FORMULATION AND EVALUATION OF ORGANIC MEALS FROM KCPL EFFLUENT SLURRY

By

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THESIS

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**Department of Agronomy
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DECLARATION

I hereby declare that the thesis entitled "**Formulation and Evaluation of Organic Meals from KCPL Effluent Slurry**" is a bonafide record of the research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Socieity.

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CERTIFICATE

Certified that the thesis entitled "**Formulation and Evaluation of Organic Meals from KCPL Effluent Slurry**" is a record of research work done independently by **Ms. Lency Thomas** 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.

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CONTENTS

LIST OF TABLES

List of Tables contd...

List of Tables contd...

LIST OF FIGURES

List of figures contd....

List of plates

List of plates contd....

LIST OF APPENDICES

Introduction

Chapter 1

INTRODUCTION

The chemical inputs have become the mainstay of Indian agriculture after the advent of green revolution. Nevertheless this led to a decline in the use of organic manures. Despite the advantages the complete dependence on chemical fertilisers also led to many problems in modern agriculture, the major one being soil degradation. There has been a slow but steady decline in the productive and recuperative capacity of the soil. Sustainable production could be achieved only when factors leading to continued maintenance of soil health are taken care of. Hence the complementary role of organics as supplements to chemical fertilisers is important for keeping the soil health in order and sustain higher crop production.

The organic manures being bulky in nature are low in nutrients and thus have to be applied in large quantities to meet the nutrient demand of the crops. Moreover due to high temperature and rainfall in the tropics there is faster depletion of organic matter and this necessitates the search for good quality manures to sustain soil health.

The major problem that the farmers face today is the non-availability of adequate quantity of organic manures due to decreasing cattle population, improper collection methods and diversion of agricultural wastes into different byproducts. At the same time as a result of growing urbanisation and industrialisation enormous quantities of solid wastes, both domestic as well as industrial, is generated each year and their accumulation is causing severe environmental problems. Most of these waste materials contain many major and minor nutrients and can serve as a good source of organic manure and soil amendment. Thus there is a growing need to develop ways and means to utilise these industrial wastes effectively. Moreover, greater concern about environmental pollution, health and hygiene coupled with the need to maintain soil fertility has diverted the attention of farmers to adopt organic waste recycling.

Recycling of organic wastes not only helps to consume natural resources and save energy but also offers the potential of reutilising secondary materials for beneficial uses as well rather than their discharge into the environment, which cause detrimental effects on man. Recycling is essential for persistent agriculture as well as to maintain a pollution free environment. Hence the conversion of solid wastes into useful organic fertilisers by efficient and effective technology and their effective utilisation would be complementary sources of plant nutrients under different soil crop management systems. Thus land application of waste in agriculture is one of the most economical and attractive methods of solving the dual problem of waste disposal and necessity to maintain organic matter content of soils.

There are several instances of successful utilisation of agro-industrial wastes like coir pith, press mud, flyash, phosphogypsum, lime sludge etc in agriculture. One such industrial waste generated in huge quantity that requires effective disposal mechanism is KCPL sludge produced by Kerala Chemicals and Proteins Ltd (KCPL). The KCPL factory situated at Kathikudam near Koratty in Thrissur district produces *ossein* an intermediate product in the manufacture of gelatine and dicalcium phosphate from crushed animal bones using hydrochloric acid (HCl) and hydrated lime ($Ca(OH)_2$) treatment. During the above process about 15 t of effluent sludge diluted to an approximate volume of 100 m^3 is accumulated daily for which no effective disposal mechanism is in vogue. This is a major problem to the company as well as to the nearby inhabitants since the accumulated sludge is causing a lot of environmental problems to the extent of denying clean and pleasant air in the surroundings, nauseating and asphyxiant tendencies to nearby locals for want of scientific and effective disposal techniques. Gopinathan (1996) in a preliminary study found that it is a rich source of nutrient especially P and Ca and has the potential to be used as soil enricher or organic fertiliser based on proper bioprocessing techniques. Initial observational trials were so much encouraging that the sludge on proper processing can form a phosphorus rich organic manure, besides providing an effective disposal techqniue for a hitherto unattempted material of environmental risk. The utilisation of KCPL sludge as an organic source appears to be environmentally, agronomically and economically safe and a sound alternative since they provide a locally available source of nutrients and reduce the risks of pollution and cost of disposal. Thus the present study was taken up with the following objectives.

(1) Study on the basic properties of the material

(2) Standardisation of formulation techniques of organic meals and its properties

(3) Evaluation of the influence of organic meal on crop and soil under laboratory and field condition

Being a new material and in the absence of previous information on the limitations and advantages of substrate induced environment, the present study, as evident from the methodological approaches, assumes a matter of designing and redesigning operating system for developing a practically viable solution to the target problem. Repeated experiments were necessitated especially with the standardisation and formulation part of the study involving a variety of engineering devices and modified support facilities. This approach was very much essential to avoid a situation such that no operational, nutritional, environmental or other conceivable factor becomes limiting. Yet another fact of limiting factor principle is its positive relation to sound economics. This most sensitive aspect which ultimately decides the acceptability of any organic manure predominated all the formulation efforts and finally the aerobic composting option proved itself as a possibly profitable method for the effective utilisation of the sludge material. Subsequent chapters of this dissertation carry the details of exhaustive sets of experiments right from the basic property evaluation, followed by a variety of bio-processing options, engineering support devices and finally a series of pot, plot and farm culture studies to judge the properties and utilisation of the end product.

Review of Literature

Chapter 2

REVIEW OF LITERATURE

2.1. The Problem

Wastes are inevitably produced by agricultural, industrial and human activities, the most important problem being their disposal. Open dumping and other improper disposal measures caused serious hazards to public health including pollution of air and water resources and interfered with community life and development especially in climatic conditions characterised by high rainfall and temperature (Canter, 1978).

The solid wastes more recently referred to as biosolids, have traditionally been placed in municipal landfills, incinerated, ocean dumped or applied to agricultural land. Lesser amounts were used for reclamation of disturbed lands (Logan and Harrison, 1995). Problems caused to modern society by solid wastes became more severe over the last ten years because of increasing amounts of waste and decreasing availability of land fill space (Alter, 1991; Finstein, 1992).

India generated 345 million tonnes of solid waste annually of which approximately 25 million tonnes were MSW and 320 million tonnes were agricultural residues (Thimmaiah and Bhatnagar, 1999). In Delhi alone 4000 plus tonnes of solid waste was produced each day and the nine major cities in India produced 8.5 million tonnes of solid waste per annum (Bhatnagar, 1994).

The content and quality of waste produced depend on the standard of living of the people. According to Goyal (1994) an average Indian produced 0.4 kg of solid refuse per day whereas an American produced seven times and an average Japanese four times more. The city of New York alone produced 30,000 tons per day, the highest in the world with per person average of 2 kg per day of MSW. The corresponding figures for Mumbai were 600 t per day and 600 g per day respectively.

According to Bhinde (1999) the urban population may be double that of 1991 in 2011 but the quantity of waste generated will triple. It will increase from 20.71 million tonnes in 1991 to 39.38 in 2001 and to 56.33 million tonnes in 2011. He also opined that 30 mt of solid waste was generated each year in urban India.

The Central Pollution Board Survey revealed that the total quantity of solid waste generated by 23 large cities in the country was of the order of 30,058 tonnes per day. Mumbai generated the maximum with 5,335 tonnes per day and Vishakapatanam the least at 300 tonnes per day. The respective per capita values were 0.436 and 0.4 kg per day. In Kochi 347 tonnes of solid wastes was generated per day and the per capita waste generation was 0.518 kg per day. According to the survey per capita waste generation in India was 200-400 g per day (Ahmed and Jamwal, 2000).

A rapid exploratory survey in Thrissur municipality revealed that daily MSW production was about 90 tonnes with per person average of 1.2 kg per day (Gopinathan, 1994).

According to Hamza (1989) uncontrolled discharge and open dumping of agro industrial wastes contributed to appreciable environmental deterioration which was manifested as:

- Serious hazards to public health
- Pollution of air and water bodies
- Increased eutrophication due to excessive discharge of nutrients
- Depletion of dissolved oxygen in surface water
- Offensive odours due to anaerobic decomposition of organic residues
- Unsightly conditions in waste storage and land disposal sites

Kuroda *et al.* (1996) also stated that large amount of malodorous gas emitted from wastes caused complaints from nearby residents.

2.2. Importance of recycling organic wastes

Resource recycling, reprocessing and utilization are now considered as the only sensible way to tackle the problem of solid waste management (Thippaiah, 1996).

The International Union of Pure and Applied Chemistry (IUPAC) established a committee on recycling of solid wastes in 1976. Examining the effects of recycling and/or heat energy transformation on agricultural as well as municipal wastes such as sewage sludge, city refuse and industrial wastes, the committee concluded that biological conversion method is as important in the utilization of urban and industrial as of agricultural wastes (IUPAC, 1977). A survey on the recycling of waste materials from animals, human wastes, crops etc revealed that complete return of organic wastes to farm lands was the most effective method for maintaining soil productivity and stabilising agricultural production (FAO, 1977).

USDA (1978) reported a growing shortage of good quality on farm organic wastes for use as soil conditioners and biofertilizers because of competitive use as fuel, fodder and fibre. Jaag (1978) opined that different waste materials could be processed to fertilizer and by this wastes were reintegrated into the natural cycle. The nutrients in livestock wastes were efficiently recycled on the farm and it helped in the conservation of world's exploitable natural resources particularly phosphate resources (Russell, 1978).

The USDA committee on Organic Farming (1980) recommended that not only agricultural wastes but sewage sludge and other municipal and industrial refuse be recycled to farm lands to restore and maintain soil productivity at a high level. About 75 per cent of crop residues and animal manures generated in the US were returned to the land (Parr and Wilson, 1980).

The restoration and rehabilitation of degraded and marginal soils to an acceptable level of productivity could be enhanced by using various off-farm sources of organic wastes including sewage sludge, MSW and agricultural and industrial processing wastes (Hornick and Parr, 1987; Parr and Hornick, 1992).

At the national level Biswas (1991) reported that there is a potential for supplying 3.44, 1.31 and 2.21 mt of N, P_2O_5 and K_2O respectively from the annual production of cattle and buffalo wastes. The nutrients present in these could be recycled either by composting, mulching or direct incorporation into the soil. According to Gill (1993) the wastes could be processed by conversion processes and the final product should be non-pollutant and safely used in economic or agricultural activity. Jain (1993) emphasized on the importance of agricultural residues and these could supplement chemical fertilizer needs of next crop.

Bhardwaj (1995) reported on the possibility of gathering 750 million tonnes of cattle dung, 250 million tonnes of buffalo manure and hundreds of million tonnes of rural and urban compost. He also opined that the organic wastes available in India were estimated to supply 7.1, 3.0 and 7.6 mt of N, P_2O_5 and K_2O respectively. The crop residues alone supplied 1.13, 1.41 and 3.54 mt of N, P_2O_5 and K_2O respectively. Kair (1996) reported that 6 mt of plant nutrients were wasted through improper utilization of farm organic wastes. By proper recycling about 50 thousand tonnes of plant nutrients were added back to soil. Organic recycling practices allowed farmers to maximise their crop production with negligible soil erosion and nutrient run off (Parr *et al.*, 1994).

The technologies used for recycling varied greatly depending on waste material and site characteristics. An understanding of principles and problems of various technologies is essential to make a wise choice (Smith and Chambers, 1995).

2.3. Industrial, farm and domestic organic wastes

The increased use of animal waste, poultry waste, agricultural residues and digested sludge as nutrient sources and recycling of urban solid wastes have been advocated for providing futuristic energy and fertilizer source (Hobson *et al.*, 1981; Vimal and Talashilkar, 1983).

The major sources of organic wastes available in India are farmyard manure, rural and urban compost, sewage sludge, agro-industrial by products and industrial wastewater. Nutrient potential of these sources come to 6.08 mt N, 5.1 mt P_2O_5 and 7.86 mt K_2O respectively (Gaur, 1992).

Farmyard manure is the traditional manure that supported our crop production system for ages. According to Gaur *et al.* 1971 the production of dung and urine from bovine was about 1002.6 and 658.9 mt respectively. Biswas (1991) reported that the annual excretion of wet dung and urine from cattle and buffalo worked out to 1228 and 800 mt respectively. Several long term manurial studies involving farmyard manure have been carried out throughout the country and its efficacy has been amply demonstrated (Sahu and Nayak, 1971; Varghese and Pillai, 1990; Anilakumar *et al.*, 1993; Verma and Bhagat, 1993).

Poultry manure could be used as a good source of nutrient with 60 per cent nitrogen as uric acid, 30 per cent as more stable organic nitrogen and balance as mineral nitrogen (Srivastava, 1988). Singh and Srivastava (1971) and Singh *et al.* (1973) also attributed the higher efficiency of poultry manure to its narrow C: N ratio and comparatively higher content of readily mineralisable nitrogen. Budhar *et al.* (1991) also emphasised the superiority of poultry manure as an organic source.

Organic wastes like ammonium humate from coal, blood meal manure, paper mill sludge, pencillin waste, cotton wastes, rice husk, sea weeds, silk worm litter, press mud, poultry and pig manures on different crops could supplemented 1/3 to 1/2 of nutrients required for field crops besides leaving residual effect which resulted in 10-20 per cent yield improvement (Gaur, 1982 (a); Maskina *et al.*, 1988; Sahu, 1990; Palaniappan and Prasad, 1994). Govi *et al.* (1996) also reported that leather meal, poultry manure, blood meal, fish meal and distillery wastes were good organic fertilizers and of these the most widely used nitrogen organic fertilizer in Italy was leather meal.

Utilization of crop residues to provide plant nutrients directly to the crops and to maintain soil fertility status is important. Crop residues alone could supply about 0.5, 0.6 and 1.5 million tonnes of N, P_2O_5 and K_2O respectively (Veeraraghavan *et al.*, 1983). According to Gaur (1992) the potential of cereal straw residues from rice, wheat, sorghum, pearl millet and bajra were 1.13, 1.41 and 3.54 mt of N, P_2O_5 and K_2O respectively. Bhardwaj (1995) estimated that the major crops of India annually generated a total of about 274 mt of crop residues.

Among the different agro-industries, sugar industry is the biggest one producing 274 million tonnes of press mud annually (Rai *et al.*, 1980). They also reported that for every 100 metric tonnes of cane crushed, the factory produced 3.0 tonnes of press mud a waste by product. The vast quantities of cellulosic wastes generated during the processing of rice, sugarcane, cotton, timber and other crops could be applied safely to crop land (Silva and Breitenbeck, 1997).

