lowest content of available potassium was obtained from T_{14} (206.00 kg K_2O ha^{-1}), which was on par with T_4 (208.00 kg K_2O ha^{-1}).

4.6.1.4.5 Sodium

The content of sodium (Table 40) in soil was highest in T_{10} (194.33 kg ha^{-1}) followed by T_8 (170.67 kg ha^{-1}). There was significant difference among the treatments with respect to sodium content. The lowest Na content of soil was found in T_5 (82.67 kg ha^{-1}) which was significantly lower than all other treatments.

4.6.1.4.6 Soil pH

The pH of soil (Table 40) in different plots was found to be significantly influenced by the different treatments. The highest pH was recorded in T_6 (4.73) which was on par with T_7 (4.67). The lowest pH was observed in T_4 (3.47) which was significantly lower than all other treatments. T_{13} showed a pH of 3.63 and was on par with T_{14} (3.67).

4.6.1.4.7 Soil Electrical Conductivity

The electrical conductivity of soil (Table 40) was significantly influenced by the different treatments. The highest value of EC was recorded in T_9 (1.20 dS m^{-1}) which was on par with T_{10}, T_{11} and T_{12}. The lowest EC was found in T_6 (0.47 dS m^{-1}) and was on par with T_{14} (0.57 dS m^{-1}).

4.6.2 Second crop

The growth characters, yield and yield attributes, quality parameters, and nutrient uptake by plants were recorded in the same manner as for first crop. The results are given in Tables 41-46.

4.6.2.1 Growth characters

The observations on the growth characters of second crop were subjected to statistical analysis and the results are presented in Table 41.

4.6.2.1.1 Plant height

The height of plants (Table 41) varied from 27.70 cm in T_7 to 39.20 cm in T_9. There was no significant effect of treatments on the height of plants.

4.6.2.1.2 Number of leaves per plant

The treatments showed no significant effect on the number of leaves per plant (Table41). The values ranged from 24.00 (T_6) to 71.00 (T_{12}).

4.6.2.1.3 Stem girth

The influence of different treatments on the stem girth of plants (Table 41) was not significant. The highest stem girth was 4.50 cm in T_{13} and the lowest was 2.50 cm in T_6.

4.6.2.1.4 Number of branches per plant

The number of branches per plant (Table 41) was significantly affected by the treatments and the values ranged from 1.33 in T_4 to 7.00 in T_{12}. T_{12} was on par with T_2. T_4 was on par with T_{14}, T_1, T_{11}, T_7, T_6, T_9 and T_3.

Table 41. Growth characters of second crop

Treatment	Plant height (cm)	Number of leaves plant^{-1}	Stem girth (cm)	Number of branches plant^{-1}	Leaf: Stem
T_1	29.30	31.00	2.97	1.67	0.943
T_2	35.83	40.00	3.70	5.00	0.890
T_3	29.00	41.67	3.77	2.67	1.123
T_4	30.80	41.67	3.43	1.33	0.970
T_5	32.83	39.00	3.53	3.00	1.153
T_6	29.13	24.00	2.50	2.33	1.197
T_7	27.70	40.67	3.50	2.00	0.987
T_8	31.37	42.33	2.83	3.67	0.990
T_9	39.20	40.67	2.97	2.33	0.859
T_{10}	31.83	46.33	3.00	3.33	1.320
T_{11}	28.43	38.33	3.47	1.67	1.030
T_{12}	35.27	71.00	3.30	7.00	1.130
T_{13}	32.77	50.00	4.50	3.67	0.977
T_{14}	29.33	40.67	3.53	1.67	1.323
SE	3.36	8.95	0.402	0.819	0.097
CD	NS	NS	NS	2.382	0.283

Table 42. Yield and yield attributes of second crop

Treatment	Yield (t ha^{-1})	Total yield per plant (g plant^{-1})	Total marketable yield (t ha^{-1})	Total dry matter production (kg ha^{-1})
T_1	6.78	27.63	6.12	727.6
T_2	7.22	27.45	6.44	770.1
T_3	6.89	26.05	6.27	775.4
T_4	8.22	32.45	7.34	936.3
T_5	10.56	44.91	9.72	1227.4
T_6	9.55	37.59	8.64	1156.1
T_7	12.23	46.87	10.93	1420.4
T_8	9.78	37.14	8.49	1076.0
T_9	10.56	40.59	9.36	1196.3
T_{10}	9.33	36.17	8.25	920.6
T_{11}	7.00	26.47	6.09	850.0
T_{12}	9.11	34.71	8.20	880.8
T_{13}	10.55	41.08	9.64	1257.5
T_{14}	5.67	21.43	5.02	593.7
SE	0.443	2.61	0.447	111.09
CD	1.29	7.59	1.29	323.01

4.6.2.1.5 Leaf: Stem Ratio

The leaf: stem ratio of plants (Table 41) in second crop was significantly affected by the treatments. The ratio was highest in T_{14} (1.323) which was on par with T_{10}, T_6, T_5, T_{12} andT_3. The lowest ratio between leaf and stem was found in T_9 (0.859) and it was on par with T_2, T_1, T_4, T_{13}, T_7, T_8, T_{11} and T_3.

4.6.2.2 Yield and yield attributes

The data on the yield and yield attributes of the second crop are presented in Table 42.

4.6.2.2.1. Yield

Statistical analysis of the yield data (Table 42) of second crop showed that the treatments had significant effect on the yield. The highest yield (12.23 t ha^{-1}) was recorded in T_7 followed by T_5, T_9, T_{13}, T_8, T_6 and T_{10} which were all on par with each other. The lowest yield (5.67 t ha^{-1}) was recorded in T_{14} and was on par with T_1.

4.6.2.2.2. Total dry matter production

The total dry matter production of the second crop (Table 42) was significantly influenced by the various treatments. The highest DMP was obtained in T_7 (1420.4 kg ha^{-1}) which was on par with the DMP in treatments T_{13}, T_5, T_9 and T_6. The lowest DMP was noted in T_{14} (593.7 kg ha^{-1}) which was on par with T_1, T_2, T_3 and T_{11}.

4.6.2.2.3. Total marketable yield

The damaged and flowered plants were excluded from the total yield and the total marketable yield was calculated. The data after statistical analysis (Table 42) showed that the highest marketable yield was obtained from T_7 (10.93 t ha^{-1}) followed by T_5 and T_{13} which were all on par with each other. The marketable yield was lowest in control plots (T_{14}) which was only 5.02 t ha^{-1} and it was on par with T_{11}, T_1, T_2, T_3 and T_4.

4.6.2.2.4. *Total yield per plant*

The total yield obtained per plant (Table 42) from each plot was significantly influenced by the treatments applied to the plots. The yield per plant was highest in the treatment T_7 (46.87 g plant^{-1}) followed by T_5, T_{13} and T_9. The lowest yield per plant was recorded in T_{14} (21.43 g plant^{-1}) and it was on par with T_3, T_{11} and T_2.

4.6.2.2.5 Nutrient uptake by the crop

The uptake of nitrogen, phosphorus, potassium and sodium by the second crop were determined and the statistically analysed data are given in Table 43.

4.6.2.2.5.1. Nitrogen uptake

The uptake of nitrogen (Table 43) by the crop was highest in the treatment T_7 (61.57 kg ha^{-1}) followed by T_5, T_9 and T_{13} which were not significantly different from each other. The uptake was lowest in T_{14} (16 .38 kg ha^{-1}) and was on par with T_2 (21. 59 kg ha^{-1}).

4.6.2.2.5.2. Phosphorus uptake

The crop removal of phosphorus (Table 43) from soil was highest in the treatment T_6 (5.55 kg ha^{-1}) followed by T_8, T_7, T_{13} and T_9. The lowest uptake of P was noticed in T_{14} (1.36 kg ha^{-1}), and was on par with T_{11} and T_4.

4.6.2.2.5.3. Potassium uptake

The uptake of K (Table 43) by the crop was highest in the treatment T_7 (71.09 kg ha^{-1}) followed by T_8, T_5, T_4, T_9, and T_{13} which were all on par with each other. The lowest K uptake was recorded in T_{14} (22.75 kg ha^{-1}) and was on par with T_2.

4.6.2.2.5.4. Sodium uptake

The uptake of sodium (Table 43) from the soil by the crop was highest in treatment T_7 (5.69 kg ha^{-1}) followed by T_4 (4.33 kg ha^{-1}), T_{12} (4.14 kg ha^{-1}) and T_5 (4.09 kg ha^{-1}). The uptake was lowest in T_2 (1.67 kg ha^{-1}) and was on par with T_{14} and T_6.

4.6.2.3 Plant Analysis

4.6.2.3.1 Quality Parameters

The data on the quality parameters of the crop are given in Table 44.

Table 43. Uptake of plant nutrients by second crop

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sodium (kg ha^{-1})
T_1	21.68	2.50	35.94	2.53
T_2	21.59	2.60	30.40	1.67
T_3	23.50	3.07	45.89	3.50
T_4	31.03	2.35	57.33	4.33
T_5	50.85	2.49	58.60	4.09
T_6	35.42	5.55	48.61	2.47
T_7	61.57	4.88	71.09	5.69
T_8	36.88	4.95	60.67	3.94
T_9	48.98	4.57	56.24	3.38
T_{10}	33.14	3.37	49.14	3.66
T_{11}	35.53	2.19	36.60	3.95
T_{12}	29.74	3.38	37.17	4.14
T_{13}	48.07	4.63	54.40	4.01
T_{14}	16.38	1.36	22.75	1.73
SE	5.17	0.366	5.83	0.573
CD	15.019	1.064	16.953	1.666

Table 44. Quality parameters of second crop

Treatment	Moisture (%)	Crude fibre (%)	Crude Protein (%)	B-carotene (µg 100g^{-1})	Oxalate (%)	Ash (%)
T_1	87.88	11.83	18.54	1243.7	1.64	15.87
T_2	88.12	12.17	17.50	1250.2	1.60	15.47
T_3	88.38	11.83	18.54	1250.7	1.62	17.77
T_4	88.51	10.83	20.84	1249.1	1.51	18.73
T_5	88.94	10.67	25.83	1252.4	1.44	17.70
T_6	90.31	12.00	19.17	1252.9	1.48	18.43
T_7	88.69	12.17	26.88	1249.0	1.59	18.83
T_8	88.69	11.33	21.25	1255.3	1.83	17.90
T_9	90.43	12.83	25.63	1238.7	1.93	19.63
T_{10}	88.78	13.67	22.92	1240.9	2.02	19.27
T_{11}	89.29	11.67	26.04	1240.9	2.04	16.67
T_{12}	87.97	11.67	21.04	1242.0	2.08	18.43
T_{13}	89.42	12.33	23.75	1239.7	2.13	18.80
T_{14}	89.84	13.83	17.50	1235.8	2.42	16.27
SE	0.943	0.387	1.106	0.226	0.008	1.34
CD	NS	1.1239	3.214	0.658	0.0245	NS

4.6.2.3.1.1 Moisture content

The moisture content (Table 44) of plants in second crop was not significantly influenced by the treatments. The moisture content was highest in T_9 (90.43 per cent) and lowest in T_1 (87.88 per cent).

4.6.2.3.1.2 Crude fibre content

The crude fibre content (Table 44) of plants was significantly influenced by the different treatments. The crude fibre percentage was highest in T_{14} (13.83) which was on par with T_{10} and T_9. The lowest crude fibre content was recorded in T_5 (10.67 per cent) which was on par with T_4 (10.83 per cent).

4.6.2.3.1.3 Crude Protein content

The crude protein content (Table 44) of plants was significantly influenced by treatments applied to plots. The crude protein content was highest in T_7 (26.88 per cent) which was on par with T_{11}, T_5, T_9 and T_{13}. The lowest crude protein content was recorded in T_{14} (17.50 per cent) and it was on par with T_2 and T_3.

4.6.2.3.1.4 β-Carotene content

The treatments differed significantly with regard to their effect on β- carotene content of plants (Table 44). The highest β -carotene content was recorded in T_8 (1255.3 µg $100g^{-1}$) which was significantly superior to all other treatments. It was followed by T_6 andT_5 which were on par with each other. The lowest carotene content was recorded in T_{14} (1235.8 µg $100g^{-1}$).

4.6.2.3.1.5 Oxalate content

The oxalate content (Table 44) of plants in T_{14} (2.42 per cent) was the highest compared to all other treatments. It was followed by T_{13} (2.13 per cent) and T_{12} (2.08 per cent). The lowest oxalate content was in T_5 (1.44 per cent) which was significantly different from T_6 and T_4, which were the next higher values.

4.6.2.3.1.6 Ash content

The ash content (Table 44) of plants was not significantly influenced by the treatments. The highest value was recorded in T_9 (19.63 per cent) and the lowest value was in T_2 (15.47 per cent).

4.6.2.3.2 Nutrient content of plants

The plant samples were analysed for their contents of nitrogen, phosphorus, potassium and sodium. The data are presented in Table 45.

4.6.2.3.2.1. Nitrogen

The nitrogen content (Table 45) of plants was significantly affected by treatments. The highest N content was observed in T_7 (4.30 per cent) which was on par with T_{11}, T_5, T_9 and T_{13}. The lowest N content was recorded in T_{14} (2.80 per cent) and was on par with T_2 and T_3.

4.6.2.3.2.2. Phosphorus

The P content (Table 45) was highest in plants raised in T_6 (0.480 per cent) and was on par with T_8 (0.459 per cent). The lowest content of P in plants was noticed in T_5 (0.203 per cent) and was on par with T_{14}, T_4 and T_{11}.

4.6.2.3.2.3 Potassium

The K content (Table 45) of plants was significantly influenced by treatments and T_4 recorded the highest K content of 6.15 per cent. It was on par with T_3 and T_8.The lowest K content was in T_{14} (3.91 per cent) and it was on par with T_2 and T_6.

4.6.2.3.2.4 Sodium

The sodium content (Table 45) of plants was highest in treatment T_4 which recorded a value of 0.467 per cent. It was on par with T_{11}, T_{12}, T_3, T_7, T_{10} andT_8. The Na content was lowest in T_2 (0.217per cent) which was on par with T_6 and T_{14}.

4.6.2.4 Soil Analysis after Second Crop

The soil samples collected after the harvest of second crop was analysed for the contents of organic carbon, nitrogen, phosphorus, potassium and sodium, and also for pH and EC. The results are presented in Table 46.

4.6.2.4.1 Soil Organic Carbon

The soil organic carbon content (Table 46) was significantly influenced by treatments applied to plots. The organic carbon content was significantly higher in T_8 (1.52 per cent). It was followed by T_{11} (1.39 per cent) and T_6 (1.34 per cent) which were on par. The lowest carbon content was in the soil of T_{14} (1.06 per cent) and it was on par with T_7, T_4 and T_9.

Table 45. Nutrient content in plants in second crop

Treatment	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sodium (%)
T_1	2.97	0.354	4.97	0.333
T_2	2.80	0.338	3.95	0.217
T_3	2.97	0.398	5.94	0.450
T_4	3.33	0.251	6.15	0.467
T_5	4.13	0.203	4.75	0.333
T_6	3.07	0.480	4.22	0.217
T_7	4.30	0.348	4.98	0.400
T_8	3.40	0.459	5.61	0.367
T_9	4.10	0.385	4.66	0.283
T_{10}	3.67	0.371	5.31	0.400
T_{11}	4.17	0.256	4.30	0.467
T_{12}	3.37	0.381	4.26	0.467
T_{13}	3.80	0.369	4.33	0.317
T_{14}	2.80	0.232	3.91	0.283
SE	0.177	0.019	0.209	0.035
CD	0.514	0.0571	0.607	0.102

Table 46. Soil properties after second crop

Treatment	Organic carbon (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Available Na (kg ha^{-1})	pH	EC (dSm^{-1})
T_1	1.19	323.00	158.99	375.20	92.00	4.03	1.00
T_2	1.15	497.67	231.87	424.40	91.33	4.77	0.83
T_3	1.21	295.67	148.62	493.37	140.00	4.07	1.03
T_4	1.09	342.67	149.94	227.00	105.67	3.57	0.63
T_5	1.23	384.33	209.31	276.20	75.00	4.03	0.87
T_6	1.34	375.67	116.51	542.63	122.33	4.87	0.43
T_7	1.08	343.67	264.05	358.47	140.33	4.90	1.00
T_8	1.52	494.00	238.55	269.30	159.00	4.20	0.80
T_9	1.12	445.33	210.54	715.27	121.67	4.20	1.23
T_{10}	1.28	360.67	232.04	1000.6	172.33	4.37	1.17
T_{11}	1.39	434.33	211.58	493.83	91.33	4.57	1.03
T_{12}	1.30	318.00	225.21	397.87	138.33	4.23	1.20
T_{13}	1.22	359.67	153.34	309.30	106.00	3.77	0.73
T_{14}	1.06	392.00	148.19	180.90	90.67	3.77	0.53
SE	0.030	5.92	1.38	1.51	2.87	0.044	0.046
CD	0.087	17.208	4.014	4.380	8.349	0.128	0.133

4.6.2.4.2 Available Nitrogen

The available N content (Table 46) of soil ranged from 295.67 kg ha^{-1} in T_3 to 497.67 kg ha^{-1}(T_2). The N contents were significantly influenced by treatments. The highest value was recorded in T_2 which was on par with T_8. The lowest N content was in T_3 which was significantly less than all others. The treatments T_{12} andT_1 were on par and they were next to T_3 in low N content.T_9 and T_{11} were on par with each other as was T_{14}, T_5 and T_6. T_{13}, T_7 and T_4 were also on par.

4.6.2.4.3 Available Phosphorus

The available P content (Table 46) of soil was highest in T_7 which recorded a value of 264.05 kg P_2O_5 ha^{-1}. It was significantly superior to all other treatments. The second best value was recorded in T_8 (238.55 kg ha^{-1}). The lowest P_2O_5 content was in T_6 (116.5 kg ha^{-1}).

4.6.2.4.4 Available Potassium

The available K_2O content (Table 46) of soil was highest in T_{10} and lowest in T_{14}. The highest value was 1000.6 kg K_2O ha^{-1} and lowest was 180.90 kg ha^{-1}.All the treatments showed significant difference with respect to their available K_2O contents except T_{11} and T_3 which were on par.

4.6.2.4.5 Sodium

The content of sodium in soil (Table 46) was found to vary from 75.00 kg ha^{-1} in T_5 to 172.33 kg ha^{-1} in T_{10}. T_{10} was significantly superior to all the other treatments. T_7, T_3 and T_{12} were on par with each other. T_6 and T_9 were on par, also T_{13} and T_4 as well as T_1, T_{11}, T_2 and T_{14} were also on par.

4.6.2.4.6 Soil pH

The soil pH after harvest of second crop (Table 46) was significantly influenced by the treatments. The pH was highest (4.90) in T_7 which was on par with T_6 (4.87). The lowest pH was recorded in T_4 (3.57). Both T_{13} and T_{14} recorded a pH of 3.77.

4.6.2.4.7 Soil Electrical Conductivity

The EC of soil after second crop (Table 46) showed significant variation with respect to different treatments. The EC was highest in T_9 (1.23 dS m^{-1}) which was on par with T_{12} and T_{10}. The lowest EC was observed in T_6 (0.43 dS m^{-1}).

4.6.2.4.8 Economics of cultivation

The economics of cultivation (Table 47) was worked out using benefit –cost ratio and the actual profit (benefit-cost) obtained from the direct crop and residual crop together. The highest B: C ratio was 1.31 recorded in T_4 and the lowest value was in T_{14} (absolute control) which had a B:C ratio of 0.90.The B: C ratio of COMs ranged from 0.98 in T_1 to 1.31 in T_4. Among SCMs, T_{10} registered the highest B: C ratio of 1.09, followed by 1.08 in T_{12}. The B: C ratio of T_{13} (P.O.P) was 1.15. The highest profit was obtained from T_4 (Rs.143269.50 per hectare), followed by T_{13} (Rs.62384.60 per hectare) and T_2 (Rs.53616.00 per hectare). The least profitable treatments were found to be T_{11} (net loss of Rs.80084.00 per hectare) followed by T_{14} (net loss of Rs.35779.00 per hectare) and T_1(net loss of Rs.11911.10 per hectare).

Table 47. Economics of cultivation

Treatment	Gross Income per hectare (Rs.)	Total Expenditure per hectare (Rs.)	Benefit/Cost	Profit (Benefit-Cost) (Rs.)
T_1	469000.00	480911.10	0.98	-11911.10
T_2	516670.00	463054.00	1.12	53616.00
T_3	492380.00	454916.50	1.08	37463.50
T_4	599830.00	456560.50	1.31	143269.50
T_5	520310.00	476371.20	1.09	43938.80
T_6	512890.00	472270.60	1.09	40620.00
T_7	518140.00	493666.20	1.05	24473.80
T_8	547260.00	493666.20	1.11	53593.80
T_9	518070.00	489664.60	1.06	28405.40
T_{10}	466900.00	427339.70	1.09	39560.30
T_{11}	382970.00	463054.00	0.83	-80084.00
T_{12}	449820.00	415434.90	1.08	34385.10
T_{13}	468510.00	406125.40	1.15	62384.60
T_{14}	331730.00	367509.00	0.90	-35779.00

DISCUSSION

5. DISCUSSION

An investigation was conducted to evaluate the quality of various commercial organic manures manufactured in Kerala, to develop a protocol for the quality standards of COMs, to study their mineralization pattern and to assess their efficacy in a field experiment with amaranthus as test crop. The results of the investigation are discussed in this chapter.

5.1 CHARACTERIZATION OF ORGANIC MANURES AND RAW MATERIALS

The physical, chemical and biochemical characters of the 44 commercial organic manures, standard compost manures and their raw materials were analysed and the results are discussed below.

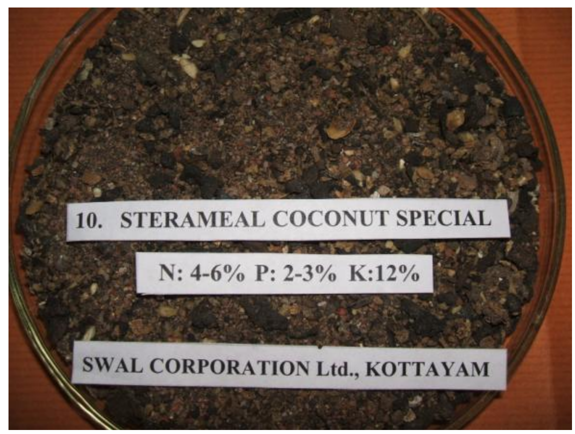
5.1.1 Characterization of COMs

5.1.1.1 *Physical characters of COMs*

5.1.1.1.1 Colour

The colour of COMs presented in Table 7 showed that COMs which were manufactured from a single raw material usually had a homogenous nature with respect to their colour. The variation in colour of the different COMs can be seen in Plate 1.The colour of the product was related to the colour of the raw material. Those COMs which were manufactured by mixing various raw materials like bone meal, leather meal and neem cake etc appeared heterogeneous in colour, with different shades of brown, black, yellow and white. The leather meal portion was mostly black or greyish black in colour, while the bone meal part was yellow, yellowish white, white or brown. Neem cake was mostly dark brown in appearance. Pressmud usually had a dark brown to black colour. The composted organic wastes used as an ingredient of COMs were also uniform in their colour. The presence of the inorganic fertilizer MOP could be detected by the presence of reddish particles in the COMs. Lekasi et al. (2001) observed that the undecomposed material consisting of heterogeneous mixture of organic materials differing in colours will give a mottled appearance. As the decomposition process progresses such materials could be expected to be more homogeneous appearing a uniform dark brown or black at maturity. The colour of the organic manure is an indication of its ingredients as well

Plate 1 – Commercial Organic Manures



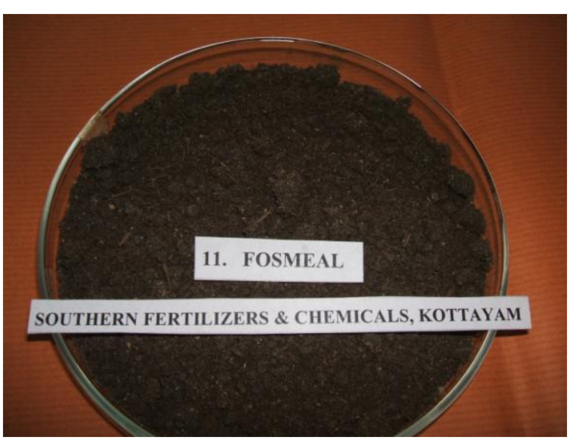


Plate 1 – Commercial Organic Manures

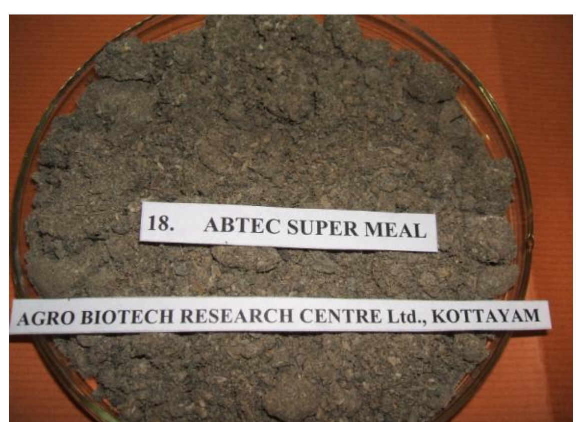


Plate 1 – Commercial Organic Manures

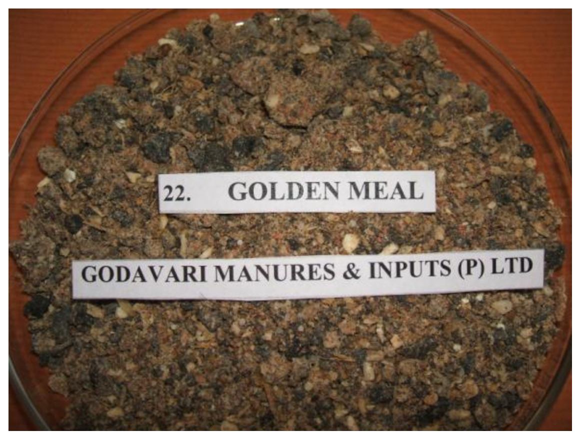
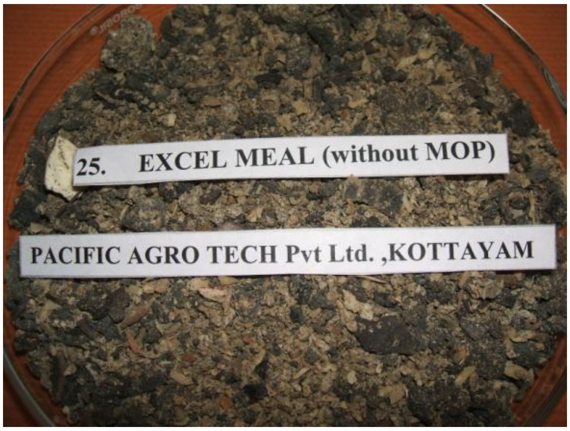


Plate 1 – Commercial Organic Manures



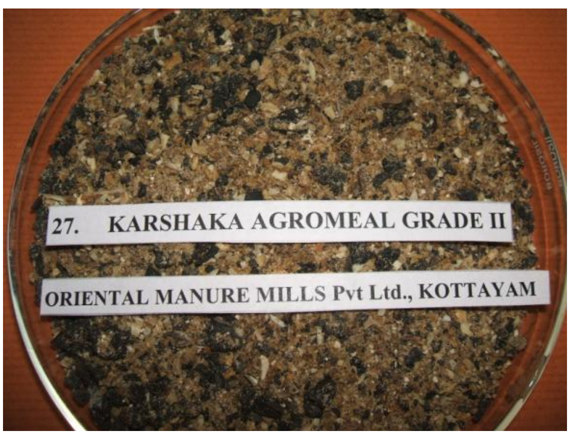
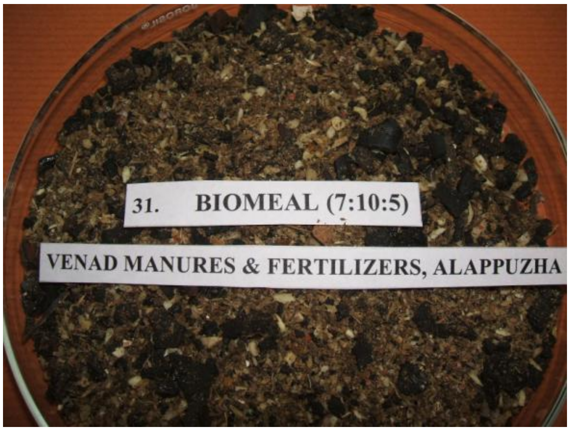


Plate 1 – Commercial Organic Manures



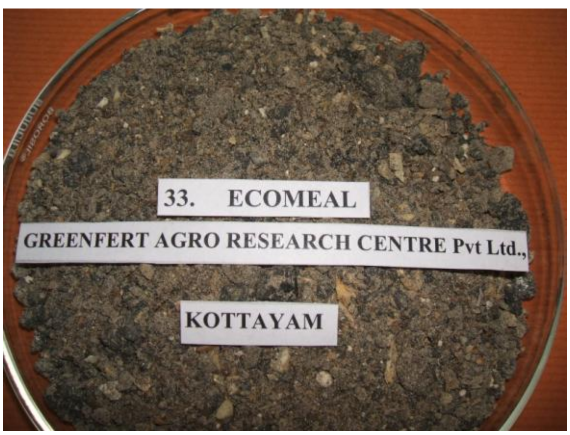


Plate 1 – Commercial Organic Manures

Plate 1 – Commercial Organic Manures

Plate 1 – Commercial Organic Manures

as state of degradation. Venugopal (2004) had reported that dark deep brownish colour of compost with earthy smell is an indicator of good quality.

5.1.1.1.2 Odour

The odour of the COMs (Table 7) varied as no odour, earthy odour, fruity odour, slightly foul odour and pungent odour. The COMs which produced no foul odour or had an earthy smell are safe to use in cropped soil. Those products that had a fruity odour usually contained neem cake as an ingredient and the odour could be a result of decomposition of neem cake. The COMs which contained bone meal or fish meal usually had a foul odour because of the bad odour of the ingredients.

The pungent odour emanating from some of the COMs was due to the production of ammonia gas (Lekasi et al., 2001). It could be due to the continued degradation of organic nitrogen compounds present in the manures finally releasing ammonia. According to Jager and Jager (1980) the foul odour of decomposing organic residues was caused by fatty acids, alcohols, aldehydes and ketones produced in the chemical reactions at high temperature. Volatile compounds like pyridine and pyrazine, dimethylsulphide, dimethyldisulphide and dimethyltrisulphide were also observed in such residues. Hydrogen sulphide appeared only under completely anaerobic conditions. Chanyasak et al. (1982) stated that lower volatile fatty acids were one of the major components causing the obnoxious odour of domestic refuse. Acetic acid was the main component detected; followed by propionic, butyric, valeric and caproic acids. Several workers have reported that the production of such phytotoxic substances by the decomposing organic residues may give rise to inhibition of seed germination (Hunt, 1970; Hunt et al, 1972; Volk et al., 1973). Golueke (1977) and Wong (1985) reported that the phytotoxic effect of immature compost is due, among other causes, to the emission of ammonia and the presence of ammonia in the soil, even in small quantities has been described as toxic to the roots and normal development of plants (Van der Eerden, 1982) and to seed germination (Okuda and Takahasi, 1961).

A good organic manure should have no foul odour. The presence of foul odour indicates that the material contains undecomposed matter and the process of microbial decomposition produces the foul odour. If such a material is added to the soil, it could cause immobilization of plant nutrient elements by the micro organisms as well as damage to the crop by the high temperature and toxic organic compounds released during decomposition of the materials (Venugopal, 2004). The characteristic odour similar to that of damp forest ground noted in mature composts is a consequence of the excretion of geosmine, a secondary metabolite produced by mesophilic actinomycetes which predominate during the cooling phase of the bio-oxidative period and the maturation phase (De Bertoldi and Zucconi, 1980).

Hence it could be concluded that the COMs with foul/pungent odour viz., SN 15, SN 17, SN 28, SN 29, SN 31, SN 35 and SN 40 might contain toxic compounds harmful to plants and hence they might not be safe for application to the crop.

5.1.1.1.3 Moisture content

The moisture content by weight of the COMs varied from 0.72 per cent to 46.17 per cent (Table 7). According to the Fertilizer (Control) Amendment Order, 2006, the acceptable moisture content for good quality composts is 15.0 per cent to 25.0per cent, while for pressmud, the maximum allowed moisture content is 15.0 per cent. The excess moisture could lead to fungal growth and caking of the manure. Thus the COMs viz., SN1, SN 5, SN 11, SN 16, SN 19, SN 28, SN 29 and SN 44 were of inferior quality with regard to their high moisture content. Some of the COMs which were too dry could have the problem of being blown away by wind during application in the field. The COMs viz., SN 2, SN 7, SN 9, SN 10, SN 12, SN 13, SN 14, SN 24, SN 27, SN 30, SN 31, SN 39, SN 40, and SN 43 recorded moisture content less than 5.0 per cent. Venugopal (2004) had observed that compost with less than 20-25% moisture is often dusty and difficult to handle. He also reported that high moisture content is not a desirable attribute and may also lead to foul smell during storage of immature compost.

5.1.1.1.4 Bulk density

The bulk densities of the COMs were in the range of 0.40 to 0.83 Mg m^{-3} (Table 7). The products were mostly free flowing and easy to handle. The ingredients were not caked together or hard. The Fertilizer (Control) Amendment Order, 2006, states that the bulk density of a good quality compost should be between 0.7 Mg m^{-3} and 0.9 Mg m^{-3}. The COMs having bulk density values in this range were SN 2, SN 7, SN 9, SN 10, SN 12, SN 15 and SN 30.Majorityof the COMs recorded bulk density values less than 0.7 Mg m^{-3}.The low bulk density could be due to the lighter material used as ingredients of the manure such as ash, ground nut seed shell powder, decomposed coirpith etc. Such low density manures might be difficult to handle and could cause wind drift loss while application in field.

5.1.1.2 Chemical characters of COMs

5.1.1.2.1 Ash content

The data in Table 8 showed that all the COMs recorded ash contents more than 27 per cent and upto 68.17 per cent. The ash content of COMs and SCMs are presented in Figure 3. The ash contents of 28 COMs were more than 40 per cent. The ash content of the manures may be related to the inorganic materials present in them and thus it could be an indication of adulteration. According to Matthiessen et al. (2005) ash content is the reciprocal of organic matter content and it can be used to identify the quality and maturity of compost. Ash content represents the mineral constituents which are likely to persist during composting, while the organic constituents are susceptible to decomposition. Relatively low ash content is desirable for good quality organic manure according to Fares *et al*. (2005) who reported that anaerobically produced biogas manure and aerobically composted FYM contained less ash (30 per cent) and seemed superior to municipal waste compost that contained 65 per cent ash. Thus it may be concluded that those COMs with high ash content could not be recommended for application to crops.

5.1.1.2.2 Organic carbon content

The data given in Table 8 revealed that the oxidisable organic carbon contents of COMs varied from 6.02 per cent to 31.72 per cent. The organic carbon contents of COMs and SCMs are presented in Figure 4. Constantinides and Fownes (1994) and Jansen (1996) had reported that the organic carbon content of manures was an important determinant of the mineralization/ immobilisation processes. This was shown by positive correlation with mineralization at the initial stages of decomposition. Nitrogen and carbon were found to be the primary needs for soil microbes for energy and biomass accumulation. Hadas and Portnoy (1994) also reported that N per cent, C per cent and efficacy with which C was assimilated were important in determining mineralization patterns of organic materials. High organic carbon content may contribute to a wide C/N ratio of the organic manure which will lead to immobilization of plant nutrients when such a manure is added to soil (Tisdale

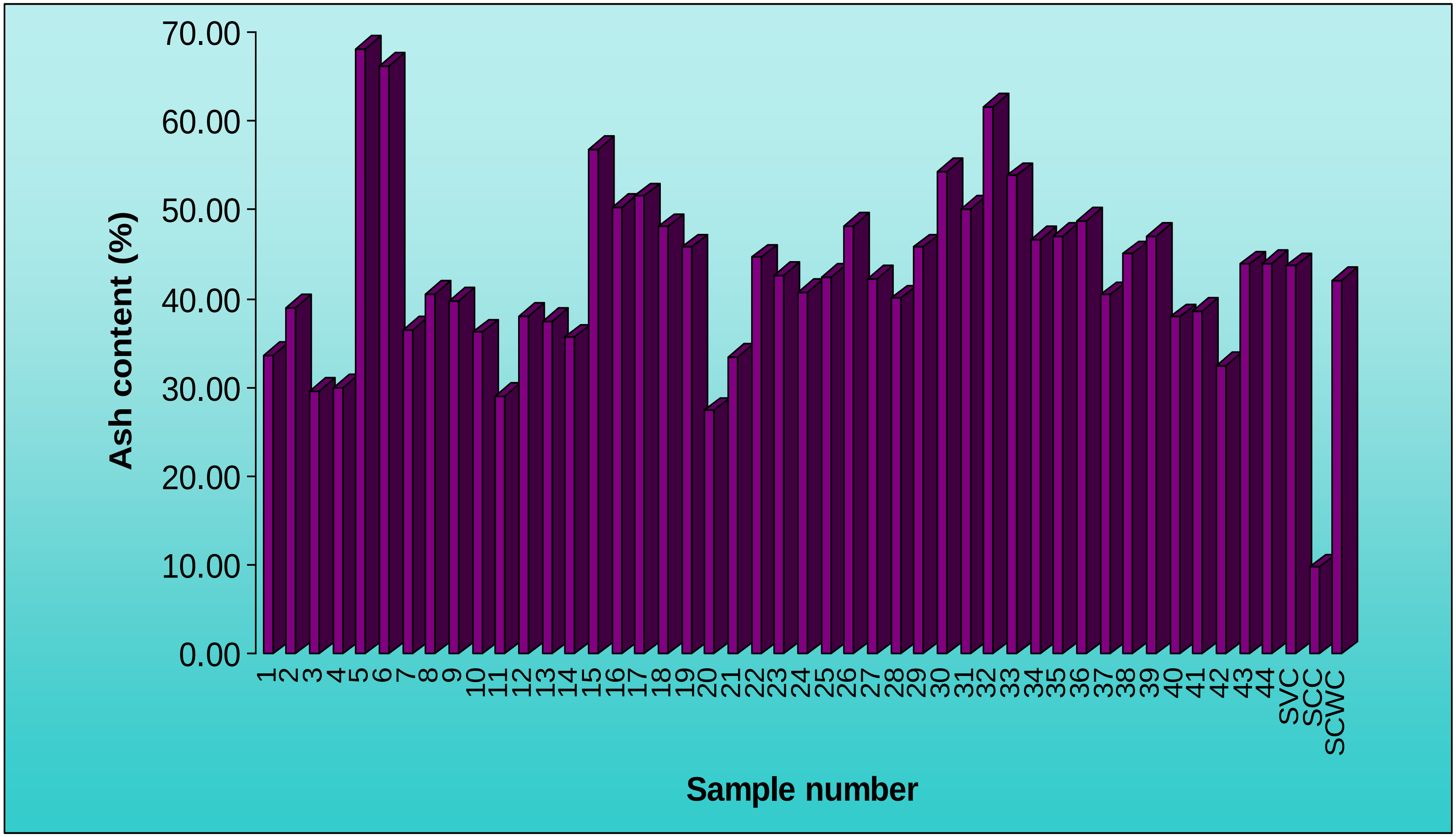


Figure 3. Ash content of COMs and SCMs

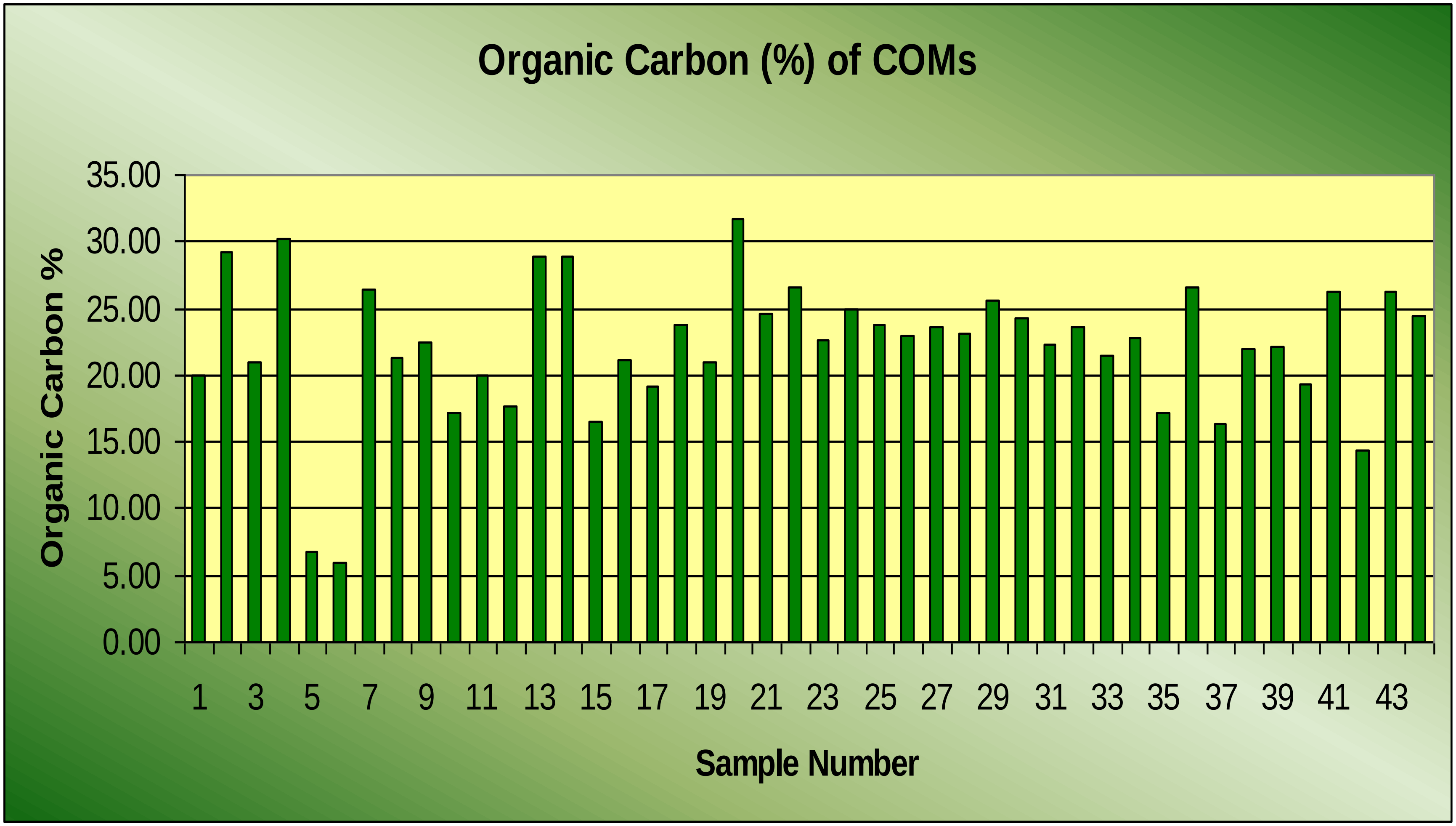


Figure 4.Organic carbon content (%) of COMs

et al., 1997). A properly decomposed organic manure should have a low content of organic carbon as the microbial activity would have degraded the easily decomposable compounds in the raw materials.