Coir pith a highly lignocellulosic material is available in large quantities as a by product of coconut coir industry. According to Arumughan and Damodharan (1993) there are about 84,000 retting and coir extracting units in Kerala producing white fibre and about 650 brown coir units located in Tamil Nadu, Karnataka and AndraPradesh. These produce considerable amount of coir pith, which goes mainly unutilized. Ravichandran (1988) stated that coir pith contained 0.68 per cent N, 0.026 per cent P, 0.36 per cent K and small amounts of secondary and micronutrients. Coir pith was capable of adsorbing heavy metals and improving leaching properties of soils (Singarum and Pothiraj, 1991). The unique property was its high water holding capacity in the range of 400-600 per cent (Savithri and Khan, 1994). The wider C/N ratio of 112:1 coupled with low N content, presence of soluble tannin and phenolic compounds (8-12%), low biodegradability were some of the problems associated with the direct application of coir pith to field crops (Fan *et al.*, 1982).

Oil cakes of non-edible type like castor, neem and karang were widely used as organic manure. The non-edible oil cakes contained high amount of plant nutrients (Joseph *et al.*, 1983). Most of the non-edible oil cakes were valued much due to their alkaloid contents, which inhibited nitrification process in soils (Reddy and Prasad, 1975; Rajkumar and Sekhon, 1981).

Vast amounts of nutrient rich industrial wastes are available as a result of growing urbanization and industrialisation (Arya *et al.*, 1981). The fly ash, a waste material from thermal power stations is an amorphous ferro-alumino silicate mineral containing 50 per cent silica and rich in Ca, Mg, Na and K (Fisher *et al.*, 1976). The alkaline nature of fly ash added to its use as liming agent to replace $CaCO_3$ on acidic agricultural soils (Martens, 1971; Adriano *et al.*, 1980; Moliner and Street, 1982). At low application rates fly ash improved certain agronomic properties of soils (Chang *et al.*, 1977). Coal residues were used as a supplementary sources to supply of Ca, S, B, Mo and Se to soils (Adriano *et al.*, 1980). Boron was the major limiting factor in the successful utilization of ashes in crop production (Elseewi *et al.*, 1978; Ciravolo and Adriano, 1979).

Patnaik *et al.*, 1968 recommended industrial by products like paper mill sludge and blast furnace slag as substitutes for lime in correcting soil acidity and increasing rice yields. Simson *et al.* (1981) reported that a lime sludge mixture contained about 94% $CaCO_3$ and 5% $MgCO_3$ and very low concentration of metals. The slag from ferrochrome industry with considerable amount of Ca (31%) and Mg (6%) could be used as a liming material for acid soils without any deleterious effect on rice plant (Sarkunan *et al.*, 1993). Paper mill sludge and lime by products were found to be more effective than agricultural lime at neutralizing soil acidity when applied at equivalent rates based on their calcium carbonate equivalent. Moreover these could provide supplemental quantities of P, K, Ca, Mg and other plant nutrients (Muse and Mitchell, 1995). Organic rich paper sludge and sludge-based composts served as soil amendments and also alleviated disposal problems (Bellamy *et al.*, 1995).

Mishra (1980) reported that phosphogypsum, by product of fertilizer industry was used primarily as soil amendment or conditioner for sodic soils. According to Alcordo and Rechigl (1993) phosphogypsum is essentially hydrated $CaSO_4$ with small proportions of P, F, Si, Fe and Al and it could be used as a source of sulphur and calcium for crops and as an ameliorant for subsoil acidity and as a bulk carrier for micronutrient and other low analysis fertilizers.

The rapidly increasing amounts of municipal wastes could serve as an alternate source of organic amendment that can be used safely and beneficially to increase productivity (Bhardwaj and Gaur, 1985). Adding MSW material improved the soil water and nutrient holding capacities due to the presence of low concentrations of essential elements (Chaney *et al.*, 1980). The biodegradable fraction of MSW could be composted or co-composted for beneficial use as soil conditioner and biofertilizer (Parr and Hornick, 1992). The use of MSW composts in agriculture is a practical alternative to other disposal methods (Hampton *et al.*, 1994).

Sewage sludge has been utilized in agriculture for many years and represents a good source of nutrients for plant growth and as a soil conditioner to improve soil physical properties (Matthews, 1984; Bowen *et al.*, 1992; Logan and Harrison, 1995). Sludges are valuable liming materials due to high Ca content (Sommers *et al.*, 1976). Due to their relatively high P content urban sewage sludge have been used as source of P for agricultural crops (Kirkham, 1982). The addition of sludge to soils have increased the soil available P, plant uptake P or even both (McCoy *et al.*, 1986; Frossard *et al.*, 1996 and Condron *et al.*, 1996). According to Mchaughlin and Champion (1987) sewage sludge exhibited the characteristics of a P fertilizer in two P deficient soils. Efficiency of sludge P as a fertilizer P source increased with time. It also served as an efficient resource of N because of its high N content (2-6 per cent) and faster mineralisation rate (Sims, 1995). Sewage sludge is continually used as source of nutrients and as an organic amendment for improvement of soil physical properties (Bansol and Gupta, 1998).

2.4. Liquid waste and sludge disposal

According to Farel (1974) the sludge production in India was in the order of 40 kg primary, secondary and tertiary sludge per person per annum on dry weight basis. In the past, application to arable land has been the common way to recycle organic wastes, solid urban refuses and sewage sludge after treatment (Duncan, 1974; Anon, 1976). Before 1980's, the sludge was biologically digested as a means to stabilise the organics and to reduce pathogens. In the 1980's, more advanced technologies for sludge treatment were emerged that produced a pathogen free stabilised organic matter (Logan and Harrison, 1993). The most widely used two approaches are biological composting and alkaline stabilisation (Logan and Harrison, 1995).

The land application of compost from sludge could be one of the most economical and attractive methods of solving two problems - waste disposal and necessity to increase organic matter content of soils (FAO, 1975; Chen and Avnimelech, 1986).

Sewage sludge is an important source of organic matter and plant nutrients (Halderson and Zenz, 1978; Biswas and Mukherjee, 1990). By proper situation specific management techniques sludge could substitute chemical fertilizers to certain extent (Farel, 1974). Sewage sludge @ 300-500 t $ha^{-1}a^{-1}$ on dry weight basis on strongly acid mine soils was reported to have raised the pH from 2.5 to 6.0 and to enhance establishment of protective and productive vegetation (Cunningham *et al.*, 1975). Kirkham (1982) found that application of sewage sludge increased the nutrient status of soil.

The physical condition of the soil was improved by application of sludge (Hall and Williams, 1984). In many developed and developing countries sewage sludge was effectively utilized for agricultural purposes and for fisheries (Maiti *et al.*, 1992). Studies in Coimbatore revealed that sewage sludge high in nutritive content could be applied at 5-20 t/ha so that available sludge could be spread over wider area and adverse effects eliminated or reduced (Paulraj and Sreeramulu, 1994). According to Bellamy *et al.* (1995) organic constituents in sludge are potential soil conditioners hence composting and land application were attractive alternatives to disposal. Adhikari *et al.* (1993) opined that long-term application of sludge, as manures in large scale on agricultural land incorporated huge amounts of heavy metals into the soil. Sewage sludge in landfills is considered as a potential source of non-point P pollution (Ryden, 1996).

The sludge from paper mills were placed in landfills but increasing land fill costs and decreasing land fill space forced these mills to seek alternative disposal methods (Hatch and Pepin, 1985). Only less than ten per cent was land applied (Erich and Ohno, 1992). Since these contain high organic matter there is potential for increased land application (Muse and Mitchell, 1995).

About 60 per cent of sludge from Swedish treatment plants was spread on agricultural land (Bollmark, 1991). In the US more than 30 per cent of sludge produced was utilized beneficially on agricultural and non-agricultural land as compost or by land spreading and liquid sludge injection (Parr and Hornick, 1992). In Japan liquid waste was subjected to sewage disposal treatments such as activated sludge system and solid waste was composted (Kuroda *et al.*, 1996). Due to economic reasons sludge was usually spread on arable land near urban areas (Ryden and Ottabbong, 1997).

According to Manna and Ganguly (1998) the different options available for sewage sludge are recycling and ocean dumping, spreading sludge on land, composting and sequential treatment of sewage. Proper situation specific management technology should be selected for effective disposal.

Liquid wastes in general include large volume of effluents from industries, sewage from cities and animal wastewaters. Although solid wastes could be utilized as compost the utilization of wastewater was very difficult due to transportation and storage problems (Harada, 1990).

The quality of wastewater varied with the type of industry and type of use (Som *et al.*, 1994). Many industries in India presently discharge their untreated wastewater on land or nutrient streams. About 65 to 70 per cent of wastewater do not get any treatment (Kaul *et al.*, 1989). About 13,153 million gallons of wastewater was released everyday in India. Moreover about 350 sugar mills and 212 distilleries, small scale dairies, slaughter houses, tanneries and pulp and paper mills are also generating waste water (Manna and Biswas, 1996).

In North Arcot, Ambethkar district of Tamil Nadu, about 35,000 ha of cultivable land was affected either fully or partially due to tannery effluent pollution (Perumal and Singarum, 1996). Large scale discharge of waste water into water courses under untreated or partially treated condition caused depletion of oxygen in receiving waters which resulted in large scale mortality of fish and other aquatic life (Joshi *et al.*, 1996). Indiscriminate disposal of liquid wastes caused pollution of air, soil as well as underground water supplies (Baddesha *et al.*, 1997).

Effluents from sugar factory, fertilizer factory and paper industry are rich in nutrients and could be used after proper treatment (Sivaramakrishnan *et al.*, 1983). Azad *et al.* (1986) observed an increase in total and available content of N, P and K in soils by use of sewage water for irrigation. Calcutta sewage was extensively used for irrigating foliage, vegetables and in fisheries (Mitra *et al.*, 1995).

40 million litres of effluent generated every day from the paper factory at Pallipalagam near Erode was pre-treated and used for raising sugarcane in 2000 acres. This was used continuously and analysis of soils and crops did not show any adverse effect (Sreeramulu, 1994). In the Howrah sewage treatment plant sewage was treated by trickling filter method and effluent was used to irrigate nearly 550 ha of agricultural land

(Som *et al.*, 1994). Mitra and Gupta (1999) also stated that the industrial and domestic effluents with solid and liquid components was disposed of on land for irrigation purposes due to non-availability of fresh water.

A limiting factor in the long term and indiscriminate application of sewage effluent to agricultural land was the excessive accumulation of heavy metals such as Zn, Cd, Pb, Cr and Ni in the soil and resultant phytotoxicity (Taddesse *et al.*, 1991). Many sewage and industrial wastes contained high amount of Cd and their disposal on agricultural land increased its level in soils (Azad, 1981). But sewage irrigated soils with high pH, organic C and CEC retained higher amount of Cd and acted as sink for disposal of Cd (Rana and Kansal, 1983). Long term and indiscriminate application of raw sewage effluent, which contained heavy metals in association with suspended sludge particles, caused accumulation of heavy metal in surface and subsurface soils (Gupta, 1990).

Characterisation of sewage effluent and sludge of Calcutta city revealed that sewage effluent was neutral to slightly alkaline in reaction, rich in NH_4-N, NO_3-N, available P but bicarbonate and chloride ions were at toxic level. Hence toxicity due to micronutrients need to be considered before their application to soil (Maiti *et al.*, 1992). The animal wastewater was usually treated by activated sludge process (Osada *et al.*, 1991). Small scale farms treated their wastes by drying them. Wastewater was evaporated by the heat generated from fermentation of compost or wind or solar power or by use of a fan (Harada *et al.*, 1990).

High value liquid produced during an aerobic digestion of organic wastes was used for its soil conditioner and fertilizer value (Kimchie *et al.*, 1988). The liquid fraction was used as an amendment for fresh water fish ponds (Lumbroso *et al.*, 1980).

The use of biogas slurry in proper combination with chemical fertilizers was one of the major steps of integrated nutrient management for sustainable agriculture (Jain, 1993).

The distillery effluent characterised by its large volume, foul odour and dark colour was applied on land as irrigation water and as a source of plant nutrient (Jadhav and Savant, 1975). Farmers in Maharashtra and Andhra Pradesh utilized the distillery effluent by direct application and making spent wash cakes whereas in Uttar Pradesh post methanation effluent was applied to the crops (Joshi *et al.*, 1996).

2.5. Biomethanation

Anaerobic fermentation of organic wastes that produces a mixture of methane and CO_2 and leaves behind digested residue enriched in nutrients is called biomethanation. The technology of efficient recovery of both gas and manure is popularly known as biogas technology.

A large number of feed stocks ranging from different animal manures, crop residues, agro industrial wastes, fruits and vegetable processing wastes, weeds were evaluated for their biogas generating potential and some of these have been extended to field level testing (Maheshwari and Jain, 1990). A maximum yield of 0.419 m^3 of biogas per kg volatile solid added with 62 per cent methane was obtained in digesters fed with cow dung slurry of 8 per cent total solids at 30 days hydraulic retention time (HRT) (Xavier and Nand, 1990).

Methane production from dairy cattle waste was investigated in anaerobic reactors at 60°C with retention time of 3, 6 and 9 days. Influent concentrations of volatile solids were increased in steps of 2 per cent from 4 to 14 per cent volatile solids. The maximum concentration of volatile solids (VS) in the substrate for highest volumetric fermentation efficiency was 8-10, 10-12 and 12 for HRT of 3,6 and 9 days respectively. The corresponding methane production rates were 0.09-0.12, 0.11-0.14 and 0.11-0.16 l/day/g of VS in substrate. The gas contained 51-56 per cent methane with rest mainly CO_2 (Wohlt *et al.*, 1990). Rorick *et al.*, 1980 also reported similar values of methane production from dairy cattle waste.

The effect of water, buffer and sludge addition on enhancement of gas production revealed that an increase in moisture content coupled with buffering to a pH around 7 and addition of nutrients decreased the lag time while increasing both the yield and rate of methane generation (Emcon Associates 1981; Klink and Ham, 1981 and Wise *et al.*, 1981). Agricultural waste mixed with animal waste when fed to digester produced more gas than using animal waste only (Vijay and Kotwaliwale, 1990).

According to Buivid *et al.* (1981) methane production significantly increased with a conversion of over 50 per cent of the biodegradable MSW to methane. Several workers have demonstrated that the fermentations operating at thermophilic temperatures resulted in more rapid degradation of organic matter (Hashimoto *et al.*, 1981; Lo and Marsh, 1985; Kimchie *et al.*, 1988). In a commercial plant treating a mixture of sewage sludge and MSW @ 80 t per day 1.5 million m^3 biogas was produced per year at HRT of ten days (Cecchi *et al.*, 1988).