5.1.1.2.3 Total Organic carbon content (TOC)

In the COMs, the content of TOC varied from 17.68 per cent to 40.30 per cent (Table 8). The Fertilizer (Control) Amendment Order, 2006 specified a minimum of 16.0-18.0 per cent by weight of total organic carbon content in good quality composts. Hence the COMs could be assumed to contain satisfactory level of total organic carbon.

5.1.1.2.4 Acid Insoluble Matter

The acid insoluble matter represents the non-degradable mineral fractions such as gravel and sand which could be the adulterants in the organic manures. The data presented in Table 8 and Figure 5 showed that this fraction was highest in SN5 (56.97 per cent) which could be due to the presence of such adulterants. As per government regulations in Korea to control the quality of organic fertilizers, hydrochloric acid (HCl) insoluble matter in organic fertilizers should be below 30 per cent (Lee and Kim, 1997). The higher contents of acid insoluble matter in SN 6, SN 15, SN 37, SN 25 and SN 14 could also indicate the presence of non-degradable inorganic materials in the manures.

5.1.1.2.5 pH

The pH values of COMs (Table 8) showed that there were both acidic and alkaline products. The pH of COMs and SCMs are presented in Figure 6. The COMs which recorded pH in the neutral range of 6.5 to 7.5 were SN 5, SN9, SN 10, SN 11, SN 12, SN 13, SN 18, SN 19, SN 20, SN 25, SN 28, SN 32, SN 34, SN 36, and SN 43. Manures with pH in the neutral range i.e., 6.5- 7.5 is preferred for use in all types of crops and soils. The acidity/alkalinity of the manure could affect the availability of nutrients by influencing the microbial flora, fixation as well as mineralization of the organic compounds in soil. According to Wilson (1989), most well stabilized composts had a pH between 6.5 and 7.5. Adjusting the pH downwards to near neutral reduced the volatilization of NH_3 and other odorous compounds. Kalaiselvi and Ramasamy (1996) reported that the most common pH value of mature compost ranged from 6.5 to 8.0.

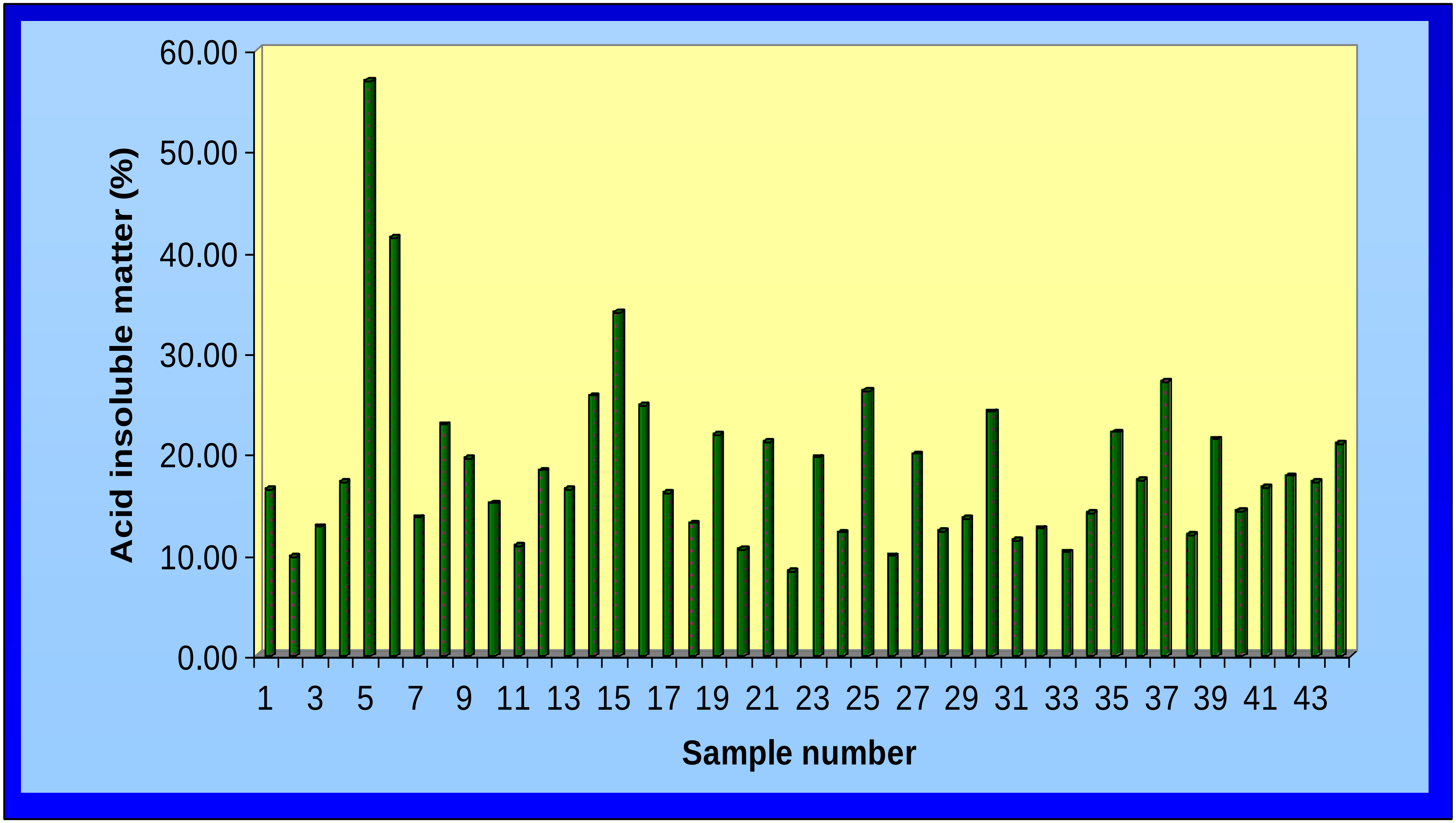


Figure 5. Acid insoluble matter content (%) of COMs

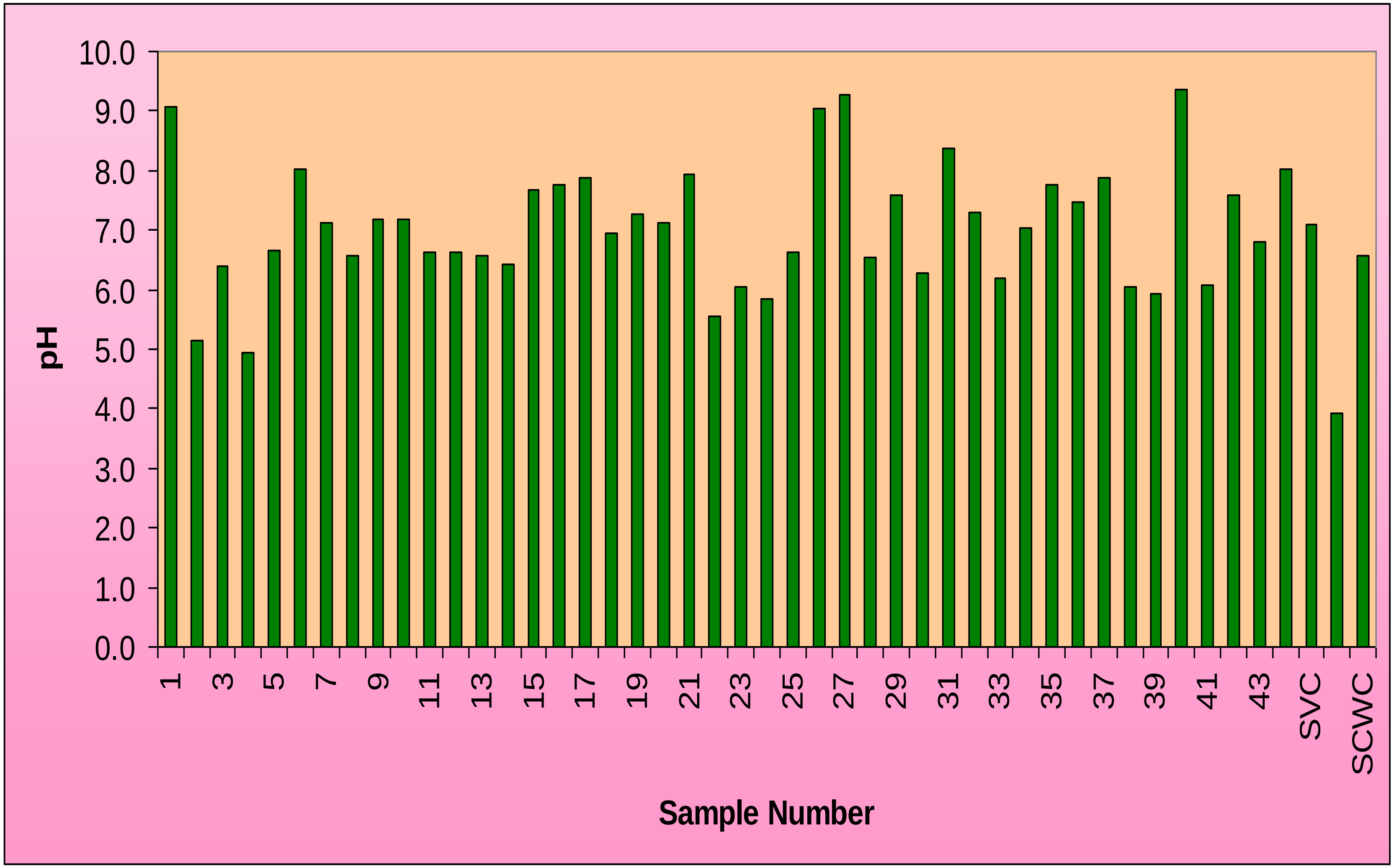


Figure 6. pH of COMs and SCMs

5.1.1.2.6. Electrical conductivity

The electrical conductivity of the COMs varied from 1.53 dS m^{-1} to 20.17 dS m^{-1} (Table 8). EC of more than 4 dS m^{-1} is not preferred for organic manures as per the Fertilizer (Control) Amendment Order, 2006. Kalaiselvi and Ramasamy (1996) reported that the total salinity of mature compost should not exceed 2 g salt. The high electrical conductivity could be indicative of the high salt content which might cause damage to the plants. Hence it could be concluded that only the COMs with EC values less than 4dS m^{-1} viz., SN2, SN 5, SN 12, SN 13 and SN 41 are safe for application to crop.

5.1.1.2.7 Total Nitrogen content

The total nitrogen contents of COMs varied from 0.7 per cent to 7.87 per cent as given in Table 9 and Figure 7. A minimum total nitrogen content of 0.5 to 1.0 per cent by weight of compost is required to qualify as a good organic manure as per the Fertilizer (Control) Amendment Order, 2006. Hence it could be stated that all the COMs had more than the minimum requirement of total nitrogen content. The total nitrogen contents of the COMs could be rated as low, medium and high and the COMs could be categorized accordingly. The quartile values of the range of total nitrogen content of COMs i.e. from 0.7 per cent to 7.87 per cent were found out and are presented in a box plot (Figure 8). The first quartile (Q1) which denotes the bottom 25 per cent of values was 2.8 per cent. The median value (Q2) was 4.35 per cent and the third quartile (Q3) which separates the top 25 per cent of the values was 5.85 per cent. The COMs with total nitrogen content falling within the top 25 per cent were SN 2, SN 7, SN 13, SN 18, SN 24, SN 25, SN 26, SN 27, SN 31, SN 41 and SN 43 all of which recorded nitrogen content more than 5.85 per cent. Majority of the COMs had total nitrogen contents between 2.8 per cent (Q1) and 5.85 per cent (Q3). A high content of total nitrogen is preferable as it could facilitate reduction in the bulk of organic manure required to be transported and stored for application in field as well as less chance of immobilization of nitrogen in soil (Tisdale et al., 1997; Lekasi et al., 2001).

5.1.1.2.8 Ammoniacal Nitrogen content

The contents of total nitrogen, organic nitrogen, ammoniacal nitrogen and water soluble nitrogen are shown in Figure 9.The ammoniacal N content of COMs

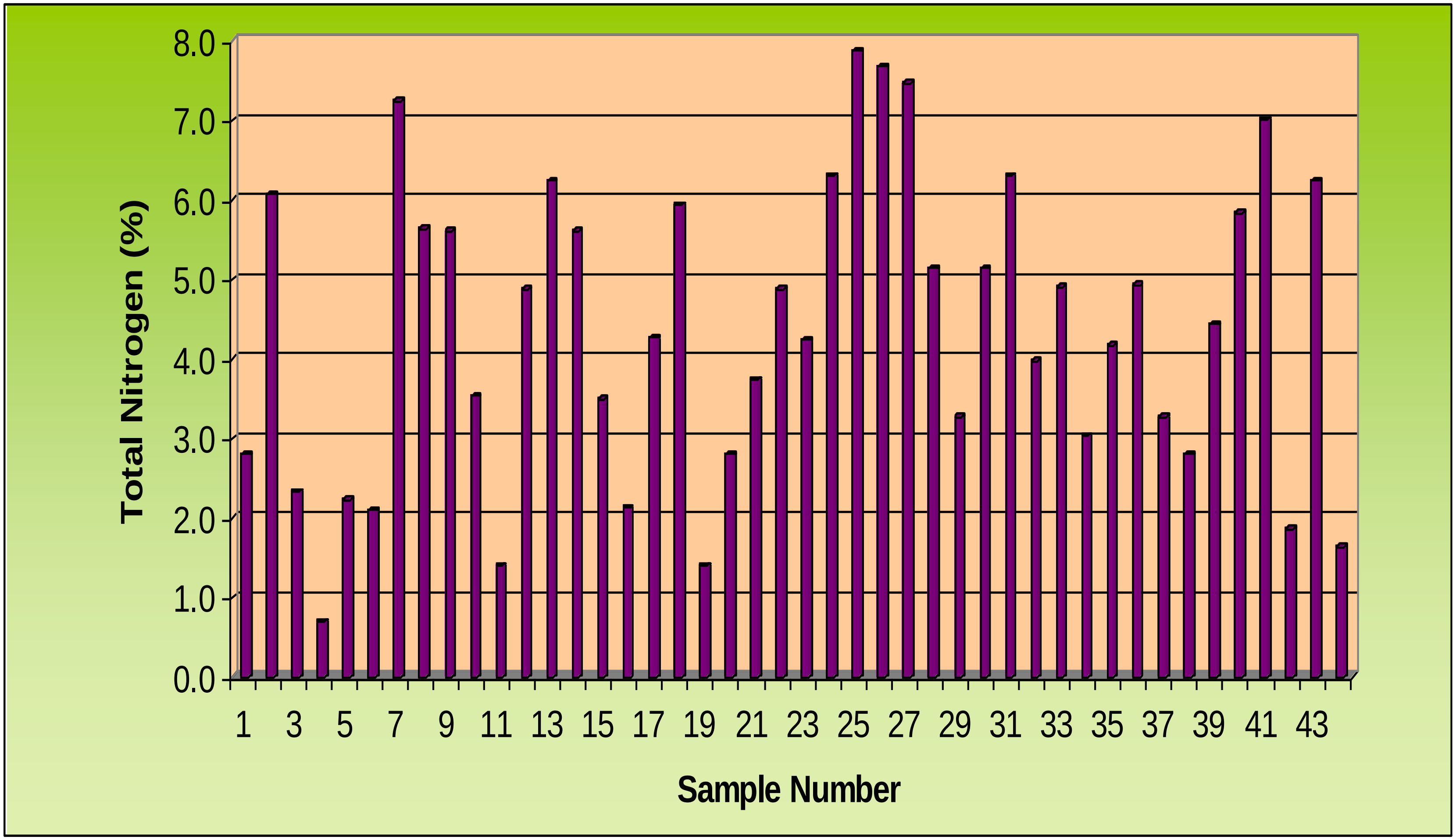


Figure 7. Total nitrogen contents (%) of COMs

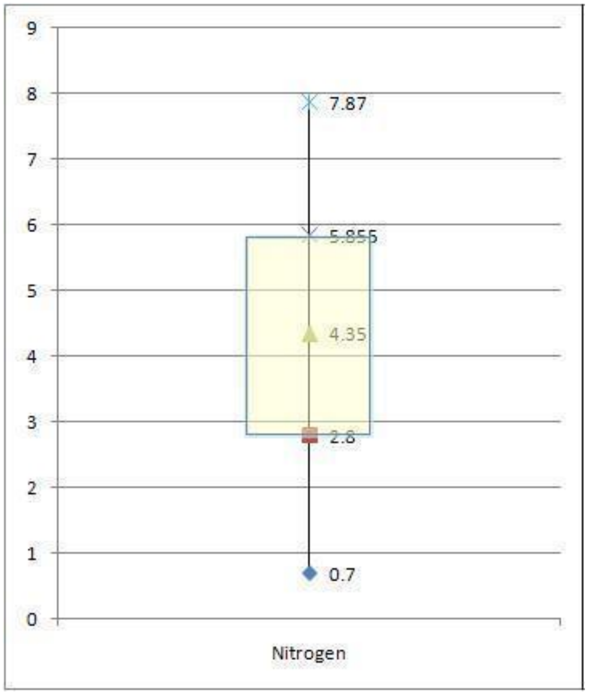


Figure 8. Total nitrogen contents in COMs- Box plot

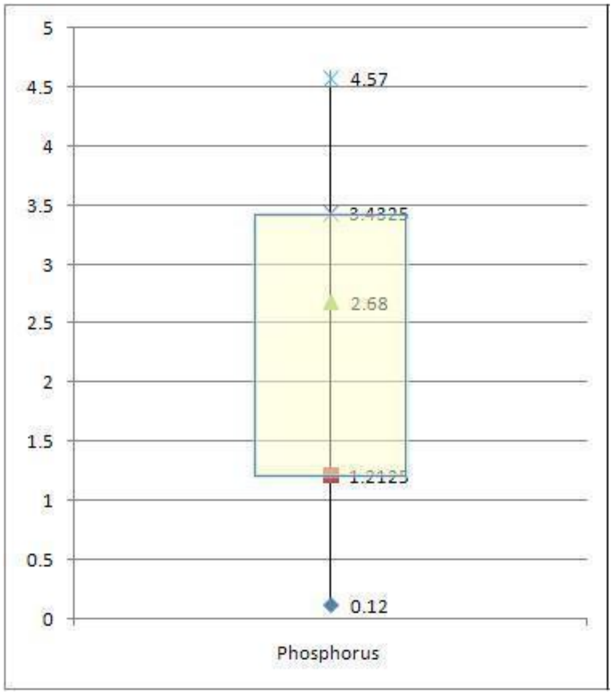


Figure 12. Total P contents of COMs-Box plot

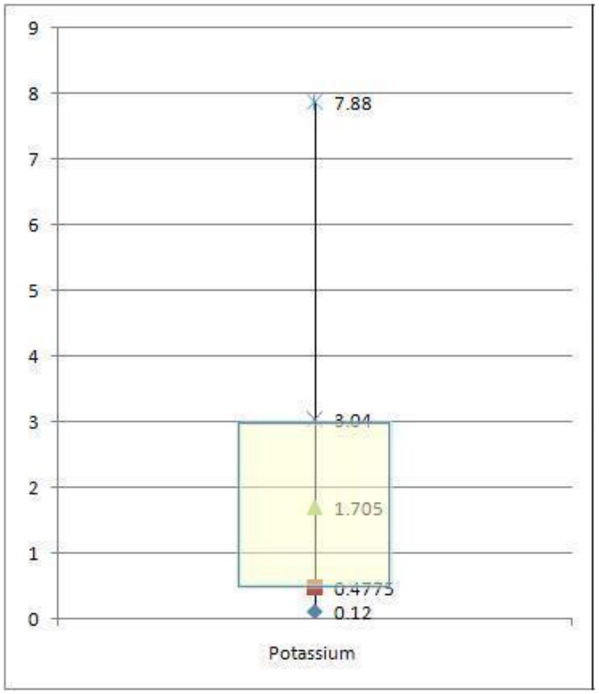


Figure 14. Total K contents in COMs- Box plot

Legend:

- Minimum value
- First quartile
- Median value
- Third quartile
- Maximum value

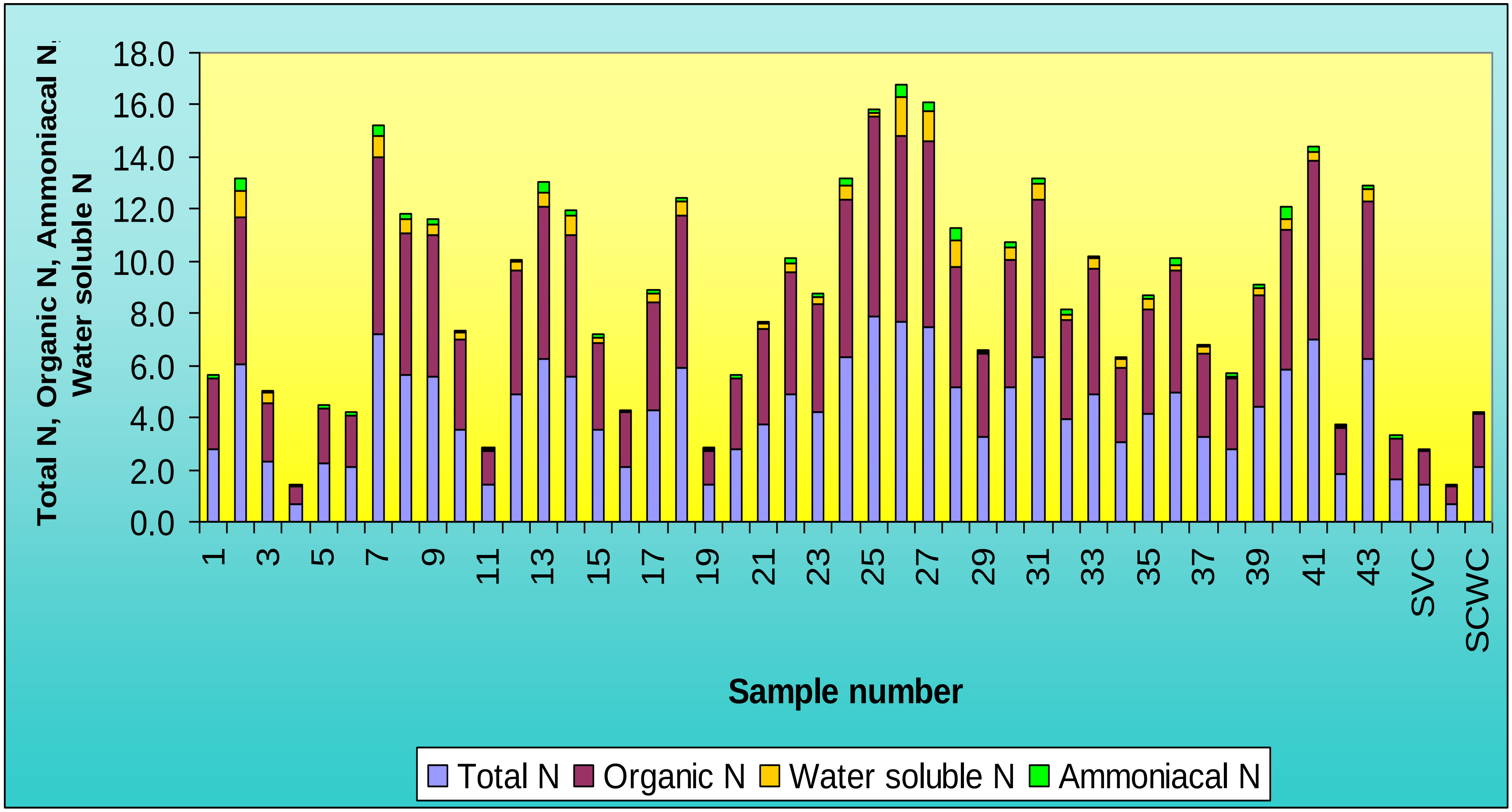


Figure 9. Total N, Organic N, Water soluble N and Ammoniacal N of COMs and SCMs

(Table 9) was highest in SN 26 (0.53 per cent) which also had high total nitrogen content second only to SN 25. The ammoniacal N content was lowest in SN 4 (0.01 per cent) which also recorded the lowest total nitrogen content. It showed that SN 4 (Neem cake) could be a poor source of nitrogen and it might cause immobilization of N when applied to soil and lead to N deficiency in standing crop.

The ammoniacal nitrogen represented the inorganic fraction of total nitrogen in organic manures. This form of N is immediately available to plants when applied to soil. But a high content of inorganic nitrogen could also be indicative of the adulteration of organic manures with inorganic fertilizers like urea.

5.1.1.2.9 Organic nitrogen content

The fraction of nitrogen obtained by subtracting the ammoniacal nitrogen from total nitrogen is the organic nitrogen. It was found to vary from 0.69 per cent to 7.69 per cent (Table 9). The highest value was recorded in SN 25 (7.69 per cent) which had also registered the highest value of total nitrogen. The lowest organic nitrogen was found in SN4, which could be attributed to its lowest total nitrogen content.

The organic form of N will become available for plant uptake only after decomposition and mineralization by microbial activity.

5.1.1.2.10 Water soluble nitrogen

The water soluble nitrogen content in COMs varied from 0.017 to 1.48 per cent (Table 9). The water soluble nitrogen content is considered as an indicator of presence of inorganic additives in organic manures to boost their nutrient content. The presence of a high content of water soluble nitrogen could be a proof of adulteration of organic manures with nitrogenous fertilizers like urea. The highest content was recorded in SN26 which also had the highest total nitrogen content. It might be doubted that this commercial organic manure product (SN 26) along with other products showing a similar trend contained chemical fertilizer additives.

5.1.1.2.11 Carbon / Nitrogen Ratio

The C/N ratios of COMs varied from 2.86 to 43.18 (Table 9, Figure 10). Only one product viz., SN4 had a C/N ratio higher than 20:1 and all others recorded narrower ratios. The carbon/ nitrogen ratio determines the availability of nitrogen from the applied manure as well as from native soil N to plants. A wide C/N ratio

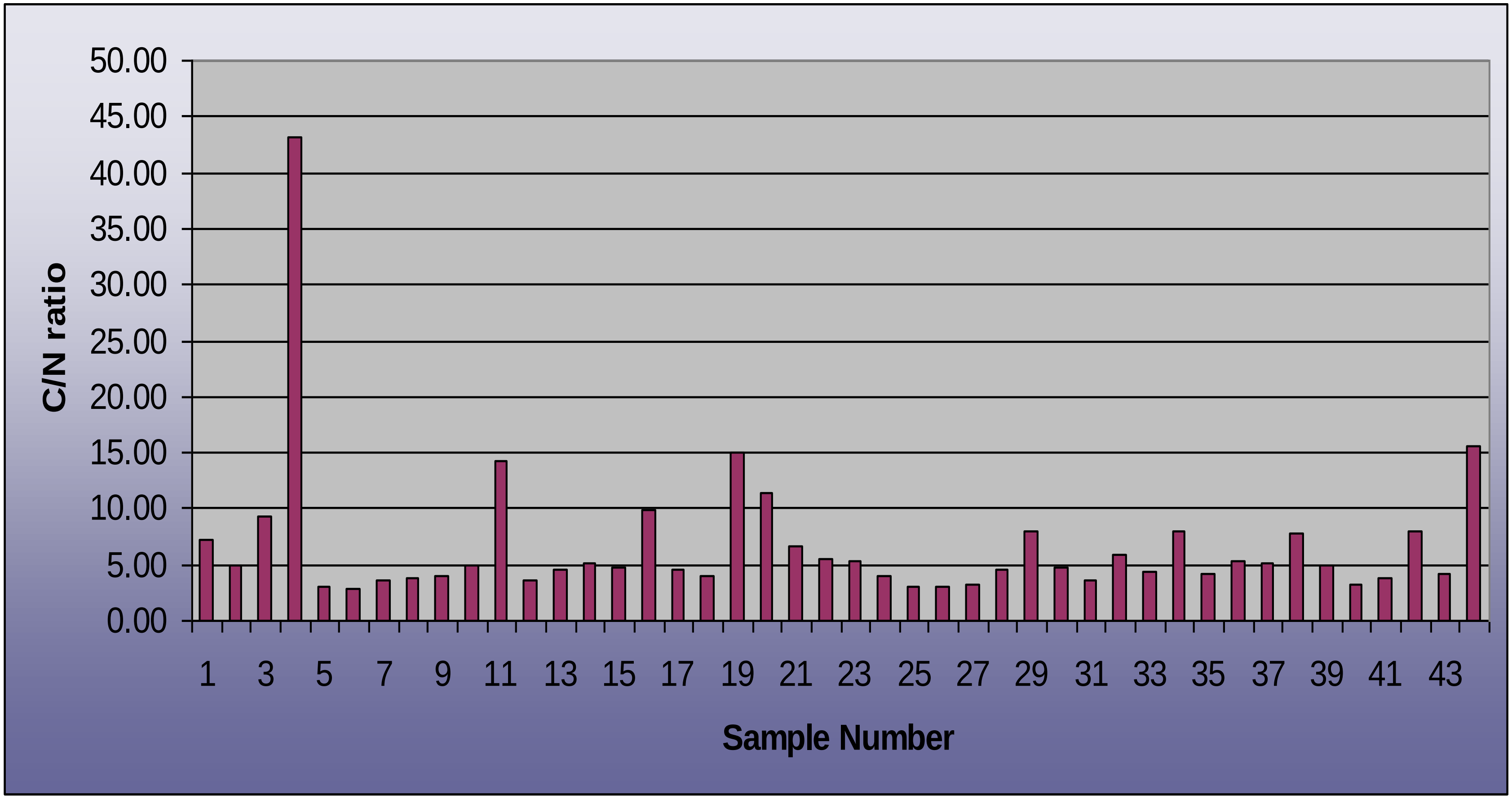


Figure 10. C/N ratios of COMs

leads to immobilization of nitrogen in the microbial cells whereas a narrow ratio favours nitrogen mineralization and availability to plants (Rubins and Bear, 1942; Allison and Klein, 1945; Rao an d Mikkleson, 1976; Parr and Papendick,1978). A C/N ratio of 20:1 or less is optimum for assuring nitrogen mineralization (Poincelot, 1974, 1975; Cardenas and Wang, 1980; Golueke, 1981; Tisdale et al., 1997). The Fertilizer (Control) Amendment Order, 2006 also states that a good quality compost should have a C/N ratio of 20:1 or less. Thus, it could be concluded that the COMs except SN 4 favour nitrogen mineralization. SN 4 could be declared as a poor quality organic manure.

However, some authors have reported that sometimes C/N value may be above 20 in relatively mature compost since part of the organic carbon may be in the form of compounds more resistant to biodegradation (fundamentally lignin), and not immediately available to micro-organisms (Regan and Jeris, 1970; Jeris and Regan, 1973). As Hirai et al. (1983) stated the C/N ratio of compost cannot be used as an absolute indicator of the state of maturation since the C/N ratio found in well-composted materials presents great variability due, above all, to the type of original material. Morel et al. (1985) noted that C/N ratios below 20 were often found in materials not yet degraded, due to the relative N-richness of the original material. Therefore, a C/N ratio less than 20 can only be considered a necessary, but not sufficient, condition for establishing the degree of maturity and quality of organic manure (Jimenez and Garcia, 1989). Lekasi et al. (2001) had also opined that C/N ratio alone cannot be taken as a reliable index of manure quality.

5.1.1.2.12 Total Organic Carbon/ Total Nitrogen Ratio

The TOC/ TN ratio of COMs as given in Table 10 showed variation from 3.75 to 55.56.The highest value was recorded in SN4 which also had the highest organic carbon to nitrogen (C/N) ratio. SN 26 registered the lowest TOC/TN ratio and it might be attributed to the high total nitrogen content of the product.

The total organic carbon to total nitrogen ratio is also an indicator of the state of decomposition of the organic matter in the manure. As organic matter decomposes the TOC decreases and total nitrogen increases, hence leading to a narrow ratio between them at final stages of decomposition. A high ratio indicates relatively high content of TOC and the incomplete nature of degradation.

5.1.1.2.13 Total Phosphorus

The data presented in Table 10 revealed that a minimum phosphorus content of 0.12 per cent was present in all the COMs. The data on total P content of COMs and SCMs is also depicted in Figure 11. The critical value of P in organic material to serve as a balance between immobilization and mineralization is calculated to be about 0.2 per cent (Alexander, 1977). Tisdale et al. (1997) had stated that the C/P ratio of the decomposing residues regulated the predominance of P mineralization over immobilization. A C/P ratio of more than 200 caused net mineralization of organic P, a ratio of less than 300 caused net immobilization while a ratio between 200 and 300 resulted in no gain or loss of inorganic P. Expressed as a percentage P in the degrading residue, net P immobilization occurred when percentage P was less than 0.2 per cent and net mineralization occurred with more than 0.3 per cent P. The minimum P_2O_5 content specified by the Fertilizer (Control) Amendment Order, 2006 was 0.5 per cent or a minimum P content of 0.22 per cent. Only SN 4 recorded a P content less than 0.22 per cent and all other COMs had 0.33 per cent or more total P. Thus it could be assumed that COMs with P content more than 0.22 per cent could be safely applied to crops. The range of P content of COMs was divided into quartiles and the median (Q2) was 2.68 per cent P. The box plot representing the quartile values of the distribution of P content in COMs is given in Figure 12. The COMs with P contents in the top 25 per cent (Q3= 3.48 per cent) were: SN 9, SN 17, SN 24, SN 25, SN 26, SN 27, SN 31, SN 35, SN 41 and SN 43.

5.1.1.2.14 Water Soluble Phosphorus

The data given in Table 10 showed that the water soluble P content of COMs was detected in trace quantities only. The water soluble fraction of total phosphorus present in significant quantities in commercial organic manures could be an indicator of inorganic P sources added to manures to increase the P content. Rock phosphate is a natural P source and is permitted for restricted use in organic farming (NPOP, 2000). Other inorganic P fertilizers are not allowed in organic farming. Hence it could be assumed that no chemical P fertilizers are mixed with COMs, which might be due to the scarcity of such fertilizers. Because of the low content of water soluble P in COMs the P from such manures will be available in a slow manner to the plants which would facilitate long term availability of phosphorus to the plants.

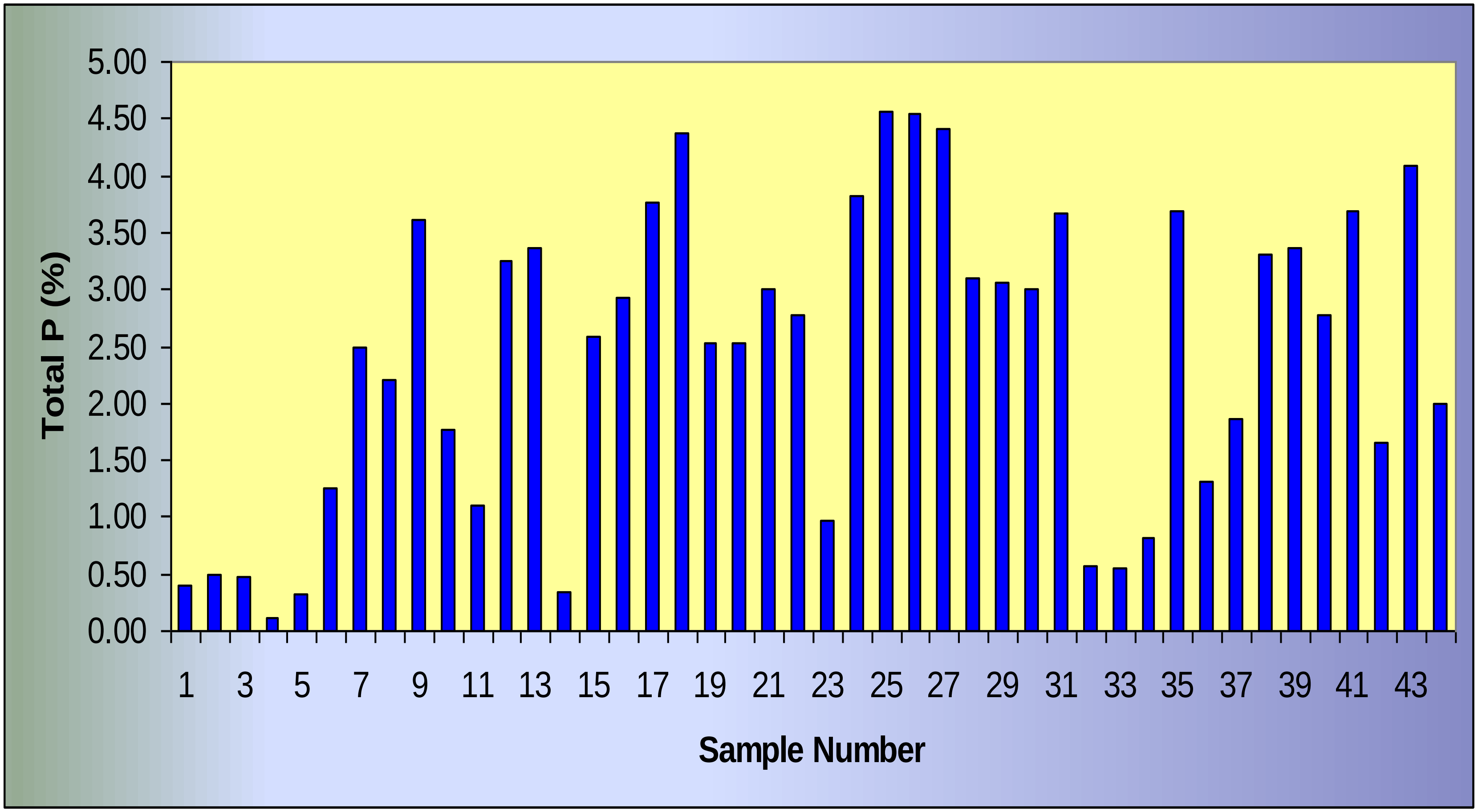


Figure 11. Total phosphorus contents (%) of COMs

5.1.1.2.15 Total Potassium

The total potassium content of COMs ranged from 0.12 per cent to 7.87 per cent (Table 10, Figure 13). In some of the COMs muriate of potash (MOP) was an ingredient, used as a source of K. MOP is not a permitted input in organic farming (NPOP, 2000). The manufacturers argued that the organic materials were low in K content and to produce COMs conforming to the specifications of the Fertilizer Control Order, they had to supplement organic K with MOP. According to the Fertilizer (Control) Amendment Order, 2006 a minimum total K_2O content of 1.0 per cent by weight is required in composts. This corresponds to 0.83 per cent of total K. Majority of the COMs contained more than 0.83 per cent total K. The quartile values of the range of total K content in COMs were found out (Figure 14). The median (Q2) was 1.705 per cent and the third quartile (Q3) was 3.04 per cent K. The COMs with K content falling in the top 25 per cent of the range (more than 3.04 per cent K) were: SN 9, SN 10, SN 22, SN 24, SN 26, SN 27, SN 28, SN 30, SN 31, SN 40, and SN 44.

5.1.1.2.16 Water soluble potassium

The water soluble potassium content in COMs ranged from 0.043 to 6.18 per cent (Table 10). The presence of high amount of water soluble potassium is an indicator of chemical fertilizer addition to the COMs. The high content of water soluble fraction of K in SN 27, SN 24, SN 10, SN 9, SN 30 etc indicates that there might be adulteration of organic manures with MOP. The composition of the COMs (Table 1) showed that SN 24, SN 26, SN 27, SN 28, SN 29, SN 30, SN 31 and SN 41 contained MOP as an ingredient.