Fruit and vegetable processing wastes were highly biodegradable as they were rich in organic matter and had high moisture content. Above 50 per cent of moisture content it is found that bioconversion processes were more suitable than thermo conversion processes (Bardiya, 1991). A mixture of fruit and vegetable wastes subjected to anaerobic digestion produced 0.12 m^3 biogas/kg TS added at an HRT of 16 days (Prema *et al.*, 1992). While Mata-Alvarez *et al.* (1992) observed a gas production of

0.64 m^3 biogas/kg TS added in case of food market waste. Bardiya *et al.* (1996) stated that higher rate of gas was produced at lower retention time.

2.6. Composting

Sludge composting has increased in both use and acceptability in recent years since it reduced offensive odours and difficulties in handling, inactivateed pathogens, parasites and weed seeds, stabilized the organic constituents thus producing a uniform material suitable as soil amendment (Harada, 1990; Parr and Hornick, 1992). Composting has become an attractive option for MSW management having the capacity of reducing the volume and weight by approximately 50 per cent and resulting in a stable product that could be beneficial to agriculture (He *et al.*, 1992).

2.6.1. Co-composting

A waste material in the condition in which it is available may not possess all the characteristics essential for composting. Selective co-composting of these wastes with sewage sludge, night soil, MSW and industrial wastes provided a readily compostable mixture and higher quality product (Wilson, 1989).

Composting of wide C/N ratio materials such as bark wastes, rice straw, saw dust with low C/N ratio material such as poultry manure resulted in a more favourable ratio for composting and compost produced had higher nutrient content (Dai *et al.*, 1972; Sailo *et al.*, 1972; Parr and Colacicco, 1987; Echeandia and Menoyo, 1991; Rynk, 1992). Fogg (1988) summarised a negative effect of nitrogen in organic matter with higher C/N ratio and vice versa. Wilson (1989) stated that if the initial mixture of materials had a C/N ratio of 15-40, moisture content of 40-60 per cent, pH of 5-12 and greater than 30 per cent air space, it would be ideal to operate an effective composting process. The addition of other nitrogen sources such as sewage sludge, fish scrap, vegetable wastes, night soil, industrial wastes etc to wide C/N wastes resulted in reduction of C/N ratio to 30-40 in a shorter time (Parr *et al.*, 1994; Gaur *et al.* 1995; Verma, 1995).

Among the different methods tried, decomposition process was found to be the efficient method in bringing down the C/N ratio of coir pith (Thambirajah and Kuthubutheen, 1989). Moorthy *et al.* (1996) proved the composting of coir pith in a period of four months using coffee husk with the dual advantages of high moisture retention of coir pith and good nutritional status of cherry husk for continuous application to perennial crops. Many reports are there on composting of animal wastes containing more than 80 per cent moisture by adding moisture regulating materials such as straw and leaves (Wilson, 1971; Martin *et al.*, 1972; Bell, 1973). Sewage sludge, which is too wet is usually co-composted with wood chips, sawdust, MSW bark or dry compost or fly ash to reduce the moisture content. Addition of wood chips also increased the C/N ratio of wastes to the optimum range (Wilson, 1989). He also reported that in case of wastes from food and feed processing plants dewatering could help reduce the amount of bulk material required. Fruits and vegetables wastes are mostly deficient in nitrogen and these could be effectively composted by judiciously blending them with other wastes.

The biodegradable fraction of MSW could be composted or co-composted for beneficial use as soil conditioners and biofertilizers (Parr and Hornick, 1992). Under Indian farming condition co-composting of manure slurries with plant residues is a more viable and profitable proposition (Gaur and Sadasivam, 1993).

2.6.2. *Compost enrichment*

The nutrient content of final compost could be improved by enriching it with chemical fertilizers, organic additives or microbial cultures. The need for adding inorganic N to improve the manurial value of compost was realised quite early (Hutchinson and Richards, 1921). Gupta and Idani (1970) and Gaur *et al.* (1971) recommended that compost with a C/N ratio of 20:1 should be treated with ammonium sulphate or urea solution so as to bring the C/N ratio to less than 10:1 and N content to more than 2.5 per cent. Addition of mineral N increased the N content of finished compost to 1.8 - 2.5 per cent (Asija, 1984; Bhriguvanshi, 1988). Joshi *et al.* (1985) reported that blending of urea and rockphosphate with coir pith resulted in immobilisation of urea nitrogen and controlled release of nitrogen.

Composting with initially high level of N induced the production of free ammonia. The loss of N was about 85 per cent where two per cent urea N was added and 75 per cent where 1 per cent urea N was added (Bangar, 1988). Addition of dung as inoculum in the proportion of 10 per cent dry weight in presence of two per cent rockphosphate was ideal for efficient composting of resistant materials such as wool waste (Tiwari *et al.*, 1989). Dung slurry and biogas spent slurry were found to be good additives for improving the rate of decomposition of crop waste composts (Gaur and Mathur, 1990). The volatilisation loss of ammoniacal nitrogen from poultry manure can be minimised by composting it with substrates having wide C/N ratio. Rice straw mixed with ten per cent poultry waste yielded a more friable and nitrogen rich compost. The output was more by 15 per cent compared to compost made from poultry manure alone (Sims and Wolf, 1994).

Bopaiah (1991) recommended five spawn bottle of pleurotus sajur-caju fungus and 5 kg urea for decomposing 1 tonne coir pith. The inclusion of coir pith and inoculants with inorganic fertilizers further improved the nitrogen status as observed by Perumal *et al.* (1991). Composting of coir pith using enrichners like urea and rockphosphate for increasing the nutrient availability was reported by Jothimani (1993) and Jothimani and Sushama (1994). Joseph (1995) reported the simplest way to convert coir pith into organic manure by adding activated charcoal (pith plus) and urea. At the end of 30 days the compost contained 1.26, 0.06 and 1.2 per cent N, P and K respectively. Moorthy *et al.* (1996) proved the beneficial effect of using cow dung for the enrichment of coir dust. Enriched coir pith compost produced using coir pith, KCPL sludge, cow dung and MSW in the ratio 1:1:1:1 was superior to ordinary coir pith compost (Naija, 1997).

The subject of adding super phosphate, dicalcium phosphate or rockphosphate during composting engaged the attention of several workers since long (Acharya, 1954; Dhar, 1962; Singh and Subbiah, 1969; Murthy, 1978). Blending of compost with single super phosphate raised the P_2O_5 content of enriched manure up to 5 per cent (Gupta and Idani, 1970). Gaur (1982 b) reported that rockphosphate enriched compost contained 7 per cent more P_2O_5 compared to ordinary compost. Krishna and Sreeramulu (1983) reported the blending of coirwaste with mussoriephos. Mathur and Debnath (1983) reported that quality of compost prepared from mixture of paddy straw, grass and water hyacinth was improved when rockphosphate was applied to it with and without pyrite.

Rockphosphate was found to be good starter material to stimulate microbial activity in the compost system (Bhardwaj, and Gaur, 1985). Talashilkar and Vimal (1986) enriched 21 days old mechanical compost by mixing urea and SSP and covered it for three months. The N and P content increased from 0.76 to1.5 and 0.23 to 0.66 per cent respectively. Similar studies were conducted by Shinde and Patil (1984). They were of the opinion that higher level of rockphosphate immobilised available N temporarily and therefore lower level N and P should be used for blending.

Effect of addition of nitrogen on enrichment of phosphocompost was studied by Bangar (1988, 1989) and Singh *et al.* (1992). The N content of compost was increased to 2 per cent. Rasal (1988) showed that enrichment of compost by use of microorganisms improved the quality of the compost but did not increase the nutrient content as obtained by the use of inorganic fertilizers. Organic wastes poor in nitrogen was enriched by incorporating fishmeal, non-edible oil cakes, poultry manure or one per cent N as urea (Jaggi, 1991).

Verma (1995) reported that addition of rockphosphate @ 3 per cent and rice straw as substitute increased the available P level in the compost. Gowda (1996) reported that rockphosphate equivalent to 5 per cent P_2O_5 (250 kg MRP/ton of waste) mixed with ten per cent cow dung and five per cent soil and 5 per cent well decomposed manure served as inoculum for composting any organic waste and compost obtained after 90-120 days decomposition can be used as substitute to SSP using double the quantity. The cheaper source of rockphosphate is the perspective amendment, which in association with compatible microbial cultures contributed greatly to the enrichment of city garbage compost (Hajra *et al.*, 1992; Manna *et al.*, 1997). Mishra (1995) observed that it is not ideal to enrich manures to N and P contents of more than 5-6 per cent dry weight basis since the addition of at least 2.5 - 3 t of wet manure per hactare was needed to obtain beneficial effects on nutrient use efficiency.

2.6.3. *Compost maturity*

Numerous studies have been carried out to assess compost maturity. Clairon *et al.*, 1962; Poincelot, 1975; Golueke, 1977 and Chanyasak *et al.* 1982 recommended the use of C/N ratio as index of maturity. Garcia *et al.* (1987) demonstrated that though WSC/N was a good index of degree of maturity it was not useful for materials such as sludge with lower C/N ratio values at the beginning than after composting or maturation process. Harada *et al.* (1981) and Hirai *et al.* (1983) reported that though C/N ratio was the most common parameter used to define decomposition levels it cannot be a reliable indicator of compost maturity. This was confirmed by Chefetz *et al.* (1996) during studies on composting of MSW. The C/N ratio decreased dramatically from 28 to 12 with in 60 days during the second phase of composting but no changes occurred during curing phase in spite of instability of organic matter in the compost. A C/N ratio of 10 to 12 is usually considered to be an indicator of stable and decomposed organic matter (Jimenez and Garcia, 1992).

The progress of composting is normally evaluated by physico-chemical parameters such as variation in C/N ratio, loss of weight, increase in ash, formation of humic substances (Lobo *et al.*, 1987; Diaz-Burgos and Polo, 1991; Garcia *et al.*, 1992). Physical parameters such as temperature, odour and colour have also been proposed to characterise compost maturity (Golueke, 1972; Sugahara *et al.*, 1979; Guisquiani *et al.*, 1989). Changes in the composition of the odorous compounds emitted during the composting of swine wastes were studied by Haga (1978). The odorous fumes containing sulphur compounds were present in large quantities at the initial stage of composting but decreased rapidly as compost matured.

The colour changes of different mixtures of sewage sludge or city refuse during composting and maturation processes showed that the stimulus value (degree of lightness) and Munsell notation value decreased rapidly during the first 65 days of piling and then reached a constant value. This parameter significantly correlated with WSC/N ratio considered as a good index of degree of maturity (Garcia *et al.*, 1990a).

Eghball *et al.* (1997) reported that during composting of cattle feed lot manure, the temperature reached 65°C within 24 hours at all depths within the compost pile. After 65 days the temperature decreased to 40°C. The temperature was near ambient after 110 days.

The CEC of cattle waste compost increased up to 110 meq/100 g during the first 4 to 5 weeks and thereafter remained constant (Harada and Inoko, 1980; Harada, 1983). Estrada *et al.* (1987) reported that CEC value of city refuse compost increased progressively from 40 meq/100 g to about 80 meq/100 g after composting. Kalaiselvi and Ramasamy (1996) stated that CEC content of same type of compost might vary due to blocking of their exchange sites by certain ions such as Fe, Cu or Al.

Ganapini *et al.* (1979) suggested the use of pH value as an indicator of maturity. According to Wilson (1989) most well stabilised composts had a pH between 6.5 and 7.5. Adjusting the pH downward to near neutral reduced the volatilisation of ammonia and other odorous compounds.

Kaiser (1983); Morel *et al.* (1986); Nannipieri *et al.* (1990); Benedetti *et al.* (1991) and Wittling *et al.* (1995) proposed microbial criteria as indicator of compost maturity. De Bertoldi *et al.*1982 found that during initial stages of composting, ammonia producing and proteolytic bacteria increased considerably reaching numbers greater than

10^6cells/g dry weight. As compost matured their population decreased while the nitrogen fixing bacterial population increased again.

Kostov *et al.* (1994) evaluated microbial index ratios during aerobic composting of sawdust and bark and found that ratios of number of fungi, ammonifying microorganisms and nitrogen fixing bacteria to the actinomycetes were found to decrease with age of compost. Faster growth of actinomycetes in the advanced stages of bark decomposition was similarly reported by Hardy and Sivasithamparam (1989).

Kimber (1973) observed that aim of maturation processes was to eliminate phytotoxic substances of the raw materials, which were harmful to the germination and to growth of plants. Biological methods including germination index of seeds in compost extracts (Zucconi *et al.*, 1981; Harada, 1995) and seedling tests (Kawada, 1981; Hoitink and Kuter, 1986) are used to characterize compost maturity. Garcia *et al.* (1988) also reported that a certain period of maturation (four months) after composting (90 days) was necessary for organic matter of compost to become stable and to avoid phytotoxicity in plants.

Plant bioassay provided reliable results on compost maturity (Hoitink and Kuter, 1986; Inbar *et al.*, 1993). Plants grown in media containing fresh composts (14 days) exhibited inhibited growth compared to plants grown on older compost. As organic matter decomposed, the compost became a better substrate for plant growth. In immature composts low molecular weight organic acids induced phytotoxicity in addition to competition for oxygen and nutrients due to high rates of organic matter decomposition (Chefetz *et al.*, 1996). Plant growth response test and germination index were useful under laboratory conditions to distinguish composts from raw material. They had limited diagnostic value as regards to plant yield (Blanco and Almendros, 1995).

Composting and maturation increased the concentration of heavy metals in aerobic sewage sludge, city refuse composts due to loss of weight of materials during the process. The metals became insoluble and extractants removed larger amount of metals from raw composts than from mature composts. The load Zn equivalent increased during maturation and Cd/Zn ratio decreased (Garcia *et al.*, 1990b).

2.6.4. Compost quality

Inoko (1979) and Harada and Inoko (1980) concluded that a city refuse compost having C/N ratio below 20, total nitrogen above two per cent and CEC 60 meq/100 g could be applied safely to the soil. Similar results were obtained by Das (1988). Composting of solid manure sharply decreased the carbon content and soluble organic matter but increased the content of most major and minor nutrients and humic substances on a dry matter basis (Ott and Vogtmann, 1982; Inbar *et al.*, 1989). Immature compost applied to crops could result in plant phytotoxicity from intermediate organic compounds (Zucconi *et al.*, 1981).