5.1.1.2.17 Calcium

The calcium content of COMs varied from 0.76 per cent to 10.1 per cent (Table 10). The highest content was in fishmeal which could be attributed to the presence of fish bones and other calcium rich materials in fish waste. The lowest Ca content was recorded in neem cake. As most of the COMs contained bone meal as a raw material, the Ca content was found to be satisfactory. Calcium is an important secondary nutrient and the COMs could be applied as good sources of Ca to plants. Olsen et al. (1970) inferred that the application of manures increased exchangeable Ca and Mg particularly at higher rates of their application. Selvi and Selvaseelan (2003) had reported that that the combined application of organics and inorganics in potato

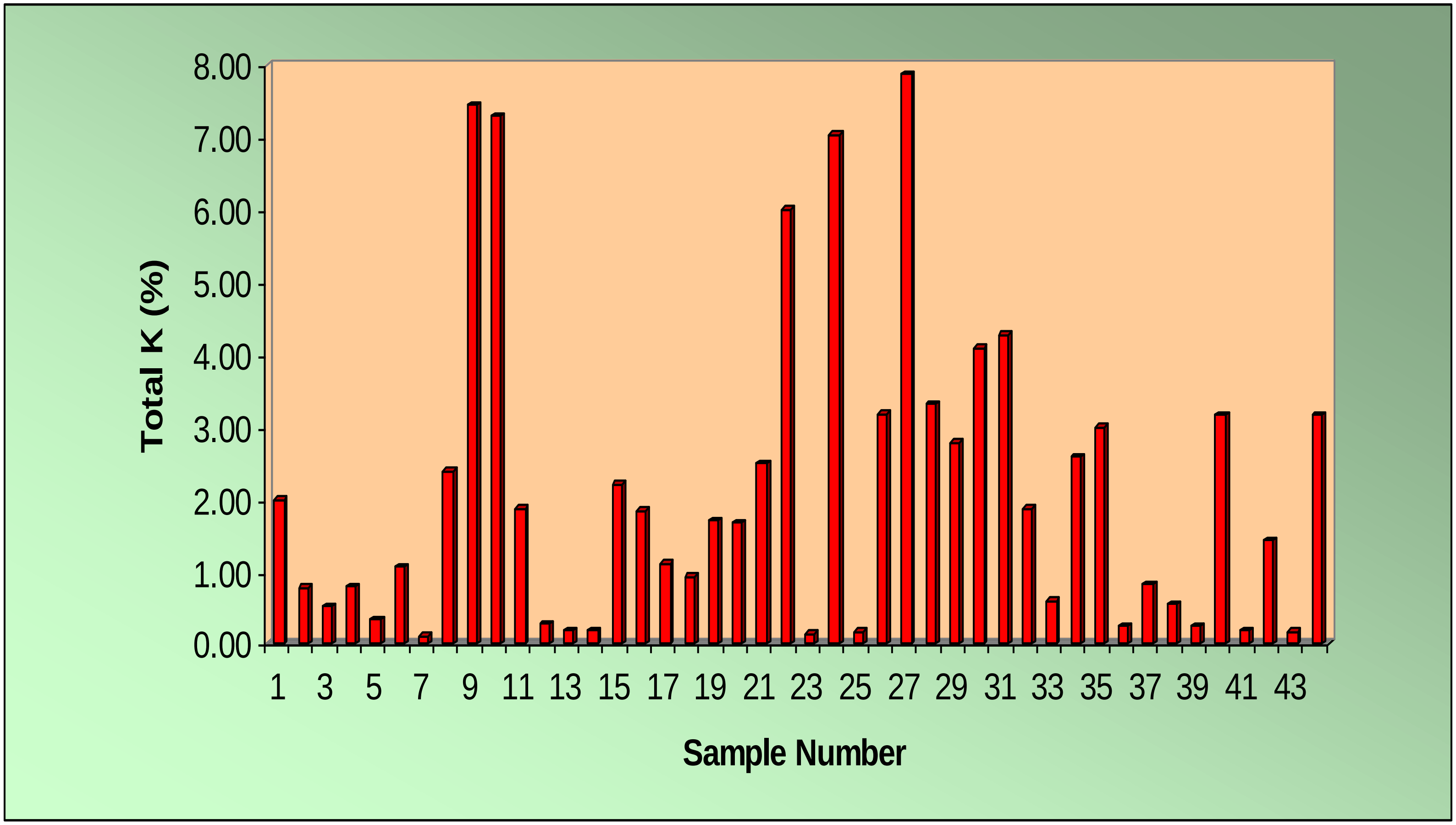


Figure 13. Total potassium contents (%) of COMs

crop had a positive influence on Ca and Mg availability, possibly due to favourable microbial activity.

5.1.1.2.18 Magnesium

The magnesium content of COMs varied from 0.07 per cent to 2.16 per cent (Table 10). Most of the COMs had a content of more than 0.50 per cent of Mg, which could be assumed as satisfactory.

The analytical results of COMs showed that the manures were good sources of not only the primary nutrients, but they could also supply secondary nutrients in appreciable quantities. Thus organic manures are suitable to supply balanced nutreition to crop plants.

5.1.1.2.19 Sodium

The sodium content of the COMs ranged between 0.08 per cent and 4.21 per cent (Table 10). High sodium content in organic manures is not preferred as long term application of the manure might lead to build up of soil sodium adversely affecting soil physical properties and leading to soil sodicity. The COMs viz., SN3, 4, 5, 18, 22, 32, 33, 34, 38 and 39 contained more than 1.0 per cent of sodium and hence long term application of these COMs may not be recommended.

5.1.1.2.20 Trace Metals

The iron content (Table 11) varied from 847.17 mg kg^{-1} to 9078.17 mg kg^{-1} in the COMs. Iron deficiency in plants could be prevented by the addition of iron rich organic manures. The zinc content of COMs varied from non detectable level to 374.8 mg kg^{-1}. The permitted maximum level of zinc in composts was 1000.0 mg kg^{-1} as per Fertilizer (Control) Amendment Order, 2006. Thus the Zn contents of COMs were found to be within the safe limit. The manganese content of COMs ranged between non detectable level to 597 mg kg^{-1}. In soils with Mn deficiency, it is preferable to use organic manures rich in Mn, along with inorganic fertilizers to supplement Mn.

In the COMs, copper content (Table 11) was found to vary from non detectable level in most of the samples to 287.30 mg kg^{-1} in SN 16. The permitted content of copper in composts is 300 mg kg^{-1} as per Fertilizer (Control) Amendment Order, 2006. Hence the COMs could be safely used without the hazard of copper contamination of soils. The lead content of COMs was mostly in trace quantities and the highest content was in SN 39 (87.65 mg kg^{-1}). The permissible maximum limit for lead was 100.0 mg kg^{-1} as per Fertilizer (Control) Amendment Order, 2006. Therefore all the COMs could be used without causing lead contamination hazard. But for the manure SN 39, since the lead content is high, though it is below the maximum permitted limit, it might cause lead accumulation in soil if applied continuously for a long term. Hence it is safer to apply different COMs rather than sticking on to a single product for a long time. The cadmium content of COMs were ranging from traces to the highest level of 6.82 mg kg^{-1} in SN 20 (Haritha Super), followed by 5.64 mg kg^{-1} in SN 43 (Skymeal). Compared to a permissible maximum limit of 5.00 mg kg^{-1} as per Fertilizer (Control) Amendment Order, 2006, it could be concluded that these two COMs are not safe to be used in agriculture. The continuous application could lead to serious cadmium pollution in soils and crops, which could also pose a threat to human and animal health (Aggarwal et al., 2006). Hence the production and sale of such COMs should be discouraged.

5.1.1.3 Biochemical characters of COMs

5.1.1.3.1 Lignin

The lignin content of the COMs varied from zero to 64.58 per cent (Table 12). The lignin content of manures is a factor influencing the nitrogen mineralization when they are added to soil. Lignin is abundant in plant tissues while they are absent in manures prepared from animal wastes alone. Hence lignin was absent in COMs viz.,SN 6, SN 7, SN 8, SN 9, SN 30 and 31. While lignin and polyphenols are important intrinsic factors in plant materials, the relatively low values in the manures analysed render the parameter less influential in the decomposition processes. Melillo et al. (1982) found that when plant materials contain higher concentrations of lignin, there was little mineralization of N in spite of high N concentrations in the plant tissue. Palm and Sanchez (1991) reported threshold values of lignin as 15% in leaves of tropical legumes for net N mineralization to occur immediately. In the short term the lignin content did not affect the N mineralization but became important in the later stages. Lignin resists decomposition by microbes and hence the lignin content increases with progress of decomposition process (Manna et al., 2000). Hence COMs with comparatively high lignin content viz., SN 4, SN 5, SN 16, SN 17, SN 19, SN 28, SN 29, SN 32, SN 33, SN 34, SN 35, SN 37, SN 39, SN 41, SN 42 and SN 44, could be prone to N immobilization.

5.1.1.3.2 Cellulose

The cellulose content in COMs varied from zero to 15.09 per cent (Table 12). Cellulose is present only in plant tissues and it is absent in the manures containing only animal wastes. Hence cellulose was absent in SN 6, SN 7, SN 8, SN 9, SN 30 and 31.The cellulose content decreases as the decomposition of plant materials advances (Manna et al., 2000).Hence the COMs with comparatively low cellulose content viz., SN 3, SN 10, SN 12, SN 22, SN 23, SN 24, SN 25, and SN 43 could be assumed to be more advanced in degradation process, or it could be attributed to the low proportion of raw materials of plant origin in those manures as evident from Table 1.

5.1.1.3.3 Lignin/ Cellulose Ratio

The lignin/ cellulose ratio of COMs varied from 1.46 in SN 21 to 10.83 in SN 29 (Table 12). The ratio between lignin and cellulose is an indicator of manure maturity (Chanyasak and Kubota, 1981; Harada and Inoko, 1980; Baeca et al.,1995). Lignin content increases and cellulose content decreases as decomposition progresses and hence the ratio attains a higher value towards maturity (Manna *et al*., 2000). Lignin and cellulose were absent in manures prepared from animal wastes alone and hence lignin cellulose ratio was also zero in SN 6, SN 7, SN 8, SN 9, SN 30 and SN 31. The COMs with comparatively higher values of lignin/ cellulose ratio viz., SN 18, SN 19, SN 29, SN 33, SN 36, SN 37 and SN 39, could be more advanced in decomposition process than other COMs.

5.1.1.3.4 Total Phenols

The total phenol contents of COMs ranged from 31.51 mg $100g^{-1}$ in SN 4 to 113.10 mg $100g^{-1}$ in SN 41 (Table 12).The increase in phenol is one of the indicators of completion of humification and the composts having reached maturity level (Singh, 2005a). The effect of polyphenols in plant materials applied to the soil has been those of reduced N release through their protein binding capacity. They also bind enzymes which catalyse mineralization, in the nitrification process in particular. However, under aerobic conditions most polyphenols are quickly degraded (Paul *et al*., 1994).The negative relationship between polyphenols and N mineralization had been reported by Oglesby and Fownes (1992) and Reddy (2005).Thus the higher phenol contents in COMs could cause inhibition of N mineralization from the manures.

5.1.1.3.5 Water Soluble Carbohydrates (WSC)

The WSC content of COMs ranged from 0.237 per cent in SN 22 to 1.363 per cent in SN 32 (Table 13). The WSC represents the most easily biodegradable C fraction during the composting process because it consists of sugars, organic acids and phenols, apart from the soluble fraction of fulvic acids (Garcia *et al*., 1991). The content of water soluble carbohydrates decreased with days of decomposition process, indicating that easily biodegradable carbon diminished much faster than resistant carbon materials. It could be concluded that the easily degradable carbon content was small in the COMs in view of their comparatively low WSC contents.

5.1.1.3.6 Water Soluble Organic Carbon (WSOC)

The WSOC content of COMs ranged from 0.13 per cent to 0.46 per cent (Table 13). The water soluble carbon is a fraction of the total organic carbon which is easily degradable. It can be assumed that the COMs contained fewer amounts of easily degradable carbon compounds and more of resistant carbon.

5.1.1.3.7 Biodegradability Index (BI)

The biodegradability index of the COMs ranged from 3.15 in SN 5 to 4.21 in SN 4 (Table 13). Morel et al. (1979) reported that with BI values less than 2.4, compost may be considered sufficiently mature, and above 2.7 the maturation of compost is insufficient. Manna et al. (2000) reported that BI of composts decreased with days of maturation and further decreased when bio- inocula were used. They found that the values of BI in mature composts ranged between 3.5 to 4.6 in uninoculated and 3.1 to 3.9 in inoculated composts during 120 days of decomposition. From this it could be concluded that the low value of BI indicates advanced state of decomposition and maturity of the COMs. None of the COMs had BI values less than 2.7. But this may be due to the fact that the COMs were only mixtures of different raw materials and not composted during their manufacturing process.

5.1.2 Characterization of SCMs

5.1.2.1 *Physical characters of SCMs*

5.1.2.1.1 Colour

The colour of the city compost and vermicompost specified by the Fertilizer (Control) Amendment Order, 2006 is dark brown to black. The colour of standard

Plate 2 – Standard Compost Manures

vermicompost, standard coir pith compost and standard city waste compost conformed to the specification as they were black, dark brown and brown and black respectively. The raw materials used for composting had decomposed completely and the individual particles of each raw material could no longer be identified. Thus each compost had a homogenous appearance. The three standard compost manures are shown in Plate 2.

5.1.2.1.2 Odour

The Fertilizer (Control) Amendment Order, 2006 specifies that there should be no foul odour for city compost and vermicompost to be of good quality. The standard vermicompost, standard coir pith compost and standard city waste compost had no foul odour and hence it could be assured that they contained no undecomposed or toxic organic compounds.

5.1.2.1.3 Bulk Density

The bulk density for city compost and vermicompost as specified by the Fertilizer (Control) Amendment Order, 2006 is 0.7- 0.9 Mg m^{-3}. The bulk densities of standard vermicompost and standard coir pith compost were 0.38 and 0.30 Mg m^{-3} respectively. The standard city waste compost had a bulk density of 0.78 Mg m^{-3}. Thus, SVC and SCC might be too light for conforming to the specification.

5.1.2.1.4 Moisture content

The moisture content for a good quality city compost and vermicompost was fixed as 15.0- 25.0 per cent by weight as per the Fertilizer (Control) Amendment Order, 2006. The moisture contents of SVC, SCC and SCWC were 69.03, 80.88 and 4.93 per cent respectively. It is evident that the moisture contents of SCMs did not conform to the specification as those of SVC and SCC were too high and that of SCWC was too low compared to the prescribed moisture content.

5.1.2.2 Chemical characters of SCMs

5.1.2.2.1 Ash content

The ash contents of SVC and SCWC were above 40 per cent while that of SCC was only 9.81 per cent. It could be attributed to the resistant nature of coir pith to decomposition. The ash content of mature vermicompost was 52.5 to 54.0 per cent (Singh, 2005a).

5.1.2.2.2 Organic carbon content

The oxidisable organic carbon contents of SCMs were below 15 per cent. Most of the easily oxidisable organic compounds present in the raw materials could have decomposed by the microbes during composting process and this could be the reason for the low content of organic carbon in SCMs.

5.1.2.2.3 Total Organic carbon content (TOC)

The total organic carbon contents of SCMs were above 30 per cent and the highest TOC was in SCC (50.11 per cent). It could be indicative of the presence of resistant organic compounds in coir pith, slowing down its decomposition, or preventing its complete decomposition. Manna et al. (2000) reported that the TOC decreased significantly during maturation of the compost irrespective of the raw materials. The TOC of mature compost made from soybean straw was 33-36 per cent. According to Singh (2005a), the TOC of vermicompost produced by heap method was 26.5 per cent and that produced by pit method was 25.5 per cent.

5.1.2.2.4 Acid Insoluble Matter

The acid insoluble matter in SVC was 21.71 per cent and that in SCWC was 20.93 per cent. SCC contained only 5.87 per cent acid insoluble matter. It indicated that the proportion of non –biodegradable inorganic materials in SVC and SCWC was high which may be due to the heterogeneous nature of raw materials used in composting.

5.1.2.2.5 pH

The Fertilizer (Control) Amendment Order, 2006, specifies that the pH of composts should be in the neutral range, 6.5- 7.5. The pH of SVC and SCWC were within the required limits while SCC was more acidic with pH of 3.93. Thus SVC and SCWC were suitable for application in different types of soils and crops, while SCC could be a suitable amendment for soils with alkaline pH.

5.1.2.2.6. Electrical conductivity

The electrical conductivity of the SCMs ranged from 0.33 to 3.4 dS m^{-1}.The highest value was recorded in SCC and the lowest was in SCWC. The higher EC of SCC could be attributed to its comparatively higher contents of Ca, Mg and Na.

5.1.2.2.7 Total Nitrogen

The minimum total nitrogen content required for vermicompost was 1.0 and for city compost was 0.5 according to the Fertilizer (Control) Amendment Order, 2006. SVC had a total nitrogen content of 1.4 per cent and SCWC had 2.1 per cent total nitrogen. Thus both SVC and SCWC had a satisfactory level of total nitrogen, whereas SCC had only 0.7 per cent nitrogen.

5.1.2.2.8 Ammoniacal Nitrogen

The inorganic nitrogen was estimated as ammoniacal nitrogen and it was uniformly 0.05 per cent in all three SCMs.

5.1.2.2.9 Organic Nitrogen

The organic nitrogen fraction needs to be mineralized by the microorganisms before it becomes available to plants. The highest organic nitrogen content was in SCWC (2.05 per cent) which could be attributed to its high total nitrogen content and the lowest was in SCC (0.65 per cent) which also recorded the lowest nitrogen content.

5.1.2.2.10 Water soluble nitrogen

The water soluble nitrogen fraction of SCMs was very low and it was uniformly 0.01 per cent. It could be because the SCMs contained the major fraction of total nitrogen in the organic form.

5.1.2.2.11 Carbon / Nitrogen Ratio (C/N)

A C/N ratio of 20:1 or less is required for the composts to qualify as per the recommendation of the Fertilizer (Control) Amendment Order, 2006. All the three SCMs recorded ratios below 20 and hence they had no possibility of causing nitrogen immobilization when applied to soil.

5.1.2.2.12 Total Organic Carbon/Total Nitrogen Ratio (TOC/TN)

The TOC/TN of composts should narrow down as the degradation process advanced. Due to the activity of microbes, the TOC decreased and total nitrogen content increased. In SCC the ratio was 71.58 which could be attributed to the high content of resistant organic compounds in coir pith. SVC and SCWC were more mature with regard to TOC/TN ratio.

5.1.2.2.13 Total Phosphorus

SCWC contained 0.76 per cent total P and SVC contained 0.47 per cent P. The minimum total phosphorus as P_2O_5 required in city compost is 0.5 per cent (0.22 per cent as P) and in vermicompost is 1.0 per cent (0.44 per cent as P) as per Fertilizer (Control) Amendment Order, 2006. Thus both these composts had satisfactory levels of total P. SCC contained only 0.05 per cent total P which was very low and it might lead to P deficiency in crops, if not properly supplemented with other sources of P.

5.1.2.2.14 Water soluble Phosphorus

The water soluble P content of SCMs was negligible and it could be because all the P in composts was present in water-insoluble forms not immediately available to plants.

5.1.2.2.15 Total potassium

The minimum potassium content as K_2O required by the specifications of the Fertilizer (Control) Amendment Order, 2006 is 1.0 per cent (0.83 per cent as K) by weight. The three SCMs did not contain enough total K as the highest K content was only 0.43 per cent recorded in SVC. The application of such composts to crops could lead to K deficiency in plants and hence integrated application of inorganic K sources or other organic manures rich in K would be necessary.

5.1.2.2.16 Water soluble potassium

The water soluble fraction of total K in SCMs was below 0.2 per cent.

5.1.2.2.17 Calcium

The calcium content was in the range of 0.23 to 0.47 per cent in the three SCMs

5.1.2.2.18 Magnesium

The magnesium content of SCMs was less than 0.15 per cent.

5.1.2.2.19 Sodium

The highest sodium content was found in SCC. It could contribute to a build up of soil sodium if applied for considerably long term.

5.1.2.2.20 Trace metals

The iron contents of SCMs (Table 11) showed that SCWC was a rich source of iron with 2084.35 mg kg^{-1} Fe. All the three SCMs were good sources of iron and could be used to alleviate iron deficiency in soils. SVC had relatively higher amount of Zn (266.17 mg kg^{-1}), but in general the Zn contents of SCMs were very low compared to the maximum limits prescribed (1000.0 ppm) by the Fertilizer (Control) Amendment Order, 2006. 253.17 mg kg^{-1} of manganese was present in SVC, but no traces of Mn were found in SCC and SCWC. The maximum copper content specified in the Fertilizer (Control) Amendment Order, 2006 for city compost was 300.00 mg kg^{-1} while SCWC had only 0.346 mg kg^{-1} of copper. SCC and SVC had no detectable copper. Lead and cadmium could not be detected in the SCMs. Thus it could be concluded that the SCMs are safe organic manures for application in cropped soils without any hazard of heavy metal pollution.

5.1.2.3 **Biochemical characters of SCMs**

5.1.2.3.1 Lignin

The lignin contents of SCMs were higher than 45 per cent by weight. Lignin is resistant to microbial degradation and its content increases as humification advances. The higher lignin contents of the SCMs could be indicative of the maturity of the composts. Kadalli et al. (2000) reported lignin contents of 24.10 to 33 .05 per cent in matured coir dust based composts. Manna et al. (2000) also reported that the lignin content of mature composts ranged from 22 to 48 per cent. They also concluded that composting proceeded faster in materials low in lignin content.

5.1.2.3.2 Cellulose

The cellulose contents of SVC and SCWC were below 8.0 per cent while that of SCC was 16.61 per cent. The reduction in cellulose content is associated with the maturity of compost. Manna et al. (2000) reported cellulose contents of 6.0 – 20.0 per cent in matured composts. Kadalli et al. (2000) found that cellulose content varied between 18.18 and 22.61 per cent in mature coir dust based composts.

5.1.2.3.3 Lignin/ Cellulose Ratio

In SCMs the ratio varied from 2.78 to 8.69. The lignin/cellulose ratio increased as organic matter decomposition progressed. Manna et al. (2000) reported that lignin/ cellulose ration increased with days of composting and the maximum was 12.5 in chickpea straw based compost.

5.1.2.3.4 Total Phenols

The content of total phenols in SCMs varied from 73.95 mg $100g^{-1}$ to 100.42 mg $100g^{-1}$. The increase in phenol is one of the indicators of completion of humification and the composts having reached maturity level (Singh, 2005a). Kadalli et al. (2000) reported that the total phenol content of mature composts varied from 44.06 to 58.70 mg $100g^{-1}$.

5.1.2.3.5 Water Soluble Carbohydrates (WSC)

The WSC contents of SCMs varied from 0.28 to 0.39 per cent. The WSC represents the most easily biodegradable C fraction during the composting process because it consists of sugars, organic acids and phenols apart from the soluble fraction of fulvic acids. The concentration of WSC declined with composting time. The greatest decline occurred in the first days of composting and continued even when the material was transferred to the maturation area (Singh, 2005a). The WSC contents of SCMs conforms to the findings of Manna et al. (2000) who reported that the WSC content of raw materials under composting decreased from its initial value to below 1.0 per cent at maturity. Singh (2005b) reported that the WSC content of conventional compost was around 1.6 per cent and that of vermicompost was around 0.85 per cent.

5.1.2.3.6 Water Soluble Organic Carbon

The water soluble organic carbon content of SCMs ranged from 0.19 per cent to 0.23 per cent. The water soluble carbon fraction is easily degraded by microbes and hence its content would be less at maturity stage of compost.

5.1.2.3.7 Biodegradability Index (BI)

The biodegradability index of the SCMs varied from 3.63 in SVC to 4.45 in SCC. SCWC recorded a value of 3.72. Manna et al. (2000) reported that BI of composts decreased with days of maturation and further decreased when bio- inocula were used. They found that the values of BI in mature composts ranged between 3.5 to 4.6 in uninoculated and 3.1 to 3.9 in inoculated composts during 120 days of decomposition. From this it could be concluded that the SCMs under study were well decomposed and had attained maturity.

5.1.3. Characterization of raw materials

The results of analysis of the raw materials are discussed below.

5.1.3.1 Physical characters of raw materials

5.1.3.1.1 Colour

The colour of the same type of raw material collected from different sources varied in such away indicating the wide variation present in the available raw materials (Table 14). The different raw materials are shown in Plate 3.The colour of a material is dependent upon its moisture content, fineness of particle, chemical composition etc. Hence the variation in the colour of the same raw material from different sources could be attributed to the variations in their physical and chemical characters.

5.1.3.1.2 Odour

The odour of the raw materials (Table 14) varied from fruity odour to pungent odour. The fruity odour is indicative of the fermentation process going on in the materials. The foul odour could be attributed to the presence of various toxic and foul smelling volatile organic compound released during organic matter decomposition. Pressmud, castor cake, essence extracted coffee beans powder, Abtec biocompost (RM 13) and Abtec vermicompost (RM 14), ash and ground nut seed shell (RM 48) had no recognizable odour, which could be attributed to the absence of any such volatile compounds in them.

5.1.3.1.3 Moisture content

The highest moisture content was recorded in RM56 (87.66 per cent) which was decomposed coir pith (Table 14). This is in agreement with the report of Mapa and Kumara (1995) which stated that coir pith has very high moisture retention capacity of 500-600 per cent. The lowest moisture content (1.06 per cent) was in castor cake (RM 7).

Within the same type of raw material, the different samples varied in their moisture contents indicating the differences due to source of material, method of processing, drying, storage, packing etc.

Plate 3 – Raw Materials

Plate 3 – Raw Materials

5.1.3.1.4 Bulk density

The bulk densities of the various raw materials varied from 0.17 Mg m^{-3} to 0.63 Mg m^{-3}(Table 14).The lowest bulk density was recorded in ash which could be because it is made of very fine and light particles and dry nature. LM5 and BM1 were found to have the highest bulk density.

5.1.3.2 Chemical characters of raw materials

5.1.3.2.1 Organic carbon

The raw materials contained organic carbon in the range of 5.66 to 32.87 per cent (Table 15, Figure 15). The highest organic carbon content was present in RM5 and the lowest was in BM3. Among the different types of raw materials bone meal had the lowest group mean value for organic carbon.

5.1.3.2.2 Nitrogen

The total nitrogen content of raw materials ranged from 0.40 per cent in ash to 9.03 per cent in LM2 (Table 15, Figure 16). The group mean value of leather meal (5.75 per cent) was higher than that of all others and hence leather meal could be considered as a good source of nitrogen in organic manures. This is in conformation with the report of Panda and Hota (2007). Raw materials having high nitrogen content are preferable for making organic manures and composts as the final products will also have high total nitrogen content. A low nitrogen content could lead to nitrogen immobilization in soil.

5.1.3.2.3 Phosphorus

The phosphorus content of raw materials ranged from 0.12 per cent to 10.36 per cent (Table 15, Figure 17). Ash had the lowest P content as it is poor in all nutrients. Bone meal with a group mean value of 8.83 per cent P was found to be the best source for P, which is in agreement with the report of Panda and Hota (2007). But there was variation (6.18 per cent to 10.36 per cent) in the P content of the different types of bone meal. According to Panda and Hota (2007) the percentage of phosphoric acid varies with the quality of bones and age of the animal from which these are obtained. Normally bones of grown up animals contain more phosphoric acid than those of young ones. Pressmud also contained a good proportion of

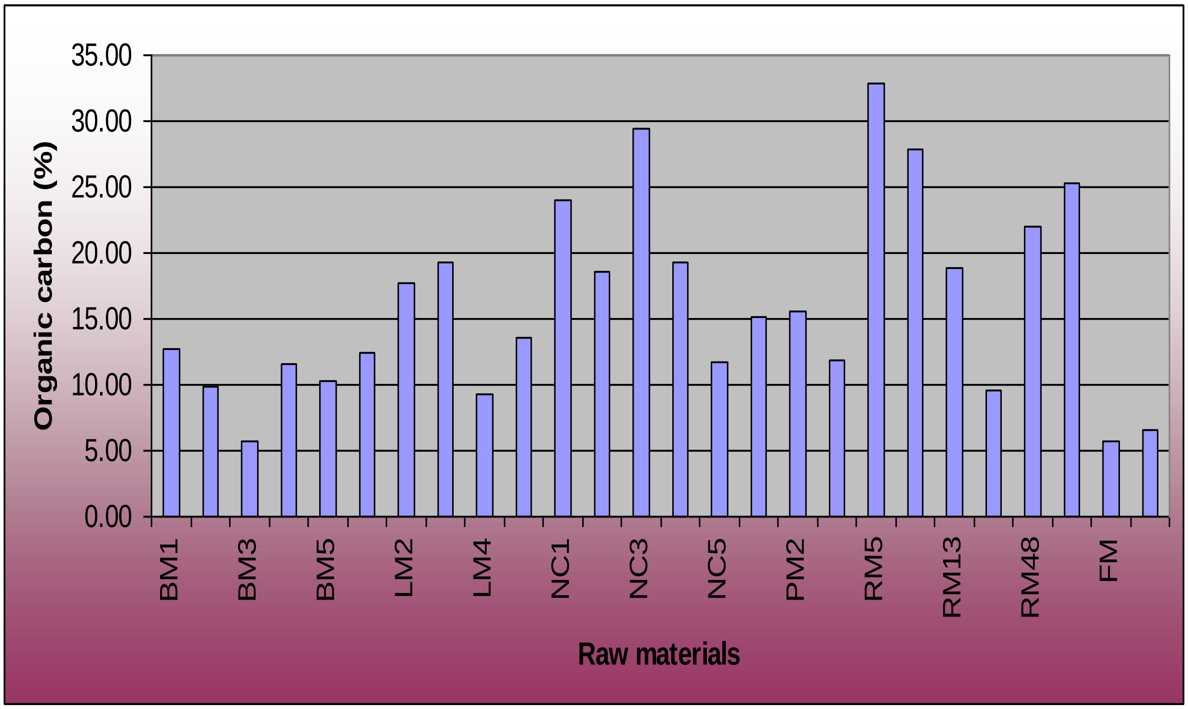


Figure 15. Organic carbon content of raw materials.

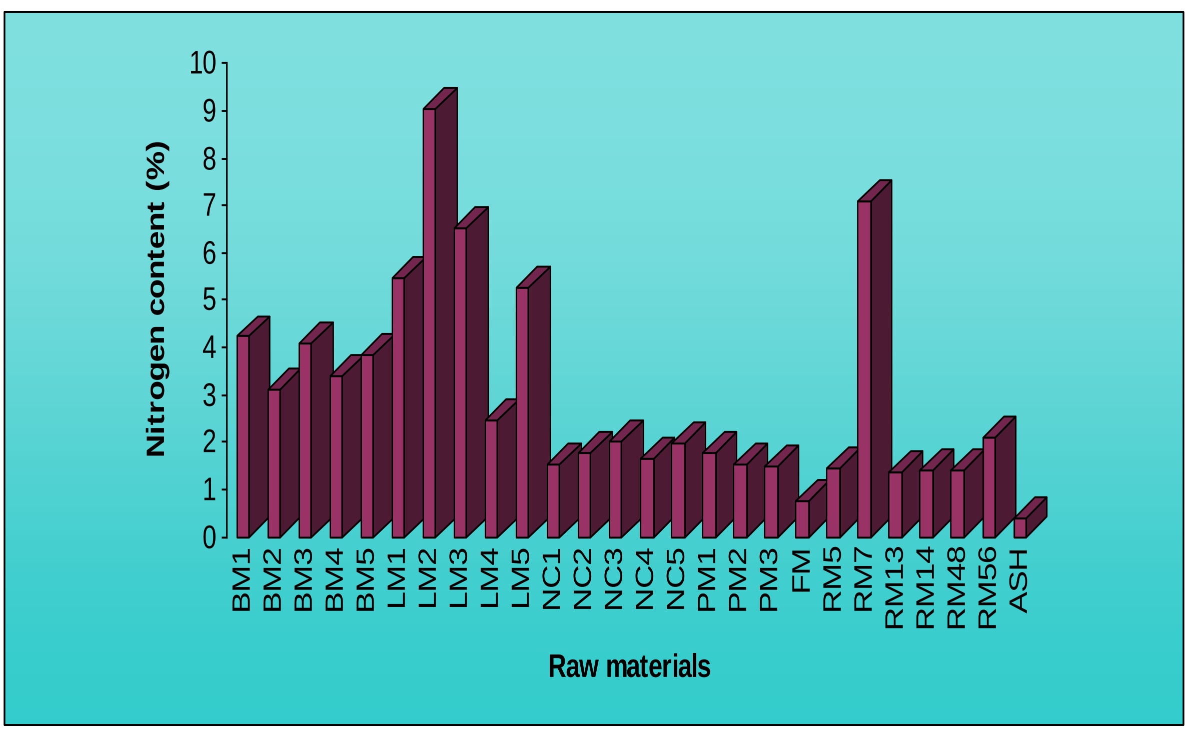


Figure 16. Nitrogen content of raw materials

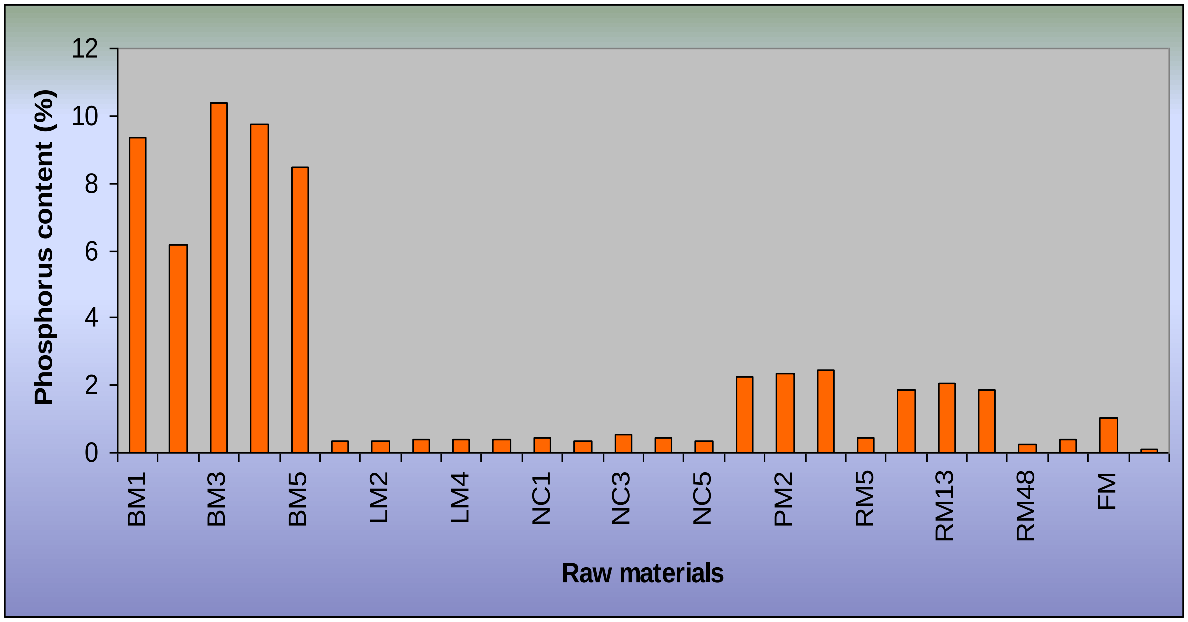


Figure 17. Phosphorus content of raw materials

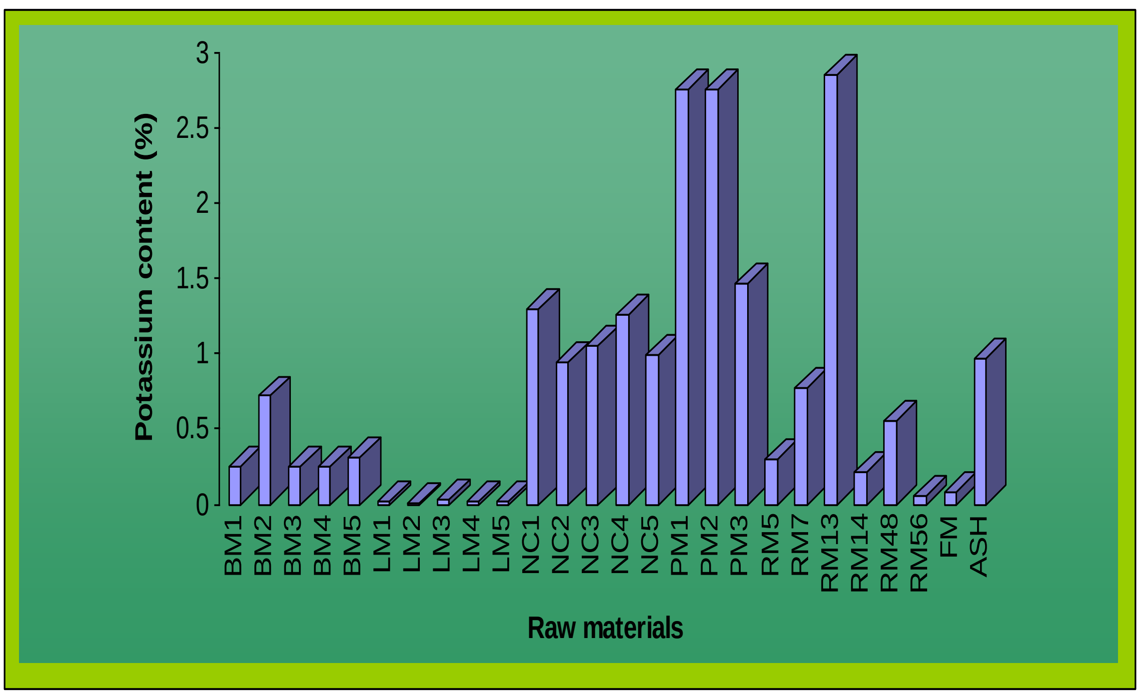


Figure 18. Potassium content of raw materials

phosphorus having a mean P content of 2.33 per cent which is in agreement with the findings of Palaniappan and Annadurai (1998).

5.1.3.2.4 Potassium

The potassium contents of raw materials ranged from 0.01 per cent to 2.86 per cent (Table 15, Figure 18). Pressmud was identified as the best source for K among the various groups. It had a group mean K content of 2.33 per cent.

5.1.3.2.5 Sodium

The sodium content of raw materials ranged from 0.11 per cent in PM1 to 1.68 per cent in NC2 (Table 15). Neem cake was found to be a good source of sodium compared to all other raw materials.

5.1.4 EFFECT OF COMPOSITION OF RAW MATERIALS ON QUALITY OF ORGANIC MEAL MIXTURES (OMMs)

To study the effect of physical and chemical properties of raw materials on the characters of the final product, different organic meal mixtures (OMMs) were prepared by mixing together selected raw materials in fixed ratios. The results of analysis of the OMMs are discussed below.

The physical properties of the OMMs showed distinct relationship with those of the component raw materials viz., bone meal, leather meal and neem cake. The colours of the OMMs were mixtures of the colours of the different raw materials. The odour of the OMMs depended on the odours of the raw materials used in their manufacture. The moisture content and bulk density were also found to be correlated with those of the raw materials used in preparing the OMMs. The chemical properties viz., organic carbon, nitrogen, phosphorus and potassium content of the OMMs were also clearly correlated with those of the raw materials. Based on this correlation, a mathematical model was developed and was applied to predict the quality of different mixtures of bone meal, leather meal and neem cake.

5.2 PROTOCOL FOR QUALITY STANDARDS OF COMS

The mathematical model developed could be used to predict the contents of nitrogen, phosphorus and potassium in mixtures of bone meal, leather meal and neem cake. As this is only a preliminary investigation the most important quality parameters of organic manures viz, N, P and K were considered for the development of protocol.

Using this model the estimated values of N, P and K of a particular mixture of bone meal, leather meal and neem cake can be calculated and if the actual N, P and K contents of the manure are higher than this it could be due to adulteration by addition of chemical fertilizers. Thus the model could be used to find out adulteration in COMs.

The model could be used to identify mixtures which would supply a particular level of N, P and K depending on soil fertility status and crop requirement. In this way location specific organic manures could be prepared. From the various mixtures of bone meal, leather meal and neem cake examined in Table 19b, it could be seen that nitrogen content did not vary much with the different proportions of raw materials. Phosphorus content mainly depended upon bone meal and it decreased with deceasing proportion of BM in the mixture. The potassium content of mixtures was found to vary directly with the neem cake fraction of the mixture. As neem cake content increased, potassium content of the mixture also increased. This information could be used in deciding organic manures suitable for different crops and soils. For crops which require more of potassium, a manure mixture with relatively high content of neem cake could be selected. For soils with low phosphorus content, a mixture with bone meal as the major ingredient can be selected.

5.3 STORAGE STUDY

The changes occurring to the physical and chemical properties of COMs and SCMs during long term storage are discussed in this section.

5.3.1Changes in Physical Properties

5.3.1.1 *Colour*

There was no change in the colour of the COMs and SCMs selected for storage study during the period of one year.

5.3.1.2 *Odour*

The samples SN8, SN16, SN37 and the SCMs viz., SCC, SVC and SCWC did not have any foul odour from the beginning to the end of storage study (Table 20). This could be because any chemical or microbial processes that took place in the manures during storage did not produce any odorous compounds. SN 1 and SN 21 developed pungent odour after being stored for several months. This could be due to the release of ammonia gas after mineralization of organic nitrogen compounds in the COMs due to the activity of micro organisms (Lekasi et al., 2001). Other foul smelling organic compounds might also have been produced as a result of organic matter decomposition as reported earlier by Jager and Jager (1980) and Chanyasak et al. (1982).

5.3.1.3 Moisture Content

The changes in moisture content of different COMs in storage showed varying trends (Table 21, Figure 19). Loss of moisture could have occurred due to evaporation.

5.3.1.4 Bulk Density

The changes in bulk densities of the stored manures showed varying patterns (Table 22, Figure 20).

5.3.2 Changes in chemical properties

5.3.2.1 Organic Carbon

The organic carbon content of organic manures stored for one year showed a decreasing trend (Table 23, Figure 21). For all the stored COMs, the decrease was fast during the initial quarter and then the organic carbon content reached almost constant level. This could be explained as due to the microbial decomposition of organic matter in the manures. The easily degradable carbon compounds are rapidly consumed by the microbes thus resulting in a reduction in organic carbon content of the manure after some time. Later when the microbial population reaches the ageing stage, the carbon content of the manure reaches a stable value. In the case of SCC and SVC, the carbon degradation had progressed much during the composting process itself and had reached an almost stable state. Hence they did not show much reduction in organic carbon content compared to the COMs.

5.3.2.2 Nitrogen

The changes in nitrogen content of organic manures showed varying patterns during storage (Table 24, Figure 22). The decrease in nitrogen content could be due to the fixation of nitrogen in microbial cells. Once the micro organisms reached ageing stage, the nitrogen contained in the cells was released and that could be the reason for increase in nitrogen later during storage.

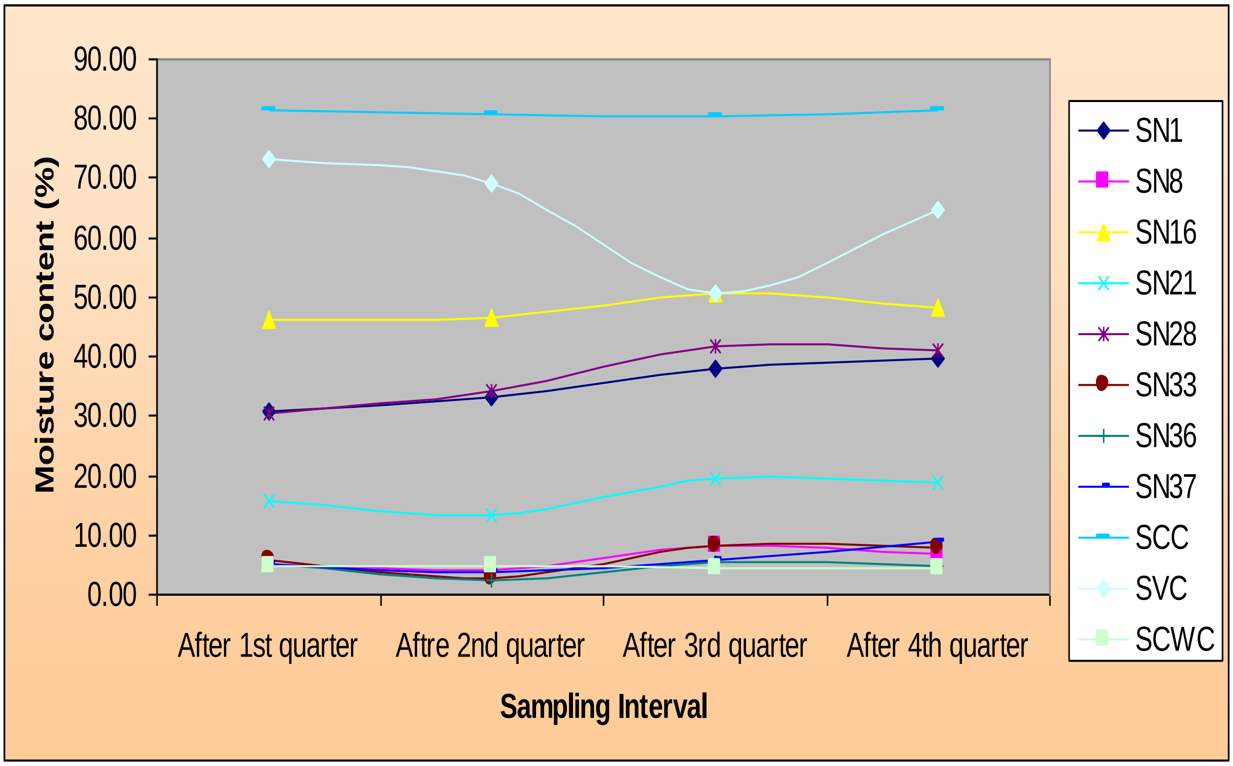


Figure 19. Change in moisture content of stored organic manures

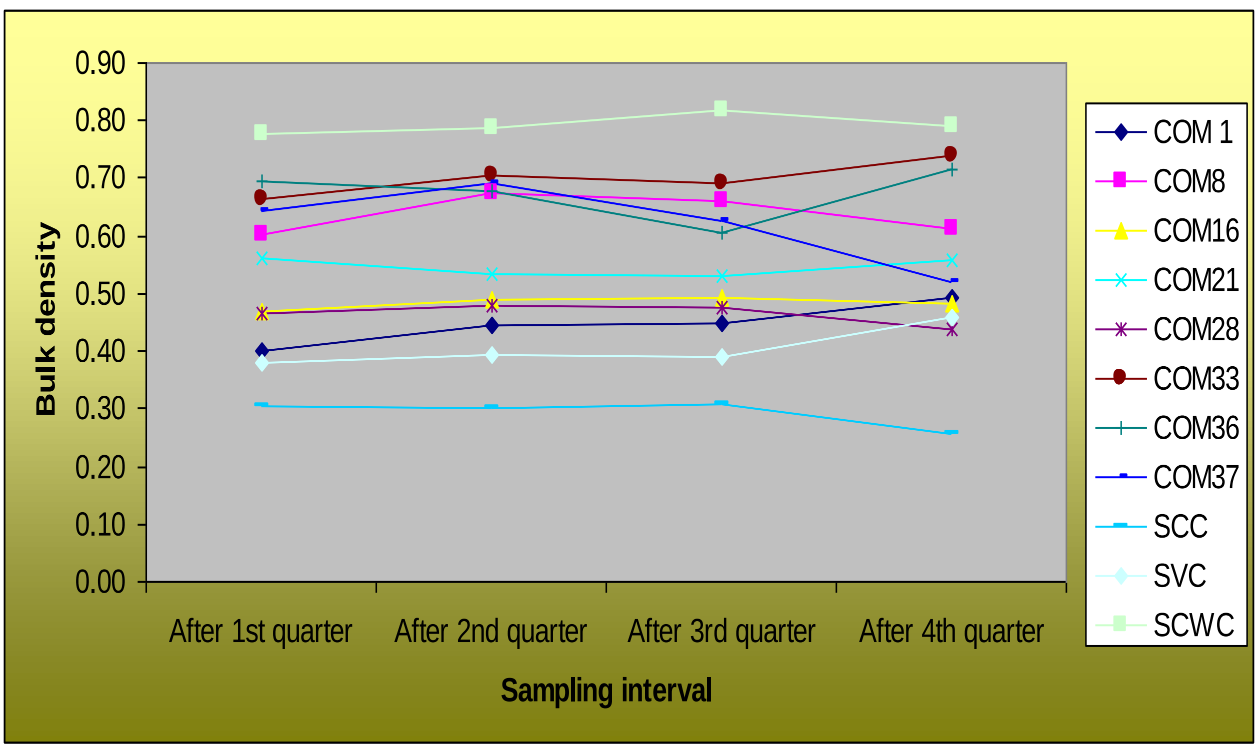


Figure 20. Change in bulk density of stored organic manures

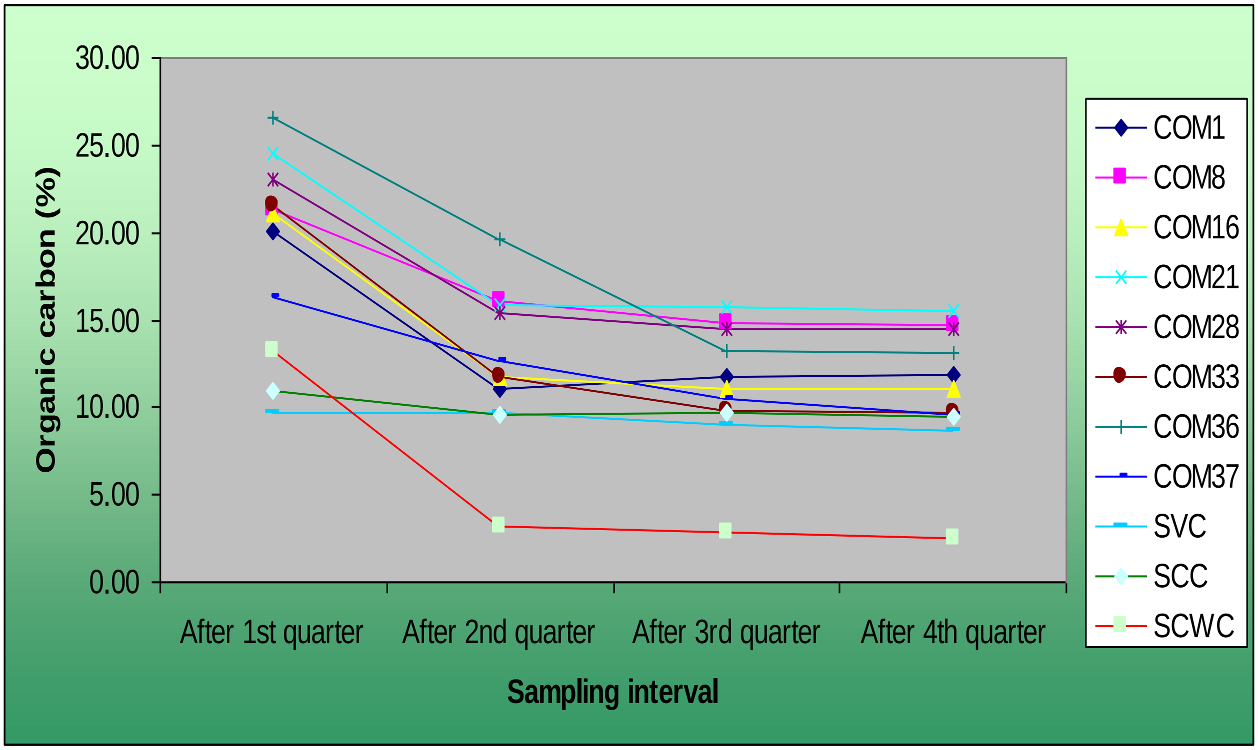


Figure 21. Change in organic carbon content of stored organic manures

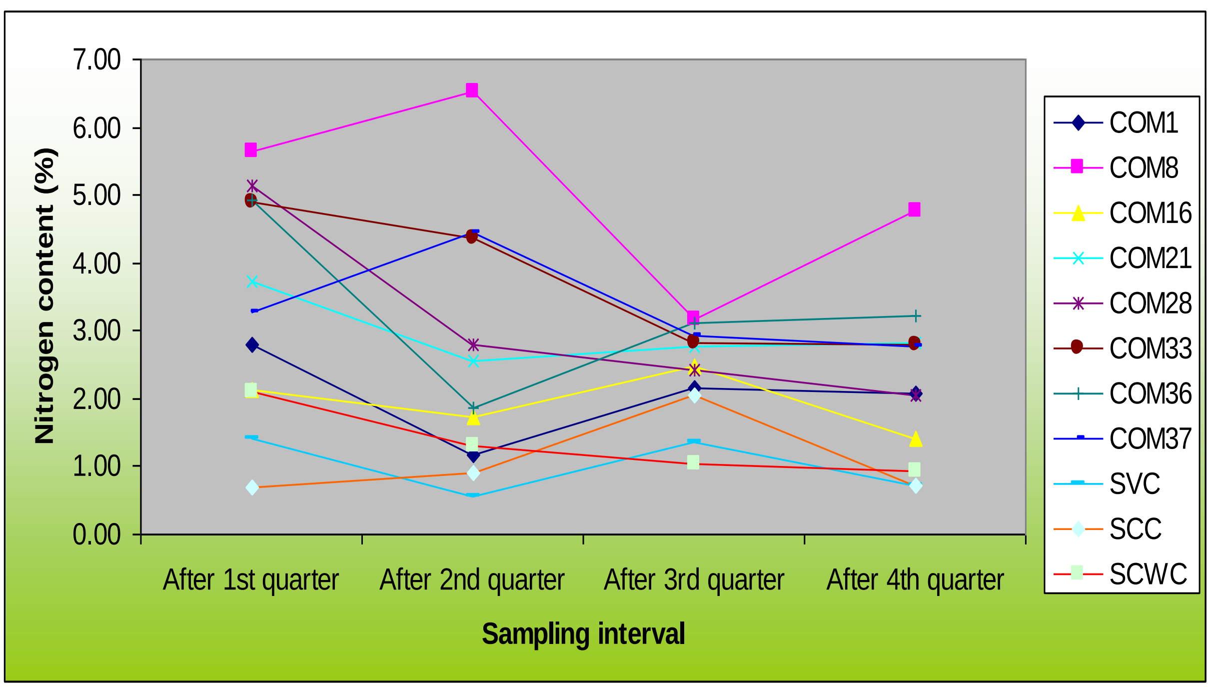


Figure 22. Change in nitrogen content of stored organic manures

5.3.2.3 Phosphorus

The changes in phosphorus contents of various organic manures in the storage study showed varying patterns (Table 25, Figure 23). The organic manures under storage study were dissimilar with regard to their physical and chemical characters as they were prepared from different raw materials with widely varying nutrient contents. This could have led to the inconsistent behaviour of the manures with regard to their P content with the progress of storage period. The activity of microorganisms feeding on the carbon rich manures leading to immobilization as well as mineralization of phosphorus might be the reason behind the undulating pattern of P content in the manures.

5.3.2.4 Potassium

The variations in potassium contents of the stored organic manures showed different patterns (Table 26, Figure 24). This could be due to the activity of micro organisms on manures with widely varying physical and chemical characters as well as initial potassium contents.

5.3.2.5 Sodium

The changes in the sodium content of various organic manures under storage conditions for one year varied in their patterns (Table 27, Figure 25). The initial sodium contents of the organic manures were dissimilar and further degradation due to microbial breakdown of the organic matter could have contributed to the varying trends of changes in Na content of manures under storage study.

5.4 QUALITY OF MARKET SAMPLES OF COMs

To study the change in quality of commercial organic manures after marketing, samples of selected COMs were collected from the market outlets. Their physical and chemical properties were analysed and the results are discussed below.

5.4.1 Physical Properties

5.4.1.1 Colour

The colours of the market samples (Table 28) did not vary much from the original colours of their factory samples.

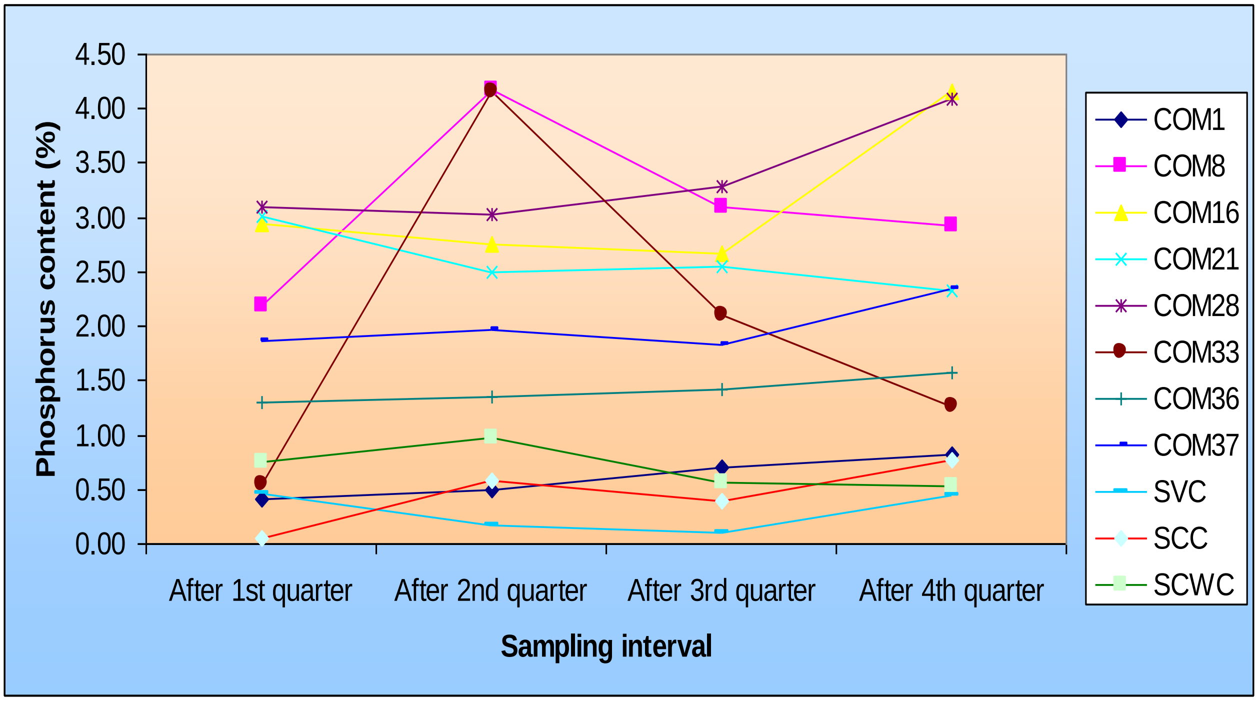


Figure 23. Change in phosphorus content of stored organic manures

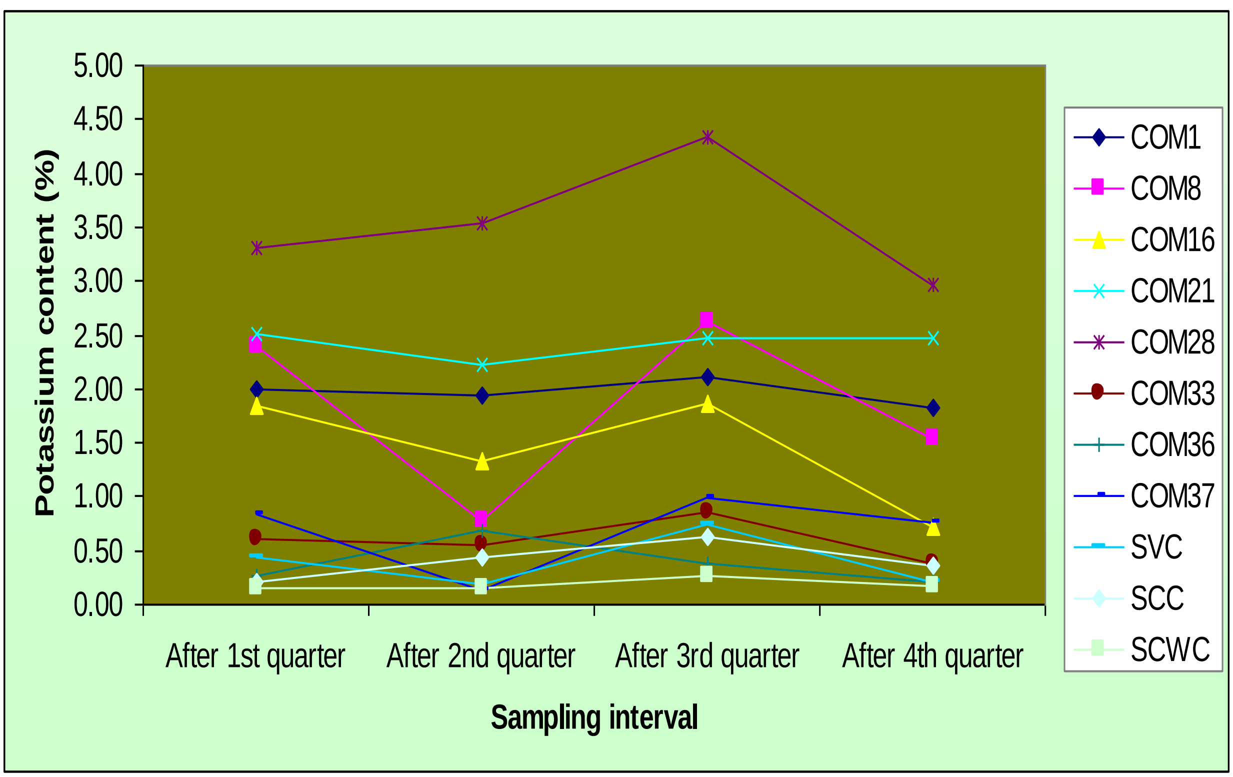


Figure 24. Change in potassium content of stored organic manures

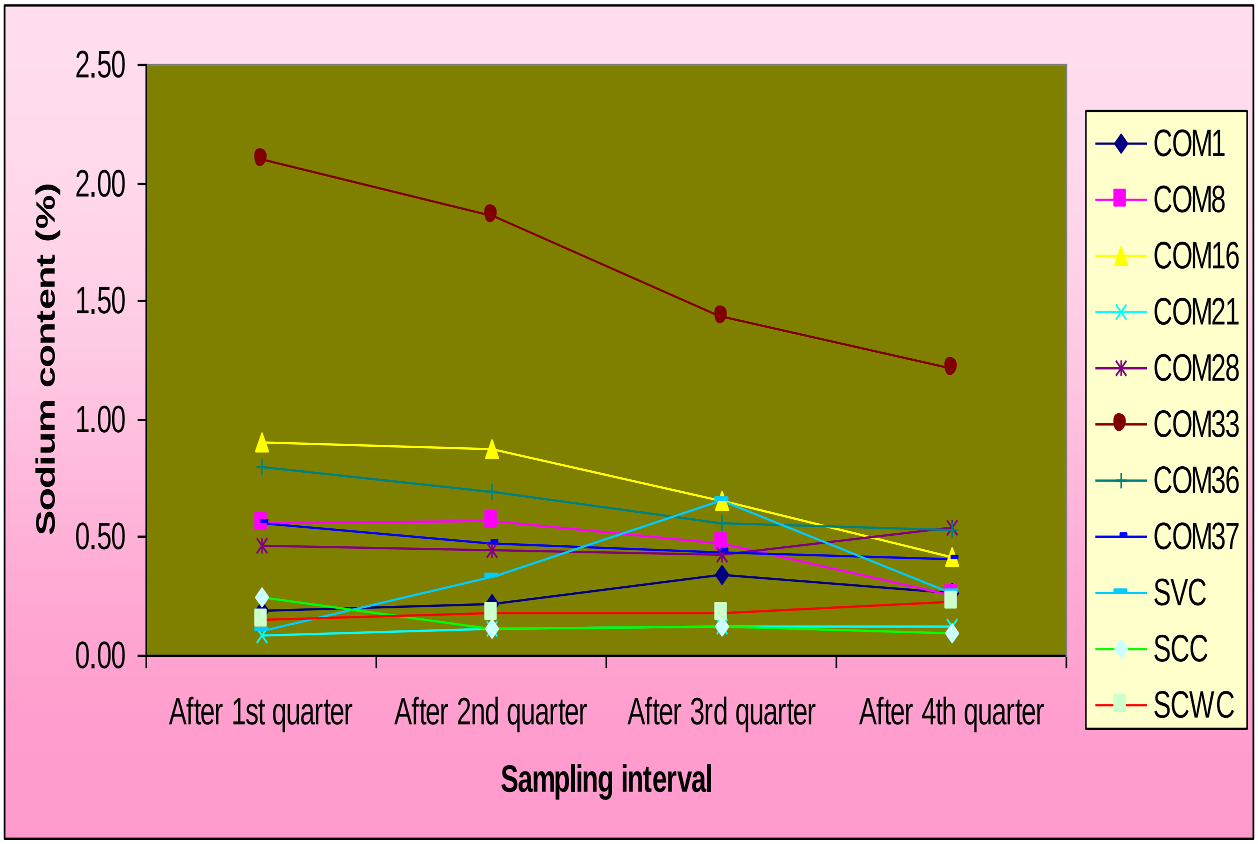


Figure 25. Change in sodium content of stored organic manures

5.4.1.2 Odour

There were some variations in the odour of some of the market samples compared to that of their factory samples (Table 28). It could be due to the progress of decomposition process during storage and transportation after they leave factory. The differences in the characters of raw materials used for the manufacture of different batches of COMs could also be a reason for the variation in their odour.

5.4.1.3 Moisture Content

The market samples were found to be drier than their factory samples (Table 29). It could be because of the further loss of moisture by evaporation during storage and transportation.

5.4.1.4 Bulk Density

There were no significant differences between the bulk densities of market sample and their corresponding factory samples (Table 29).

5.4.2 Chemical Properties

5.4.2.1 Organic Carbon

The organic carbon contents of all the market samples were significantly less than their corresponding factory samples (Table 29, Figure 26). This could be because of the microbial decomposition of the organic materials taking place in the COMs during their storage and transportation. The easily degradable organic carbon is consumed by the microbes during their fast multiplication. The differences in the organic carbon contents of raw materials used for the manufacture of different batches of COMs could also be a reason for the variation in their carbon content.

5.4.2.2. Nitrogen

The nitrogen contents of all the market samples were significantly less than their corresponding factory samples (Table 30, Figure 27). This may be attributed to the fixation of nitrogen in the cells of micro organisms acting on the decomposing organic materials. Due to the high organic matter content of the manures microbes multiply rapidly thereby immobilizing the nitrogen for a short period. Loss of nitrogen by volatilization and denitrification could also occur if the organic manure is stored for a long period. The differences in the nitrogen contents of raw materials

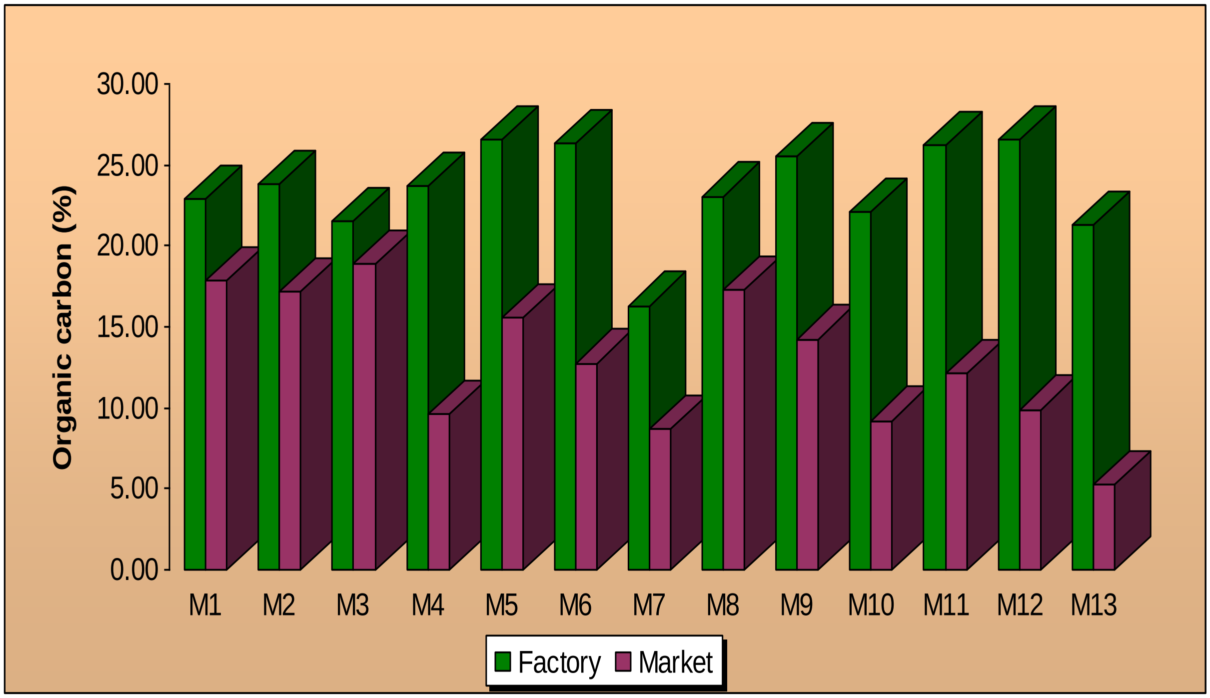


Figure 26. Organic carbon contents of factory and market samples of COMs

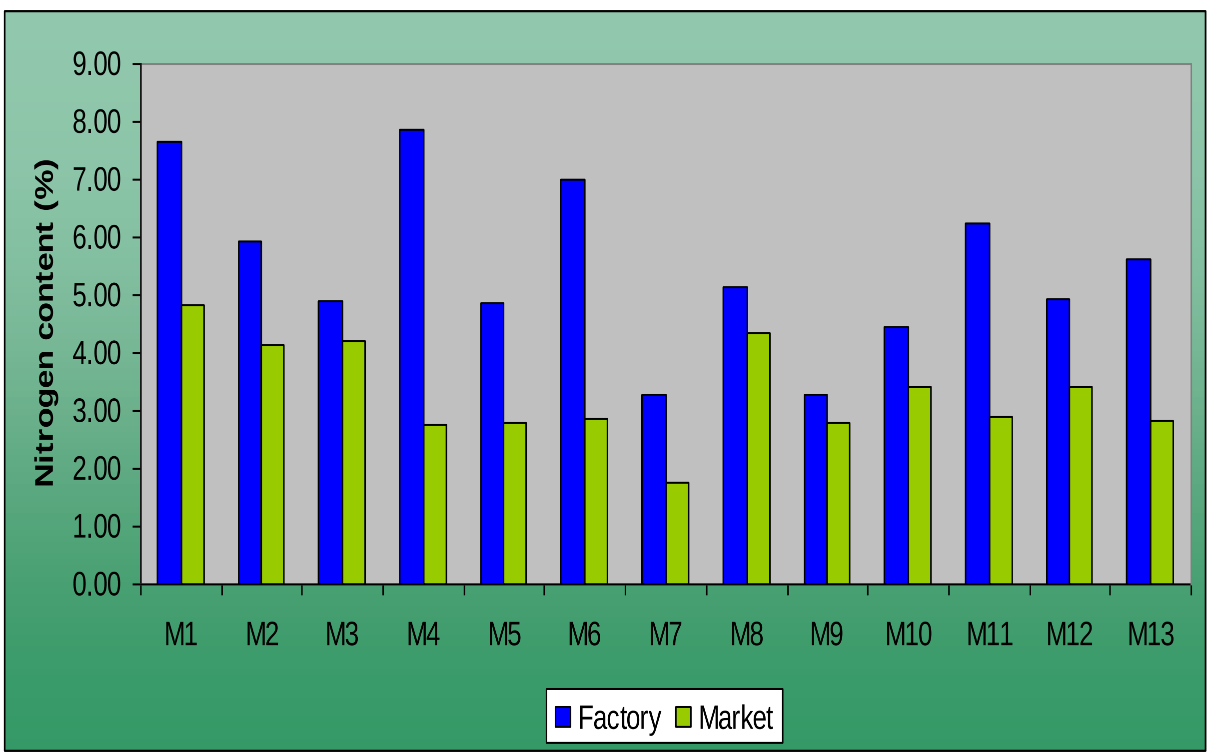


Figure 27. Nitrogen contents of factory and market samples of COMs

used for the manufacture of different batches of COMs could also be a reason for the variation in their nitrogen content.

5.4.2.3 Phosphorus

There were variations in the P contents of market samples compared to their factory samples (Table 30, Figure 28). Some of the market samples had significantly lower P content while some others had higher P and still some others did not show significant difference in their P contents. This could be because of the differences in P contents of the raw materials from different sources used for the manufacture of different batches of COMs.

5.4.2.4 Potassium

The potassium contents of the market samples also followed a similar trend as that of phosphorus (Table 30, Figure 29). Some of the samples collected from market outlets contained significantly less K compared to their corresponding factory samples while some others contained significantly higher amounts of K. Some of the market samples were on par with the K contents of their factory samples. This inconsistent pattern might be caused by the activity of microorganisms varying with the composition of each COM as well as due to the variation in chemical characters of raw materials used for the manufacture of different batches of the products.

5.4.2.5 Sodium

The sodium contents of all the market samples were significantly less than their corresponding factory samples (Table 30) except M_8 and M_9 which were on par. The factory samples and market samples of COMs belonged to different batches manufactured probably from different lots of raw materials differing in their sodium contents. This could lead to a difference in the sodium contents of different batches of the same COM product.

5.5 INCUBATION EXPERIMENT

An incubation experiment was conducted in the laboratory to study the mineralization pattern of selected commercial organic manures, organic meal mixtures and standard compost manures in soil (Plate 4) and the results obtained are discussed below.

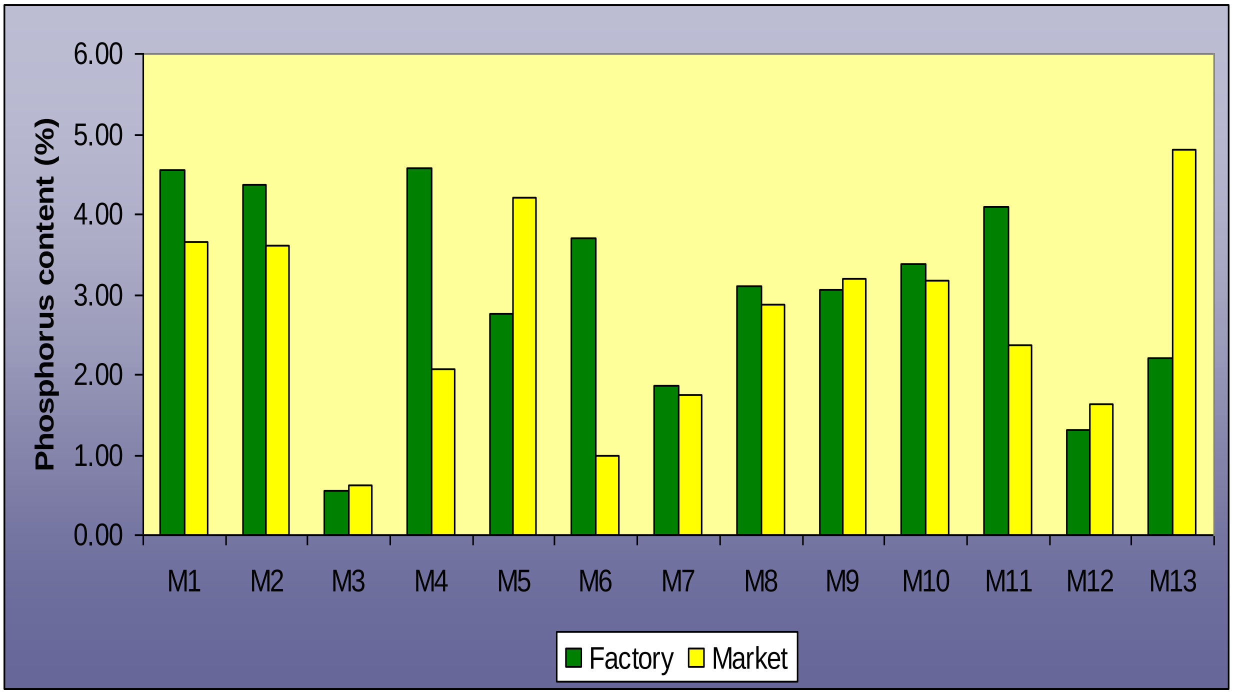


Figure 28. Phosphorus contents of factory and market samples of COMs

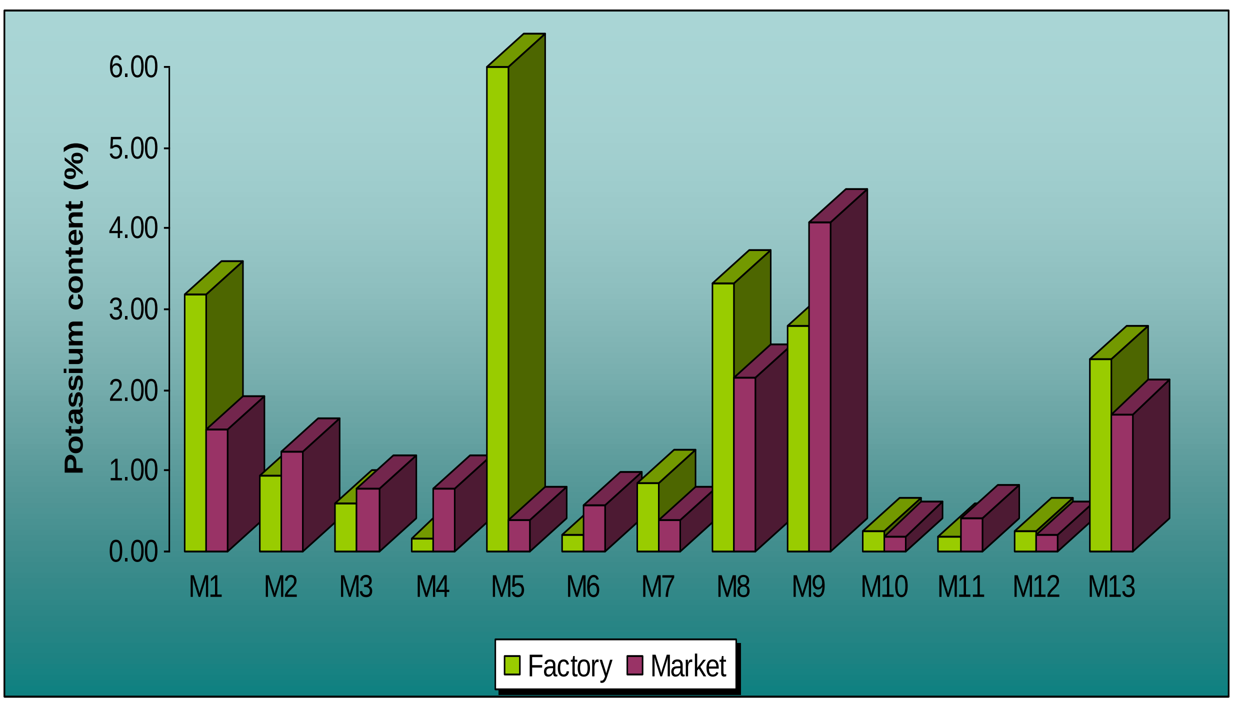


Figure 29. Potassium contents of factory and market samples of COMs

Plate 4 - Incubation

5.5.1 Mineralization pattern of nitrogen

The data given in Table 31 indicated that there was pronounced variation in mineralization pattern of nitrogen from various organic manures with advancement of time (Figure 30). Similar findings have been reported by Asha (2006).In general, the available nitrogen content in soils treated with organic manures increased upto 30DAI and in some cases upto 45DAI and decreased thereafter. This is in conformity with the findings of Melero et al. (2006) who reported that the processes of ammonification and nitrification run more intensively under organic management. Lekshmisree (2003) also reported that pH of the treated soil increased after compost application. In this suitable pH range the population of N fixing bacteria and actinomycetes will flourish resulting in increased N content of soil (Brady, 1996).

In the case of treatments viz., T_2, T_3, T_4, T_5, T_8, T_{10} and T_{11}, there was an initial decrease in available N content upto 15DAI. This may be due to the immobilization of nitrogen by the activity of microorganisms. In T_{10} and T_{11} which were SCC and SCWC respectively, the C/N ratio was comparatively higher (15.66 and 6.33 respcetively). In the treatments T_2, T_3, T_4, T_5 and T_8, the organic manures contained neem cake as one of the raw materials and this might have contributed to the inhibition of nitrification as neem cake contains the alkaloids nimbin and nimbidin, which effectively inhibit the nitrification (Reddy and Prasad, 1985).It was also reported that neem cake along with some other oil cakes, has great value as an immobilizer, thus conserving the applied an soil nitrogen and mineralizing steadily over a longer period (Hulagur, 1996). In an incubation study Hulagur (1996) found that the amount of mineralized N from neem cake increased upto 7 days after incubation. Recovery of mineral nitrogen from neem cake diminished at 14^{th} day of incubation and thereafter there was gradual increase. In an incubation study using vermicompost Bijulal (1997) observed that available N content increased upto 90 days of incubation and declined thereafter. Nagarajan *et al*. (1990) reported that inferior performance of coir pith compost may be due to its lower N content and wider C/N ratio (24.2) coupled with its nitrification inhibition property due to the presence off soluble tannins.

Hue and Silva (2000) reported that the nutrient release pattern of the nitrogen contained in various organic amendments can differ greatly. N in poultry manure is quickly available than nitrogen in manure and composts. Unlike poultry manure,

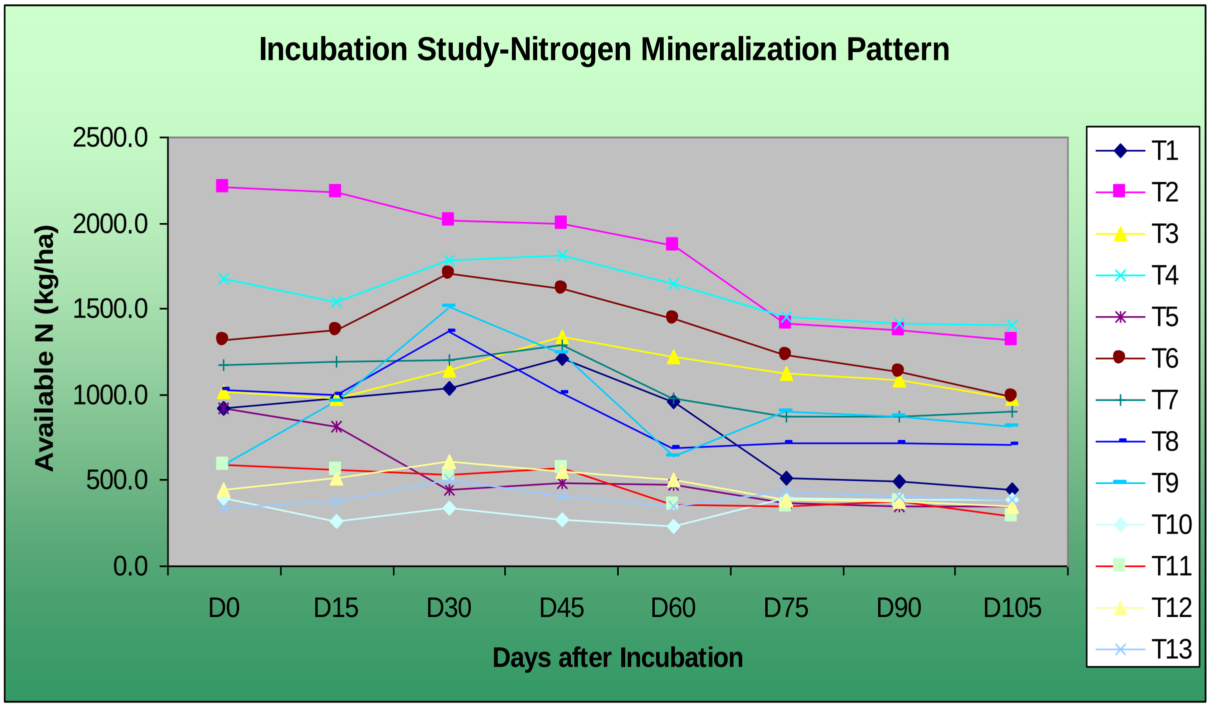


Figure 30. Incubation study- Nitrogen mineralization pattern

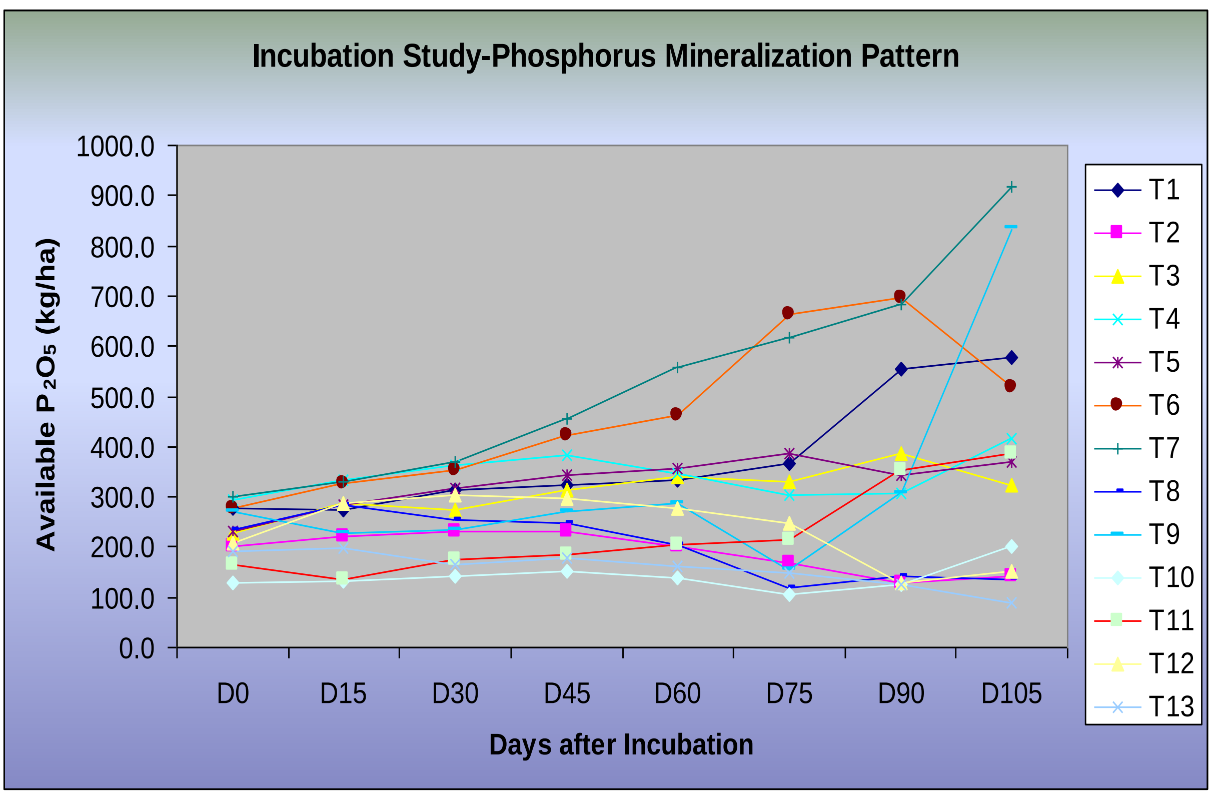


Figure 31. Incubation study- Phosphorus mineralization pattern

compost is a highly stable form. Nitrogen from compost must first be released from its organic substrates and thus process takes from several days to several weeks. Hence N availability from compost is extended for a longer period. In an incubation study conducted with FYM, poultry manure and vermicompost, Nair (2003) observed a progressive increase in the availability of N and P_2O_5 till 90^{th} day for all three manures. Sheeba (2004) inferred from an incubation experiment that available N content of soil increased upto 45 days of incubation, and then the availability slowly decreased. She also reported that the available nutrient contents were higher for vermicompost enriched with neem cake and bone meal as compared to that of ordinary vermicompost and FYM. Thus it could be concluded that the mineralization pattern of nitrogen from different organic manures did not follow a uniform pattern. This finding is in conformation with the report of Berry *et al*. (2002).