Wong (1985) and Wong and Chu (1985) postulated that the contents of ammonia, ethylene and heavy metals in compost were inversely correlated with seed germination and root elongation of different crops. Hence compost should be stored at least 115 days before being applied to crops. The excess of salts and heavy metals and lack of stability were the characteristics of the compost to be controlled to avoid detrimental effects on plants (Juste and Pommel, 1987) and soil organisms (Diaz-Ravina *et al.*, 1989). Rosen *et al.* (1993) also opined that high levels of heavy metals in compost made from municipal wastes and faecal pathogens in sewage sludge were important considerations when using compost for the production of horticultural crops. High soluble salt concentrations could be a major concern when sewage sludge compost was used (Gouin, 1993). Eghball *et al.* (1997) observed lower electrical conductivity, NH_4^+, total N and C concentration in composted feed lot manure than in the initial manure whereas total P, Ca, Mg, NO_3^- and ash contents were increased. Good quality compost contained more than 20-30 per cent organic matter and less than stipulated levels of heavy metals such as arsenic (<50 mg/kg), cadmium (<5 mg/kg), mercury (<2 mg/kg), lead (150 mg/kg), chromium (<300 mg/kg) and copper (<500 mg/kg).

Kurihara (1984) stated that if the moisture content of compost exceeded 60 per cent it should be stock piled and matured for 1-2 months to accelerate decomposition of absorbents. High initial moisture content in compost hindered aeration and induced undesirable anaerobic conditions during composting which was identified with low temperature below 35°C and occurrence of foul odours (Haug, 1980).

Numerous studies showed that at adequate aeration the temperature in the compost pile increased to greater than 60°C. This accelerated the decomposition process and resulted in complete destruction of pathogens, parasites and weed seeds (Bishop and Chesbro, 1982; Bishop and Godfrey, 1983; Harada and Haga, 1983; Parr *et al.*, 1994). The amount of inert materials such as plastics and glasses and their particle size must be taken into account when assessing the quality and consistency of the product (Zucconi and De Bertoldi, 1987; Costa *et al.*, 1991). Kalaiselvi and Ramasamy (1996) in their review on compost maturity listed out the following characteristics as criteria for quality compost.

- Mature compost should have a tea brown colour, no noxious smell and good stability, which could no longer produce high temperatures

- Maximum diameter should not exceed 10 mm, with 5 mm as optimum and water holding capacity below 30 per cent
- Most common pH values ranged from 6.5 to 8.0
- Total salinity should not exceed 2 g salt
- C/N ratio of mature compost should be less than 20 and CEC should be more than 70 meq/100 g of ash free material
- At least 10 per cent of the total organic carbon present in the original material should be humified at the end of the composting
- Good quality compost should contain minimum levels of toxic components and non-biodegradable materials.

2.7. Soil enrichment with organic additives

The role of FYM application in increasing the organic carbon level has been reported by many workers (Biswas *et al.*, 1969; Bijay Singh *et al.*, 1983; Prasad *et al.*, 1983). Hoffmann (1983) conducted long term field experiments on acid soils and showed that raising compost application rates soil organic matter content increased from 2 per cent to 6.9 per cent. Similar results were reported by Guidi *et al.* (1983). Bohn *et al.* (1985) reported that decomposition rate of organic materials in soils was proportional to the amount added and the more added, the more rapidly it disappeared. Srivastava (1985) found that organic C, total N, total P and K status increased with FYM addition. Continuous application of FYM increased the organic carbon content of soil (Singh *et al.*, 1988; Sud *et al.*, 1990). Maskina *et al.* (1988) reported that application of poultry manure increased the organic carbon content in rice-wheat cropping sequence. Jagdeesh *et al.* (1994) reported that application of biogas slurry improved total nitrogen content and carbon build up of soil. Guisquiani *et al.* (1995) observed that total and humified organic carbon increased as compost rates were increased but the rise in soil carbon was not proportional to the amount of organic carbon added with compost. Coir pith improved the soil organic carbon from 0.47 - 0.65 per cent (Jothimani *et al.*, 1996). Adhikari *et al.* (1997) reported that compost treated soil maintained higher organic carbon and microbial biomass carbon compared to untreated soil. Repeated application of 5 Mt/ha of composted material on dry weight basis each year for 50 years accumulated about 1.5 - 2.7 per cent carbon in the plough layer (Shiga, 1997).

Increase in available N content of soil and increased N recovery due to organic sources of nitrogen were reported by several workers (Muthuvel *et al.*, 1977; Srivastava, 1985; Azam, 1990). Ramaswamy and Raj (1976) stated that organic manure application was beneficial in increasing the ammonifying power of the soil. Kanwar and Prihar (1982) reported that continuous application of FYM increased the organic carbon as well as N content of soil. Higher available N content of soil under FYM addition could be due to favourable microbial activity and enhanced biomass addition to the soil as a result of improved soil physical properties (Muthuvel *et al.*, 1990). Mukherjee *et al.* (1991) reported that edible oil cakes released more inorganic N to the soil whereas non-edible oil cakes liberated more available P. Neem cake maintained least amount of total N in soil. More (1994) observed that due to application of organic wastes and manures the content of organic carbon, N, P and K in soil increased. Available N and K content of soil increased due to incorporation of coir pith (Jothimani *et al.*, 1996).

A number of workers have reported the beneficial effect of organic manures viz. FYM in increasing the available P content of soil (Havangi and Mann, 1970; Azar *et al.*, 1980; Dhillon and Dev, 1986; Singh and Sarkar, 1986; Mathan and Joseph, 1998). Cattle feed lot manure application increased soil levels of total, inorganic and available P and decreased P sorption capacity (Sharpley *et al.*, 1984). Release of P was much faster in slurry treated soil (Bathla and Chaudhary, 1987).

Press mud and coir pith application increased the available P status of soil due to dissolution of inorganic P fractions by the organic acids released during the decomposition process (Mayalagu *et al.*, 1988). Cline *et al.* (1985) and Sharpley *et al.* (1993) reported greater desorption of P with poultry manure and sludge treated soils. Superiority of poultry manure in increasing available P was due to high content of P in manure (More and Ghonsikar, 1988). Harris *et al* (1994) found that manure application to a calcareous sandy soil increased P solubility due to presence of organic acids, Mg, Si and lack of formation of Ca-P minerals.

Zhang *et al.* (1994) reported that combinations of organic manure with mineral fertilizers increased solubility and mobility of P in paddy soils. High rates of repeated application of manure caused significant build up of nutrients in soils (Eghball *et al.*, 1996). A single application of 180 mg ha^{-1} manure in 1971 doubled the sodium bicarbonate P level of a silty clay soil in 1979 (Meek *et al.*, 1982). Bray and Kurtz P test values in 1982 increased linearly from 45 to 391 mg/kg with 0 to 360 mg ha^{-1} manure applications made in 1974 (Vivekanandan and Fixen, 1990).

The organic matter of soil was positively correlated with availability of K (Verma and Verma, 1970). Chellamuthu *et al.* (1988) reported that influence of FYM was significant in increasing the availability of K in soils. Similar observations were made by Nishita *et al.* (1973) and Sankaran (1977). Guisquiani *et al.* (1988) reported significant difference in K availability between enriched soils and control. The increase in concentration of exchangeable K was three fold compared to control. The addition of farm wastes and organic manures increased the availability of N, P and K in Vertisols (More, 1994). Compost addition also increased the sulphur content of soils (De Haan, 1981).

Swarup (1984) reported that application of 10 t/ha FYM enhanced availability of native micronutrient cations in soil. Continuous application of organic manure increased the zinc level from 0.48 to 0.87 per cent (Randhav and Takkar, 1975). Mann *et al.* (1978) also reported increased availability of Zn due to FYM application. Gallardo-Lara *et al.* (1984) found that increasing application of town refuse compost linearly increased the residual extractable zinc in two soils of different fertility. SISS (1985) and Guisquiani *et al.* (1988) observed remarkable increase in Zn and Mn concentration due to addition of urban waste compost. These results were in close association with the findings of Selvi Ranganathan and Augustine (1997). Application of compost produced undesirable effects due to increase in amount of micronutrients to toxic levels (Purves and Mckenzie, 1974) or to increase in uptake of other heavy metals (Giordano and Mays, 1981).

The potential hazards associated with heavy metal contamination of soils increased with time due to decrease in soil pH especially when the N and S content of waste products were high and lime content low (De Haan, 1983). Gonzalez *et al.* (1989) observed that application of pig slurry and poultry manure compost caused no adverse effect on soil properties. Falahi-Ardakani *et al.* (1987,1988) reported that Zn and Cd did not accumulate to levels high enough to be toxic to plants. The agronomic utilization of urban waste compost over a four-year period resulted in heavy metal accumulation in soil. The mean increase for each ton of compost added were 0.38 mg kg^{-1} for Pb, 0.21 mg kg^{-1} for Zn, 0.157 mg kg^{-1} for Cu and 0.04 mg kg^{-1} for Ni (Guisquiani *et al.*, 1995). Heavy application of organic materials to cropland might cause a reduced condition in soil, oxygen deficiency in plant roots and production of harmful substances such as organic acids or phenolic compounds (Shiga, 1997). In general composts had long term positive effects on biological and chemical properties of soils (Leinweber and Reuter, 1992; Schlegel, 1992).

2.8. Crop response to organic additives

The use of different organic amendments in crop production like farmyard manure, biogas slurry, poultry manure and coir pith produced higher yields as well as nutrient build up (Anon, 1991)

Gaur (1982 a) showed that in rice response to application of 12.6 t of FYM or compost per ha varied from 100 kg to 216 kg yield per ha the average being 168 kg/ha. Combined application of rock phosphate and FYM registered the highest grain and straw yield (Karuppaiah, 1983). Verma and Bhagat (1993) also reported that FYM produced higher grain and straw yield. Anilakumar *et al.* (1993) reported that continuous application of cattle manure produced 24 per cent more yield than complete fertilizer source.

Biogas digested slurry as basal manure enhanced the yield of cereals, pulses and oil seeds (Jeyabal, 1990; Kuppusamy, 1992). Budhar *et al.* (1991) observed that biodigested slurry produced grain yield of 5.49 t/ha. Biogas slurry at 10 t/ha gave an additional grain yield of 1.8 t/ha in rice (Kuppusamy, 1993). Increased yield to the tune of 36 per cent in rice was reported due to slurry application (Tripathi, 1993). Rice grain yield was increased by 24 per cent with biodigested slurry application (Velayutham and Arunachalam, 1995). Application of biodigested slurry at 5 t/ha recorded markedly higher grain and straw yields in rice, ADT-36 (Gopal, 1996).

The application of farm wastes like farmyard manure, biogas slurry and poultry manure at 5 t/ha along with recommended dose of inorganic fertilizer significantly increased grain yield of rice. Poultry manure recorded the highest grain yield of 6.6 t/ha over control (5.2 t/ha) (Budhar *et al.*, 1991). Rainay *et al.* (1992) stated that composted poultry litter at 5 t/ha on dry weight basis increased rice yields, but the benefit varied from field to field.

The use of granulated compost increased the grain yield and N-use efficiency of rice in wide range of soil and climatic condition (AICARP, 1980, 81). Composts contained macronutrients such as P that contributed to greater yield of different crops (Hornick *et al.*, 1984; Sikora and Yakovchenko, 1996). Sikora *et al.* (1980) observed that some composts added lime that resulted in greater yields in acid soils. Trials conducted at different locations in India also showed phosphocompost as a good alternate source of phosphatic fertilizer (AICRPM, 1982). Talashilkar and Vimal (1986) reported that 25 per cent of the recommended dose of nitrogen and 50 per cent of P to rice could be substituted by enriched compost. Compost prepared from rice straw and animal manure @ 2 t/ha supplied the basal fertilizer requirement of crop. Only 40 per cent of recommended inorganic fertilizer was further required for crop growth (Cuevas, 1991). Enriched compost could sustain highest yield till third crop in rice-rice-blackgram cropping sequence (Hajra *et al.*, 1992). Phosphocompost applied @ 5 t/ha was comparable to SSP in terms of crop yield, nutrient uptake and nutrient status of soil (Sharma and Sharma, 1997).

Application of rice straw compost @ 12.5 t/ha increased grain yield to the tune of 20 per cent over 100 per cent NPK. The macro and micronutrients availability also increased considerably (Selvi Ranganathan and Augustine, 1997).

2.9. Phosphorus release and transformation in soil

2.9.1. Effect of moisture regimes

Moisture increased the availability of both native and applied soil phosphorus and the efficiency of moisture levels varied with the type of soils (Datta and Goswami, 1962). Roy and Sinha (1975) reported that release of P was more at 50 per cent moisture level than under submerged condition in phosphate treated soils. According to Mohanty and Patnaik (1977) and Randhawa and Arora (1997) submergence increased available P for 30 days because of reduction of Fe and Mn compounds, and afterwards, there was a decrease because of precipitation of phosphates.

Boro (1980) opined that continuous submergence of rice was an effective management practice for increasing the efficiency of P fertilizers. Mathews and Jose (1984) reported that flooding the soil resulted in an increase in the content of available P in laterite compared to kari soil. Pattanayak and Misra (1989) and Patel and Trivedi (1994) observed similar beneficial effect of increasing soil water content on availability of phosphorus in soil. Debnath and Basak (1986) and Dhillon and Dev (1986) found more P remaining in solution under aerobic conditions as compared to anaerobic conditions.

Transformation of P into different inorganic P fractions followed a similar pattern under field capacity and submergence (Kumaraswamy and Sreeramulu, 1992). The same observation was made by Singh and Ram (1976). Mandal and Khan (1977) did not find significant effect for irrigation treatments on the phosphate transformation in rice soils.

According to Gupta and Bhriguvanshi (1997) there was remarkable increase in available P with increase in soil water content up to 0.24 kg/kg but on subsequent increase in soil water content the availability of P reduced drastically.

Mongia *et al.* (1997) found that mean increase in available P content of soil was less at alternate submergence and saturation or continuous saturation moisture regime than when the soils were kept under continuous submergence.

2.9.2. Effect of added P fertilizer

Minhas and Kick (1974) reported that a major part of the added rock phosphate was transformed into water soluble P and loosely bound Al-P and Fe-P. According to Sarangamath *et al.* (1977) application of water soluble and citrate soluble P to acid soils increased the Al-P and Fe-P fractions whereas application of rockphosphates increased Ca-P. Similar observations were made by Menhilal and Mahapatra (1979) and Chandrappa (1990). Application of increasing amounts of fertilizer P resulted in almost a linear rise in the recovery of applied P (Chakravorthi *et al.*, 1982). Mathews and Jose (1984) observed that when P was applied at the rate of 45 kg P_2O_5 /ha only 468 ppm P was recovered as available P and when the rate of application increased from 45 to 90 kg P_2O_5 /ha, the additional increase in available P was only 0.17 ppm. Thus only a constant level of P out of the added P was retained in the available form and further increase in the rate of application resulted in the retention of P in the unavailable pool in the soil.