On an average, the highest available nitrogen content among all the treatments at various stages of incubation was recorded in T_2 followed by T_4.This may be attributed to the higher total nitrogen content of the manures viz., Kalpameal (T_2) and Karshaka Agromeal (T_4).

5.5.2 Mineralization Pattern of Phosphorus

The data presented in Table 32 indicates the effects of various organic manure treatments and periods of incubation on the available P_2O_5 content in soil (Figure 31). In general the available P_2O_5 content in soil was found to increase during the initial period (45 DAI) of incubation. This may be because the P from organic sources if readily available to plants. Organic matter from the manure interacts with clay minerals and reduces the P sorption by the soil thereby increasing the P availability to plants (Hue, 1990). The highest available P_2O_5 content was recorded in T_7 at 105DAI which was 919.06 ka ha^{-1}. The lowest P content was found in T_{10} (SCC) upto 75DAI and afterwards it was replaced by T_{13} (soil alone). Alexander (1977) reported that the organic carbon to organic P ratio of soil and added substances may be used to predict the net immobilization and mineralization of P in soil. If the ratio is 300:1 of more immobilization occurs. The critical level of P in organic materials to serve as a balance between immobilization and mineralization is calculated to be about 0.2 per cent. A higher P content in the manures lowers the C:P ratio and thus favours rapid mineralization whereas a low P content favours immobilization. Saravanapandian (1998) reported that increasing the level of FYM and applied P increased the available

P in all types of soils under study. The P availability was increased at 30 days of incubation as compared to 15 days with FYM whereas without FYM it increased with the progress in incubation. In an incubation study using vermicompost Bijulal (1997) observed that the release of available P increased steadily upto 120 days of incubation. In an incubation study conducted with FYM, poultry manure and vermicompost, Nair (2003) observed a progressive increase in the availability of N and P_2O_5 till 90th day for all 3 manures. Sheeba (2004) inferred from an incubation experiment that available P_2O_5 content of soil increased upto 45 days of incubation, and then the availability slowly decreased. Asha (2006) observed that since the P content of FYM and neem cake were quite low, a wider C/P ratio slowed down the mineralization process over a longer period of 120 days. Berry et al. (2002) had reported that because composition of compost is notoriously variable, and mineralization of OM in the soil is mediated by a host of factors such as temperature, moisture, soil chemistry and microbial communities predicting the timing and quality of nutrient supply in soil becomes difficult.

5.5.3 Mineralization Pattern of Potassium

Table 33 presents the pattern of mineralization of K from different organic manures and it indicated a pronounced variation among treatments and with advancement in time (Figure 32). All treatments with organic manures recorded higher K_2O content than soil alone (T_{13}). This might be due to the addition of K through organic manures and is in conformity with the report of Bharadwaj (1995). In several treatments there was a decline in K content during initial stages of incubation. Debnath and Hajra (1972) observed from their incubation studies that available K_2O content increased upto 16th day, a decrease on 30th day followed by an increase and then stabilized when FYM and daincha were used. Sheeba (2004) reported that available K_2O content of soil in an incubation experiment increased upto 45 days of incubation, and then the availability slowly decreased. Asha (2006) observed that available K_2O increased progressively upto 60 to 75 DAI for all organic manure treatments and thereafter decreased. Similar reports were also made by Bijulal (1997) and Nair (2003). Longer period to reach peak values indicated longer retention of K_2O in humic complexes and their slow release. The inconsistent behaviour of different organic manures in the release of potassium is explained by the findings of Berry *et al*. (2002) who had opined that because composition of compost is notoriously

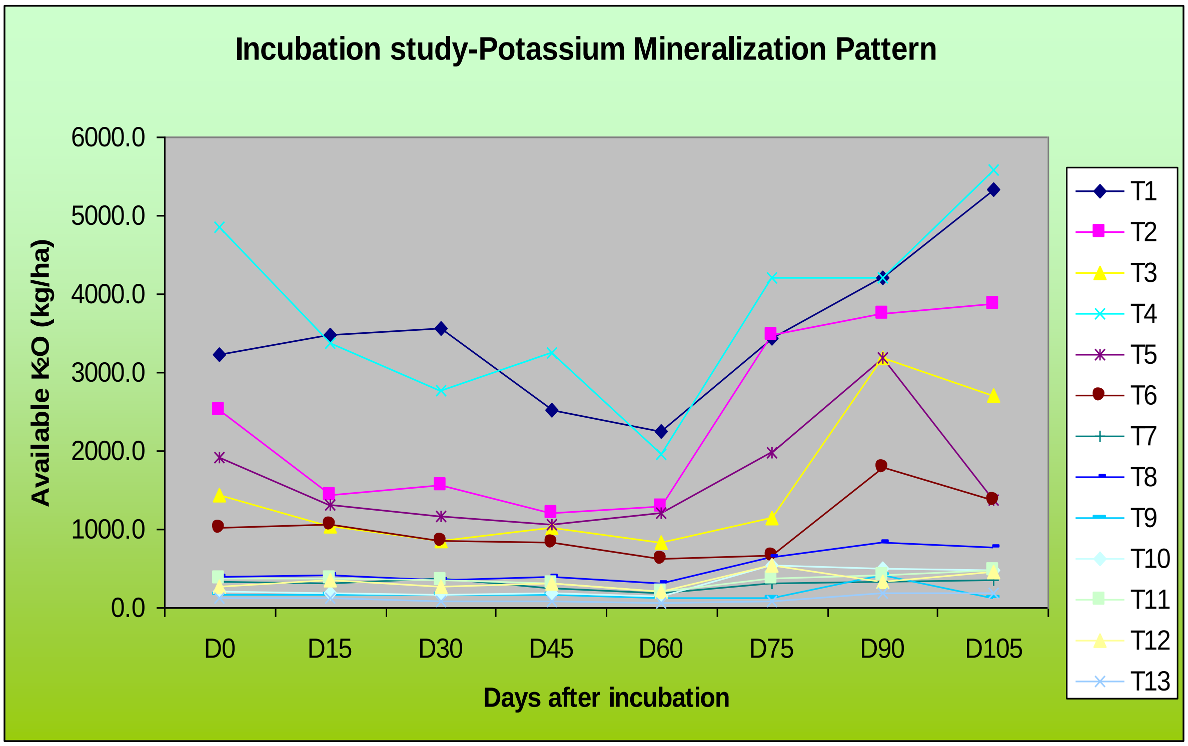


Figure 32. Incubation study- Potassium mineralization pattern

variable, and mineralization of organic matter in the soil is mediated by a host of factors such as temperature, moisture, soil chemistry and microbial communities, predicting the timing and quality of nutrient supply in soil becomes difficult.

The highest K contents during all stages were recorded in T_4 and the peak value was at 105DAI (5581.00 kg K_2O ha^{-1}).This may be attributed to the high total K content (3.18 per cent) of the organic manure applied in T_4 viz., Karshaka Agromeal grade I.

5.6 FIELD EXPERIMENT

5.6.1 First Crop

5.6.1.1 Growth characters

The data given in Table 34 showed that there was no significant difference between the treatments with regard to plant height, number of leaves per plant, number of branches per plant and stem girth. The leaf: stem ratio was highest in T_6 and lowest in T_1. Plate 5 shows different stages of field experiment.

5.6.1.2 Yield and Yield Attributes

The highest yield was recorded in T_4 at both first and second cuttings and the lowest yield was obtained from T_{14} at both times of harvest (Table 35, Figure 33). The total marketable yield, yield per plant and total dry matter production (Figure 35) were also highest in T_4 and the lowest was in T_{14}.This maybe attributed to the high nitrogen, phosphorus and potassium contents of Karshaka Agromeal grade I applied along with fertilizers in T_4. Arunkumar (2000) had reported that the application of coir pith compost recorded lower green yield in amaranthus as compared to FYM, poultry manure, vermicompost and POP recommendation on equivalent N basis. The control treatment T_{14} received no fertilizers and manures which could be the reason for its inferior performance. Singh and Ram (1982) had opined that the increased yields in crops due to the application of organic manures could be associated with release of macro and micro nutrients during the course of microbial decomposition. Prabha et al. (2008) reported that vermicompost application stimulated root growth, facilitating nutrient absorption and thereby favouring higher yield in crops.

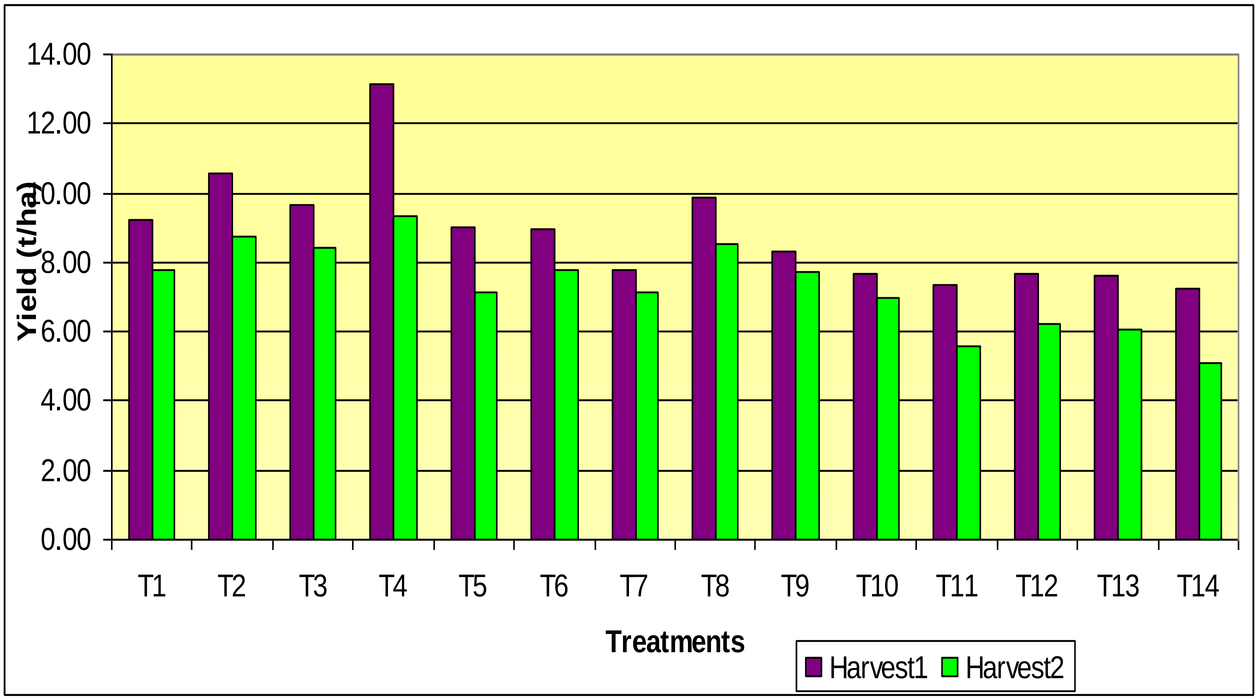


Figure 33. Yield of first crop (t ha^{-1})-Harvest 1 and Harvest 2

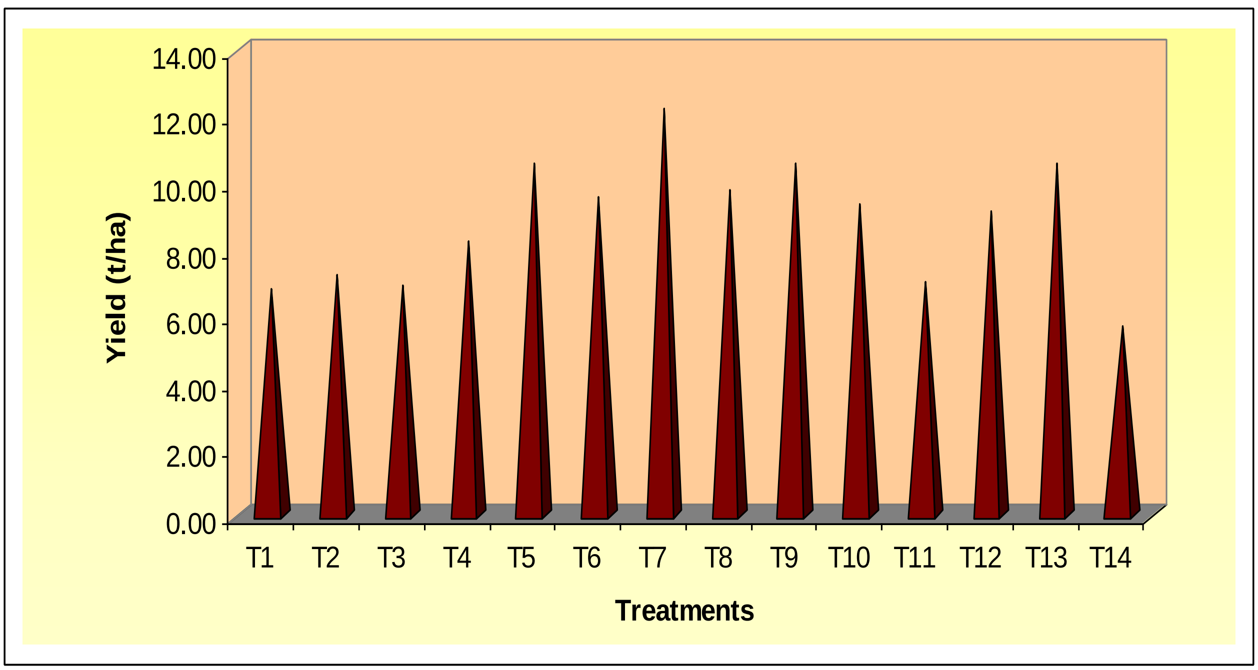


Figure 34. Yield (t ha^{-1}) of second crop

5.6.1.3 Uptake of nutrients by the crop

The data presented in Table 36 revealed that the uptake of N, K and Na were highest in T_4 while that of P was highest in T_6 (Figures 36, 37, 38 and 39).The lowest quantity of uptake was recorded inT_{14} for all nutrients. The high content of nutrients present inT_4 could be the reason for the higher uptake. Asha (2006) reported that more of nutrients and plant growth promoting substances in organic manures increased the uptake and improved the metabolic activity of plants. Similar findings were also reported by Zachariah (1995) in chilli and Sheeba (2004) in amaranthus. Nambiar (1994) reported that the nitrogen, phosphorus and potassium use efficiency of various crops improved appreciably with the incorporation of organic manures along with NPK fertilizers.

5.6.1.4 Quality Parameters

The data on quality parameters of the first crop presented in Table 37 showed that the moisture content did not vary significantly among treatments. Crude fibre content was highest inT_{14} and lowest in $T_{4.}$ The highest protein control was recorded in T_7 and the lowest protein content was observed in T_{14}. The highest β -carotene content was registered in T_5 and the lowest was in T_{14}.The antinutritional factor oxalate was highest in T_{14} and significantly lower oxalate content was recorded in T_5. The ash contents of the plants indifferent treatments were not significantly different from one another. The application of organic manures was found to improve the quality aspects of the crop which is in conformity with the findings of several workers (Joseph, 1998; Arunkumar, 2000; Bhadoria *et al*.,2002; Sheeba, 2004).

5.6.1.5 Nutrient content of plants

The nitrogen content in plants (Table 38) was highest in T_7 and the lowest was in T_{14}. Chen et al. (2001) reported that the soil in the plot with combined chemicals and organic inputs had the best ability to build up soil nitrogen and produced the highest crop yield, and the nitrate content of the harvested crop was also high. The control plot (T_{14}) which did not receive any nitrogen input had only the soil native nitrogen for crop uptake. This could be the reason for the low N content of plants in T_{14}.

For P, the highest content was in T_6 and the lowest was in T_5 on par with T_{14}.The highest P uptake was also recorded in T_6 which might be the reason for the

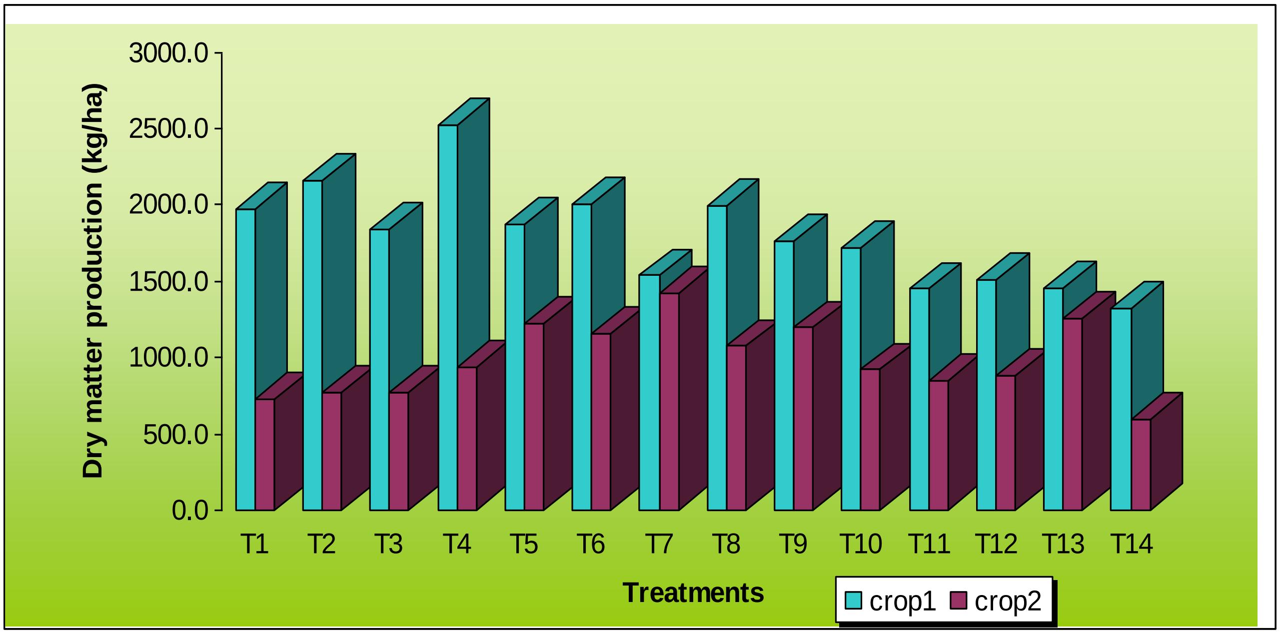


Figure 35. Dry matter production (kg ha^{-1}) of crop 1 and crop 2

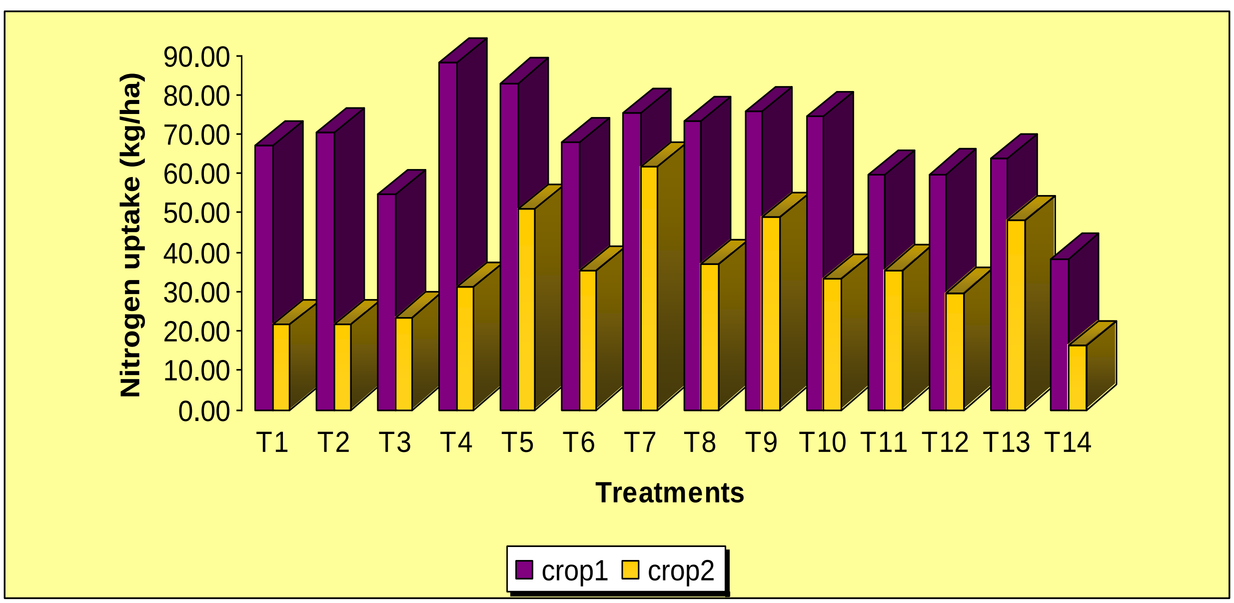


Figure 36. Nitrogen uptake (kg ha^{-1}) by crop1 and crop 2

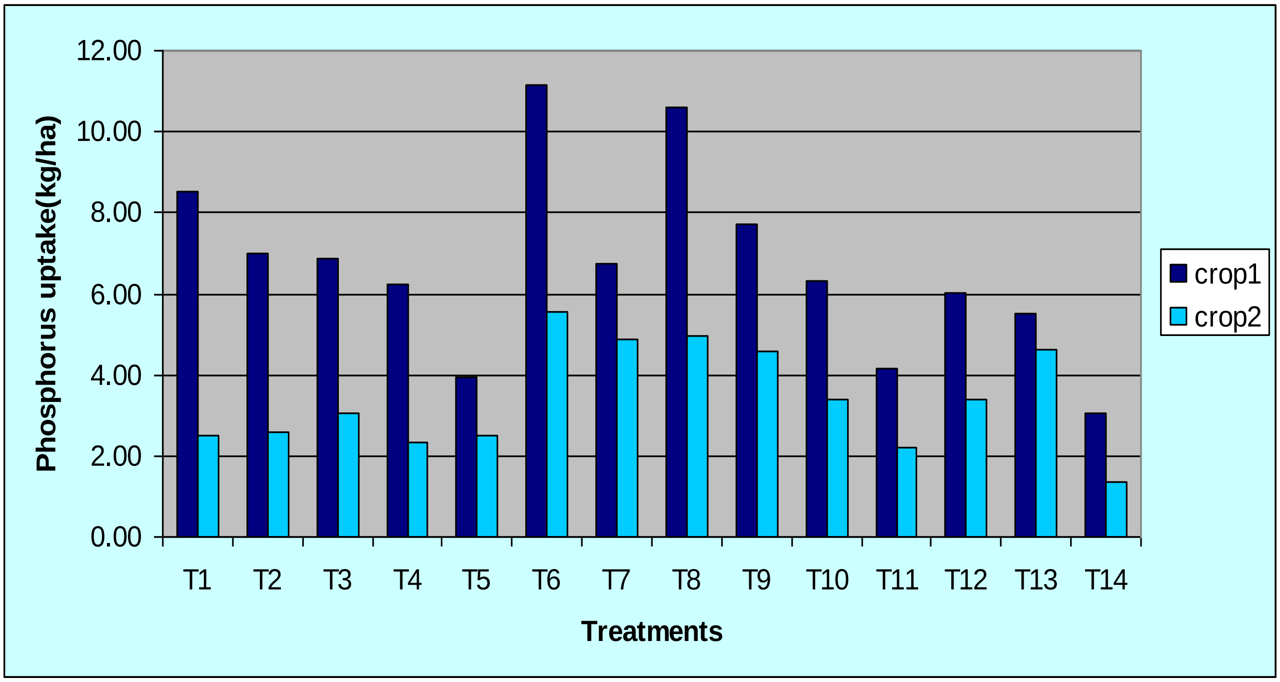


Figure 37. Phosphorus uptake (kg ha^{-1}) by crop 1 and crop 2.

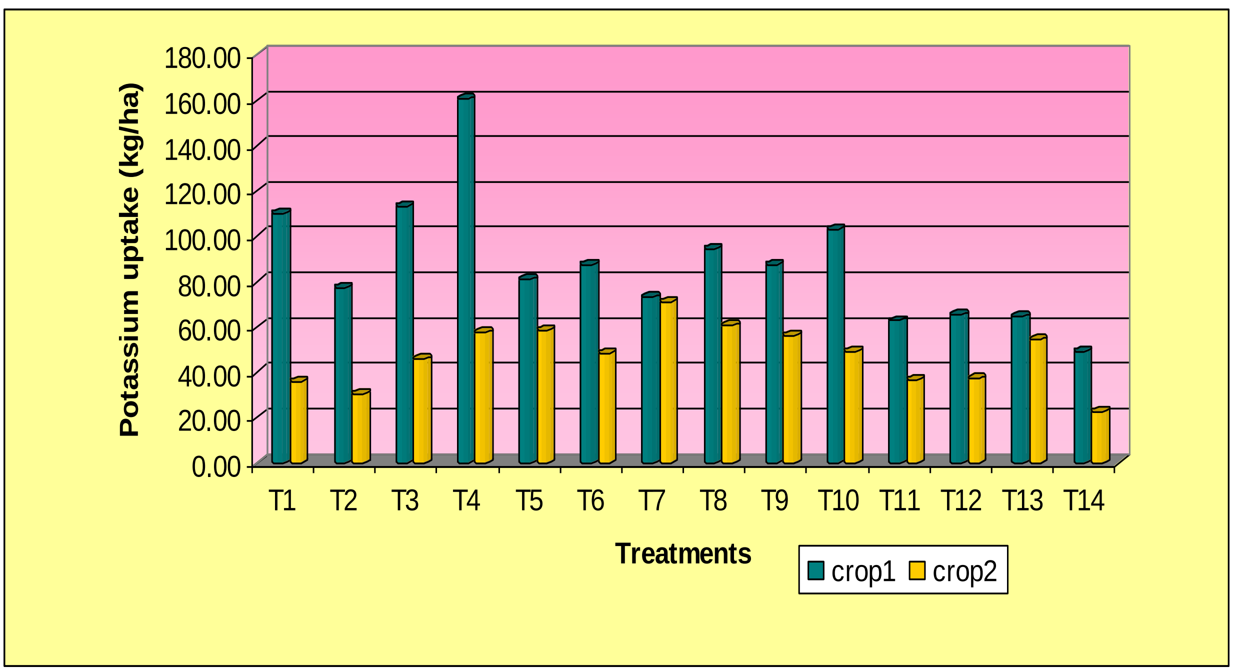


Figure 38. **Potassium uptake (kg ha^{-1}) by crop1 and crop 2**.

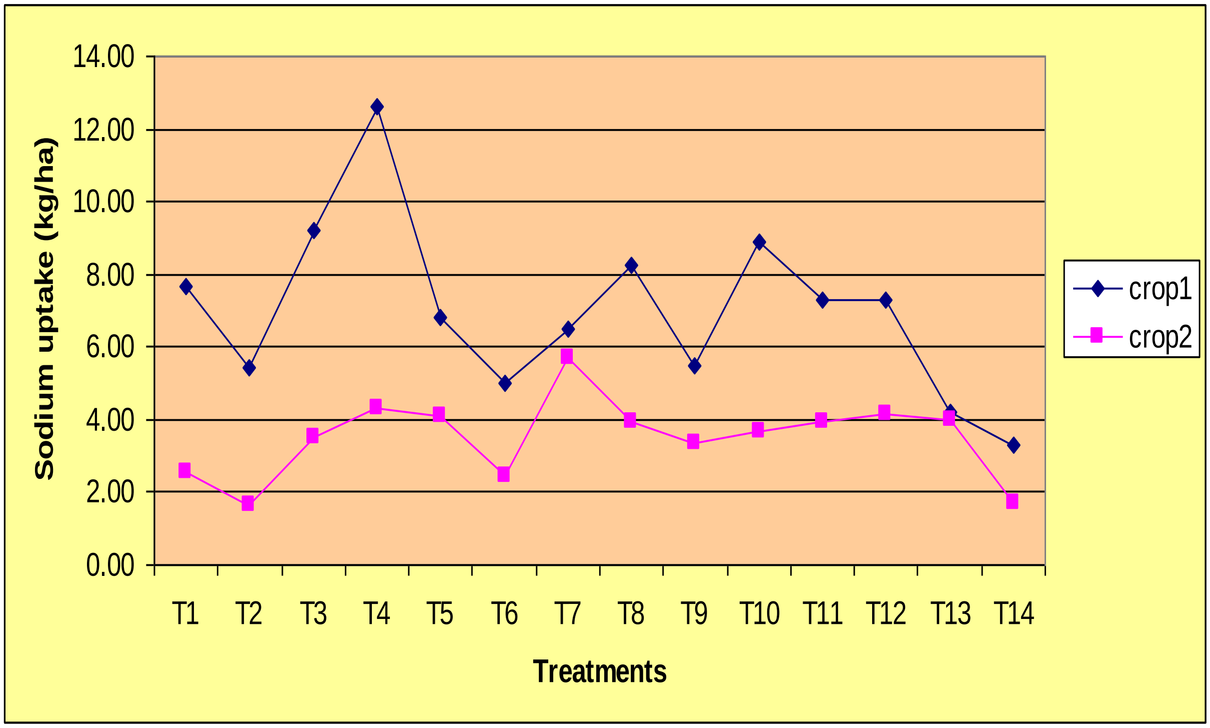


Figure 39. Sodium uptake (kg ha^{-1}) by crop1 and crop 2.

high P content in plants in T_6. The highest K content was in T_4 and the lowest was in T_2 on par with T_{14}. The plants in T_4 registered the highest K uptake which could be the reason for their high K content. In the case of sodium content, the highest was in T_{10} and the lowest in T_{14}. In general the nutrient contents in plants receiving manures and fertilizers were higher than that in the control treatment. This was evidently due to the higher amount of nutrients supplied by the manures and fertilizers. The uptake pattern of nutrients also is in conformity with the plant content of nutrients. Since the quantity of fertilisers applied to all the treatments except T_{14} is the same, the properties of the organic manures must have contributed to the variations in nutrient uptake as well as plant nutrient content. The positive effect of organic manures in improving nutrient uptake and thereby increasing plant nutrient content was reported by Venkitaswamy (2003), Wijeratne and Premathunga (2005) and Mohanty et al.(2006).

5.6.1.6 Soil Analysis

5.6.1.6.1 Organic Carbon

The highest organic carbon content of 1.80 per cent was in T_{11} (Table 40, Figure 40) which was given fertilizers along with SCC. The lowest organic carbon (1.02 per cent) was found in T_{14} (control). Selvi and Selvaseelan (2003) had reported that coir pith compost having higher proportion of fibrous carbonaceous residues contributed towards increasing soil organic carbon content in a potato crop. Deepa (2005) reported that five organic manures viz., Poabs Green, Bharath Meal, Haritha Super, FYM and enriched vermicompost increased the organic carbon content of the soil and they differed significantly with respect to post harvest organic carbon level in soil. Poabs Green and FYM were found to cause about three fold increase in carbon content of soil. In control plots, no fertilizers or organic manures were applied. The native soil organic matter could have been degraded by soil microflora and in the absence of replenishment of organic matter, the soil organic carbon content showed a decline from the value before cultivation of amaranthus.

5.6.1.6.2 Available Nitrogen

The highest content of available N in soil after harvest of first crop (Table 40,Figure 41) was recorded in T_{10} and lowest available N content was observed in T_4.The low content of N in T_4 might be attributed to the higher yield of crop (13.16 t

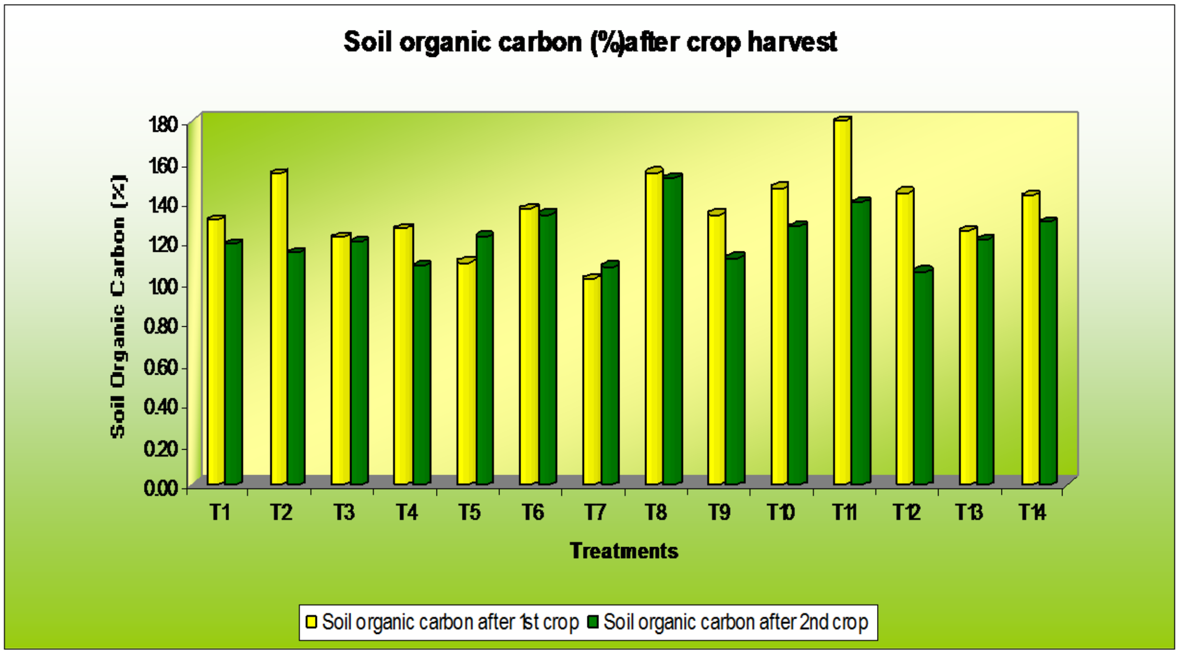


Figure 40 . Soil organic carbon (%) after crop harvest

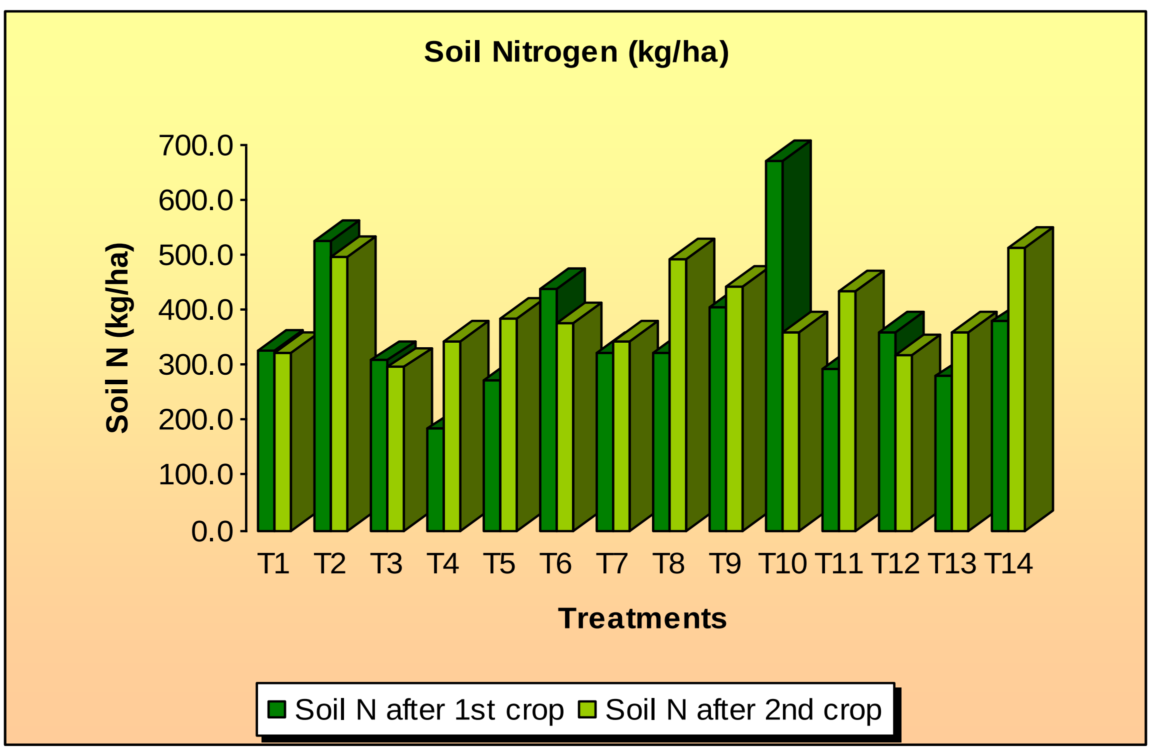


Figure 41. Soil nitrogen (kg ha^{-1}) after crop harvest

ha^{-1}) obtained in T_4. The crop removed more N from soil for its growth as compared to other treatments with lower yield than T_4. The high available N content in T_{10} which had received SVC along with fertilizers could be because of the beneficial effects of vermicompost. Biological N fixation by the large population of microbes and enhanced urease activity might have improved the available N content in the SVC treated plots. Similar results were reported by Asha (2006), Sheeba (2004), Sailajakumari (1999) and Bijulal (1997). Hue and Silva (2000) had reported that the N availability from composts is extended for a longer period because N from composts must first be released from its organic substrates and this process takes from several days to several weeks. The treatments with COMs containing neem cake viz., $T_{2,}$ $T_{3,}$ $T_{4,}$ $T_{5,}$ $T_{6,,}$ T_7 and T_8 could have undergone nitrification inhibition due to the presence of the alkaloids nimbin and nimbidin in neem cake which possessed nitrification inhibition property. Therefore neem cake could at as an immobilizer, thus conserving the applied and soil N and mineralizing steadily over a longer period (Reddy and Prasad, 1985). Kale et al. (1992) recorded high level of total N in plots applied with vermicompost and comparatively low quantity of fertilizers, which they attributed to the high count of N fixers in treated lots than in control plot. The inferior performance of coir pith compost (SCC in T_{11}) maybe due to its low N content and wider C/N ratio, coupled with its nitrification inhibition property due to the presence of soluble tannins (Nagarajan et al., 1990).

5.6.1.6.3 Available Phosphorus

The available phosphorus content after harvest of first crop (Table 40, Figure 42) was highest in T_7 and the lowest value of available P_2O_5 was observed in T_6. This was because of the significantly high plant uptake of P from T_6 (11.17 kg ha^{-1}). Eghball and Power (1999) reported that applying enough manure or compost to meet the nitrogen requirements of crops may greatly increase the levels of P and other ions in the soil probably because the N/P ratio in most livestock manure, even after composting, was lower than the N/P uptake ratio of most crops. This was supported by the findings of Eghball and Power (1995). The organic manures containing animal wastes and neem cake usually have a wider C:P ratio due to the low P content of these ingredients which slowed down the P mineralization process over a longer period of more than three months. This has been reported earlier by Asha (2006). In T_{10} which had received SVC along with fertilizers, the relatively high available P status could be

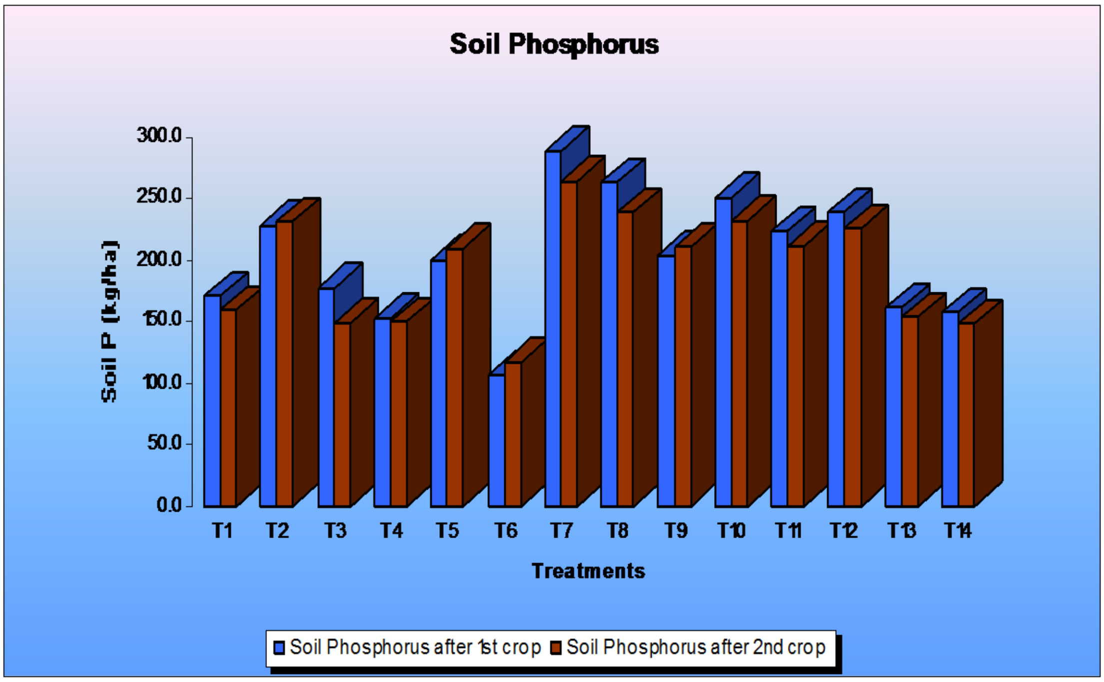


Figure 42. Soil phosphorus (kg ha^{-1}) after crop harvest

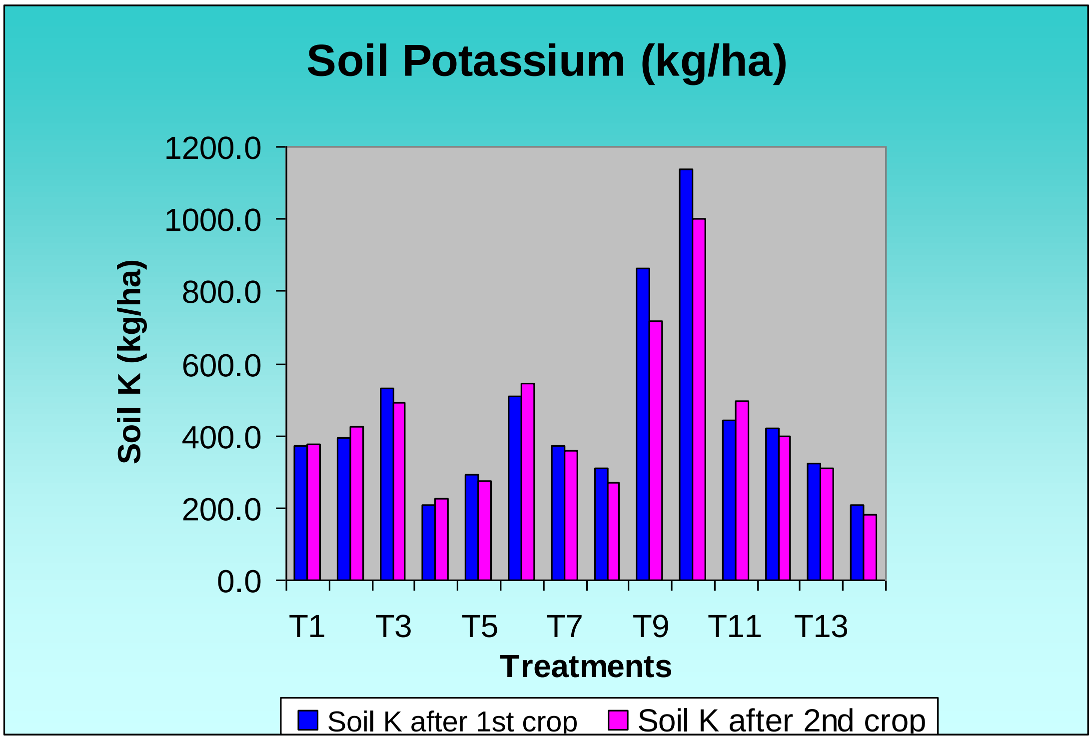


Figure 43. Soil potassium (kg ha^{-1}) after crop harvest

due to increased availability of P by activity of microbes and phosphatase activity (Sharpley and Syres, 1977). Increase in available P_2O_5 in soil by vermicompost application was reported by Sailajakumari (1999) also. Scow et al. (1994) and Clark et al. (1998) had also reported the increase in available P in soils under organic management.

5.6.1.6.4 Available Potassium

The available potassium content (Table 40, Figure 43) was highest in T_{10} and the lowest content of available potassium was obtained from T_{14}. In T_{10} the fertilisers were applied along with SVC and the vermicompost might have contributed to the long term availability of K in soil. This is in agreement with the findings of Sailajakumari (1999), Scow et al. (1994), Clark et al. (1998), Basker et al. (1992) and Deepa (2005). The control treatment (T_{14}) was depleted of its K content by the crop as it received no fertilisers or manures.

5.6.1.6.5 Sodium

The content of sodium in soil (Table 40, Figure 44) was highest in T_{10} which received SVC along with fertilizers and the lowest Na content of soil was found in T_5. The increased availability of soil sodium due to the beneficial effect of SVC as well as supply of sodium by SVC could have contributed to the high sodium content in T_{10}.

5.6.1.6.6 Soil Reaction

Application of organic manures was found to raise the pH of the soil in treatment plots (Table 40, Figure 45). The highest pH was recorded in T_6 and the lowest pH was observed in T_4. This is in conformity with the findings of Olsen et al. (1970), Bijulal (1997) and Lekshmisree (2003). According to Haini and Hubta (1990) after manure addition there will be conversion of organic nitrogen to NH_3 and further to NH_4 which will reduce the pool of H^+ ions in soil and thus increase the pH was due to increase in concentration of ammoniacal nitrogen. The pH rise may also be due to ion exchange between organic acids and hydroxyl groups of Al or Fe hydroxides (Hue, 1992).

5.6.1.6.7 Soil Electrical conductivity

The data presented in Table 40 indicated that the electrical conductivity of soil was significantly influenced by the different treatments. The highest value of EC was

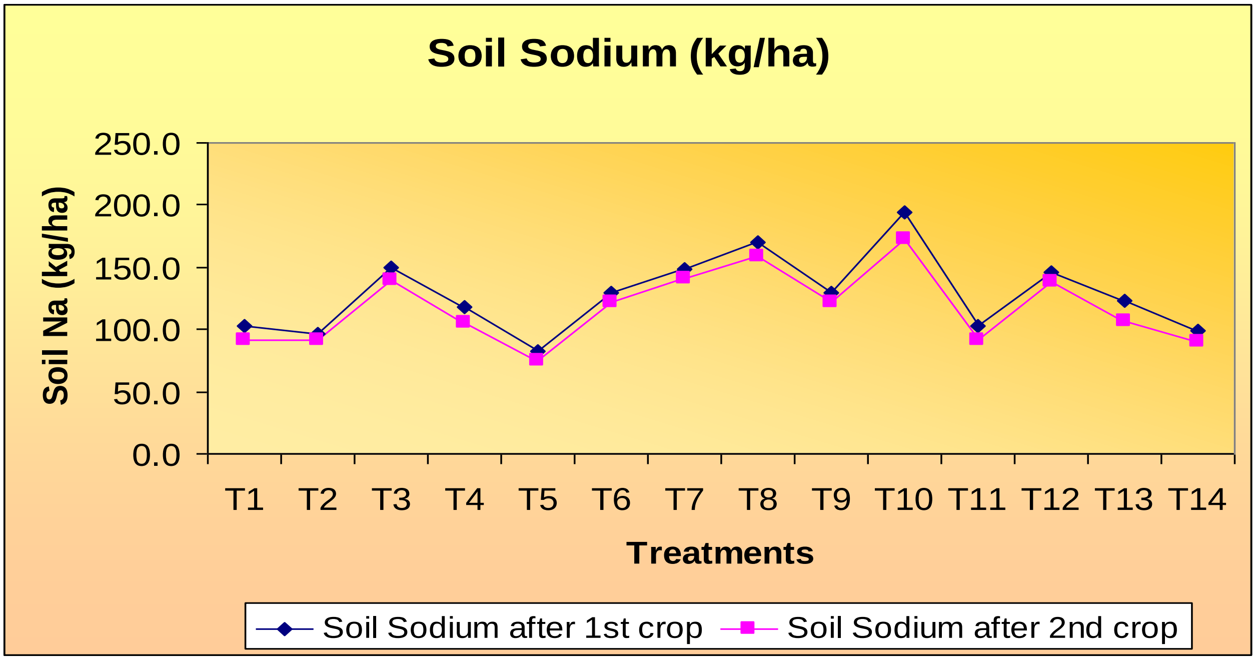


Figure 44. Soil sodium (kg ha^{-1}) after crop harvest

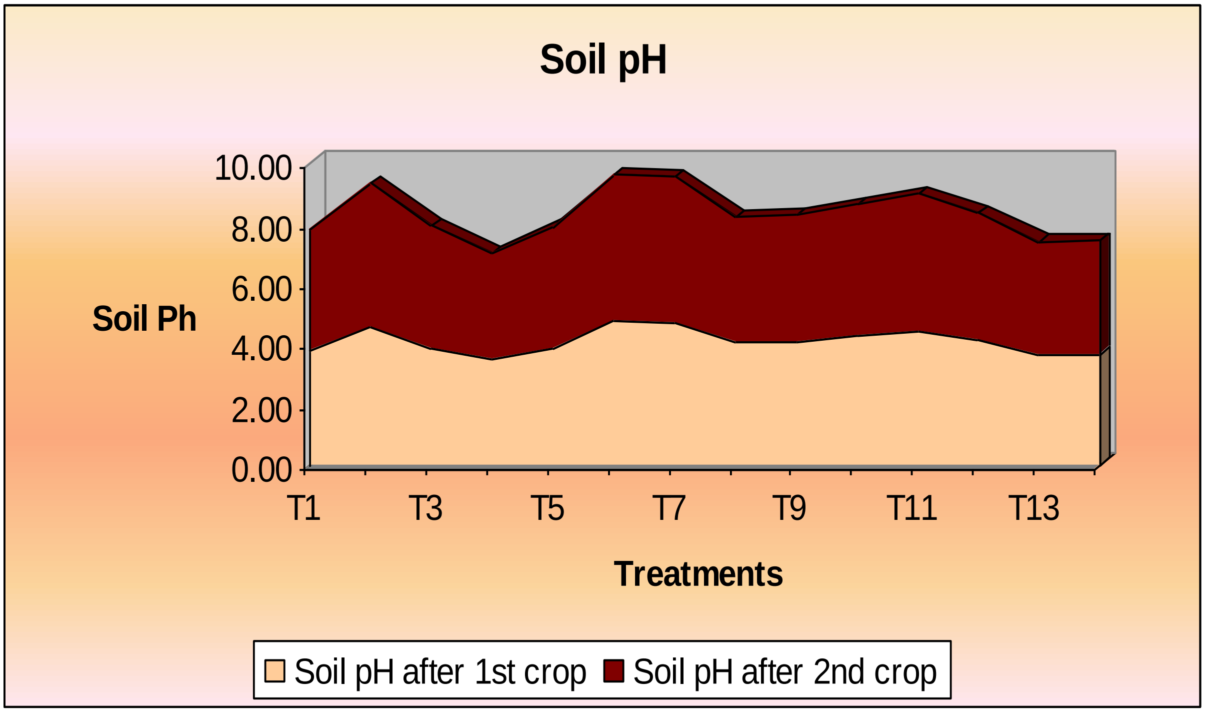


Figure 45. Soil pH after crop harvest

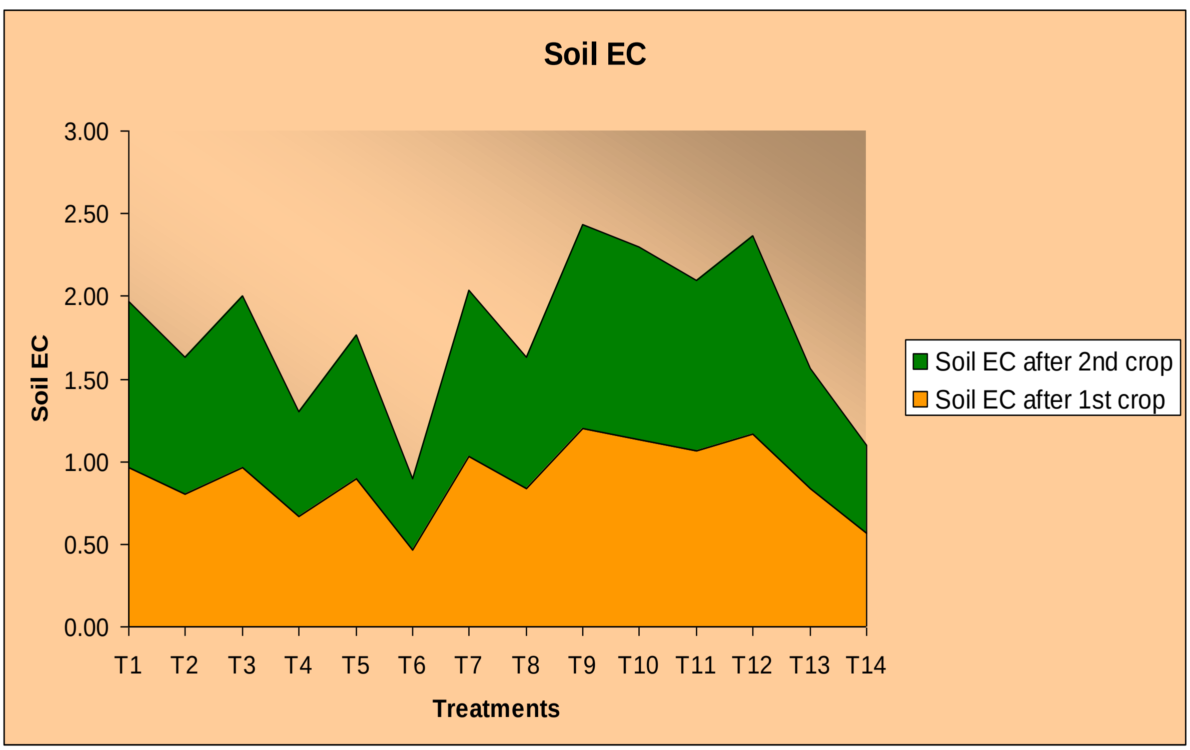


Figure 46. Soil EC (dS m^{-1}) after crop harvest

recorded in T_9 and lowest EC was found in T_6 (Figure 46). Hortenstine and Rothwell (1972) and Stewart and Meek (1977) had reported that the excessive supply of soluble salts through the application of compost could cause an increase in electrical conductivity of soil.

5.6.2 Second Crop

The second crop of amaranthus was raised to assess the residual effects of the organic manures applied to first crop. The results are discussed in this section.

5.6.2.1 Growth characters

The various growth characters (Table 41) like plant height, number of leaves per plant, number of branches per plant and stem girth were not significantly affected by treatments effects. The leaf: stem ratio was highest in T_{14} and the lowest was found in T_9.

5.6.2.2. Yield and yield attributes

The highest yield, total dry matter production, total marketable yield and total yield per plant of the second crop was recorded in T_7 and the lowest was in T_{14} (Table 42, Figure 34).This could be attributed to the long lasting residual effect of the organic manure applied in T_7 viz, Golden meal. The control plot received no fertilizers or manures during the first crop. The plants in first crop removed considerable quantities of nutrients from the soil native pool and the depleted soil could not supply the nutrients in sufficient quantities to the second crop. This might be the reason for the poor performance of T_{14}. This is in agreement with the findings of Asha (2006).

5.6.2.3 Nutrient uptake by the crop

The uptake of nitrogen, potassium and sodium (Table 43, Figure 36- 39) was highest in T_7 and the lowest uptake was recorded in T_{14}. This could be attributed to the highest yield obtained inT_7 while T_{14} had the lowest yield. The long term residual effect of T_7 is evident form this data.T_7 included application of the COM Golden meal (SN 22) which contained 4.87 per cent total nitrogen, 6.00 per cent total potassium and 1.03 per cent sodium. It can be assumed that the nutrients are released slowly form Golden meal and hence it would be more suitable for application in crops with peak nutrient demand occurring after three to four months after planting and manure application. In the case of phosphorus, the highest uptake was found in T_6 and the lowest was in T_{14}. The COM Skymeal (SN 43) was applied in T_6 during first crop and it contained 4.09 per cent total P. From the data of the field experiment it can be assumed that the P content in Skymeal is released slowly and hence it is more suitable to long duration crops. The depleted nutrient level of control plot which did not receive any fertilizer or manure might be the reason for the low nutrient uptake in T_{14}.

5.6.2.4 Plant Analysis

5.6.2.4.1 Quality Parameters

The moisture content of the crop (Table 44) was not significantly influenced by the treatments. This followed the same trend as that of first crop. The crude fibre content was highest in T_{14} and the lowest content was noticed in T_5.The protein content was significantly higher in T_7 and it was lowest in T_{14}. The highest β -carotene content was recorded in T_8 and lowest carotene content was recorded in T_{14}.The sufficient supply of nitrogen in soil due to the residual effect of manures and fertilizers applied to first crop could have contributed to the higher amounts of protein and β –carotene in all treatments compared to control plot (T_{14}). The oxalate content of plants in T_{14} was the highest compared to all other treatments and the lowest oxalate content was in T_5. The high crude fibre and oxalate content in control plots indicate the unfavourable conditions in soil which could have resulted in growth retardation and greater production of antinutritional factors. This is in agreement with the report of Sheeba (2004).The ash content of plants was not significantly influenced by the treatments.

5.6.2.4.2 Nutrient content of plant

The data on nutrient content of second crop are given in Table 45.The highest N content was observed in T_7 and the lowest N content was recorded in T_{14}. The P content was highest in plants raised in T_6 and the lowest content of P in plants was noticed in T_5. T_4 recorded the highest K content and the lowest K percentage was in T_{14}. The sodium content of plants was highest in treatment T_4 and it was lowest in T_2.

First Crop - Planting

First Crop - 2 Weeks after planting

First Crop – General view of the field

First Crop - Harvest

First Crop – First Cutting

Plate 5 – Field Experiment

Second Crop – Planting

Second Crop – 2 Weeks after planting

Second Crop – General View

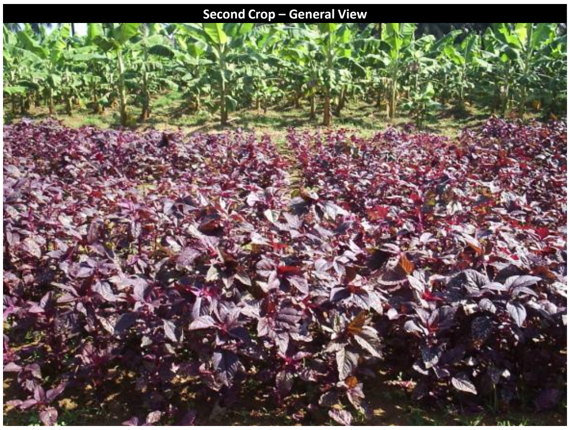


Plate 5 – Field Experiment

5.6.4.2.4 Soil Analysis after Second Crop

5.6.4.2.4.1 Soil Organic Carbon

The highest organic carbon content was observed in T_8 (Table 46). Organic carbon depletion was highest in T_{12}, T_7, T_4 and T_9. Thus it might be concluded that the contribution of SN 33 (Ecomeal) used in T_8 towards organic carbon accumulation in soil is significant. The positive effect of organic manures on residual availability of organic carbon was reported by Kadam (2000) and Yaduvanshi and Swarup (2006).

5.6.4.2.4.2 Available Nitrogen

The highest available nitrogen content was recorded in T_2 (497.67 kg ha^{-1}) and the lowest N content (295.67 kg ha^{-1}) was in T_3 (Table 46). The highest N content in T_2 may be due to higher amount of nitrogen released form T2 (SN 41. Kalpameal) and also comparatively lower nitrogen uptake (21.59 kg ha^{-1}). The low nitrogen content in T_3 could be due to higher crop removal coupled with other losses of nitrogen.

5.6.4.2.4.3 Available Phosphorus

The available P content of soil (Table 46) was highest in T_7 (264.05 kg P_2O_5 ha^{-1}) and the lowest P_2O_5 content was in T_6 (116.5 kg ha^{-1}).This could be because of the high uptake of P in T_6 by the first crop and a resultant low P content of soil at the beginning of second crop. The highest available P_2O_5 content of soil after the harvest of first crop was also recorded in T_7 which could have contributed to the high level of soil P after second crop. From the data it is evident that T_7 (Goldenmeal) had more residual effect which could be due to the slow release of its nutrients.

5.6.4.2.4.4 Available Potassium

The available K_2O content of soil (Table 46) was highest in T_{10} and lowest in T_{14}. Plants show luxury consumption of potassium and this could be the reason behind the low content of available K in T_{14}, as it did not receive any fertilizer or manure. The treatment T_{10} received standard vermicompost for the first crop and the high K content after second crop might be due to the slow release of K and residual effect of SVC. Sharu (2000) observed high residual soil K in plots which received higher level of neem cake along with chemical fertilizers in the ratio 3:1.

5.6.4.2.4.5 Sodium

The highest Na content in soil was found in T_{10} and the lowest was in T_5. The high sodium content of T_{10} could be due to the slow release of sodium from the standard vermicompost applied to the first crop. Crop removal of sodium might have resulted in the lowest Na content of T_5.

5.6.4.2.4.6 Soil pH

The soil pH was found to increase from the value after first crop. It maybe assumed that the organic manures improved soil reaction in a positive manner for more than one season.

5.6.4.2.4.7 Soil Electrical Conductivity

The soil EC did not vary much after cultivation of the second crop. The highest EC was in T_9 and the lowest was in T_6.Thus it may be concluded that the residual effect of organic manures was not significant on the EC of soil.

5.6.4.2.4.8 Economics of cultivation

The B:C ratios of treatments using the pooled data form both first and second crop are given in Table 47. The highest B: C ratio was 1.31 recorded in T_4 and the lowest value was in T_{14} (absolute control) which had a B:C ratio of 0.90. The B:C ratios of COM treatments were above 1.0 except for T_1 (0.98). The low nutrient contents of COMs compared to chemical fertilizers and their higher cost (Rs.10.00 per kilogram) could be the reason for low B:C ratios. The B:C ratios of compost treatments indicated that cultivation with such composts could be economical only if on-farm production was practiced. Their low nutrient contents necessitate higher bulk of the compost for application leading to a very high cost of cultivation if they were purchased from outside. Mixed farming including both crops and livestock and composting of wastes are thus vital factors for organic farming. In T_{14} no fertilizers or manures were added, as a result the yield was low leading to a low B:C ratio 0f 0.90. The actual economics of cultivation with organic manures could be revealed only by long term experiments. After several seasons of cultivation with organic manures, the soil nutrient status attains a stable value and later onwards, the dose of manures could be adjusted to the crop requirements and soil nutrient status.

SUMMARY

6. SUMMARY

A study was conducted at the College of Agriculture, Vellayani with the objectives of quality evaluation of the major commercial organic manures in Kerala, development of a quality protocol for assessing quality and detecting adulteration in commercial organic manures, studying the mineralization pattern of major nutrients in selected manures and their comparative effect on crop performance. The salient findings of the study are summarized in this chapter.

6.1 Quality Evaluation of Organic Manures

The physical, chemical and biochemical analyses of the commercial organic manures revealed that:

- The colour of COMs varied depending on their raw materials (ingredients)
- The odour of COMs varied depending on raw materials and the state of decomposition.
- The moisture content by weight of the COMs varied from 0.72 per cent to 46.17 per cent.
- The bulk densities of the COMs were in the range of 0.40 to 0.83 Mg m^{-3}
- The ash content varied from 27.45 per cent to 68.17 per cent.
- The oxidisable organic carbon content varied from 6.02 per cent to 31.72 per cent.
- The total organic carbon (TOC) content ranged from 17.68 per cent to 40.30 per cent.
- The acid insoluble matter varied from 8.26 per cent to 56.97 per cent.
- The pH values ranged from 4.93 to 9.37.
- The electrical conductivity varied from 1.53 dS m^{-1} to 20.17 dS m^{-1}
- The total nitrogen contents of COMs varied from 0.7 per cent to 7.87 per cent. Majority of the COMs had total nitrogen contents between 2.8 per cent and 5.85 per cent.
- The ammoniacal nitrogen content varied from 0.01 per cent to 0.53 per cent.

- The organic nitrogen content was found to vary from 0.69 per cent to 7.69 per cent.
- The water soluble nitrogen fraction in COMs ranged from 0.017 per cent to 1.48 per cent.
- The C/N ratio of COMs varied from 2.86 to 43.18.
- The TOC/TN ratio ranged from 3.75 to 55.56.
- The total P content ranged from 0.12 per cent to 4.57 per cent.
- The water soluble fraction of P ranged from non detectable to 0.016 per cent.
- The total K content varied from 0.12 per cent to 7.87 per cent.
- The water soluble potassium content varied from 0.04 per cent to 6.18 per cent.
- The calcium content in COMs ranged from 0.76 per cent to 10.10 per cent.
- The magnesium content ranged from 0.07 per cent to 2.16 per cent.
- The sodium content showed variation from 0.09 per cent to 4.21 per cent.
- All the COMs had the heavy metal contents within safe limits except SN 20 (Haritha Super) and SN 43 (Skymeal) which had cadmium contents more than the permissible limit.
- The lignin content of the COMs varied from zero to 64.58 per cent.
- The cellulose content in COMs varied from zero to 15.09 per cent.
- The lignin/ cellulose ratio of COMs varied from 1.46 to 10.83.
- The total phenol contents of COMs ranged from 31.51 mg $100g^{-1}$ to 113.10 mg $100g^{-1}$
- The Water Soluble Carbohydrates content of COMs ranged from 0.237 per cent to 1.363 per cent.
- The Water Soluble Organic Carbon content of COMs ranged from 0.13 per cent to 0.46 per cent.
- The biodegradability index of the COMs ranged from 3.15 to 4.21.

The analysis of physical, chemical and biochemical characters of standard compost manures revealed that:

- The standard compost manures (SCMs) conformed to the standards specified by Fertilizer (Control) Amendment Order, 2006, with respect to colour and odour.
- Bulk density values of SVC and SCC were lower than the standard

specified by Fertilizer (Control) Amendment Order, 2006.

- The moisture content of SCMs did not conform to the standard

specified by Fertilizer (Control) Amendment Order, 2006.

- The ash contents of SVC and SCWC were above 40 per cent while that of SCC was 9.81 per cent.
- The organic carbon contents of SCMs were below 15 per cent.
- The total organic carbon contents of SCMs were above 30 per cent.
- The acid insoluble matter in SVC was 21.71 per cent and that in SCWC was 20.93 per cent. SCC contained 5.87 per cent acid insoluble matter.
- The pH of SVC and SCWC were within the neutral range of 6.5- 7.5, while SCC was more acidic with pH of 3.93.
- The electrical conductivity of the SCMs ranged from 0.33 to 3.4dS m^{-1}
- The total nitrogen content of SVC was 1.4 per cent, SCC 0.7 per cent and SCWC 2.1 per cent.
- The ammoniacal N content was 0.05 per cent in all three SCMs.
- The organic nitrogen content was in the range of 0.65 per cent to 2.05 per cent.
- The water soluble N content was 0.01 per cent in all SCMs.
- All the three SCMs recorded C/N ratios below 20.
- SCC had a high TOC/TN ratio, while SVC and SCWC showed lower values.
- SVC and SCWC had satisfactory levels of total P while SCC was poor in total P.
- The water soluble P content of SCMs was negligible.

- The three SCMs did not contain enough total K to conform to the minimum limit prescribed by the Fertilizer (Control) Amendment Order, 2006.
- The water soluble fraction of total K in SCMs was below 0.2 per cent.
- The calcium content was in the range of 0.23 to 0.47 per cent.
- The magnesium content of SCMs was less than 0.15 per cent.
- The highest sodium content was found in SCC (0.25 per cent).
- SCMs had heavy metal contents below the maximum limits prescribed by the Fertilizer (Control) Amendment Order, 2006.
- The lignin contents of SCMs were higher than 45 per cent.
- The cellulose contents of SVC and SCWC were below 8.0 per cent while that of SCC was 16.61 per cent.
- Lignin/ cellulose ratio varied from 2.78 to 8.69.
- The content of total phenols in SCMs varied from 73.95 mg $100g^{-1}$ to 100.42 mg $100g^{-1}$.
- The WSC contents of SCMs varied from 0.28 to 0.39 per cent.
- The water soluble organic carbon content of SCMs ranged from 0.19 per cent to 0.23 per cent.
- The biodegradability index of the SCMs varied from 3.63 in SVC to 4.45 in SCC.

6.2 Characterization of raw materials

The important characteristics of raw materials used in the preparation of the COMs were:

- The raw materials contained organic carbon in the range of 5.66 to 32.87 per cent.
- The total nitrogen content of raw materials ranged from 0.40 per cent to 9.03 per cent. Leather meal was found to be a good source of N.
- The phosphorus content of raw materials ranged from 0.12 per cent to 10.36 per cent. Bone meal and pressmud were found to be good sources of P.
- The potassium contents of raw materials ranged from 0.01 per cent to 2.86 per cent. Pressmud was identified as the best source for K.

- The sodium content of raw materials ranged from 0.11 per cent to 1.68 per cent. Neem cake was found to be a good source of sodium.

6.3 Protocol for quality standards of COMs

A mathematical model was developed for predicting the quality standards viz., nitrogen, phosphorus and potassium contents of COMs prepared by mixing different proportions of bone meal, leather meal and neem cake.

N estimated= 3.62088 BM+ 6.58962 LM+ 1.74407 NC+ 4.74391 (BM)x(LM) + 7.8398 (BM) x (NC) – 9.87862 (LM)x(NC), where BM is the proportion of bone meal in the mixture, LM is the proportion of leather meal in the manure and NC is the proportion of neem cake in the mixture.

P estimated= 8.41214 BM+ 0.37157 LM+ 0.41953 NC- 2.73548 (BM) x (LM) + 10.15749 (BM) x (NC) – 8.72905 (LM) x (NC)

K estimated= 0.38543 BM+ 0.01872 LM+ 1.19747 NC+ -0.04393 (BM) x (LM) + 2.98573 (BM) x (NC) – 5.64704 (LM) x (NC)

6.4 Storage study

The change in quality parameters of the organic manures during long term storage were:

- The organic carbon content of organic manures decreased from the initial value during storage period of one year.
- The changes in nitrogen, phosphorus, potassium and sodium contents of organic manures showed varying patterns during storage.

6.5 Quality of market samples of COMs

- The organic carbon and nitrogen contents of all the market samples were significantly less than their corresponding factory samples.
- Phosphorus and potassium contents of some market samples were significantly less than their corresponding factory samples, while some were significantly more, and others were on par.

6.6 Incubation experiment

The mineralization patterns of major nutrients showed that:

- In general, the available nitrogen and phosphorus contents in soils treated with organic manures increased upto 30-45days after incubation and decreased thereafter.
- The mineralization pattern of potassium from organic manures in soil showed pronounced variation.

6.7 Field experiment

The performance of various organic manures in the test crop amaranthus revealed that:

- The highest yield for first crop was in plots which received the treatment T4 (NPK fertilizers + Karshaka Agromeal Grade I).Lowest yield was in absolute control plot.
- The uptake of N, K and Na were highest in T_4 while that of P was highest in T_6 (NPK fertilizers +Skymeal).
- The application of organic manures was found to improve the quality aspects of the crop.
- The highest organic carbon content in soil after harvest of first crop was in T_{11} (NPK fertilizers + SCC). The lowest organic carbon was found in T_{14} (control).
- The highest content of available N in soil after harvest of first crop was recorded in T_{10} (NPK fertilizers + SVC) and lowest available N content was observed in $T_{4.}$

  The available phosphorus content after harvest of first crop was highest in T_7 (NPK fertilizers + Golden meal) and the lowest value of available P_2O_5 was observed in T_6 (NPK fertilizers +Skymeal).
- The available potassium content after harvest of first crop was highest in T_{10} and the lowest content of available potassium was obtained from $T_{14.}$
- Application of organic manures was found to raise the pH of the soil in treatment plots.
- The electrical conductivity of soil was significantly influenced by the different treatments.

- The highest yield, total dry matter production, total marketable yield and total yield per plant of the second crop raised to study the residual effects of the organic manures applied to first crop was recorded in T_7 (NPK fertilizers +Golden meal) and the lowest was in T_{14}.
- The uptake of nitrogen, potassium and sodium was highest in T_7 and the lowest uptake was recorded in T_{14}. The highest P uptake was found in T_6 and the lowest was in T_{14}.
- The highest organic carbon content in soil after harvest of second crop was observed in T_8 (NPK fertilizers +Ecomeal).
- The highest available nitrogen content in soil after harvest of second crop was recorded in T_2 (497.67 kg ha^{-1}) and the lowest N content (295.67 kg ha^{-1}) was in T_3.
- The available P content of soil after second crop was highest in T_7 (264.05 kg P_2O_5 ha^{-1}) and the lowest P_2O_5 content was in T_6 (116.5 kg ha^{-1}).
- The available K_2O content of soil was highest in T_{10} and lowest in T_{14}.
- The highest B: C ratio was 1.31 recorded in T_4 and the lowest value was in T_{14} (absolute control) which had a B:C ratio of 0.90.

The conclusions reached from the results of the investigation are that as per the specifications of the Fertilizer (Control) Amendment Order, 2006, only the COMs SN 15, SN 17, SN 21, SN 35 and SN 42 were of good quality with regard to moisture content. In the case of bulk density only SN 2, SN 7, SN 9, SN 10, SN 12 and SN 15 qualified as good manures. SN 4 did not have enough nitrogen content as per the specifications. Majority of the COMs recorded satisfactory level of phosphorus and potassium. The COMs which contained MOP viz., SN 24, SN 26, SN 27, SN 28, SN 29, SN 30, SN 31 and SN 41 can not be recommended for use in organic farming, but they can be applied in integrated nutrient management system. The COMs having pH in the neutral range were SN5, SN 7, SN 8, SN 9, SN 10, SN 11, SN 12, SN 13, SN 14, SN 18, SN 19, SN 20, SN 25, SN 28, SN 30, SN 34, SN 36 and SN 43. But only SN 2, SN5 and SN 41 had EC values less than 4 dS m^{-1} and hence all other COMs were not suitable for long term application to crops. Based on heavy metal contents, SN 39 with high content of lead and SN 20 and SN 43 with high cadmium content were found to be unsuitable for continuous and long term use. All the COMs had satisfactory levels of total organic carbon and only SN 4 recorded a C/N ratio wider than 20:1. Based on acid insoluble matter content SN 5, SN 6 and SN 15 were found to contain more than permissible limits of inorganic adulterants. The sodium contents of SN 3, SN 4, SN 5, SN 18, SN 22, SN 32, SN 34, SN 38 and SN 39 were more than 1.0 per cent and hence they may not be suitable for continuous and long term application. Hence there were no COMs which qualified as a good quality organic manure as per all the specifications of the Fertilizer (Control) Amendment Order, 2006. Though SN 15 conformed to the specifications with respect to moisture content, bulk density, N, P, K and TOC contents, C/N ratio and heavy metals, it had unfavorable pH and EC values. The COM product Karshaka Agromeal Grade I was found to release the highest content of N, P and K in the incubation experiment and this COM also produced that highest yield in the field experiment with amaranthus variety Arun.

Future line of work

- Long term experiments are required to study the effects of commercial organic manures on soil quality.
- More quality parameters of the commercial organic manures viz., boron, chromium, arsenic and other toxic contents are to be studied.
- Protocol for more quality parameters including secondary and micro nutrients of organic manures are to be developed.
- Microbial and enzymatic studies need to be done to explain the nutrient mineralization pattern of organic manures.

REFERENCE

REFERENCE

A.O.A.C. 1960. Official Methods of Analysis. 9th Edition. Association of Official Agricultural Chemists. (ed. Horwitz,W.). Washington D.C. 832p.

A.O.A.C. 1970. *Official Methods of Analysis*, 13th edition. Association of Official Agricultural Chemists, Washington D.C. 1018p

A.O.A.C. 1984. *Official and Tentative Methods of Analysis*. Association of Official Agricultural Chemists, Washington D.C., 350p.

Abusaleha, S. 1992. Effect of different sources and farms of N on the uptake of major nutrients of okra. S. Indian Hort., 49:192-196

Adriano, D.C., Chang, A.C. and Sharpless, R. 1974. Nitrogen loss from manure as influenced by moisture and temperature. J. Environ. Qual.,3: 258-261.

Aggarwal, P.K., CHoudhary, A., Joshi, H.C., Singh, S.D. and Gupta, N. 2006. Agriculture and Environment. *Hand book of Agriculture, ICAR*, New Delhi. pp 55-71.

Ahrens, E. And Farkasdy, G. 1969. Investigations on nitrogen mineralisation in soil after application of town refuse of different degrees of decomposition. Sonderh. landw. Forsch., 23, 77-8.

Alexander, M. 1977. Introduction of the rhizosphere. In: *Introduction to soil Microbiology*. 2nd edition. John Wiley and Sons. New York. pp.423-443

Alfred, S.R. and Gunathilagaraj, K. 1996. Effect of introducing earth worms into horticultural lands. *Proc. Nat. Sem. on Organic Farming and Sustainable Agriculture, October 9-11, 1996* (ed. Veeresh, C.K.). Association for promotion of organic farming, Bangalore, pp 76-78

Allison, F.E. and Klein, C.J. 1945. Role of immobilization and release of N following additions of carbonaceous material sand N to soils. Soil Sci., 93: 383-386

Anderson, G., Williams, E.G. and Jacqueline, O.M. 1974. A comparison of the sorption of inorganic orthophosphate and inositol hexaphosphate by six acid soils. J. Soil Sci., 25: 51-62.

Andersson, A. 1977. Some aspects on the significance of heavy metals in sewage sludge and related products used as fertilizers. Swedish J. Agric. Res., 7, 1-5.

Anitha, V. 1997. Nitrogen management in vegetable chilli grown in pots with modified drip irrigation system. M.Sc. (Ag.) thesis, Kerala Agricultural

University, Thrissur, 140p.

Anon. 1992. Greener groceries at a price. *Which?* Consumer Association in UK. October 1992, 28-30

Aparna, C., Saritha, P., Himabindu, V. and Anjaneyulu, Y. 2008. Techniques for the evaluation of maturity for composts of industrially contaminated lake sediments. Waste Management. 28(10):1773-1784.

Arunkumar, K.R. 2000. Organic nutrition in amaranthus. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 123p.

Arunkumar, S. 1997. *Azotobacter* and *Azospirillum* inoculants for nitrogen economy in vegetable cultivation. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 125p.

Asha, K.R. 1999.Organic nutrition in okra (*Abelmoschus esculentus*). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, 166p.

Asha, K.R. 2006. Ecofriendly production of slicing cucumber (*Cucumis sativus* L.) through organic sources. PhD thesis, Kerala Agricultural University, Thrissur, 242p.

Atagana, H.I. 2008. Compost bioremediation of hydrocarbon- contaminated soil inoculated with organic manure. African J. Biotech., 7(10): 1516-1525, Available online 16 May,2008

Baeca, M.T. Delgado, I.C., DeNobili, M.C., Esteban, E. and Sanchez-Raya, A.J. 1995. Commun.Soil. Sci. Pl. Anal., 26, 169.

Bai, E.K.L. and Augustine, A. 1998. Performance of Kacholam (*Kaempferia galanga* L.) under varying levels of organic and inorganic fertilizers. *Proc. Tenth Kerala Science Congress, January 1998.* Science, Technology and Environment Department, Thiruvananthapuram, pp 254-256.

Baker, B. and Tracy, D. Elemental contaminants in fertilizers and soil amendments used in organic production. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy,pp. 78-81

Barrow, N.J. 1989. Testing a mechanistic model. IX. Comparison between anions for sorption by soil. J.Soil Sci., 40: 415-425.

Basker, A., Macgregor, A.N. and Kirkman, J.H. 1992. Influence of soil injustion by earth worms on the availability of K in a soil. An inoculation experiment. Bio. Fertil. Soils., 14: 300-303

Beckwith, C.P. and Parsons, J.W. 1980. The influence of mineral amendments on the changes in the organic nitrogen components of composts. Pl. Soil,54: 259-270.

Bengtson, G. W. and Cornette, J. J. 1973. Disposal of composted municipal waste in a plantation of young slash pine: effects on soil and trees. J. Environ. Qual., 2, 441-444

Bernal, M.P., Sanchez-Monedero, M.A., Paredes, C., and Roig, A. 1998. Carbon mineralization from organic wastes at different composting stages during their incubation with soil. *Agric. Ecosyst. Environ*., 69: 175–189.