The recovery of phosphorus applied in the form of monocalcium phosphate and dicalcium phosphate ranged between 16 to 21 per cent in neutral soil and 5 to 9.5 per cent in slightly acid soil after eighteen weeks (Subramanian *et al.*, 1985). Dhillon and Dev (1986) suggested that applied P was converted to saloid P and Al-P at the initial stage and later to Fe-P with increased period of incubation.

Debnath and Basak (1986) found that irrespective of soils all P sources significantly increased the available P status of soil. Taking efficiency of superphosphate as 100, the efficiency of purulia rockphosphate, mussorie rockphosphate and basic slag varied from 0-11.3, 0.7-13.2 and 4.7- 89.6 per cent respectively. Gupta and Bhriguvanshi (1997) also observed that the solubilisation of tricalcium phosphate ranged from 15 to 70 mg/kg while in MRP available P varied from 7 to 32 mg/kg. Bhatta (1993) found that MRP application resulted in higher Ca-P while superphosphate recorded higher Al-P.

2.9.3. Effect of organic manure addition

Organic residues with P content < 0.3 per cent increased P sorption, whereas residues of manures with P content >0.3 per cent decreased P sorption (Singh and Jones, 1976). A number of workers (Havangi and Mann, 1970; Ruhal and Shukla, 1979; Azar *et al.*, 1980; Dhillon and Dev, 1986; Singh and Sarkar, 1986; Mathan and Joseph, 1998) reported the beneficial effect of organic manures in increasing the available P content of soil. Cattle manure application resulted in increased soil levels of total, inorganic and available P and decreased P sorption capacity to a depth of 0.3 m (Sharpley *et al.*, 1984).

Gupta *et al.* (1988) found that the available P in a coarse loamy soil increased up to 52 days after application of FYM irrespective of the levels. Pre-incubation of phosphatic fertilizers with cattle dung increased the availability of P (Tomar *et al.*, 1987). Half period of P release showed that release of P was much faster in slurry treated soil (Bathla and Chaudhary, 1987).

Anaerobic decomposition of organic materials increased the availability of both native and applied P due to liberation of carbon dioxide and production of organic acids (Hesse, 1984). Tomar *et al.* (1984) stated that in the initial stage of incubation of soil with manure, organic compounds complexed the Al^{3+} and Fe^{3+} such that fixation by these ions was less; but at the later stages these ions were again released due to degradation of organo-metallic complexes which reacted with phosphate ions. Press mud and coir pith application increased the available P status of soil due to dissolution of inorganic P fractions by the organic acids released during the decomposition process (Mayalagu *et al.*, 1988).

Cline *et al.* (1985) and Sharpley *et al.* (1993) reported greater desorption of P with poultry manure and sludge treated soils. Application of effluent from a poultry manure anaerobic digester to a loamy soil resulted in 41 per cent reduction in P bonding strength (Field *et al.*, 1985). The superiority of poultry manure in increasing available P was due to high content of P in the manure (More and Ghonsikar, 1988). The application of organic manure under anaerobic conditions increased the availability of organic P (Mo *et al.*, 1991; Zhang *et al.*, 1994). Application of sewage sludge to soil increased soil available P and plant uptake (Condron *et al.*, 1996; Frossard *et al.*, 1996).

Li and Wang (1988) and Wang *et al.* (1995) reported that the available P content of soil was increased by the addition of humic acids in alkaline soils. Phosphate fixation was significantly retarded by mixing humic acids with ammonium dihydrogen phosphate. Harris *et al.* (1994) found that manure application to a calcareous sandy soil increased P solubility due to the presence of organic acids, Mg, Si and lack of formation of Ca-P minerals. Agbenin and Goladi (1998) reported that fertilization with cow dung alone decreased the concentrations of P fractions. Dung applied in combination with P, N+P and N+P+K increased the concentrations of extractable P pools in the soils.

2.10 Availability of major nutrients as affected by P nutrition to rice

Ramanathan and Krishnamoorthy (1973) observed an increase in the uptake of N by straw in the presence of added P. According to Ramaswamy and Raj (1976) P and K uptake was enhanced by P application. Mathews and Jose (1984) reported that application of P resulted in better utilization of major nutrients by the rice plant. Response to K increased with increasing amount of P (Umar *et al.*, 1986). Sushama (1990) reported a higher availability of N and K for rice crop with increased levels of P application. Srinivasamurthy *et al.* (1995) reported a higher availability of N when rock phosphate was applied to an acid soil, seven days before transplanting.

The concentration of P in rice grains did not increase proportionately to the amount of P applied whereas concentration of calcium increased with increasing levels of rockphosphate (Mathur and Lal, 1987). According to Policegowder *et al.* (1994) maton rockphosphate application contributed to higher content of Ca and lower content of Mg as compared to superphosphate in the soil after harvest of rice crop. Application of superphosphate increased the exchangeable calcium of soil (Sharma and Sinha, 1989).

Warnock (1970) reported an increase in DTPA-extractable Fe due to P application. According to Nair and Babu (1976) higher concentration of P retained Fe in roots, which was responsible for low transport of Fe to shoot. Gupta *et al.* (1982) found that application of phosphate resulted in decrease in contents of reducible iron. Chatterjee *et al.* (1983) studied the effect of P application on the availability of micronutrients. Application of P increased the extractable Zn and Fe, decreased the Mn and had little effect on extractable Cu in soil. Sarkunan *et al.* (1993) reported a positive interaction between P and S up to 100 mg P and 25 mg S/kg rates and an adverse effect at higher levels for rice. Mongia *et al.* (1998) found that P application reduced the Al and Fe content of grain and straw but increased the Mn content.

2.11. Residual effect

De Datta *et al.* (1966) observed that only 8 to 27 per cent of the total P in the rice plant was derived from applied P while 80 to 90 per cent of the applied P remained in the soil for the succeeding crop. Panda and Panda (1969) reported that short term evaluation of rockphosphate in laterite soil is meaningless as residual effects were more important than immediate effect. Lehr and McCellan (1972) observed that yield of rice increased by rockphosphate application in the first year but declined in subsequent years.

The fertilizer value of rock phosphate in rice-rice cropping system must be assessed on the basis of residual effect (Sarkar and Sarkar, 1982; Mathur and Lal, 1987; Sharma and Sinha, 1989). Goedert (1984) reported that 20 per cent of the P as rockphosphate remained in apatite and the efficiency ranged from 69 to 89 per cent. According to Mathews (1985) considerable amount of P applied as rock phosphate remained in the soil after growing rice for two seasons and availability of P to third and subsequent crops could be better in soils receiving rockphosphate as compared to superphosphate. Omana (1986) reported that the rice crop that followed the main crop of cowpea was benefited by the residual effect of rock phosphate than that of super phosphate alone applied to cowpea and rice. Hollord and Crocket (1991) stated a negative correlation between residual value in the second year and P recovery in the first year. They also reported that on strongly sorptive soils residual P gave higher yields than fresh P.

George and Sasidhar (1994) studied the balance sheet of phosphorus in rice-rice-cowpea system for two years and opined that in order to maintain the initial phosphorus status, phosphorus was to be applied only to third crop of cowpea. Continuous skipping of phosphate fertilizer to all three crops in rotation reduced the soil available P to a net loss of 12.9 kg ha^{-1}. Paulraj and Velayutham (1995) reported that residual effect of rockphosphate was more than that of SSP in rice-blackgram sequence.

Application of organic manures to one crop exhibited residual effect on the succeeding crop (Singh *et al.*, 1981). The residual effect of FYM applied in kharif produced almost equal grain yield of wheat in rabi season to that of the cumulative effect (Singh and Dubey, 1987). Das *et al.* (1993) observed marked residual effects on succeeding crops by amending inorganic P fertilizers with manures. Barbarika *et al.* (1980) and Colacicco (1982) estimated that the cumulative agronomic and economic value of organic materials applied to agricultural soils could be more than five times greater in the post application period than the value realized during the year of application.

The foregoing review has brought out the importance and potential of organic wastes and the necessity to utilize them efficiently. The KCPL effluent slurry is produced in the process of synthesizing ossein from crushed animal bones. This industrial waste is accumulating to the tune of $100m^3$ a day. Gopinathan(1996) revealed that KCPL slurry on proper bio-processing could be a good organic fertilizer. Hence the present study was taken up with the main objective of standardising the formulation techniques of different grades of organic meals through addition of suitable organic amendments and its influence on crop and soil.

Materials and Methods

Chapter 3

MATERIALS AND METHODS

The investigations on the formulation and evaluation of organic meals from KCPL effluent slurry was conducted at KCPL (Kerala Chemicals and Proteins Ltd.) factory site located at Kathikudam near Koratty in Thrissur district and at College of Horticulture, Vellanikkara during May, 1997 to December, 1999. The study was carried out in three parts as given below:

1. Basic properties of the KCPL effluent slurry
2. Formulation techniques of organic meals and their physico-chemical properties
3. Evaluation of the influence of organic meal on crop and soil

3.1. Basic properties of the KCPL effluent slurry

The study material, the KCPL effluent slurry is a bone based effluent produced by Kerala Chemicals and Proteins Ltd. (KCPL) (Plate 1) situated at Kathikudam near Koratty in Thrissur district. The processes involved in the slurry production are described in Appendix 1. Preliminary report on its properties (Gopinathan, 1996) are summarised in Appendix 2. The magnitude of the problem is shown in Plates 2 to 4.

3.1.1 Physico-chemical properties

For confirmatory study on its properties over a period of time, the composite samples of the accumulated sludge from various source points in the plant were drawn three times every month at 10 days interval for a period of six months from May, 1997 to October, 1997. The 18 samples thus obtained were studied for different physico-chemical properties as detailed in Tables 3.1 and 3.2 for confirmation.

Plate 1 View of KCPL factory

Plate 2 Thickner slurry pump site

Plate 3 KCPL effluent slurry

Plate 4 KCPL effluent sludge accumulated to the tune of 15 t/day

Table 3.1. Physical properties of the sludge

Property	Method	Reference
Colour, Odour	Physical appearance	Jackson, 1958
Consistency	Particle analysis	
Moisture content	Gravimetric	
pH	1:2.5 suspension	

Table 3.2. Chemical properties of the sludge

Component	Method	Reference
N	Microkjeldahl digestion and distillation	Jackson, 1958
P	Diacid extract –spectrophotometry	”
K	Diacid extract – Flame photometry	”
Ca, Mg	Volumetric	”
Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometry	Lindsay and Norvell, 1978
Heavy metals	Atomic Absorption Spectrophotometry	Jackson, 1973
Organic carbon	Gravimetric	”
Neutralizing value	Volumetric	Piper, 1966

3.1.2. Incubation study on nutrient mineralisation

Being a new organic material rich in calcium, phosphorus and relatively good amount of nitrogen, as revealed from Appendix 2, an incubation study was conducted to understand its basic properties with regard to the content and availability of these nutrients, this investigation was conducted using three levels of phosphorus and moisture along with the reference material, the mussorie rock phosphate (MRP) as narrated below. The characteristics of the reference source mussorie rock phosphate is given in appendix 3.

Table 3.3. Treatment details of incubation study on nutrient mineralisation

Source	Level	
	Phosphorus	Moisture
KCPL sludge	1g, 2g and 4g per 5 kg of soil	50 % Field Capacity (50FC)
MRP		Field Capacity (FC)
		Water Logging (WL)

Four kilogram of soil that passed through 2 mm sieve was taken in polythene containers. The two P sources were applied as per the treatments. The contents were mixed thoroughly and incubated at room temperature for 120 days. The required moisture levels were adjusted by adding distilled water whenever required. In the case of continuous submergence water level was maintained at about 2.5 cm above soil surface. The containers were kept covered with plastic lids. Soil samples were drawn at 30 days interval for laboratory analysis. A control was also maintained at the three moisture levels (Plate 5).

3.2. Formulation techniques of organic meals and their physico-chemical properties

The bio processed and enriched organic manure produced from KCPL slurry is logically termed as organic meal (Gopinathan, 1996) as it is formed from a bone based slurry through suitable organic enrichment techniques. Various formulation

Plate 5 Incubation study with KCPL sludge

techniques as detailed below were tried to develop organic meal (OM) in quick and cost effective ways.

Originally the study was aimed at to standardise the formulation techniques of organic meals from the spent slurry (SS) produced after methanogenation (Gopinathan, 1996) of KCPL effluent slurry, a stage of the effluent, prior to filtration and sludge formation. The details of this process and properties of spent slurry are furnished in Appendix 4. The prototype model of biomethanation tanks and their working models developed in consultation with the engineers of KCPL and Agricultural University are depicted in Plates 6a, 6b and 7.

3.2.1. Filtration

The spent slurry being a substrate of high moisture content was initially filtered to make it handy. A centrifugal filtration unit with a daily handling capacity of 10 m^3 slurry was set up for this purpose (Plate 8).