Berry, P.M., Sylvester-Bradley, R., Philipps, L., Hatch, D.J., Cuttle, S.P., Ryans, F.W. and Gosling, P. 2002. Is the productivity of organic farms restricted by the supply of available nitrogen? *Soil Use Mgmt*. 18: 248-255

Bhadoria, P.B.S., Prakash, Y.S. and Amitavarakshit. 2002. Importance of organic manures in quality of rice and okra. *Environ. Ecol*. 20: 628-633

Bharadwaj, K.K.R. 1995. Recycling of crop residues, oil cakes and other plant products in agriculture. In: *Recycling of Crop, Animal, Human and Industrial Wastes in Agriculture (*ed. Tandon H.L.S.). Fertilizer Development and Consultation Organization, Pomposh Enclave, New Delhi, pp.9-30

Bharadwaj, K.K.R. and Gaur, A.C. 1985. *Recycling of Organic Wastes*, ICAR, New Delhi. 104

Bhowmic, B.B. and Debnath, C.R. 1985. Coir fibre, Part II. Potentiality of coir fibre products, Indian Cocon.J., 16:7-10

Bijulal, B.L. 1997. Effect of vermicompost on the electro-chemical properties and nutritional characters of variable charge soils. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 86p.

Birkhofer, K., Bezemer, T.M., Bloem, J., Bonkowski, M., Christensen, S., Dubois, D., Ekelund, F., Fließbach, A., Gunst, L., Hedlund, K., Mäder, P., Mikola, J., Robin, C., Setälä, H., Tatin-Froux, F., Van der Putten, W.H. and Scheu, S. 2008. Long-term organic farming fosters below and aboveground biota: Implications for soil quality, biological control and productivity. *Soil Biol. Biochem. Available online 11 June 2008*

Biswas, T.D., Ingole, B.N. and Jha, K.K. 1969. Changes in the physical properties of the soil by fertilizers and manures. *Fertil. News*. 14(7):23

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L. and Clark, F.E. 1965. *Methods of Soil Analysis*. American Society of Agronomy Inc., Madison, 1569p.

*Bonneau, M. and Souchier, B. 1980. Constituants et Propierties du Sol. Masson et Cie, Paris.

Brady, C.N. 1994. Sustainable Agriculture- A Research Agenda. *Stressed Ecosystem and Sustainable Agriculture* (eds. Viramani, S.M., Katyal, J.C. and Abrol, J.P.). Oxford and IBH Publishing Co.Pvt. Ltd. New Delhi, pp.21-23

Brady, C.N. 1996. *The Nature and Properties of Soils*, 10^{th} edition, Prentice hall of Inida Pvt. Ltd., New Delhi, 350p.

Bray, H.G. and Thorpe, W.V. 1954. Analysis of phenolic compounds of interest in metabolism. *Methods of Biochemical Analysis*, 1:27-52

Broadbent, P. and Baker, K.F. 1975. Soils suppressive to phytophthora root rot in Eastern Australia. In: *Biology and control of soil borne plant pathogens*. (Ed. Bruehl, G.V.) *Am. Phytopath. Soc.,* St. Paul Minnesota.p.152-157

Budhar, M.N., Palaniappan, S.P. and Rangasamy, A. 1991. Effect of farm wastes and green manures on low land rice. Indian J. Agron., 36 (2): 251

Bustamante, M.A., Paredes, C., Marhuenda-Egea, F.C., Pérez-Espinosa, A., Bernal, M.P. and Moral, R. 2008. Co-composting distillery wastes with animal manures: Carbon and nitrogen transformations in the evaluation of compost quality. Chemosphere, 72(4):551-557

Campitelli, P. and Ceppi, S. 2008. Chemical, physical and biological compost and vermicompost characterization: A chemometric study. Chemometrics and Intelligent Laboratory Systems, 90(1):64-71

Cardenas, R. R. and Wang, L. K. 1980. Composting process. In *Handbook of Environmental Engineering, Vol. II.* The Human Press, New York, pp. 269-327.

Castellanos, J.Z., and P.F. Pratt. 1981. Mineralization of manure nitrogen - correlation with laboratory indices. Soil Sci. Soc. Am. J. 45: 354-357.

Chalapathi, M.W.,Vasundhara, M., Rao, G.G.E., Thimmegowda, S. and Devakumar, N. 2003. Influence of nitrogen levels and residual effect of organic manures on growth, yield and essential oil on ratoon crop of davana (*Artemisia pallens* Wall) under two irrigation regimes. *Nat. Sem. New Perspectives in Spices, Medicinal and Aromatic Plants, November 27-29, 2003*. Indian Society for Spices. Goa, p.78

Chanyasak, V. and Kubota.H. 1981. Carbon/organic nitrogen ratio in water extract as measure of composting degradation. J. Ferment. Technol., 59, 215-19.

Chanyasak, V., Hirai, M. and Kubota, H. 1982. Changes of chemical components and nitrogen transformation in water extracts during composting of garbage. J. Ferment. Technol., 60 : 439-46.

Chanyasak, V., Katayama, A., Hirai, M., Mori, S. and Kubota, H. 1983a. Effects of compost maturity on growth of Komatsuna (*Brassica rapa* var. *pervidis*) in Neubauer's pot. I.-Comparison of growth in compost treatments with that in inorganic nutrient treatments as controls. Soil Sci. Plant Nutr., 29: 239-250.

Chanyasak, V., Katayama, A., Hirai, M., Mori, S. and Kubota, H. 1983b. Effects of compost maturity on growth of Komatsuna (*Brassica rapa* var. *pervidis*) in Neubauer's pot. II.-Growth inhibitory factors and assessment of degree of maturity by org-C/org-N ratio of water extract. Soil Sci. Plant Nutr., 29: 251-259.

Chand, S. and Somani, L.L. 2003. Balanced use of fertilizers, organics and biofertilizers in mustard. Intern. J. Trop. Agri., 21(1-4):133-140

Chandra, S. and Chauhan, S.K. 2004. Prospects f organic farming in India. Indian Farming,11-14

Chaney, R. L. 1983. Food chain pathways for toxic metals and toxic organics in wastes. *Environment and Solid Wastes*,(ed. Francis, C. W. and Auerbach, S.I.). Butterworth/Ann Arbor Science Publishers, USA, pp. 179-207.

Channabasavanna, A.S. and Biradar, D.P. 2002. Poultry by product to avoid pollution. Kisan Wld., 29(5): 52-53

Chefetz, B. Hatcher, P.G., Hadal, Y. and Chen, Y. 1996. Chemical and biological characterization of organic matter during composting of municipal solid waste. J Environ. Qual., 25: 776-785

Chen, F.I., Lin, C.J. and Lin, B.C. 2001. Study on the growth, yield, quality of wax apple and soil properties under long-term application of organic fertilizers and chemical fertilizer. Soil Fertil. Experiment Bull., *1999*: 43-48

Chen, J.H. 1995. Effects of the organic fertilizers addition on the availability and mineralization of soil phosphorus. *J. Chinese agric. chem. Soc.* 33(5): 533-549

Chen, J.H. 1996. Characterization of Inositol hexaphophate, Glucose-6-phosphate and potassium dihydrate phosphate sorption by acid and calcareous soils. J. Chinese agric. chem. Soc., 34: 112-117.

Chen, J.H., Weng, Y.E. and Wang, Y.P. 1994. Effects of organic fertilizers addition on P sorption characteristics of soils. J. Chinese agric. chem. Soc., 32(3): 332-346

Chen, Z.S. and Bejosano- Gloria, C. 2005 (eds.) Compost Production: A manual for Asian farmers. FFTC for the Asia and Pacific Region. Taiwan ROC.73p

Cheshire, M.V. and Mundie, C.M. 1966. The hydrolytic extraction of carbohydrates from soil by sulphuric acid. J. Soil Sci., 17(2): 373-380

Clark, M.S., Horwath, W.R., Shennan, C. and Scow, K.M. 1998. Changes in soil chemical properties resulting from organic and low input farming practices. Agron. J., 90: 662-671

Cochran, W.C. and Cox, G.M. 1965. *Experimental Designs*. John Wiley and Sons Inc., New York,182p.

Constantinides, M. and Fownes, J. H. 1994. Nitrogen mineralization from leaves and litter of tropical plants: Relationship to nitrogen, lignin and soluble polyphenol concentrations. Soil Biol. Biochem., 26: 49- 55.

Cornell, J.A. 2002. *Experiments with mixtures, designs, models and analysis of mixture data*. John Wiley and Sons Inc., New York, 158p.

Cottenie, A. 1981. Sludge treatment and disposal in relation to heavy metals. *International Conference on Heavy Metals in the Environment, Amsterdam, September 1981*. Commission of the European Communities, pp. 167-75.

Dalton, J.D., Russell, G.C. and Sieling, D.H. 1952. Effect of organic matter on phosphate availability. Soil Sci., 73: 173-181.

Dayakar, S., Rao, A.P. and Rao, T.K. 1995. Effect of organic and inorganic sources of N and P and certain insecticides on the build up of pod borers in pigeon pea. Andhra Agric. J., 42(1-4):14-17

*De Bertoldi, M. and Zucconi, F. 1980. Microbiologia della transformazione dei rifiuti solidi urbani in compost e Ioro utilizzazione in agricoltura. Ingegneria ambientale, 9: 209-16.

Debnath, N.C. and Hajra, J.N. 1972. Transformation of organic manure in soil inrelation to mineralization of C and nutrient availability. J. *Indian Soc. Soil Sci*. 20: 95-102

Deepa, S.2005. Field evaluation of commercial organic manures and growth promoters in bush type vegetable cowpea (*Vigna unguiculata* subsp. *sesquipedalis*). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, p. 115.

Deria, A., Bell, R.W. and O’Hara, G. 1996. Wheat production and chemical properties of organic and conventional paired sited in Western Australia. *Proc. 8th Australian Agronomy Conf.*, Australian Society of Agronomy, Toowoomba.200-202

Devleeschauwer, D., Verdonk, O. and Van Assche, P. 1981. Phytotoxicity of refuse compost. Biocycle, 22: 44-6.

Dewes, T. 1994. Nitrogen losses from manure heaps. Biological Agric. Hort., 11: 309-317.

Dhanorkar, B.A., Borkar, D.K., Puranik, R.B. and Joshi, R.P.1994. Forms of soil potassium as influenced by long term application of FYM +NPK in vertisols. J. Potass.Res., 10: 42-48

Duggan, J. C. 1973. Utilization of municipal refuse compost. I. Field-scale compost demonstrations. Compost Sci., 14, 24-5.

Eghball, B. and Power, J.F. 1995. Composted and non-composted beef feedlot manure effects on corn production and soil properties under conventional on non-till system. In: *Proceedings of Seventh International Symposium on*

Agricultural and Food Processing Waste, (ed. Ross, C.C.), Chicago, USA, pp. 557-563.

Eghball, B. and Power, J.F. 1999. Phosphorus- and nitrogen-based manure and compost application: corn production and soil phosphorus. Soil Sci., *Soc. Am.J.* 63: 895-901.

Evangelista, C.D. 1986. Earth worm cast as medium of plant growth of lettuce. CLSU Sci. J., 6: 158

Evans, JR. A. 1985. The adsorption of inorganic phosphate by a sandy soil as influenced by dissolved organic compounds. Soil Sci., 140: 251-255.

Evanylo, G., Sherony, C., Spargo,J., Starner, D., Brosius,M. and Haering, K. 2008. Agric. Ecosystems Environ., 127(1-2):50-58

Fares, F., Albalkhi, A., Dec, J., Bruns, M.A and Bollag, J.M. 2005. Physico- chemical characteristics of animal and municipal wastes decomposed in arid soils. J. Environ . Qual., 34: 1392-1403

Fauci, M. F., Dick, R. P. 1994. Plant response to organic amendments and decreasing inorganic nitrogen rates in soils from a long term experiment. Soil Sci. Soc. Am. j., 58: 134- 138.

Fertilizer (Control) Amendment Order, 2006, Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, The Gazette of India: Extraordinary,PartII-Sec.3(ii),pp72-79

Finstein, M. S. and Morris, M. L. 1975. Microbiology of municipal solid waste composting. Adv. Appl Microbiol., 19: 113-51.

Fließbach, A., Oberholzer, H.R., Gunst, L. and Mäder, P. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agric., Ecosystems Environ.,118(1-4):273-284

Frankenberger, W.T., Abdelmagid, H. M.1985. Kinetic parameters of nitrogen mineralization rates of leguminous crops incorporated into soil. Plant Soil, 87: 257- 271.

Garcia, C., Hernandez, T, Costa, F. and Ayuso, A. 1992. Evaluation of the maturity of municipal waste compost using simple chemical parameters. Commun. Soil. Sci. Pl. Anal., 23: 1501-1512.

Garcia, C., Hernandez, T. and Costa, F.1991. Changes in carbon fractions during composting and maturation of organic wastes. Environ Manage, 15:433-439

Gardner, J.C. and Clancy, S.A. 1996. Impacts of farming practices on soil quality in North Dakota. In: *Methods for assessing soil quality*. Soil Science Society of America. Madison. pp.337-343

Gaur, A.C. 1982. *A Manual of Rural Composting FAO/UNDP Regional Project RAS/75/1004* Field Document No.15, FAO, Rome, 102p

Gaur, A.C. 1983. *Proc. Int. Sym. On Biological Reclamation and Land Utilization of Urban Wastes* (ed. Zucconi, F.) 531.

Gaur, A.C. 1987. Resources and Conservation.,13:154

Gaur, A.C. 1994. Bulky organic manure and crop residues. *Fertilizers, Organic Manures, Recyclable Wastes ad Biofertilizers.* (ed. Tandon, H.L.S.). Fertilizer Development and Consultation Organization, New Delhi, 205p.

Geetha, D. Suharban, M., Vijayan, M. and Pramod R. 2005. Coir pith compost for increasing banana crop production efficiency. Indian Coconut.J., 35(9): 7-9

Genevini, P.L., Mezzanotte, V. and Garbarino, A. 1987. Analytical characterization of composts of different origins: Agronomic properties and risk factors of the environment. Waste management Res., 5(4): 501-511

Gerhardt, R.A. 1997. A comparative analysis of the effects or organic and conventional farming system on soil structure.

Ghosh, S.C., Omanwar, P.K., Scachen, R.S. and Sharma, R.B. 1981. Reserves of organic and total phosphorus in cultivated and forested Lethosals. J. Indian Soc. Soil Sci., 29: 332- 336

Giordano, P. M., Mortvedt, J. J. and Mays, D. A. 1975. Effects of municipal wastes on crop yields and uptake of heavy metals. J. Environ. Qual., 4, 394--9.

Golueke, C. G. 1977. Biological Reclamation of Solid Wastes. Rodale Press,Emmaus, USA.

Golueke, C. G. 1981. Principles of biological resource recovery. Biocycle, 22, 36-40.

Govindan, M., Prasad, R.M., Subramanian, M. and Philip, J. 2005. *Impact of Mushroom Research and Development Programmes in the Northern Region of Kerala*. Kerala Agricultural University, Thrissur, 56p.

Grant, R.F., Juma, N.G., Robertson, J.A., Izaurralde, R.C. and McGill, W.B. 2001. Long-term changes in soil carbon under different fertilizers, manures and rotation: Testing the mathematical model *ecosys* with data from the Brenton Plots. Soil Sci. Soc. Am. J., 65 (1):205-214

Gray, K. R., Sherman, K. and Biddlestone, A. J. 1971a. A review of composting. Part I. Microbiology and Biochemistry. Process Biochemistry, 6: 32-6.

Grewal,, J.S. and Trehan, S.P. 1988. Results of continuous use of phosphotic and potassic fertilizers and FYM on potato yield and nutrient status of an acidic brown hill soil. J. Potato Res., 4(1): 24-30

Gupta, A.P. Antil, R.S. and Narwal, R.P. 1988. Effect of farm yard manure on organic carbon, available nitrogen and phosphorus content of soil during different periods of wheat growth. J. Indian Soc. Soil Sci. 36: 269-273.

Gutiérrez-Miceli, F.A., Santiago-Borraz, J., Molina, J.A.M., Nafate, C.C., Abud-Archila, M., Llaven, M.A.O., Rincón-Rosales, R. and Dendooven, L. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Bioresource Technol. *98(15): 2781-2786*

Hachicha, S., Sellami, F., Cegarra, J., Hachicha, R., Drira, N., Medhioub, K. and Ammar, E. 2008. Biological activity during co-composting of sludge issued form the OMW evaporation ponds with poultry manure-Physico-chemical characterization of the processed organic matter. J. Hazardous Materials, In Press, Corrected Proof, Available online 20 May 2008

Hadas, A., Portnoy, R. 1994. Nitrogen and Carbon mineralization rates of composted manures incubated in soil. J.Environ. Qual. 23: 1184- 1189.

Haini, J.and Hubta, V. 1990. Effect o earthworms on decomposition process in raw humus forest soil-A microcosm study. Biol. Fert. Soils. 10: 178-183.

Handayanto, E., Giller, K. E. and Cadisch, G. 1997 Regulating N release from tree legume prunings by mixing residues of different quality. Soil Biol. Biochem., 29: 1417- 1426.

Harada, Y. and Inoko, A. 1980. The measurement of the cation-exchange capacity of composts for the estimation of the degree of maturity, Soil Sci. Pl. Nutri., 26: 127-134.

Hazra, J.N., Sinha,NB , Manna, MC, Islam,N and Banerjee,NC. 1994. Tropical Agric. (Trinidad). 71.147.

Hirai, M., Chanyasak, V. and Kubota, H. 1983. A standard measurement for compost maturity. Biocycle, 24: 54-6.

Hoitink, H.A.J. and Kuter, G.A. 1986. Effects of composts on growth of soil borne pathogens. *The role of Organic Matter on Modern Agriculture*. (eds. Chen, Y. and Avnimekch,Y.) Martinus Nyhoff Publishers, Netherlands, pp.28-306

Hortenstine, C. C. and Rothwell, D. F. 1972. Use of municipal compost in reclamation of phosphate-mining sand tailings. J. Environ. Qual., 1: 415-18.

Hsu, J. and Lo, S.1999. Chemical and spectroscopic analysis of organic matter transformations during composting of pig manure. Environ. Pollution, 104(2)189-196

Hue, N.V. 1992. Correcting soil acidity of a highly weathered ultisols with chicken manure and sewage sludge. Commun. Soil Sci., Pl. Anal., 23: 241-264

Hue, N.V. and Silva, V.J. 2000. Organic soil amendments for sustainable agriculture: organic sources of nitrogen, phosphorus and potassium. *Plant Nutrients Managemetn in Hawaii Soils.* (eds. Silva, J.A. and Uchilda, R.). College of Tropical Agriculture and Human Resources, University of Hawaii, Manoa. pp.133-144

Hulagar, B.F. 1996. Use of different oil cakes or fertilizers –comparison of processes of immobilization, mineralization and nitrification inhibition in soil and N uptake. *Neem and Environment-Vol. II* (eds. Singh, R.P., Chari, M.S., Raheja, A.K. and Kraus, W.). Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, pp.835-846

Hunt, P. G. 1970. Effects of composted municipal refuse on plant seed germination and soil organisms. PhD dissertation, University of Florida, Gainesville, Florida.

Hunt, P. G., Hortenstine, C. C. and Eno, C. F. 1972. Direct and indirect effects of composted municipal refuse on plant seed germination. Soil Crop Sci. Soc. Florida Proc., 32, 92-5.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice hall of India Pvt. Ltd., New Delhi, 498p.

*Jager, B. and Jager, J. 1980. Ermittlung und Bewertung von Geruchsemissionen bei der Kompostierung von Siedlungsabf'allen. Miill und Abfall, 22-8.

Jaiswal, P.C. 2003. *Soil, Plant and Water Analysis*. Kalyani Publishers, New Delhi. 441p.

Jambhakar, H.1996. Effect of vermicompost on short duration crop. *Proceedings of National Seminar on Organic Farming and sustainable agriculture.* (ed. Veeresh, C.K.) Association for promotion of organic farming, Bangalore,pp39

Janssen, B.H. 1996. Nitrogen mineralisation in relation to C: N ratio and decomposability of organic materials. Pl. Soil, 181: 39-45.

Jardé, E., Gruau, G. and Mansuy-Huault, L. 2007. Detection of manure-derived organic compounds in rivers draining agricultural areas of intensive manure spreading. Applied Geochemistry, 22(8):1814-1824

Jeris, J. S. and Regan, R. W. 1973. Controlling environmental parameters for optimal composting. Part I. Compost Sci., 14 : 10-15.

Jiji, T., Dale, D. And Padmaja, P. 1996. Vermicompost reduces the requirement for chemical fertilizers in cowpea and bitter gourd. *Proc. Nat. Sym. Organic Fmg and Sustainable Agriculture, October 9-11, 1996.* (ed. Veeresh, C.K.) Association for promotion of organic farming, Bangalore, pp.44-45

Jimenez, E.I. and Garcia, V.P. 1989. Evaluation of city refuse compost maturity: a Review. Biological Wastes.27:115-142.

Jordahl, J.L. and Karlen, D.L. 1993. Comparison of alternative farming sytem III.Soil aggregate stability. Am. J. Alt. Agric., 8:27-33

Jose, D., Shanmugavelu, K. and Thamburaj, S. 1988. Studies on the efficacy of organic vs. inorganic form of nitrogen in Brinjal. *Indian J. Hort*. 5: 100-103

Joseph, P. 1998. Evaluation of organic and inorganic sources of nutrients on yield and quality of snakegourd (*Trichosanthes anguina* L.) M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 95p.

*Juste, C. 1980. Avantages et inconvenients de l'utilisation des composts d'ordures mnagres comme amendement organique des sols ou supports de culture. International Conference on Compost, 22-26 January, Madrid, Spain. Min. Obras Pflblicas.

K.A.U. 2002. *Package of Practices Recommendations-Crops.*12th edition. Directorate of Extension, Kerala Agricultural University, Thrissur, 278p.

Kadalli, G.G., Suseela Devi, R., Siddaramappa, R. and Patil, C.R. 2000.Quality and efficiency of value added coir dust based compost. J. Indian Soc. Soil Sci. 48(4)141-144

Kadam, R.G. 2000. Effect of vermicompost and biofertilizers on changes in physico-chemical properties and available nutrients status of soil after the harvest of frost and second crops of cowpea. M.Sc. (Ag.) thesis, Konkan Krishi Vidyapeeth, Dapoli, 101p

Kalaiselvi, T. and Ramasamy, K. 1996. Compost maturity: can it be evaluated. Madras agric. J., 83: 609-618

Kale, R.D., Bano, K., Sreenivas, M.N., Vinayaka, K. and Bagyaraj, D.J. 1991. Incidence of cellulolytic and lignolytic organisms in the earth worm worked soil. S. Indian Hort. 35(5): 433-437.

Kale, R.D., Mallesh, B.C., Kubra Bano and Bagyaraj, D.J 1992. Influence of vermicompost application on the available macronutrients and selected microbial population in a paddy field. Soil Biol. Biochem., 24(12): 1317-1320.

Kansal, B.D., Singh, B. and Kaur, G. 1981. Effect of organic and inorganic sources on the yield and quality of spinach. Qualitas Pl., 31: 163-170

Katyal, J.C. 1997. Relevance of integrated concept. *The Hindu Survey of Indian Agriculture*. pp25-31.

Katyal, J.C. 2000. Organic matter maintenance: Mainstay of soil quality. J. Indian Soc. Soil Sci., 48(4):704-716.

*Kawada, H.1981. Bark compost. Kakuyusha, Tokyo

Khalil, M.I., Inubushi, K. and Schmidhalter, U. 2006. Indexing organic material Quality: A novel approach to sustain soil and crop productivity. The 18th World Congress of Soil Science, July 9-15, 2006, Philadelphia, Pennsylvania, USA, Sponsored by U.S. National Committee for Soil Science, Soil Science Society of America and International Union of Soil Sciences.

Kimber, R.W.C. 1973. Phytotoxicity from plant residues III. The relative effect of toxins and nitrogen immobilization on the germination and growth of wheat. Pl.Soil., 38: 543-545

Kinsey, N. 1994. Manure: The good, the bad, the ugly & how it works with your soil. Acres USA., 10. pp. 8- 13

Klausner, S.D., A.C. Mather and A.L. Sutton. 1984. Managing animal manure as a source of plant nutrients. *National Corn Handbook, Cooperative Extension Service*. Purdue University. West Lafayette, Indiana, USA.

Krishnaswamy, R., Manickam, T.S. and Kothandaraman, G.V. 1984. Effect of application of organic matter and P on the yield of maize grain and mobilization of P in soil. Madras agric. J., 77: 455-458.

Kuba, T., Tschöll, A., Partl, C., Meyer, K. and Insam, H. 2008. Wood ash admixture to organic wastes improves compost and its performance. Agric., Ecosystems Environ., 127(1-2):43-49

Kumar, V., Govil, B.P. and Kaore, S.V. 1999. Nutrient management through IPNS in farmer's field IFFCO experience. Fertil. News., 44(1): 89-106

Lal, S. and Mather, B.S. 1988. Effect of long term manuring, fertilization and liming on crop yield and some physico-chemical properties of acid soil. J. Indian Soc. Soil Sci., 36: 113-119

Lal. J.K., Mishra, B. and Sarkar, A.K. 2000. Effect of plant residue incorporation on specific microbial group and availability of some plant nutrients in soil. J. Indian Soc. Soil Sci., 48(1): 67-71

Lampkin, N. 1990. In: *Organic Farming*. Farming Press, Ipswich, UK. 715pp.

Larson, W.E. and Clapp, C.E. 1984. Effects of Organic Matter on soil physical properties. *Organic Matter and Rice*. International Rice Research Institute, Philippines. pp.363-386.

Lee, Y. and Kim, Y.H. 1997. *Quality control of commercial organic fertilizers in Korea.* Extension Bulletin 446.Food and Fertilizer Technology Center, Korea.9 p

Lehocka, Z., Klimekova, M. and Bielikova, M. 2008. Soil quality indicators in organic and conventional farming systems in Slovakia. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy,pp.44-47

Lekasi,J.K., Tanner,J.C., Kimani, S.K. and Harris, P.J.C.2001. Managing Manure to Sustain Smallholder Livelihoods in the East African Highlands. DFID - Natural Resources Systems Programme HDRA, Coventry, United Kingdom.

Lekshmisree, C.S. 2003. Aerobic composting and enrichment of Ayurvedic waste. M.Sc. (Ag.) thesis. Kerala Agricultural University, Thrissur, 120p.

Loes, A.K. and Ogaard, A.F. 1997. Changes in the nutrient content of agricultural soil on conversion to organic farming in relation to farm-level nutrient balances and soil contents of clay and organic matter. Acta Agric. Scan. Sect. B., 47: 201-214

Loganathan, S. 1990. Effect of certain tillage practices and amendments on physico chemical properties of problem soils. Madras agric. J., 77: 204-208.

Logsdon, S.D., Radke, J.K. and Karlen, D.L. 1993. Comparison of alternative farming system III. Infiltration techniques. Am. J. Alt. Agric., 8:15-20

Lynch, J. M. 1978. Production and phytotoxicity of acetic acid in anaerobic soils containing plant residues. Soil Biol. Biochem., 10: 131-135.

Mafongoya, P. L., Dzowela, B. H., Nair, P. K. 1997. Effect of multipurpose trees, age of cutting and drying methods on pruning quality. In: Cadisch, G., Giller, K. E. (eds.), *Driven by Nature: Plant Litter Quality and Decomposition*. CAB International, Wallingford, UK, pp. 167- 174.

Mafongoya, P.L., Giller, K.E. and Palm, C.A. 1998. Decomposition and nutrient release patterns of prunings and litter of agroforestry trees. Agroforestry Systems, 38: 77-97.

Mahimairaja, S., Bolan, N.S. and M.J. Hedley. 1995. Agronomic effectiveness of poultry manure composts. Commun. Soil Sci., Plant Anal., 26: 1843-1861.

Malhi, S.S., Brandt, S.A., Zentner, R.P. Knight, J.D., Gill, K.S, Sahota, T.S. and Schoenau, J.J. 2008. Management strategies and practices for preventing nutrient deficiencies in organic crop production. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy,pp. 82-85

Mali, M.D. 2004. Effect of organic manures on yield and quality of cucumber (*Cucumis sativus* L.) cv. Himangi. M.Sc. (Ag.) thesis, MPKV, Rahuri.123p.

Manickam,T.S. 1993. *Organics in Soil Health and Crop Production*. (ed. Thampan, P.K.) Pee Kay Tree Crops Development Foundation, Cochin.pp.88-104

Manna, M.C., Ganguly, T.K. and Ghosh, B.N. 2000**.** Evaluation of compost maturity ans mineral enrichment quality through simple chemical parameters**.** J. Indian Soc. Soil Sci**.,** 48(4): 781-786.

Manungufala, T.E., Chimuka, L. and Maswanganyi, B.X. 2008. Evaluating the quality of communities made compost manure in South Africa: A case study of content and sources of metals in compost manure from Thulamela Municipality, Limpopo province. Bioresource Technol., 99(5): 1491-1496

Mapa, R.B. and Kumara, G.K.K. P. 1995. Potential of coir dust for agricultural use. Sri Lankan J. Agric. Sci., 32: 161-164

Marderosian, A.D., Bentler, J., Pfender, W. and Chambers, J. 1980. Nitrate and oxalate content of vegetable amaranth. *Proc. Second Amaranth Conf., September 2-8*, 1980 (eds. Yoder, R., Weinsteiger, E and Sheft, J.). Rodale Press Inc., Emmaur, pp.31-40

Mathen, K.K., Sankaran, K., Kanakabushini, N. and Krishnamoorthy, K.K. 1978. Effect of continuous rotational cropping on the organic carbon content and total N content in a black soil. J. Indian Soc. Soil Sci., 26(3): 283-285

Matthiessen, M.K., Larney, F.J., Selinger, L.B. and Olson, A.F. 2005. Influence of loss-on-ignition temperature and heating time on ash content of compost and manure. Commun. Soil Sci., Plant Anal., 36:2561-2573

Maureen, A., Ramirez, E. and Garraway, J. L. 1982. Plant growth inhibitory activity of extracts of raw and treated pig slurry. J. Sci. Food Agric., 33: 1189-96.

Mbah, B.N. and Pdilli, P.N. 1998. Changes in moisture retention properties of 5 waste materials during short term mesophilic composting. Compost Sci. Utilization, 6(4): 67-73

McGill,W.B., Cannon, K.R., Robertson, J.A. and Cook, F.D. 1986. Dynamics of soil microbial biomass and water soluble carbon in Brenton L after 51 years of cropping in two rotations. Can .J. Soil Sci., 66(1): 1-19

Meera, A.V. 1998. Nutrient economy through seed coating with vermicompost in cowpea (*Vigna unguiculata* (L.) Walp.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 136p.

Meerabai, M and Raj, A.K. 2001. Biofarming in vegetables. *Kisan Wld*. 28: 15-16

Meerabai, M., Jayachandran, B.K., Ann, N. and Sudha, B. 2003. Biofarming in chilli (*Capsicum annuum* L.). *Proc. 15th Kerala Sci. Congress, 29-31 Jan 2003*. (eds. Prakashkumar, R., Prabhakumari, P. and Kokkar, K.) State Committee on Science, Technology and Environment,Thiruvananthapuram.pp780-783

Melero, S., Porras, J., Herencia, J. and Madejon , E. 2006. Chemical and biochemical properties in a silty loam soil under conventional and organic management. Soil Tillage Res., 90(1-2): 162-170.

Melillo, J. M., Aber, J. D., Muratore, J. F.1982. Nitrogen and lignin control of hard wood leaf litter decomposition dynamics. *Ecology* 63: 621- 626.

Miller, R.W. and Donahue, R.L. 1992. Soils- An Introduction to Soils and Plant Growth. Prentice Hall of India Pvt. Ltd., New Delhi. 95p

Mohanty, S., Paikaray,N.K. and Rajan, A.R. 2006.Availability and uptake of phosphorus from organic manures in groundnut (*Arachis hypogea* L.)–corn (*Zea mays* L.) sequence using radio tracer technique. Geoderma, 133(3-4): 225-230

Monaco, S., Hatch, D.J., Sacco, D., Bertora, C. and Grignani,C. 2008. Changes in chemical and biochemical soil properties induced by 11-yr repeated additions of different organic materials in maize-based forage systems. Soil Biol. Biochem., 40 (3): 608-615

Monokrousos, N., Papatheodorou, E.M. and Stamou, G.P. 2008. The response of soil biochemical variables to organic and conventional cultivation of *Asparagus* sp. Soil Biol. Biochem., 40(1):198-206

Montegue, K.D. and Gosh, K.M. 1990. Effect of forms and rates of organic and inorganic nitrogen fertilizers on the yield and some quality indices of tomato. New Zealand J. Crop. Hort. Sci., 18(1): 31-32

Morel, J. L., Colin, F., Germon, J. C., Godin, P. and Juste, C. 1985. Methods for the evaluation of the maturity of municipal refuse compost. In *Composting of*

Agricultural and other Wastes, (ed. Gasser, J. K. R.). Elsevier Applied Science Publishers, London and New York, pp. 56-72.

*Morel, J.F., Jacquin, A., Gucket, A. and Barthel, C. 1979. Contribution a la détermination de test de la maturité des compost urbain. *Cr. Contrat*, 75-124. Ministère de I'Environmental et decadre de vie ENSAIA Nancy.p.32

Moreno, E.C., Lindsay, W.L. and Osborn, G . 1960. Reaction of dicalcium phosphate dihydrate in soils. Soil Sci., 90: 58-68.

Mortvedt, J.J. 1995. Heavy metal contaminants in inorganic and organic fertilizers. Nutrient Cycling in Agroecosystems., 43(1-3):55-61

Motavalli, P.P., Singh, R.P. and Anders, M.M. 1994. Perception and management of farmyard manure in the semi-arid tropics of India. Agric. Systems, 46: 189-204.

Mugwira, L. M., Mukurumbira, L. M. 1986. Nutrient supplying power of different groups of manure from the communal areas and commercial feedlots. Zimbabwe Agric. J., 83: 25- 29.

Mugwira, L. M.1984. Relative effectiveness of fertilizers and communal area manures as plant nutrient sources. Zimbabwe Agric. J., 81: 85- 89.

Mulani, T.G., Musmade, A.M., Kadu, P.P. and Mangave, K.K. 2007. Effect of organic manures and biofertilizers on growth, yield and quality of bitter gourd (*Memordica charantia* L.) cv. Phule Green Gold. J. Soils Crops,17(2): 258-261

Muthuvel,P., Kandasamy,P. and Krishnamoorthy, K.K. 1982. Effect of long-term fertilization of the water holding capacity, bulk density and porosity of soil. Madras agric. J., 69: 614-617.

Myers, R.J.K., C.A. Palm, E. Guevas, I.U.N. Gunatilleke & M. Brossard.1994. The synchronisation of nutrient mineralisation and plant nutrient demand. pp 81-116. In: *The Biological Management of Tropical Soil Fertility:* P.L. Woomer and M.J. Swift (eds.). John Wiley and Sons, New York, USA.

Nagarajan, R., Ramaswamy,K., Savithri, P. and Manickam, T.S. 1990. Coir waste in crop production. Agricultural College and research Institute, Madurai and Central Coir Research Institute, Coir Board, Kalavoor,39p.

Nair, M. 1988. Effect of organic, inorganic fertilizers and their combination on physico-chemical and biological properties of soil cropped under clustered chilli (*Capsicum annuum* L.). MSc. (Ag) thesis, Kerala Agricultural University, Thrissur, 130.

Nair, M. and Peter, K.V. 1990. Organic fertilizers and their combinations on yield and storage life of hot chilli. Veg.Sci., 17(1):1-10

Nair, R.C. 2003. Sustainable nutritional practices for bittergourd- Amaranthus intercropping system. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 97p.

Nambiar, K.K.M.1994. Effect of long-term manuring and intensive cropping on microbial properties. Soil Fertility and Crop Productivity Under long term Fertilizer Use In India (ed. Bhatt, V.S.). Indian Council of Agricultural Research, New Delhi. pp.126-128.

Nampoothiri, K.U.K. 2001. Organic farming its relevance to plantation crops. J.Pln.Cps., 29: 1-9

Narayanan, A. 2005. Understanding organic agriculture. *Proc. Sem. On Organic Agriculture in Peninsular India,* OASIS, Coimbatore, pp11-14.

Nelson, D.W. and Sommers, L.E. 1996. Total carbon, organic carbon, and organic matter. In *Methods of Soil Analysis. Part 3*. *Chemical Methods* (ed.Sparks, D.L.) SSSA Book Series No. 5, Soil Science Society of America, Madison, Wisconsin, 961–1010.

Nguyen,M.L., Haynes, R.J. and Goh, K.M. 1995. Nutrient budgets and status in three pairs of conventional and alternative mixed cropping farms in Canterbury, New Zealand. Agric. Ecosystems Environ., 52:144-162

Niranjana, N. S. 1998. Biofarming in vegetables- Effect of biofertilizers on amaranthus (*Amaranthus tricolor* L.) M.Sc. (Ag.) thesis. Kerala Agricultural University, Thrissur.148p

NPOP. 2000. National Programme for Organic Production containing the standards for organic products. Department of Commerce, Ministry of Commerce and Industry, Government of India.64p.

Odeleye, F.O., Odeleye, O.M.O., Dada, D.A. and Olaleye, A.O. 2005. The response of okra to varying levels of poultry manure and plant population density under sole cropping. J. Food, Agric. Environ., 3(3&4):68-74

Odlare, M., Pell, M. and Svensson, K. 2008. Changes in soil chemical and microbiological properties during 4 years of application of various organic residues. Waste Management, 28(7): 1246-1253

Oglesby, K. A., Fownes, J. H. 1992. Effects of chemical composition on nitrogen mineralization from green manures of seven tropical leguminous trees. Plant Soil, 143: 127- 132.

Okuda, A. and Takahasi, E. 1961. Germination injury due to free ammonia. Chem. Abstr., 55, 15801.

Olsen ,R.J., Henslar, R.F. and Alloe, O.J.1970. Effect of manure application, aeration and soil pH on soil N transformations and on certain soil test values. Soil Sci., Agric.Proc., 34: 222-225.

Olsen, S.R. and S.A. Barber. 1977. Effect of waste application on soil phosphorus and potassium. In: *Soil for Management of Organic Waste and Water* (eds. Elliote and Stevenson). American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Wisconsin, USA, pp. 197-215.

Omae, K., Kukudome, K., Onjo, m. and Hayashi, M. 2003. Effect of application of cattle compost on yield, quality and soil properties in melon (*Cucumis melo* L.). Bull. Faculty Agric., 53:41-44

Owen, J., Lynch, D. and Fillmore, S.A.E 2008. Changes in light fraction soil organic matter and in organic carbon and nitrogen in compost amended soils. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy,pp.52-55

Palaniappan, S.P. and Annadurai, K. 1998. *Organic Farming, Theory and Practice*. Scientific Publishers, Jodhpur, 257p

Palm, C.A. 1995. Contribution of trees to nutrient requirements of intercropped plants. Agroforestry Systems, 30: 105-124

Palm, C. A., Gachengo, C. N., Delve, R. J., Cadisch, G. and Giller, K. E. 2001. Organic inputs for soil fertility management in tropical agro-ecosystems: application of an organic resource database. Agric. Ecosystems Environ,. 83: 27- 42.

Palm, C. A., Sanchez, P. A. 1991. Nitrogen release from some tropical legumes as affected by lignin and polyphenol content. Soil Biol. Biochem., 23: 83- 88.

Panda, H. and Hota, D. 2007. Biofertilizers and Organic Farming. Gene-Tech Books, New Delhi. 397p.

Parr, J.F. and Colacicco, D. 1987. In *Energy in Plant Nutrition and Pest Control* (ed. Helsel, Z.R.). Elsevier Science Publishers, Amsterdam, 81p

Parr, J.F. and Papendick, R.J. 1978. Factors affecting the decomposition of crop residues by micro organisms. Crop residue management systems. *Proc. Symp. Houston U.S.A* .Special Publication No.31: 101-129

Pathak, H. and Sarkar, M. C. 1994. Nitrogen supplying capacity of an Ustochrept amended in manure, urea and their combinations. J. Indian Soc. Soil Sci., 42: 261- 267.

Pathak, R.K. and Ram, R.A. 2002. Approaches for organic production of vegetables in India. Report of Central Institute of Sub-Tropical Horticulture, Lucknow, India.p73

Patidar, M. and Mali, A.L. 2002. Residual effect of FYM, fertilizers and biofertilizers on screening wheat (*Triticum aestivum*). Indian J. Agron., 47:26-32

*Patiram, 1996. Effect of limestone and FYM on crop yield and soil acidity on acid Inceptisol in Sikkim, India. Trop. Agric. Trinidad, 73 (3): 238-241

Paul, J. W., Covert, J. A., Beauchamp, E. G. (1994) Influence of soil temperature and moisture on water soluble phenolic compounds in manured soil. Canadian J. Soil Sci., 74: 111- 114.

Penfold, C.M., Miyan, M.S., Reeves, T.G. and Grierson, I.T.1995. Biological farming for sustainable agricultural Production. Aust.J. Exp.Agric., 35:849-856

Phoebe, J. 1997. Evaluation of organic and inorganic sources of nutrients on the yield and quality of snake gourd (*Trichosanthes anguina* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 135p.

Piper, C.S. 1967. *Soil and Plant Analysis*. Interscience Publishers, Inc, New York, 368p.

Poincelot, R. P. 1974. A scientific examination of the principles and practice of composting. Compost. Sci., 15: 24-31.

Poincelot, R. P. 1975. The biochemistry and methodology of composting. The Connecticut Agricultural Experimental Station, New Haven, *Bull. 754*, September 1975.

Prabha, K.P., Li, L.Y. and Kumari, U.R. 2008. An experimental study of vermi-biowaste composting for agricultural soil improvement. Bioresource Technol., 99(6): 1672-1681

Prabhakumari, P., Jiji, T. and Padmaja, P. 1995. Comparative efficiencies of identified earthworm species for biodegradation of organic wastes. *Proc. Seventh Kerala Sci. Cong. January 27-29*, 1995 (ed. Iyengar, P.K.), Palakkad, pp.78-79

Prabhu, S.R. and Thomas, G.V.2002. Biological conversion of coir pith into a value added organic resource and its application in agri-horticulture. Current status, prospects and perspective. J. Plantn. Crops., 30:1-17

Prasad, B. 1999. Conjoint use of fertilizers with organic, crop residues and green manuring for their efficient use in sustainable crop production. Fertil. News, 44(5): 67-73

Prasad, B. and Singh, A.P. 1980. Changes in soil properties with long term use of fertilizers, lime and farm manure. J. Indian Soc. Soil Sci., 28: 465-466

Puget, P., Chenu, C. and Balaesdent, J. 2000. Dynamics of soil organic matter associated with particle-size fractions of water-stable aggregates, Eur. J. Soil Sci., 51: 595–605

Purohit, H.S., Somani, L.L. and Sharma, V. 2003. Integrated nutrient management in cowpea-wheat crop sequence. Int. J. Trop. Agri., 21(1-4): 119-131

Pushpa, S. 1996. Effect of vermicompost on yield and quality of tomato (*Lycopersicon esculentum* Mill.) M.Sc. (Ag.)thesis. Kerala Agricultural University, Thrissur.90 p

Quemada, M. and Cabrera, M. L. 1995. Carbon and Nitrogen mineralization from leaves and stems of four cover crops. Soil Sci. Soc. Am. J., 59: 471- 477.

Rabindra, B., Narayanaswami, G.V., Gowda, N.A.J. and Shivanagappa. 1985. Long range effect of manures and fertilizers on soil physical properties and yield of sugar cane. J. Indian Soc. Soil Sci., 33: 704-706.

Rabindra, B. and Honnegowda. 1986. Long range effect of fertilizers, lime and manure on soil fertility and sugarcane yield on a red sandy loam soil (Udic Haplustalf). J. Indian Soc. Soil Sci. 34:200-202

Radics, L., Pusztai, P., Biro, B., Biro, Zs., Nemeth, T. And Monori, I. 2008. Elemental composition and quality of lettuce (*Lactuca sativa* var. Biweri), grown with sheep –manure composts. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy, pp.154-157

Rajalekshmi, K. 1996. Effect of vermicompost / vermiculture on physico-chemical properties of soil.M.Sc. (Ag.) thesis. Kerala Agricultural University, Thrissur.121 p.

Rajasree, G. 1999. Standardization of organic and inorganic fertilizer combinations for maximizing productivity in bittergourd (*Momordica charantia* L.) Ph.D. thesis , Kerala Agricultural University, Thrissur, 102p.

Ramanathan, K.M.2006. Organic farming for sustainability. J. Indian Soc. Soil Sci. 54(4):418-425.

Rani, P.J., Kannan, M. and Thamburaj, S. 1997. Nutritive value of vegetables. Kisan Wld., 24(2):53-54

Rao, D.N. and Mikkleson, D.S. 1976. Effect of acetic, propionic and butyric acids on young rice seedlings. Agron . J., 68:752-755

Recous, S., Robin, D., Darwis, D. and Mary, B. 1995. Soil inorganic N availability: Effect on maize residue decompositions. Soil Biol. Biochem. 27: 1529-1538.

Reddy, K.S. 2005. Organic manures in integrated plant nutrient supply for sustainable production. *Winter school manual on Efficient composting techniques for* *production of nutrient enriched composts from agro, industrial and city wastes and standardization of methods, December 1-21, 2005. ICAR, Indian Institute of Soil Science, Bhopal*.

Reddy, R.N.S. and Prasad, R. 1985. Studies on the mineralization of urea, coated urea and nitrification inhibitors treated urea in soil. J.Soil Sci., 26: 304

Reeja, R.S. 2002. Comparative efficiencies of lignocellulolytic fungi for bioconversion of coirpith. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 97p.

Regan, R. W. and Jeris, J. S. 1970. A review of the decomposition of cellulose and refuse. Compost Sci., 11: 17-20.

Reganold, J.P., Elliot, L.F. and Unger, Y.L. 1987. Long term effect of organic and conventional farming on soil erosion. Nature, 330: 370-372

Reganold, J.P., Palmer, A.S., Lockhart, J.S. and A.N. Macgregor. 1993. Soil quality and financial performance of biodynamic and conventional farming in New Zealand. Science, 260: 344-349

Roy, K. and Jana, M. K. 1975. Biological effects of ethyl methanesulphonate and ethylene oxide on rice. Genet. Agron., 29: 283-94.

Rubins, E.J. and Bear, F.E. 1942. On the carbon/nitrogen ratios in organic materials in relation to the availability of nitrogen. Soil Sci., 54: 411-423

Sabey, B. R. and Hart, W. E. 1975. Land application of sewage sludge. I. Effects on growth and chemical composition of plants. J. Environ. Qual., 4: 252-256.

Sable, C.R., Ghuge, T.G., Gore, A.K. and Jadhav, S.B. 2007b. Effect of organic nutrients on growth and yield of tomato variety Parbhani Yashshri. J Soils Crops., 17(2): 304-307

Sable, C.R., Ghuge, T.G., Jadhav, S.B. and Gore, A.K. 2007a. Impact of organic sources on uptake, quality and availability of nutrients after harvest of tomato. J. Soils Crops., 17(2):283-286

Sadasivam, S. and Manickam, A. 1996. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi, 246p.

Saha,J.K. 2005. Assessment of heavy metal limits in compost prepared from MSW and urban wastes. *Proceedings of Winter School on Efficient composting techniques for production of nutrient enriched composts from agro, industrial* *and city wastes and standardization of methods*. December 1-21, 2005. ICAR. Indian Institute of Soil Science, Bhopal, pp 91-98.

Sailajakumari, M.S. 1999. Effect of VC enriched with rock phosphate in cowpea (*Vigna unguiculata* (L.) Walp.) M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur.110p.

Sainju, U.M., Senwo, Z.N., Nyakatawa, E.Z., Tazisong, I.A. and Reddy,K.C. 2008. Soil carbon and nitrogen sequestration as affected by long-term tillage, cropping systems, and nitrogen fertilizer sources. Agric. Ecosystems Environ. Available online 27 May 2008.

Salazar, F.J. and Saldana, R.C. 2007. Characterization of manures from fish cage farming in Chile. Bioresource Technology, 98(17):3322-3327

Sangakkara, U.R., Weerasekara, D.N., Attanayake, K.B., and Attanayake, A.M.U. 2008. Inoculation affects nitrogen balances of composts and growth, yield and microflora of *Phaseolus* beans. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy, pp.102-105

Sanwal, S.K., Yadav, R.K. and Singh, P.K. 2007. Effect of types of organic manures on growth, yield and quality parameters of ginger (*Zingiber officinale*) *Indian J. agric. Sci*. 77(2):67-72

Saravanapandian, M. 1998. Effect of fertilizer P, FYM and incubation period on available P in different soil types of Ranga Reddy district of Andhra Pradesh. Madras agric.J., 85: 511-513

Sarawad .M., Radder, B.M. and Badanur, V. 1996. Effect of Vermicomposting in conjunction with fertilizer on soil properties and sorghum yield. *Proceedings of National Seminar on Organic Farming and sustainable agriculture.* (ed. Veeresh, C.K.) Association for promotion of organic farming, Bangalore,pp.87

Sathianathan, K.N. 1982. Increasing Nitrogen use efficiency in upland soils. M.Sc. (Ag.). Thesis, Kerala Agricultural University, Thrissur. 125p

Savithri, P., Murugappan, M. and Nagarajan, R. 1993. Possibility of economizing potassium fertilization by composted coir pith application. Fert.News. 38: 39-40

Scow, K.M., Somasco, O., Gunapala, N., Lau, S., Venette, R., Ferris, H., Miller, R. and Shennan, C. 1994. Transition from conventional low input agriculture changes soil fertility and biology. Calif. Agric., 48: 20-26

Sellami, F., Hachicha, S., Chtourou, M., Medhioub, K. and Ammar, E. 2008. Maturity assessment of composted live mill wastes using UV spectra and humification parameters. Bioresource Technol., 99(15):6900-6907

Selvaraj, N., Anitha, P., Ramaraj, P. and Mohan, L. 2005. *Modern Organic farming for Horticultural Crops (Tamil).* Horticultural Research Station, TNAU, Ooty.

Selvi, D. and Selvaseelan, A. 2003. Effect of mushroom spent rice straw compost on nutrient availability on laterite soil of Nilgiris during potato crop growth. Int. J. Trop. Agric., 21(1-4): 99-107

Sharma, N.K. and Bhalla, P.I. 1993. Influence of integrated nutrient management on growth, yield and economics in okra (*Abelmoschus esculentus* (L.) Moench). J. Veg. Sci., 22(1): 1-4

Sharma, R.C., Krishna, G. and Singh, P.M. 1988. Effect of FYM and green manures on crop yields and nitrogen needs of potato based cropping systems in Punjab. *J. Agric. Sci.*, 110: 499-564

Sharpley, A.N. and Syres, J.K. 1977. Seasonal variation in casting activity and in the amounts and release to solution of P forms in earthworm casts. Soil Biol. Biochem., 9: 227-231.

Sharpley, A.N., Daniel, T.C., Sims, J.T. and Pote, D.H. 1996. Determining environmentally sound soil phosphorus levels. *J. Soil Water Conserv.* 51: 160-166.

Sharu, S.R.2000. Integrated nutrient management in chilli (*Capsicum annuum* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur,108p.

Sheeba, P.S. 2004. Vermicompost enriched with organic additives for sustainable soil health. M.Sc. (Ag.) thesis, Kerala Agricultural University,Thrissur, 129 p

Shivananda, T.N. 1986. Mineralization of nitrogen from various organic manure

Siegrist,S., Schaub, D., Pfiffner, L. and Mader, P.1998. Does organic agriculture reduce erodibility? The results of a long term field study on loess in Switzerland. Agric Ecosystems Environ., 69: 253-264

Simpson, J.E., Adair, C.R., Kohler, G.D., Dawson, E.N., Debald, H.A, Kester, E.B. and Klick, J.I. 1965. Quality evaluation studies of foreign and domestic rices. Tech. Bull. N. 1331 Services, U.S.D.A: 1-86

Singh, A.B. 2005a. Chemical and biochemical quality assessment of compost prepared form crop residues. *Winter school manual on Efficient composting techniques for production of nutrient enriched composts from agro, industrial and city wastes and standardization of methods, December 1-21, 2005. Indian Institute of Soil Science, Bhopal*.pp 82-90

Singh, C.P. and A.A. Amberger. 1991. Solubilization and availability of phosphorus during decomposition of rock phosphate enriched straw and urine. Biology, Agric. Hort., 7: 261-269.

Singh, K.N., Khan, G.M. and Amarjit, S.B. 2001. Response of brown sarson (*Brassica campestris* subsp. *oleifera* var. brown sarson) to residual effect of organic manure,nitrogen and transplanting dates of rice. Indian J. Agron., 46: 395-399

Singh, K.P. Srivastava, T.K., Singh, P.N. and Suman, A. 2007. Enhancing soil fertility, microbial activity and sugarcane (*Saccharum officinarum*) productivity through organics in subtropical conditions.

Singh, M. 2005b.Composting: Its science, technological options, and environmental concerns for the conversion of wastes into quality manures. *Proceedings of Winter School on " Efficient composting techniques for production of nutrient enriched composts from agro, industrial and city wastes and standardization methods*" December 1-21, 2005.at Division of Soil Biology, Indian Institute of Soil Science, Bhopal. ICAR.

Singh, M. 2005c. Influence of organics on soil chemical processes –nutrient transformation. *Proceedings of Winter School on " Efficient composting techniques for production of nutrient enriched composts from agro, industrial and city wastes and standardization methods*" December 1-21, 2005.at Division of Soil Biology, Indian Institute of Soil Science, Bhopal. ICAR.

Singh, R., Sharma, R.R., Kumar, S., Gupta, R.K. and Patil, R.T. 2008. Vermicompost substitution influences growth, physiological disorders, fruit yield and quality of strawberry (Fragaria x ananassa Duch.). Bioresource Technol., In Press, Corrected Proof, Available online 19 May 2008

Singh, R.S. and Ram, H. 1982. Effect of organic matter on the transformation of inorganic P in soils. J. Indian Soc. Soil Sci., 30: 185-189

Snedecor, G.W. and Cochran,W.G. 1967. *Statistical Methods,* 16th edition. Oxford and IBH Publishing Co., Calcutta, pp 349-351

Som, M.G., Hashim, H., Mandal, A.K. and Maity, T.K. 1992. Influence of organic manures on growth and yield of brinjal (*Solanum melongena* L.) Crop Res. 5(1):80-84

Spohn, E. 1978. Determination of compost maturity. Compost Sci., 19: 26-27.

Sreekala, G.S. 2004. Effect of organic manures and microbial inoculants on growth, yield and quality of ginger. Ph.D. thesis, Kerala Agricultural University, Thrissur, 258p.

Srikanth, K., Srinivasamurthy, C.A., Ramakrishna Parama, V.R., Siddaramappa, R. and Sudhir, K. 2000. Recycling of organic wastes and evaluation of their nutrient potential. *Proc. Intern. Conf. managing Natural Resources for Sustainable Agricultural Production in the 21st Century,* New Delhi, 3: 1265-1267

Srinivas, K., Singh, H.P., Vanaja, M., Raju, A.S. and Sharma, K.L. 2006. Effect of chemical composition of plant residues in nitrogen mineralization. J. Indian Soc. Soil Sci. 54(3): 300-306

Srivastava, O.P. 1985. Role of organic matter in soil fertility. Indian J. Agric. Chem., 18(22): 257.

Srivastava, R.P and Kumar, S. 1998. *Fruit and Vegetable Preservation-Principles and Practices*. Second edition. International Book Distributing Company, Lucknow. 444p.

Staffella, P.J. and Graetz, D.A. 1996. Sugarcane filter compost influence on tomato emergence, seedling growth and yields. *The science of composting Part 2.* (eds. DeBertoldi, M., Sequi, P., Lemmas, B. and Pap,T.) Blackie Academic and Professional. New York. USA

Stewart, B. A. and Meek, B. D. 1977. Soluble salt considerations with waste application. In *Soils for Management of Organic Wastes and Waste Waters* (ed. Elliott, L. F. and Stevenson, F. J.) ASA, CSSA, SSSA, Madison, Wisconsin, USA, pp. 218-32.

Stockdale, E.A., Lampkin, N.H., Hovi, M., Keatinge, R., Lennartsson, E.K.M., Macdonald, D.W., Padel, S., Tattersale, F.H., Wolfe, M.S. and Watson, C.A.2001. Agronomic and environmental implications of organic farming systems. *Adv. Agron.* 70. (ed. Sparks, D.L.),Academic Press, New York. pp 261-327

Subbaraj, D. and Ramaswamy, P.P. 1992. Influence of organic amendments of highly permeable soils of Typic Ustipsamments. *Nat. Sem. On Development in Soil Science.* 57th Annual Convention. Indian Society of Soil Science.Nov.2

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. Current Sci., 25(8):259-260

Sugahara, K., Harada, Y. and Inoko, A. 1979. Color change of city refuse during composting process. Soil Sci. Plant Nutr., 25: 197-208

Suharban, M. Geetha, D. and Nair, M.C. 1997. Degradation of coir pith by oyster mushroom (*Pleurotus* sp.) and its effect on yield of bhindi. Mushroom Res., 6:101-102

Suja, G. 2001. Resource management for intercropping white yam (*Dioscorea rotundata* Poir) in coconut garden. PhD. thesis, Kerala Agricultural University, Thrissur, 195p

Swaminathan, M.S. 2000. For an evergreen revolution. *The Hindu Survey of Indian Agrculture*.pp9-15

Swarup, A. 1984. Effect of micronutrients and FYM on the yield and micronutrient conten of rice-wheat grown in sodic soils. J. Indian Soc. Soil Sci., 32: 397-399

Swift, M. J., Heal, O. W., Anderson, J. M. 1979. Decomposition in Terrestrial Ecosystems. Blackwell, Oxford, UK. 372pp.

Tanner, P. D. and Mugwira, L. 1984. Effectiveness of communal area manures as sources of nutrients for young maize plants. Zimbabwe agric. J., 81: 31- 35.

Tejada, M. and Gonzalez, J.L. 2004. Effects of application of a byproduct of the two-step olive oil mill process on maize yield. Agron. J., 96 : 692–699.

Tejada, M. and Gonzalez, J.L.2007. Influence of organic amendments on soil structure and soil loss under simulated rain. Soil Tillage Res., 93: 197–205

Terman, G. L., Soileau, J. M. and Allen, S. E. 1973. Municipal waste compost: Effects on crop yields and nutrient content in greenhouse pot experiments. J. Environ. Qual., 2: 84-89.

Thamburaj, S. 1994. Tomato responds to organic gardening. Kisan Wld., 21(3):49

Thampan, P.K.1993. Organics in Soil Health and Crop Production. Peekay Tree Crops Development Foundation, Kochi, Kerala.

Tisdale, S.L., Nelson, W.L., Beaten, J.D. and Havlin, J.L. 1997. *Soil Fertility and Fertilizers.* Fifth Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 634p.

Tomati, U., Galli, E., Grappelli, A. and Dielena, G.1990. Effect of earth worm casts on protein synthesis in radish and lettuce seedlings. Biologia Fertil. Soil., 9:288-289

Tusneem, M.E. and Patrick, W.H. 1971. Nitrogen transformation in water logged soils. *Bulletin No. 657*, Louisiana State University, USA.

Um,M.H and Lee,Y. 2001. Quality control for commercial compost in Korea. *Extension Bull.* 2001, FFTC for the Asia and Pacific Region.

Ushakumari, K., Prabhakumari, P. and Padmaja, P.1996. Seasonal response of bhindi (*Abelmoschus esculentus*) to vermicompost/ vermiculture. *Proc. Nat. Sem. on Organic Farming and Sustainable Agriculture* (ed. Veeresh, C.K.) Association for promotion of organic farming. Bangalore, pp 42.

Van Assche, C. and Uyttebroeck, P. 1981. Plant analysis of lettuce and spinach grown on domestic waste compost. *I Int. Congress for Soil Pollution and Protection from Pesticide Residues, 22-28 August 1981*, El Zagazig, Egypt.

Van der Eerden, L. J. M. 1982. Toxicity of ammonia to plants. Agric. Environ., 7: 223-235.

Venkitaswamy,R. 2003. Integrated nutrient management in coconut with composted coir pith. Madras. agric. J., 90: 54-56

Venugopal, V. K. 2004. Quality control of organic manure. *Proc. of the winter school on Organic farming for sustainable agriculture, November 17-December 7, 2004, ICAR, Kerala Agricultural University, College of Agriculture, Vellayani, Thiruvanathapuram.*pp323-328.

Verhagen, J.B.G.M. and Papadopoulos, A.P. 1997. CEC and saturation of the adsorption complex or coir dust. Acta Horticulturae, 481: 151-155

Virgil, M.F. and D.E. Kissel. 1995. Rate of nitrogen mineralized from incorporated crop residues as influenced by temperature. Soil Sci. Soc. Am. J., 59: 1636-1644.

Vityakon, P. and Dangthaisong, N. 2005. Environment al influences on nitrogen transformation of different quality tree litter under submerged and aerobic conditions. Agroforestry Systems, 63: 225-236.

Volk, B. G., Snyder, G. M., Gascho, G. J. and Henderson, P. H. 1973. Cropland disposal of hydropulped municipal refuse. I. A. greenhouse and growth chamber evaluation. Soil Crop Sci. Soc. Florida, 32: 95-9.

Waggoner, P.E. 1974. Connecticut agric. Exp. Stn. Bull.754, 9.

Walkley, A. and Black, I.A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 34:29-38

Wander, M.M. and Traina, S.J. 1994. Organic matter fractions form organically and conventionally managed soils. I. Carbon and nitrogen distribution. Soil Sci. Soc. Am. J., 60: 1081-1087

Warman, P.R. and Harvard, K.A. 1998. Yield, vitamin and mineral contents of organically and conventionally grown potato and sweet corn. Agric. Ecosystems Environ., 68: 207-216

Wijeratne, M.A and Premathunga, E.W.T.P. 2005. Effect of refuse-tea on soil properties and yield of mature tea in low country wet zone of Sri Lanka. J Plantation Crops., 33(1): 44-47.

Willekens, K., De Vliegher, A., Vandecasteele, B. and Carlier, L. 2008. Effect of compost versus animal manure fertilization on crop development, yield and nitrogen residue in the organic cultivation of potatoes. *Proc. Second Scientific Conference of the International Society of Organic Agriculture Research (ISOFAR) held at 16th IFOAM Organic World Congress- in Cooperation with the International Federation of Organic Agriculture Movements (IFOAM) and the Consorzio ModenaBio 2008,18-20 June*, 2008.*Volume I. Organic Crop Production*. (eds. Neuhoff, D., Halberg, N., Alfoldi, T., Lockertz, W., Thommen, A., Rasmussen, I.A., Hermansen, J., Vaarst, M., Luck, L., Caporali, F., Jesen, H.H., Migliorini, P. and Willer, H.), Modena, Italy, pp.576-579

Wilson, G.B.1989. Combining raw materials for composting. Bio Cycle, 30: 82-85

Wong, M. H. 1985. Phytotoxicity of refuse compost during the process of maturation. Environ. Pollut. Ser. A., 37 : 159-74.

Wong, M. H. and Chu, L. M. 1985. The responses on edible crops treated with extracts of refuse compost of different ages. Agric. Wastes, 14: 63-74.

Yaduvanshi, N.P.S. and Swarup, A. 2006. Farmyard manure and pressmud as alternative to gypsum use for sustaining rice-wheat system on soils irrigated with sodic ground water. Indian Farming, 56(1): 35-36

Yaduvanshi, N.P.S.2000. Sustainability of rice-wheat system in gypsum treated alkali soils through organic and inorganic fertilizer. *Proc. Intern. Conf. managing Natural Resources for Sustainable Agricultural Production in the 21st Century*, New Delhi, 3: 1261-1262

Zachariah, A.S. 1995. Vermicomposting of vegetable garbage. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 200p.

Zmora-Nahum,S., Hadar, Y. and Chen, Y. 2007. Physico-chemical properties of commercial composts varying in their source materials and country of origin. Soil Biol. Biochem., 39(6):1263-1276

Zucconi, F., Pera, A., Forte, M. and De Bertoldi, M. 1981a. Evaluating toxicity of immature compost. Biocycle, 22: 54-7.

Zucconi, F., Forte, M., Monaco, A. and De Bertoldi, M. 1981b. Biological evaluation of compost maturity. Biocycle, 22: 27-9.

Zucconi, F., Monaco, A., Forte, M. And De Bertoldi, M. 1985. Phytotoxins during the stabilization of organic matter. In *Composting of Agricultural and other Wastes*, (ed. Gasser, J. K. R.). Elsevier Applied Science Publishers, London and New York, pp. 73-85.

APPENDICES

Appendix I

Details of commercial organic manures included in the study

Sample No.	Product Name	Name and address of Manufacturer	Date of sampling
1	KARSHAKAMEAL	TIFFCO FERTILIZERS & CHEMICALS, Chengaloor, Erode(via), Pudukkad P.O., Thrissur,Kerala. Phone-04802783420 Mobile-9447352713	23.12.2006
2	G.N.VERMICAKE	"	23.12.2006
3	ORGAMEAL	"	23.12.2006
4	NEEMCAKE	"	23.12.2006
5	VERMICOMPOST	"	23.12.2006
6	FISH MEAL	MATSYAFED	05.02. 2007
7	STERAMEAL N: 5-7% P: 9-10% K: 0	SWAL CORPORATION LTD. Nattakom P.O. Kottayam-686 013 Phone: 0481-2361005,2360154	16.12.2006
8	STERAMEAL N: 5-7% P: 9-10% K: 5%	"	16.12.2006
9	STERAMEAL N: 3-5% P: 9-10% K: 10%	"	16.12.2006
10	STERAMEAL COCONUT SPECIAL N: 4-6% P: 2-3% K: 12%	"	16.12.2006
11	FOSMEAL	SOUTHERN FERTILIZERS & CHEMICALS, Salim complex, Changanassery,Kottayam-686101 Ph-0481-2424779(office) 2424771 Factory: 2727930	22.12.2006
12	ROYAL MEAL	"	22.12.2006
13	SUPERMEAL I	Matha Biofertilizers Kuruppanthara, Manjoor P.O. Kottayam-686 603 Phone: 04829-245108,242229(Office) 9447114066,9447772219	09.01. 2007
14	SUPERMEAL II	"	09.01. 2007
15	GREENRICH	Excel Organics	15.01.2007

		Mavungal, Anandashram P.O., Kanhangad, Kasaragod Phone: 2203634,9349929900	
16	ABTEC ORGANIC MANURE	Agro Bio-tech Research Centre Ltd. Industrial Area, Poovanthuruthu P.O., Kottayam-12 Phone: 2341894,2340211	23.12.2006
17	ABTEC SUPER ORGANIC PLUS	"	23.12.2006
18	ABTEC SUPER MEAL	"	23.12.2006
19	ABTEC SUPER ORGANIC MANURE	"	23.12.2006
20	HARITHA SUPER	THE GRAMAKARSHAKA FERTILIZER COMPANY Pvt Ltd. Sasthamkotta, Kollam.-690521 Phone: 0476-2831310,2832310, 2833310	22.01.2007
21	HARITHA GOLD	"	22.01.2007
22	GOLDEN MEAL N: 5-7% P: 8-10% K: 4-5%	GODAVARI MANURES & INPUTS (P) Ltd Madhavasseril Building, Opp. Plantation Corporation, K.K. road, Kanjikuzhy, Kottayam-686 004 Ph: o481-2574696,2575696	18.12. 2006
23	PAVIZHAM ORGANIC	VEMBANAD CHEMICALS & FERTILIZERS Near Kaniyanmala Jn., Channanikkadu P.O., Kottayam-686533 Phone:9447600635, 9447383791 0481-6450745,9446534112, 9249444415, 9249444416	20.01. 2007
24	EXCEL MEAL	PACIFIC AGRO TECH Pvt Ltd. No. VI/36,Poovarani P.O., Paika, Kottayam-686577 Phone: 226822 [Pacific Agro Tech Pvt Ltd. 94, Canal Road, Girinagar, Kochi- 682020 0484-2312406	18.12.2006
25	EXCEL MEAL (without MOP)	"	18.12.2006
26	KARSHAKA AGROMEAL GRADE I	ORIENTAL MANURE MILLS Pvt Ltd. Industrial Development Plot, Door No. XVII/226, Poovanthuruthu, Kottayam-686 012 Phone: 0481-2342078,2564218, 2340508	22.12.2006
27	KARSHAKA AGROMEAL GRADE II	"	22.12.2006
28	KARSHAKA ORGANIC	"	22.12.2006
29	KARSHAKA ORGANIC TOTAL	"	22.12.2006
30	SABARIMEAL	SABARI CHEMICALS & FERTILIZERS	05.01.2007

		Kombodinjamakkal, Thazhekkad P.O., PIN- 680697 Phone: 0480-2788770, 9388429043	
31	BIOMEAL (7:10:5)	VENAD MANURES &FERTILIZERS Karakkad P.O., Alappuzha-689504 Phone: 0479-2423743 9447755494	20.12.2006
32	GREEN MEAL	GREENFERT AGRO RESEARCH CENTRE(P) Ltd Kottayam Phone: 98460 20450 0481-2300205	08.01. 2007
33	ECOMEAL	"	08.01. 2007
34	BIOMEAL	"	08.01.2007
35	BIOCARE	PLANTRICH, MIE, Manarcadu, Kottayam Phone: 0481-2371877,2371477 9447066757	18.12. 2006
36	STARMEAL	"	18.12. 2006
37	KOTHARIMEAL N: 3-5% P: 4-7% K: 1-2%]	KOTHARI INDUSTRIAL CORPORATION Ltd. Fertilizer Division, 11/159, Aymanam, Kottyam-686015 Phone: 0481-2517703	16.12.2006
38	JEEVOMEAL	WESTERN FERTILIZERS & CHEMICALS Amayoor Road Karakkunnu P.O Manjeri-676123 Malappuram Phone-0483-2769873	05.01.2007
39	P.L.MEAL	PL AGRO TECHNOLOGIES Ltd. Nagambadom Kottayam Phone: 2570334 2571632 (AgriOm,35/118, Omanalayam, Palarivattom,Kochi-682025)	08.01. 2007
40	RAJAMEAL	MCP AGRO TECHNOLOGIES (P) Ltd. PB No. 50, Irinjalakkuda-680121 Thrissur Phone:0480-2825106	20.12.2006
41	KALPAMEAL	STERLING FARM RESEARCH & SERVICES Pvt Ltd. Vyttila, Kochi-682019	09.01.2007
42	KANAKAM	"	09.01.2007

43	SKYMEAL	VEMBANAD CHEMICALS & FERTILIZERS Near Kaniyanmala Jn., Channanikkadu P.O., Kottayam-686533 Phone:9447600635, 0481-6450745	15.01. 2007
44	FARM GOLD	DEEPA FARM INPUTS (P)Ltd Edens, India Enclave, KERA 14/E, N.H. Bypass Enchakkal Jn. Phone: 0471-2508409	20.01.2007

Appendix II

Particulars of the sources of raw materials used for the manufacture of COMs

RM No.	Type of RM	Company, Address	Date of Sampling
1	Leather meal	Southern Fertilizers & Chemicals, Salim complex, Changanassery,Kottayam-686101 Ph-0481-2424779(office) 2424771 Factory: 2727930	22.12.2006
2	Bone meal	"	"
3	Leather waste	"	"
4	Pressmud	"	"
5	Essence extracted coffee beans powder	"	"
6	Leather meal (N: 8-10%)	SWAL Corporation Ltd. Nattakom P.O. Kottayam-686 013 Phone: 0481-2361005,2360154	16.12.2006
7	Castor cake (N: 3.5-4.5%)	"	"
8	Bone meal (N/P: 3.5/20%)	"	"
9	Bone meal	Godavari Manures and Inputs (P) Ltd.	18.12.2007
10	Neem cake	"	"
11	Leather meal	"	"
12	Bone meal- steamed, crushed and powdered bone (N: 3%, P: 20%)	PLANTRICH, MIE, Manarcadu, Kottayam Phone: 0481-2371877,2371477 9447066757	January, 2007
13	ABTEC biocompost	Agro Bio-tech Research Centre Ltd. Industrial Area, Poovanthuruthu P.O., Kottayam-12	December, 2006
14	ABTEC Vermicompost	"	"
15	ABTEC Decomposed husk	"	"
16	ABTEC Neem cake	"	"
17	Neem powder	"	"
18	Leather meal	"	"
19	Bone meal	"	"
20	ABTEC decomposed pressmud	"	"
21	Bone meal	Sabari Chemicals & Fertilizers Kombodinjamakkal, Thazhekkad P.O., PIN- 680697 Phone: 0480-2788770, 9388429043	15.01. 2007
22	Leather meal	"	"

23	Fish meal	Vembanad Chemicals & Fertilizers Near Kaniyanmala Jn., Channanikkadu P.O., Kottayam-686533 Phone:9447600635, 9447383791 0481-6450745,9446534112, 9249444415, 9249444416	18.12. 2006
24	Neem cake powder	Kothari Industrial Corporation Ltd. Fertilizer Division, 11/159, Aymanam, Kottyam-686015 Phone: 0481-2517703	16.12. 2006
25	Bio compost(Pressmud)	"	"
26	Bone meal	"	"
27	Coir pith (powdered)	"	"
28	Leather meal	"	"
29	Neem cake	The Gramakarshaka Fertilizer Company Pvt Ltd. Sasthamkotta, Kollam.-690521 Phone: 0476-2831310,2832310, 2833310.	22.01.2007
30	Fermented compost	"	"
31	Bone meal	Venad Manures &Fertilizers Karakkad P.O., Alappuzha-689504 Phone: 0479-2423743 9447755494	"
32	Leather meal	"	"
33	Leather meal	Vembanad Chemicals & Fertilizers	20.01.2007
34	Leather meal	Matha Biofertilizers Kuruppanthara, Manjoor P.O. Kottayam-686 603 Phone: 04829-245108,242229	22.01. 2007
35	Neem cake powder	"	"
36	Calcium powder	"	"
37	Bone meal	"	"
38	Fish meal	"	"
39	Neem cake	P L Agro Technologies Ltd. Nagambadom Kottayam Phone: 2570334 2571632 (AgriOm,35/118, Omanalayam, Palarivattom,Kochi-682025)	08.01. 2007
40	Bone meal	P L Agro Technologies Ltd. Nagambadom Kottayam Phone: 2570334 2571632 (AgriOm,35/118, Omanalayam, Palarivattom,Kochi-682025)	08.01. 2007

41	Leather meal	"	"
42	Bone meal	Pacific Agro Tech Pvt Ltd. No. VI/36,Poovarani P.O., Paika, Kottayam-686577 Phone: 226822 [Pacific Agro Tech Pvt Ltd. 94, Canal Road, Girinagar, Kochi-682020 0484-2312406	18.12.2006
43	Leather meal	"	"
44	Neem powder	"	"
45	Leather meal	MCP Agro Technologies (P) Ltd. PB No. 50, Irinjalakkuda-680121 Thrissur Phone:0480-2825106	20.12.2006
46	Bone meal	"	"
47	Ash	Western Fertilizers & Chemicals Amayoor Road Karakkunnu P.O Manjeri-676123 Malappuram Phone-0483-2769873 2785247 9447383076	
48	Groundnut seed shell	"	"
49	Neem cake	"	"
50	Pressmud	"	"
51	Bone meal	"	"
52	Bone meal	Oriental Manure Mills Pvt Ltd. Industrial Development Plot, Door No. XVII/226, Poovanthuruthu, Kottayam-686 012 Phone: 0481-2342078,2564218, 2340508	22.12.2006
53	Neem cake	"	"
54	Leather meal	"	"
55	Decomposed pressmud	"	"
56	Decomposed coir pith	"	"

Appendix III

Weather data for the crop period (November, 2007 to March, 2008)

Standard weeks	Rainfall (cm)	Temperature (°C)	Evaporation (mm)	Relative Humidity (%)
week45	20.45	30.63	3.38	92.7
week46	26.6	30.55	2.86	91.25
week47	0.0	31.03	3.33	89.58
week48	8.86	31.43	3.55	89.8
week49	0.0	31.83	3.57	83.86
week50	1.2	30.88	3.66	91.25
week51	2.4	29.49	2.37	93.42
Week52	0.0	30.15	3.3	90.88
week1	0.0	31.03	3.51	87.7
week2	0.0	31.85	3.65	84.37
week3	0.0	31.6	3.89	86.07
week4	0.0	31.6	3.58	88.5
week5	0.0	31.34	3.71	89.85
week6	12.87	31.65	3.63	83.94
week7	0.0	32.43	3.97	81.71
week8	0.0	32.53	3.87	84.6
week9	1.55	32.51	3.88	85.07
week10	0.0	32.14	3.93	88.56
week11	35.57	29.44	2.83	94.5
week12	24.2	31.55	3.75	86.75

Appendix IV

Average input costs and market price of produce.

Serial No.	Items	Cost (Rs.)
1.	Labour charge (Men & Women): November ,2007	218.00 day^{-1}
	December, 2007	218.00 day^{-1}
	January, 2008	218.00 day^{-1}
	February, 2008	218.00 day^{-1}
	March, 2008	218.00 day^{-1}
2.	Amaranthus seeds	800.00 kg^{-1}
3.	Fertilizers: Urea	6.00 kg^{-1}
	Mussooriephos	6.00 kg^{-1}
	MOP	5.00 kg^{-1}
4.	Manures FYM	290.00 $tonne^{-1}$
	COMs	10.00 kg^{-1}
	SCMs	1.00 kg^{-1}
5.	Market price of amaranthus	7.00 kg^{-1}

DEVELOPMENT OF PROTOCOL FOR QUALITY CONTROL OF COMMERCIAL ORGANIC MANURES AND THEIR EVALUATION

GOWRI PRIYA

Abstract of the
thesis submitted in partial fulfillment of the requirement
for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2008

Department of Soil Science and Agricultural Chemistry
College of Agriculture
Vellayani, Thiruvananthapuram-695 522

ABSTRACT

The research project entitled "Development of protocol for quality control of commercial organic manures and their evaluation" was conducted at College of Agriculture, Vellayani during 2006-2008, with the objectives of quality evaluation of the major commercial organic manures in Kerala, development of a quality protocol for assessing quality and detecting adulteration in commercial organic manures, studying the mineralization pattern of major nutrients in selected manures and their comparative effect on crop performance.

Forty four commercial organic manure products and their raw materials were collected from the manufacturers allover Kerala and their physical, chemical and biochemical characters were analysed. Standard compost manures viz., standard vermicompost, standard coirpith compost and standard city waste compost were prepared at the Instructional Farm, College of Agriculture, Vellayani and their physical, chemical and biochemical characters were analysed. The raw materials viz. bone meal, leather meal and neem cake were mixed in different proportions and the characters of the resulting organic meal mixtures were estimated. Based on these data, a protocol was developed to predict the nitrogen, phosphorus and potassium contents of the organic manures prepared by mixing bone meal, leather meal and neem cake in any ratio. A storage experiment was conducted to study the changes in quality aspects of organic manures during a period of one year. The quality parameters of market samples and the corresponding factory samples of COMs were compared. An incubation experiment was conducted to study the nutrient mineralization pattern of organic manures. A field experiment was carried out to evaluate the performance of selected organic manures using amaranthus variety Arun as test crop.

The results of the investigation revealed that none among the forty four commercial organic manures conformed completely to the quality standards specified by the Fertilizer (Control) Amendment Order, 2006, of the Government of India. The colour of COMs varied depending on their raw materials (ingredients) and the odour of COMs varied depending on raw materials and the state of decomposition. The total nitrogen contents of COMs varied from 0.7 per cent to 7.87 per cent. Majority of the COMs had total nitrogen contents between 2.8 per cent and 5.85 per cent. The C/N

ratio of COMs varied from 2.86 to 43.18 and only one product viz. SN 4 (Neem cake marketed by TIFFCO Fertilizers & Chemicals) had a ratio more than 20:1. All the COMs contained satisfactory level of total organic carbon. The total phosphorus content varied from 0.12 per cent to 4.57 per cent and the total potassium content in COMs varied from 0.12 per cent to 7.87 per cent. Only eighteen of the COMs had pH in the neutral range and with respect to EC, only three COMs were good for use having EC values less than 4 dS m^{-1}. Based on heavy metal contents, the COMs P.L.meal (PL Agro Technologies Ltd.), Skymeal (Vembanad Chemicals & Fertilizers) and Haritha Super (The Gramakarshaka Fertilizer Company Pvt Ltd.) were found unsuitable for long term application to soil.

The standard compost manures did not conform to the specifications of moisture content and bulk density as per Fertilizer (Control) Amendment Order, 2006. The total nitrogen content of SVC was 1.4 per cent, SCC 0.7 per cent and SCWC 2.1 per cent. All the three SCMs recorded C/N ratios below 20. SVC and SCWC had satisfactory levels of total P while SCC was poor in total P. The three SCMs did not contain enough total K to conform to the minimum limit prescribed by the Fertilizer (Control) Amendment Order, 2006. The pH of SVC and SCWC were within the neutral range of 6.5- 7.5, while SCC was more acidic with pH of 3.93. The electrical conductivity of the SCMs ranged from 0.33 to 3.4dS m^{-1}. The total organic carbon contents of SCMs were above 30 per cent. SCMs had heavy metal contents below the maximum limits prescribed by the Fertilizer (Control) Amendment Order, 2006.

The analysis of raw materials revealed that leather meal was a good source of nitrogen, bone meal and pressmud were good sources of phosphorus and pressmud was the best source for potassium.

The mathematical models developed for predicting the N, P and K contents of any mixture of bone meal, leather meal and neem cake were:

N estimated= 3.62088 BM+ 6.58962 LM+ 1.74407 NC+ 4.74391 (BM)x(LM) + 7.8398 (BM) x (NC) – 9.87862 (LM)x(NC), where BM is the proportion of bone meal in the mixture, LM is the proportion of leather meal in the manure and NC is the proportion of neem cake in the mixture.

P estimated= 8.41214 BM+ 0.37157 LM+ 0.41953 NC- 2.73548 (BM) x (LM) + 10.15749 (BM) x (NC) – 8.72905 (LM) x (NC)

K estimated= 0.38543 BM+ 0.01872 LM+ 1.19747 NC+ -0.04393 (BM) x (LM) + 2.98573 (BM) x (NC) – 5.64704 (LM) x (NC)

The model could be used for finding out adulteration of organic manures with inorganic fertilizers to boost their nutrient contents. Different ratios of bone meal, leather meal and neem cake were worked out to prepare organic manures with different levels of N, P and K.

The results of the storage study showed that the organic carbon content of organic manures decreased from the initial value during the storage period of one year. The changes in nitrogen, phosphorus, potassium and sodium contents of organic manures showed varying patterns during storage.

Comparison of quality of market and factory samples of COMs revealed that the organic carbon and nitrogen content of all the market samples were significantly less than their corresponding factory samples while P and K contents showed varying patterns.

The mineralization patterns of major nutrients from the organic manures in incubation experiment indicated that in general, the available nitrogen and phosphorus contents in soils treated with organic manures increased upto 30-45days after incubation and decreased thereafter. The mineralization pattern of potassium from organic manures in soil showed pronounced variation. The treatment with Karshaka Agromeal Grade I (SN 26) recorded higher contents of N, P and K.

In the field experiment the highest yield in the first crop was in the treatment with NPK fertilizers + Karshaka Agromeal Grade I. The control treatment with no fertilizers and manures recorded the lowest yield. The application of organic manures was found to improve the quality aspects of the crop. The highest content of available N in soil after harvest of first crop was recorded in T_{10} (NPK fertilizers + SVC) and lowest available N content was observed in T_{4}. The available phosphorus content after harvest of first crop was highest in T_7 (NPK fertilizers + Golden meal) and the lowest value of available P_2O_5 was observed in T_6 (NPK fertilizers +Skymeal). The available potassium content after harvest of first crop was highest in T_{10} and the lowest content of available potassium was obtained from T_{14}. Application of organic manures was found to raise the pH of the soil in treatment plots. The electrical conductivity of soil was significantly influenced by the different treatments. The highest yield, total dry matter production, total marketable yield and total yield per plant of the second crop was recorded in T_7 (NPK fertilizers +Golden meal) and the lowest was in T_{14}. The highest B: C ratio of 1.31 was recorded in T_4 and the lowest value was recorded in T_{14} (absolute control) which had a B:C ratio of 0.90.