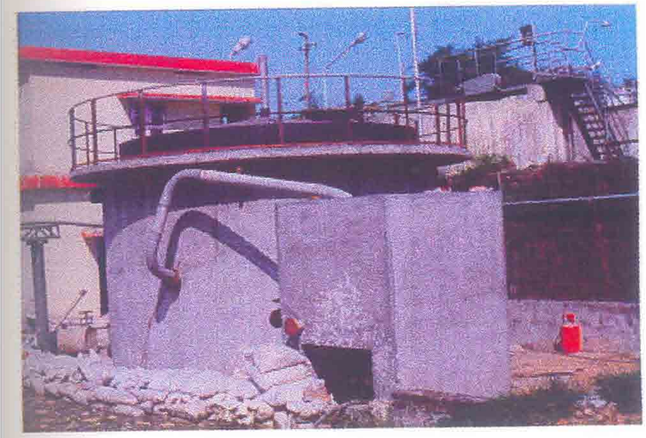
3.2.2. Enrichment

The filtered slurry was mixed with different organic enrichers like neem cake (NC), goat manure (GM), cow dung (CD), poultry manure (PM), composted coir pith (CP), and natural colouring material mussorie rock phosphate (MRP) in different proportions as per the treatment combinations for improving the appearance, acceptability and manurial value. Rockphosphate was used as a low cost colouring material to improve the physical appearance of the meal. The other enrichners like neemcake, goat manure, poultry manure, cowdung were basically used as organic source of nitrogen enrichner. The coirpith which is a serious problem of coir industry was used as enrichner to improve the physical condition of the meal as well as to

Plate 6a

Formulation technique of organic meals –Biomethanation technique

Plate 6b



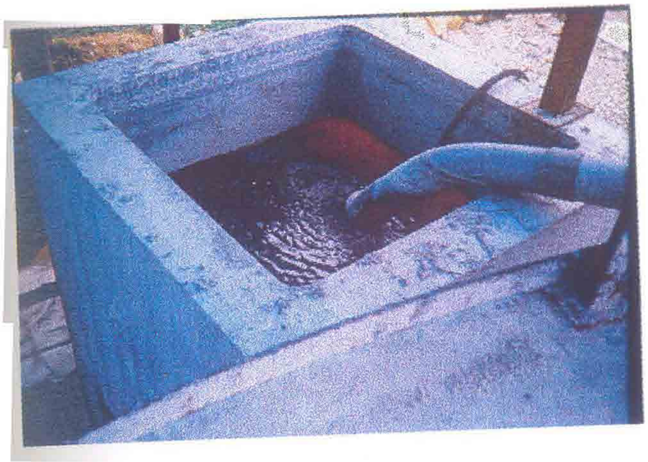


Plate 7 Collection of spent slurry in the tank

Plate 8 Centrifuging unit of spent slurry

Plate 9 a

Pellatisation unit of organic meals

Plate 9 b

Table 3.4. Components and ratio of enriching materials in organic meals from spent slurry

Organic meal No.	Components	Level of additives
1	SS + NC + MRP	NC 5 per cent
2	SS + NC + MRP	NC 10 per cent
3	SS + NC + MRP	NC 15 per cent
4	SS + PM + MRP	PM 5 per cent
5	SS + PM + MRP	PM 10 per cent
6	SS + PM + MRP	PM 15 per cent
7	SS + CP + MRP	CP 5 per cent
8	SS + CP + MRP	CP 10 per cent
9	SS + CP + MRP	CP 20 per cent
10	SS + CP + MRP	CP 30 per cent
11	SS + CP + MRP	CP 40 per cent
12	SS + CP + MRP	CP 50 per cent
13	SS + CD + MRP	CD 5 per cent
14	SS + CD + MRP	CD 10 per cent
15	SS + CD + MRP	CD 15 per cent
16	SS + NC + CP + MRP	NC 5 per cent, CP 5 per cent
17	SS + NC + CP + MRP	NC 5 per cent, CP 10 per cent
18	SS + PM + CP + MRP	PM 5 per cent, CP 10 per cent
19	SS + CD + CP + MRP	CD 10 per cent, CP 10 per cent
20	SS + NC + CP + MRP	NC 5 per cent, CP 20 per cent

Note: SS – spent slurry, NC – neem cake, PM – poultry manure, CP – composted coir pith, CD-cow dung, MRP –mussorie rock phosphate.
In all cases MRP was tried at 5 per cent level.

improve the acceptability of coir pith as manure. The components and ratio of enriching materials are given in Table 3.4.

3.2.2. Formulation

The enriched and coloured organic meal was fed to a rotary drier and pelletisation unit (Plate 9a, 9b). It was then suitably powdered / pelleted to form different grades of meals.

3.2.3. Rapid method of organic meal production

While experimenting with the spent slurry to form organic meals as described above, a clue to a still more rapid way was noticed accidentally. The fresh filtered sludge when mixed with organic enrichers and kept in heaps in open showed high exothermic properties from the second day onwards. This led to another set of experiment involving the principle of activated composting technique. This was later proved as a rapid technique for the production of an innocuous form of organic meal as compared to the cumbersome procedure involving the spent slurry. Two techniques were employed here.

3.2.3.1. Pit method of composting

Seven different combinations of sludge and organic additives as shown in Table 3.5. were tried for pit method in randomised block design (RBD) with three replications. Pits of size 1.5 m x 1 m x 0.5 m were dug and bottom of the pit was covered with polythene sheet. Judged from the bulk density (0.15 g/cc) about 375 kg of sludge was approximated as the capacity of the pit. To 375 kg sludge material different additives as per treatments were added on fresh weight basis and mixed thoroughly. It was then charged in the pits. The pits, covered with a layer of soil were maintained properly for a period of 90 days (Plates 10 and 11).

Plate 10.

Pit method of composting

Plate 11.

Table 3.5. Treatment combination for pit method of composting

No.	Combination	Level of additives
1	S + NC + MRP + U	NC 5 percent
2	S + PM + MRP + U	PM 5 percent
3	S + CD + MRP + U	CD 5 percent
4	S + NC + CP + MRP + U	NC 5 percent CP 5 percent
5	S + NC + CP + MRP + U	NC 5 percent CP 10 percent
6	S + CD + CP + MRP + U	CD 10 percent CP 10 percent
7	S + NC + CP + MRP +U	NC 5 percent CP 20 percent

S – Sludge; NC – Neem cake; PM – Poultry manure; CD – Cow dung; MRP – Mussorie rock phosphate; CP – Composted Coir pith; U - Urea
(For all the above combinations MRP was tried at 5 per cent level and Urea at 1per cent level)

3.2.4.2. Open heap method of composting

The same combinations were tried in open heaps also to encourage aerobic activities as narrated in Table 3.6 and Plates (12 to 15). The heaps were laid out in randomised block design and replicated twice.

Table 3.6. Heaping techniques and covering materials for composting

Heaping technique	Covering materials
Open heap	No covering material
Polythene covered heap	Recycled low quality plastic sheet
Gunny bag covered heap	Discarded gunny bag stitched to appropriate size

375 kg of KCPL sludge was mixed with enrichers as per the treatment combination. It was then placed in circular heaps of 1 m diameter. The moisture

Plate 12 Aerobic open heap composting technique

Plate 13 Turning operation of the compost heaps at intervals

Plate 14 Gunny covered heap

Plate 15 Plastic covered heap

content of the entire substrate mass was maintained around 40 per cent by sprinkling water as when required. The heap was turned and mixed thoroughly at fortnightly intervals to facilitate proper aeration. Perforated polythene tube of 2 cm diameter and 1.5 m height was also inserted at the centre of the heap for periodical recording of temperature. Direct insertion of thermometer was also subsequently proved better for this. The heaps were maintained properly till decomposition was completed/stopped to form the compost.

3.3. Observations

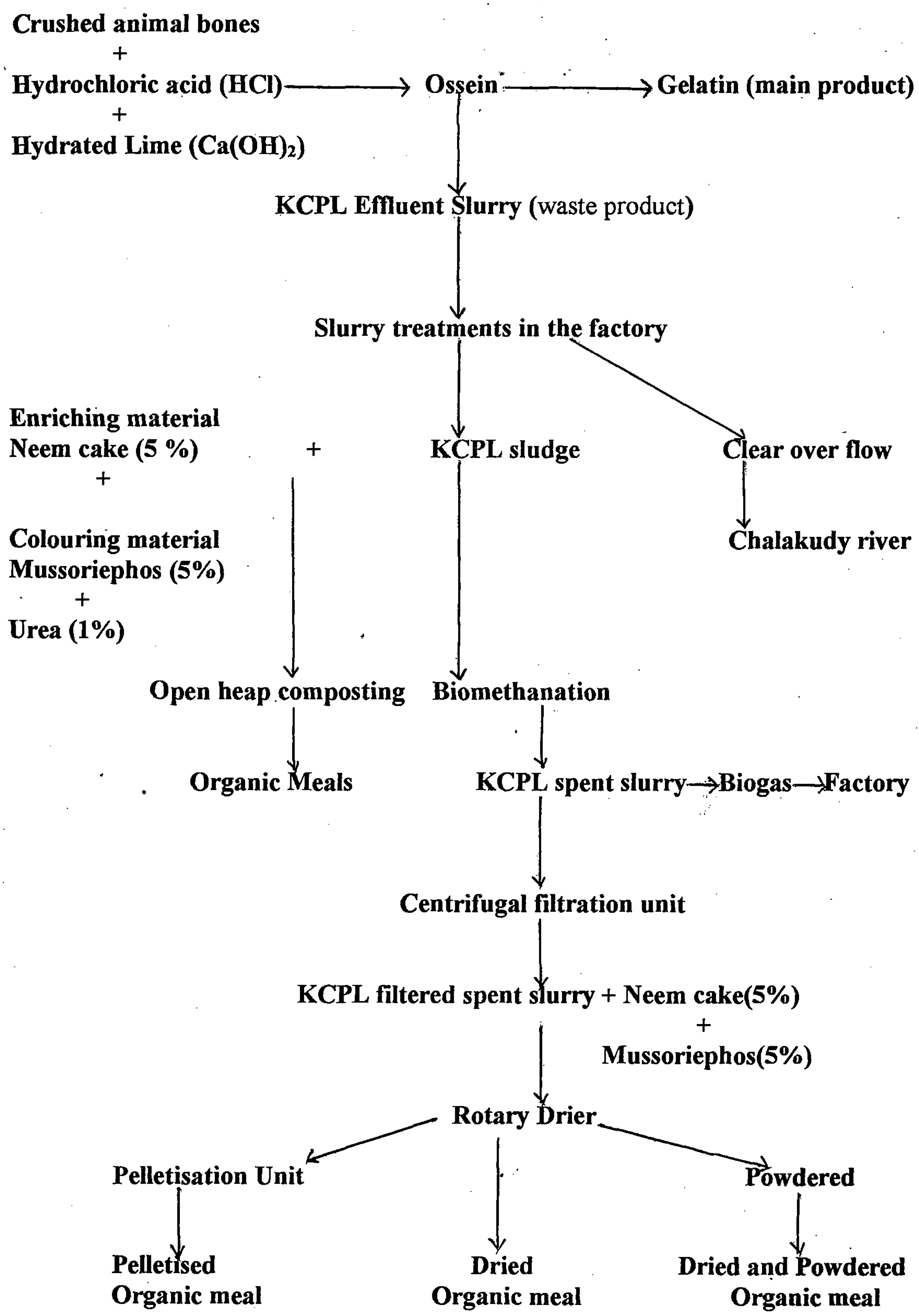
Daily measurement of temperature helped to determine the microbial activity and stages of compost maturity. Microbial count was taken in mesophilic, thermophilic and maturity stages following serial dilution and plate count method (Johnson and Curl, 1972). For bacteria, nutrient agar medium was used. For fungi and actinomycetes, potato dextrose and Czapekdose agar media were used. Qualitative observations on odour, consistency and colour at different stages were also conducted to judge the effectiveness of each treatment in converting the sludge into innocuous form of organic meal.

The flow diagram in Fig.1 depicts the important steps/processes involved in the formulation of organic meal.

3.3.1. Physico-chemical properties of organic meals

Selected organic meals based on desirability and acceptability criteria were studied in detail for determining their physico-chemical properties. The methodologies followed were same as those listed in Tables 3.1 and 3.2.

Fig. 1. Flow diagram of the production of Organic meals from KCPL effluent sludge



3.4. Influence of organic meal on crop and soil

3.4.1. Pot culture studies

The best organic meal as revealed from their desirable physico-chemical properties were initially pot tested to assess their influence on crop and soil. The ill effects if any were also studied under higher doses. The organic meal formulation viz. S + 5% NC + 5% MRP + 1% U was selected for this. It was tried at seven levels as below:

5, 10, 20, 40, 60, 80, 100 t/ha. The experiment was replicated thrice in CRD (Plates 16 and 17).

Earthern pots filled with 8 kg soil taken from paddy field were used to test the defined doses of organic meals. A control pot was also maintained. 25 days old rice seedlings of variety Matta Triveni were planted at the rate of three hills per pot maintaining 2 cm of standing water throughout. Periodical prophylactic measures were resorted to against pest and disease attack. Observations on growth and yield were recorded. Plant samples were analysed for N, P, K, Ca, Mg, Fe, Mn, Zn and Cu.

3.4.2. Field study

Field experiments were conducted with the same organic meal used for pot culture study. Both the direct and residual influence of the organic meal was assessed. An on-farm study was also undertaken with lower doses of organic meal. The methodological details of these experiments are given below:

3.4.2.1. Site, Soil and Climate

The field experiments were conducted in the farmer's field near KCPL factory site (Plates 18 and 19). On-farm trial to evaluate the influence and acceptability of the

Plate 16 Exploratory pot culture study with selected organic meal

Plate 17 Pot culture study with selected organic meals on rice – a general view

Plate 18 Field experiment with organic meal on rice –
initial stage

Plate 19 Field experiment with organic meal on rice –
full grown stage

Plate 20 Onfarm trial with organic meals harvest stage

organic meal among farmers was taken up in the Muriyad Kole lands of Irinjalakuda block in Thrissur district (Plate 20). In the experimental area at the factory site four crops including the residual crops were taken during Mundakan, Puncha and Virippu season during 1997-1998. On farm trial in Kole lands was conducted during Puncha season of January 1999. The edapho-climatological condition of the sites is provided in Appendices 5, 6a, 6b and 6c and in Figures 2a, 2b and 2c.

3.4.2.2. Variety and season

A short duration high yielding variety Matta Triveni and a medium duration local high yielding cultivar, Chemeen were selected for the experiments at the factory site. In Kole lands of Muriyad the high yielding short duration variety of high local acceptability Jyothi was used. The experiments were conducted during three seasons Virippu, Mundakan and Puncha during 1997-1999. The details of the field experiments are given in Table 3.7.

Table 3.7. Field experiments to evaluate the effect of organic meal

Sl. No.	Experiment	Field No/Site	Variety/ cultivar	Season	Period
1.	Effect of OM	KCPL1	Chemeen	Mundakan	02.10.97 – 14.01.98
		KCPL2	Chemeen	Puncha	26.01.98 – 11.06.98
2.	Residual effect	KCPL1	Chemeen	Puncha	26.01.98 – 12.06.98
		KCPL1	Matta Triveni	Virippu	18.06.98 - 19-09-98
3.	On-farm trial	Muriyad Kole lands	Jyothi	Puncha	23.01.99 – 07.05.99

3.4.2.3. Field study at factory site

To study the effect of organic meal, different levels viz., 5, 10, 15 and 20 t/ha in combination with NPK as shown below in Table 3.8 were field-tested. The same plots ($5x4m^2$) were used in subsequent seasons to evaluate the residual effect of the

Fig.2(a) Weather data for the cropping period - Oct. 1997 - Jan. 1998

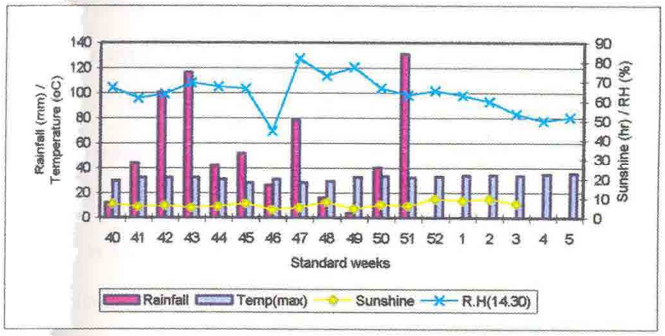


Fig.2(b) Weather data for the cropping period Jan.98 - Jun. 98 (Puncha crop)

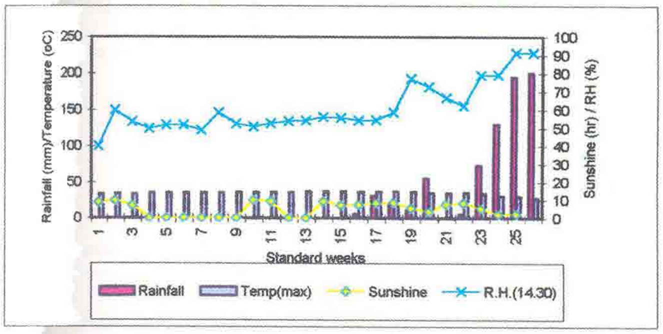
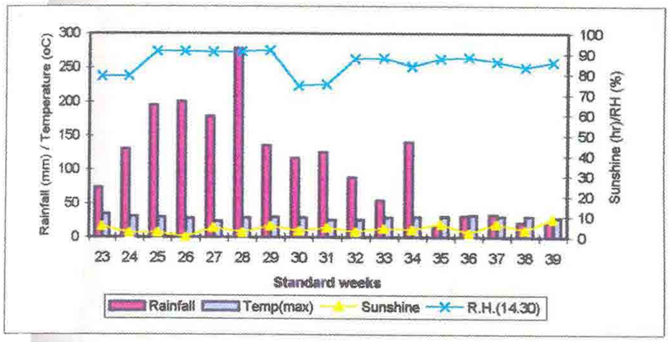


Fig.2(c) Weather data for the cropping period - Jun. 98 - Sept.98 (Virippu crop



respective treatments in randomised block design (RBD) with three replication. P was skipped in the residual study part of the experiment in those plots, which previously received different levels of organic meal.

3.4.2.4. On-farm Trial

The on-farm trial in farmer's fields of Muriyad Kole lands was conducted simultaneously in 15 plots each with one-acre size in different locations. The same organic meal formulation, which was used for the field study, was applied at two lower levels of 1.25 and 2.5t/ha in combination with recommended inorganic fertilizers selecting five plots for each level. Another five plots were maintained as control with the normal manurial practices as per the package of practices recommendation of KAU (KAU, 1996). No lime was added in plots treated with organic meal.

Table 3.8. Treatments for field study of the organic meal

Treatment	Code	Expansion
T_1	OM 5 NPK	Organic meal 5 t/ha + NPK recommended dose
T_2	0M 10 ½ NPK	Organic meal 10 t/ha + ½ recommended NPK dose
T_3	0M 10 ¾ NPK	Organic meal 10 t/ha + ¾ recommended NPK dose
T_4	0M 10 NPK	Organic meal 10 t/ha + NPK recommended dose
T_5	0M 15 ½ NPK	Organic meal 15 t/ha + ½ NPK recommended dose
T_6	0M 15 ¾ NPK	Organic meal 15 t/ha + ¾ NPK recommended dose
T_7	0M 15 NPK	Organic meal 15 t/ha + NPK recommended dose
T_8	OM 20 ½ NPK	Organic meal 20 t/ha + ½ NPK recommended dose
T_9	OM 20 ¾ NPK	Organic meal 20 t/ha + ¾ NPK recommended dose
T_{10}	OM 20 NPK	Organic meal 20 t/ha + NPK recommended dose
T_{11}	Control I	FYM5 t/ha + NPK recommended dose (KAU, 1996)
T_{12}	Control II	Absolute control

3.4.2.5. Nutrient source and agronomic practices

In all the experiments N and K were supplied as urea (46 per cent N) and muriate of potash (60 per cent K_2O) respectively. P was supplied as OM formulation (S+5% NC + 5%MRP +1%U) and MRP wherever required. Except for the P nutrient sources and specialities to suit the specificities of organic meal treatments, all other agronomic practices were as per the recommendation (KAU, 1996). In residual study the plots were hand digged to avoid inter plot mixing of soil and possible errors there upon in P levels.

3.4.2.6. Observations

Biometric observations at critical growth stages and yield parameters as summarised in Table 3.9 were recorded.

Table 3.9. Biometric and yield parameters observed

	Biometric observations	Yield parameters
1	Height of plants (cm)	Productive tillers/hill (No.)
2	Tiller count (No./hill) at four stages (tillering, panicle initiation, flowering and harvest)	Panicle details: Length (cm), Number of filled grains per panicle.
3	LAI at three stages	Thousand grain weight (g)
4	Dry matter production at two stages (tillering and harvest)	Straw yield (t/ha), Grain yield (t/ha)

3.4.2.7. Chemical analysis

Plant and soil samples were analysed for nutrient contents following standard procedures as provided in Table 3.10.

Table 3.10. Methods used for soil and plant analysis

No.	Character	Method	Reference
A	**Soil Analysis**		
1	pH	1:2.5 soil water suspension	Jackson, 1958
2	Organic carbon	Walkley and Black titration	Walkley and Black, 1934
3	Available N	Alkalane permanganate distillation	Subbiah and Asija, 1956
4	Available P	Bray-1 extractant ascorbic acid reductant – Spectrophotometry	Bray and Kurtz, 1945
5	Available K	Neutral normal ammonium acetate – Flame photometry	Jackson, 1958
6	Available Ca, Mg	Neutral normal ammonium acetate – EDTA titration	Jackson, 1958
7	Available Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometry	Jackson, 1958
B	**Plant Analysis**		
1	N	Microkjeldahl digestion and distillation	Jackson, 1958
2	P	Vanadomolybdo phosphoric yellow colour – Spectrophotometry	Jackson, 1958
3	K	Flame photometry	Jackson, 1958
4	Ca, Mg	Diacid extract – EDTA titration	Jackson, 1958
5	Fe, Mn, Zn, Cu	Atomic Absorption Spectrophotometry	Jackson, 1958

3.5. Statistical analysis

The data were compiled, tabulated and analysed by applying the analysis of variance technique (Panse and Sukhatme, 1985). Whenever F tests were significant appropriate critical differences were calculated to test the level of significance among treatment means.

Results

Chapter 4

RESULTS

Studies on the formulation and evaluation of organic meals from KCPL effluent slurry were carried out as described under Chapter 3 and the results of various experiments are presented in this chapter.

4.1. Basic properties of KCPL effluent sludge

Being a new material, the physico-chemical properties of KCPL effluent sludge was studied in detail using the composite samples drawn for the purpose.

4.1.1. Physical properties of the sludge

The KCPL effluent sludge is light to deep grey in colour with an offensive, irritating, nauseating odour. It is in wet cobbled flakes form. The consistency of the material remained more or less semi-solid with plasticity limit varying around non-plastic to slightly plastic. All the samples studied showed an almost uniform particle size distribution with dominance of fine particles in the range of 0.002-0.02 mm (59.92%) followed by particles size below 0.002 (30.19%) and particles above 0.02 mm (9.88%) in that order. The data are provided in Table 4.1

The mean moisture content of the samples drawn for the six months period ranged from 53.78 to 59.71 percent. Higher values were observed during the months of June-July and lower values during May (Table.4.1). There was no significant difference in moisture content within the different dates of sampling.

Table 4.1. Consistency of KCPL sludge – particle size and moisture content

Property	Months						
Particle size (mm)	May	Jun.	Jul.	Aug.	Sep.	Oct.	Mean
< 0.002 (%)	31.41	28.47	29.23	28.74	31.94	31.39	30.19
0.002 – 0.02 (%)	57.95	58.14	60.25	59.50	61.77	61.91	59.92
0.02 – 0.2 (%)	10.65	13.39	10.52	11.75	6.29	6.70	9.88
Moisture content (%)	53.78	59.61	59.71	56.36	58.16	55.78	57.23

Table 4.2. pH, neutralizing value and major nutrient content of KCPL sludge

Elements	Months						
	May	Jun.	Jul.	Aug.	Sep.	Oct.	Mean
Nitrogen (%)	1.74^{b}	1.89^{a}	1.79^{b}	1.89^{a}	1.92^{a}	1.91^{a}	1.86
Phosphorus (%)	7.93^{b}	8.60^{a}	8.71^{a}	8.12^{b}	8.61^{a}	8.69^{a}	8.44
Potassium (%)	0.27^{c}	0.29^{b}	0.28^{b}	0.30^{a}	0.28^{b}	0.28^{b}	0.28
Calcium (%)	20.8^{ab}	20.2^{b}	19.6^{c}	20.3^{ab}	20.9^{a}	20.2^{b}	20.34
Magnesium (%)	0.42	0.42	0.42	0.42	0.41	0.43	0.42
Sulphur (%)	0.33	0.33	0.35	0.35	0.34	0.35	0.34
Organic carbon (%)	31.4^{b}	34.3^{a}	33.6^{a}	33.6^{a}	34.4^{a}	33.6^{a}	33.49
pH	6.73^{b}	6.76^{b}	6.72^{b}	6.84^{a}	6.74^{b}	6.69^{b}	6.75
Neutralizing Value	57.5^{b}	55.1^{c}	57.3^{b}	58.6^{a}	59.3^{a}	58.8^{a}	57.7

The material was near neutral in reaction with a mean pH value of 6.75 (Table 4.2). Maximum value of 6.84 was recorded during August. During other months the pH value ranged from 6.69 to 6.76 and these were statistically on par with each other.

4.1.2. Chemical properties of the sludge

Monthly mean values of major, minor nutrients and heavy metal content of the sludge are furnished in Tables 4.2, 4.3 and 4.4 respectively. Detailed data are presented in Appendices 7a to 7p.

The nutrient analysis revealed that the sludge is a calcium and phosphorus rich material with average content of calcium being 20.34 per cent and that of phosphorus 8.44 per cent. Other major nutrients followed the order nitrogen (1.86), magnesium (0.42), sulphur (0.34) and potassium (0.28) per cent. The monthly variations in the respective nutrients were also not significant in general. The average carbon content of the material was 33.49 per cent. The neutralizing value of the sludge during the sampling period ranged from 55.1 to 59.3 with mean value of 57.7.

Among the minor nutrients iron content was the highest with average value of 1654 ppm. Zinc > manganese > copper followed that order and their average contents were 125.5, 106.8 and 8 ppm respectively. As revealed from Table 4.4 heavy metal contents of nickel, chromium, lead and cadmium were 17.3, 12, 13.3 and 3 ppm respectively. Barring iron, variations in the monthly values of the minor nutrients as well as that of the heavy metals were also not that significant as in the case of major nutrients.

Table 4.3. Minor nutrient content of KCPL sludge (ppm)

Elements	Months						
	May	Jun.	Jul.	Aug.	Sep.	Oct.	Mean
Iron	1101^{e}	1719^{c}	1882^{a}	1554^{d}	1830^{b}	1839^{b}	1654
Zinc	121^{d}	129^{a}	127^{ab}	123^{cd}	125^{bc}	128^{a}	125.5
Manganese	107^{b}	105^{c}	107^{b}	109^{a}	107^{b}	106^{b}	106.8
Copper	8	8	8	8	8	8	8

Table 4.4. Heavy metal content of KCPL sludge (ppm)

Elements	Months						
	May	Jun.	Jul.	Aug.	Sep.	Oct.	Mean
Nickel	18^{a}	17^{b}	17^{b}	17^{b}	17^{b}	17^{b}	17.3
Chromium	12	12	12	12	12	12	12
Lead	11^{c}	13^{b}	14^{a}	14^{a}	14^{a}	14^{a}	13.3
Cadmium	3	3	3	3	3	3	3

Permissible Limit : Cadmium - < 5 ppm ; Lead - < 150 ppm ; Chromium - < 300 ppm
Copper - < 500 ppm

(Source: Eghball *et al.* 1997)

4.1.3. Incubation study

As a part of the basic study, KCPL sludge was incubated to understand the pattern and nature of nutrient mineralisation. The sludge in comparison with mussorie rock phosphate, a known P source, at three levels and at three moisture regimes was evaluated. The treatment effects were analysed using simple CRD (completely randomised design) and their interaction by augmented CRD techniques. The results are presented below.

4.1.3.1. Soil reaction

The average pH of the incubated medium ranged from 5.87 to 6.74 (Table 4.5). Irrespective of treatments the pH of the soil gradually decreased with period of incubation and reached stabilised values after an initial hike at 15th day of incubation. The treatments KCPL sludge @ 4 g P and rock phosphate @ 4 g P both under waterlogged condition were significantly superior to rest of the treatments in stabilised pH levels with average values of 6.71 and 6.74 respectively. It was followed by sludge @ 1 g P (6.65) and 2 g P (6.64) under waterlogged condition. The control treatments registered significantly lower pH in all cases.

The overall effect of source, levels and moisture regimes on pH is furnished in Table 4.6. In general, KCPL sludge maintained significantly higher pH (6.52) as compared to the second source, the rock phosphate (6.36). With a pH of 6.71 at the 15th day of incubation the KCPL sludge maintained a higher value of 6.39 at the final stage. Corresponding values for rock phosphate were 6.56 and 6.20 respectively.

Application of different levels of phosphorus through both sources also increased the pH, the increase being proportional to the level applied. Water logging

Table 4.5. Influence of treatments on the pH of soil at different periods of incubation

Treatment combination	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP 1g 50 FC	5.95	6.05^{gh}	6.20^{g}	6.05^{gh}	5.90^{ij}	5.90^{jk}	5.90^{e}	5.99
MRP 2g 50 FC	6.00	6.45^{ef}	6.30^{fg}	6.30^{defg}	6.15^{fghij}	6.00^{ijk}	6.25^{bcde}	6.21
MRP 4g 50 FC	6.00	6.45^{ef}	6.55^{de}	6.45^{bcd}	6.00^{hij}	6.30^{ef}	6.40^{abcd}	6.31
MRP 1g FC	5.90	6.40^{ef}	6.30^{fg}	6.10^{fgh}	6.15^{fghij}	5.90^{jk}	6.05^{de}	6.11
MRP 2g FC	5.90	6.38^{ef}	6.45^{def}	6.55^{bcd}	6.25^{defghu}	6.15^{fghi}	6.20^{bcde}	6.27
MRP 4g FC	6.10	6.90^{abc}	6.35^{efg}	6.40^{bcde}	6.30^{defgh}	6.30^{ef}	6.40^{abcd}	6.40
MRP 1g WL	6.10	6.70^{cd}	6.65^{cd}	6.65^{abc}	6.35^{cdefgh}	6.30^{ef}	6.70^{a}	6.50
MRP 2g WL	6.10	6.75^{cd}	6.60^{cd}	6.50^{bcd}	6.40^{bcdefg}	6.30^{ef}	6.70^{a}	6.49
MRP 4g WL	6.20	7.00^{ab}	6.95^{ab}	6.90^{a}	6.85^{a}	6.85^{a}	6.45^{abc}	6.74
Sludge 1g 50 FC	5.90	6.30^{f}	6.20^{g}	6.05^{gh}	6.30^{defgh}	6.05^{hij}	6.10^{cde}	6.13
Sludge 2g 50 FC	5.90	6.28^{f}	6.50^{def}	6.40^{bcde}	6.20^{efghij}	6.10^{ghi}	6.10^{cde}	6.21
Sludge 4g 50 FC	6.0	6.55^{de}	6.60^{cd}	6.50^{bcd}	6.50^{abcdef}	6.40^{de}	6.45^{abc}	6.43
Sludge 1g FC	6.0	6.25^{fg}	6.20^{g}	6.55^{bcd}	6.30^{defgh}	6.25^{efg}	6.35^{abc}	6.27
Sludge 2g FC	5.9	6.80^{bc}	6.65^{cd}	6.50^{bcd}	6.25^{defghi}	6.20^{fgh}	6.20^{bcde}	6.36
Sludge 4g FC	6.0	7.05^{a}	6.80^{bc}	6.40^{bcde}	6.70^{abc}	6.50^{cd}	6.50^{ab}	6.57
Sludge 1g WL	6.1	7.00^{ab}	7.00^{ab}	6.60^{bcd}	6.60^{abcd}	6.70^{ab}	6.50^{ab}	6.65
Sludge 2g WL	6.1	7.10^{a}	7.00^{ab}	6.50^{bcd}	6.55^{abcde}	6.80^{ab}	6.45^{abc}	6.64
Sludge 4g WL	6.1	7.10^{a}	7.05^{a}	6.70^{ab}	6.75^{ab}	6.65^{bc}	6.65^{a}	6.71
Control 1 50 FC	5.90	5.95^{h}	5.90^{h}	5.95^{h}	5.85^{j}	5.65^{l}	5.90^{e}	5.87
Control 2 FC	5.90	6.00^{h}	6.15^{g}	6.15^{efgh}	6.05^{ghij}	5.85^{k}	6.15^{bcde}	6.03
Control 3 WL	6.10	6.25^{fg}	6.20^{g}	6.35^{cdef}	6.60^{abcd}	6.85^{a}	6.20^{bcde}	6.36
CD (P=0.05)	NS	0.197	0.208	0.263	0.322	0.161	0.308	

Table 4.6. Overall effect of source, level and moisture regime on pH at different periods of incubation

Source	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP	6.02	6.56^{b}	6.48^{b}	6.43	6.26^{b}	6.22^{b}	6.20^{b}	6.36
Sludge	6.00	6.71^{a}	6.67^{a}	6.47	6.46^{a}	6.41^{a}	6.39^{a}	6.52
CD	NS	0.065	0.067	NS	0.11	0.05	0.02	
Level								
1 g P	5.99	6.45^{c}	6.42^{c}	6.33^{b}	6.27^{b}	6.18^{c}	6.20^{b}	6.31
2 g P	5.98	6.63^{b}	6.58^{b}	6.46^{a}	6.30^{b}	6.26^{b}	6.23^{b}	6.41
4 g P	6.06	6.84^{a}	6.72^{a}	6.56^{a}	6.52^{a}	6.50^{a}	6.45^{a}	6.60
CD	NS	0.08	0.08	0.11	0.13	0.06	0.05	
Moisture regime								
50 FC	5.95	6.35^{c}	6.39^{b}	6.29^{c}	6.17^{c}	6.13^{c}	6.15^{c}	6.24
FC	5.96	6.63^{b}	6.46^{b}	6.42^{b}	6.33^{b}	6.22^{b}	6.30^{b}	6.40
WL	6.17	6.94^{a}	6.88^{a}	6.64^{a}	6.58^{a}	6.60^{a}	6.43^{a}	6.68
CD	NS	0.08	0.08	0.11	0.13	0.06	0.05	
Control								
50 FC	5.90	5.95	5.90	5.95	5.85	5.65	5.90	5.87
FC	5.90	6.00	6.15	6.15	6.05	5.85	5.90	6.02
WL	6.10	6.25	6.20	6.35	6.60	6.85	6.20	6.40

significantly increased the soil pH (6.68) followed by moisture level at field capacity (6.40) and 50 per cent field capacity (6.24) in that order.

4.1.3.2. Available nitrogen

Table 4.7 suggests the significant difference between control and treatments in the release of available N from soil with average values ranging from 141.2 to 175.1ppm. The highest release was observed at 45th day of incubation. The maximum N release was observed from the treatment 4 g P sludge under field capacity with a value of 213.7 ppm. This was closely followed by 4 g P sludge waterlogged with a value of 209.7ppm. 1g P sludge (206 ppm) and 2 g P sludge (203 ppm) under waterlogged condition were also on par with that of 4 g P sludge under same moisture regime.

Viewed over the period of incubation, the treatment 4 g P sludge under water stagnation was superior over the rest both in majority of periodical values as well as the mean value (175.1ppm). Sludge at this level under field capacity was also showing comparable values at many stages and the mean value was 174.1ppm.

From Table 4.8 it is clear that KCPL sludge was significantly superior to rock phosphate in releasing N. The release of N from sludge was more during initial period while greater release occurred from rock phosphate during the later period of study (120 days). With increase in levels of P sources there was significant increase in N release also. Maximum N content of 202.46 ppm was observed at higher 4 g P level at 45 days of incubation. Moisture regimes also played a significant role in the release of available N, the pattern of release being more at water logging (168.8 ppm)

Table 4.7. Influence of treatments on the available N content of soil (ppm) at different periods of incubation

Treatment combination	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP 1g 50 FC	136.7	146.6^{j}	169.9^{gh}	188.9^{de}	180.0^{de}	162.1^{cdef}	147.8^{bcde}	161.7
MRP 2g 50 FC	136.4	157.4^{ef}	171.5^{fg}	191.9^{cde}	184.5^{cde}	155.9^{ef}	147.3^{bcde}	163.6
MRP 4g 50 FC	138.2	151.2^{hi}	162.2^{I}	186.6^{ef}	179.4^{e}	166.3^{abcd}	152.1^{ab}	162.3
MRP 1g FC	136.1	154.5^{j}	177.2^{def}	198.3^{bcd}	181.1^{de}	159.1^{def}	141.5^{ef}	163.8
MRP 2g FC	135.4	149.7^{ij}	162.6^{I}	189.5^{de}	181.9^{de}	156.3^{ef}	150.6^{b}	160.8
MRP 4g FC	136.2	162.0^{d}	176.0^{efg}	198.9^{bcd}	185.6^{bcd}	169.6^{ab}	153.4^{ab}	149.4
MRP 1g WL	136.8	151.8^{ghi}	164.1^{hi}	193.0^{cde}	184.0^{de}	155.6^{f}	150.5^{b}	162.3
MRP 2g WL	137.1	148.6^{ij}	159.0^{ij}	186.1^{ef}	179.4^{e}	163.5^{bcde}	157.2^{a}	161.6
MRP 4g WL	137.4	163.4^{d}	179.1^{cde}	206.6^{ab}	181.5^{de}	171.6^{a}	151.0^{ab}	150.5
Sludge 1g 50 FC	136.2	161.5^{de}	179.6^{cde}	193.8^{cde}	180.6^{de}	167.8^{abc}	142.9^{def}	166.1
Sludge 2g 50 FC	136.4	155.8^{fg}	153.2^{jk}	177.1^{fg}	165.9^{f}	157.5^{ef}	143.6^{cdef}	155.6
Sludge 4g 50 FC	136.2	169.9^{c}	178.1^{cdef}	199.4^{bcd}	185.0^{cde}	165.6^{abcd}	148.0^{bcd}	168.9
Sludge 1g FC	136.2	170.9^{bc}	184.3^{bc}	191.1^{de}	183.0^{de}	162.9^{bcdef}	147.1^{bcde}	167.9
Sludge 2g FC	137.1	170.7^{bc}	183.6^{bcd}	194.4^{cde}	180.5^{de}	157.6^{ef}	148.9^{bcd}	167.5
Sludge 4g FC	136.2	170.1^{c}	188.4^{ab}	213.7^{a}	191.0^{ab}	169.9^{ab}	149.6^{bc}	174.1
Sludge 1g WL	135.2	175.8^{a}	193.2^{a}	206.0^{ab}	190.1^{abc}	160.1^{def}	152.7^{ab}	153.9
Sludge 2g WL	136.1	173.1^{abc}	193.4^{a}	203.0^{abc}	182.3^{de}	160.2^{def}	151.1^{ab}	171.3
Sludge 4g WL	135.2	175.1^{ab}	190.9^{a}	209.7^{ab}	192.1^{a}	171.5^{a}	150.0^{bc}	175.1
Control 1 50 FC	136.2	137.6^{I}	142.2^{cl}	155.8^{h}	151.9^{g}	139.1^{g}	127.0^{g}	141.4
Control 2 FC	135.2	136.9^{k}	143.6^{l}	160.7^{h}	153.4^{g}	129.9^{h}	128.9^{g}	141.2
Control 3 WL	136.2	140.0^{k}	151.6^{k}	174.6^{g}	165.0^{f}	137.5^{g}	139.4^{f}	149.1
CD (P=0.05)	NS	4.19	6.14	9.98	5.18	6.58	5.64	

Table 4.8. Overall effect of source, level and moisture regime on available N (ppm) at different periods of incubation

Source	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP	136.70	153.92^b	169.06^b	193.29^b	181.92	162.23	150.16^a	163.8
Sludge	136.08	169.21^a	182.73^a	198.67^a	183.40	163.69	148.21^b	168.9
CD	NS	1.39	2.05	3.33	NS	NS	1.88	
Level								
1 g P	136.20	160.19^b	178.03^a	195.17^b	183.12^b	161.28^b	147.09^b	165.8
2 g P	136.42	159.22^b	170.55^b	190.32^c	179.10^c	158.51^b	149.78^a	163.4
4 g P	136.57	165.28^a	179.10^a	202.46^a	185.76^a	169.08^a	150.69^a	169.5
CD	NS	1.71	2.51	4.07	2.12	2.69	2.30	
Moisture regime								
50 FC	136.68	157.08^b	169.07^b	189.60^b	179.22^b	162.53	146.96^b	163.0
FC	136.20	162.99^a	178.68^a	197.65^a	183.85^a	162.58	148.53^b	166.9
WL	136.30	164.63^a	179.94^a	200.69^a	184.91^a	163.77	152.07^a	168.8
CD	NS	1.71	2.51	4.07	2.12	NS	2.30	
Control								
50 FC	136.20	137.65	142.15	155.75	151.95	139.10	127.02	141.4
FC	135.20	136.85	143.65	160.70	153.35	129.05	128.88	141.1
WL	136.20	139.95	151.55	174.55	165.00	137.50	139.40	149.1

followed by field capacity level (166.9 ppm). Lowest release occurred at 50 per cent field capacity level (163 ppm) with both of the sources.

Interaction effect between source and levels were significant at 15 and 60 days of incubation. The combination of KCPL sludge at 4 g P level was significantly superior to 4 g rock phosphate. Similarly the interaction between source and moisture regime and levels of P and moisture regimes were also significant at certain periods of study. With increasing levels of P and moisture higher was the release of available N.

4.1.3.3. Available phosphorus

The mean available P of the soil varied from 11.68 ppm in control to 38.2 ppm in sludge added soil (Table 4.9). Maximum release of available P occurred at 30 days of incubation and thereafter the P decreased. There was a further small peak at 90 days after incubation. In the early stages of incubation the best treatments in contributing to greater P release were KCPL sludge 2 g P at field capacity (96 ppm) followed by 4 g P sludge FC (85.5) and 4 g P sludge 50 FC (82.50). Towards the later period (90 and 120 days) 4 g sludge FC released more available P in the soil followed by 2 g sludge FC and 2 g sludge 50 FC. The treatments, in general, were inferior in releasing phosphorus at water stagnation.

Table 4.10 reveals that between the sources, KCPL sludge was significantly superior to rock phosphate. KCPL sludge registered higher release of available P through out the incubation period. It released the highest available P of 59.42 ppm at 30 days where as the rock phosphate could touch only at 25.8 ppm (45th day). Higher levels of sources could also increase the available P content of soil

Table 4.9. Influence of treatments on the available P content of soil (ppm) at different periods of incubation

Treatment combination	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP 1g 50 FC	6.74	7.47^{fgh}	19.80^{ghij}	35.34^{b}	11.90^{de}	17.98^{fghij}	27.28^{bcd}	18.1
MRP 2g 50 FC	6.82	8.56^{efgh}	16.79^{ghij}	22.63^{de}	10.15^{e}	22.94^{def}	14.26^{gh}	14.6
MRP 4g 50 FC	7.01	9.82^{efg}	11.40^{j}	21.08^{def}	10.40^{e}	15.50^{hij}	13.33^{h}	12.6
MRP 1g FC	6.72	14.35^{d}	21.59^{fghi}	31.62^{bc}	14.50^{bcde}	18.11^{fghij}	24.49^{def}	18.8
MRP 2g FC	6.84	9.69^{efg}	15.00^{hij}	15.50^{fg}	9.29^{e}	20.52^{fghi}	14.88^{gh}	13.1
MRP 4g FC	6.92	12.11^{de}	14.10^{ij}	23.88^{de}	8.20^{e}	21.55^{efhj}	13.33^{h}	14.3
MRP 1g WL	6.82	8.96^{efgh}	37.20^{df}	37.20^{b}	13.19^{bcde}	14.93^{ij}	21.08^{defg}	20.1
MRP 2g WL	6.01	5.47^{h}	29.40^{ef}	20.46^{def}	9.85^{e}	18.13^{fghij}	13.02^{h}	14.6
MRP 4g WL	6.11	5.75^{gh}	40.79^{d}	24.49^{de}	10.25^{e}	18.46^{fghij}	13.35^{h}	17.1
Sludge 1g 50 FC	6.82	22.74^{bc}	19.79^{ghij}	35.96^{b}	20.53^{bcde}	23.25^{cdef}	23.87^{def}	21.9
Sludge 2g 50 FC	6.84	25.74^{bc}	60.00^{c}	50.84^{a}	41.25^{a}	34.72^{b}	32.20^{abc}	35.9
Sludge 4g 50 FC	6.96	32.76^{a}	82.50^{b}	32.39^{bc}	24.44^{bcd}	27.90^{cs}	32.39^{abc}	34.1
Sludge 1g FC	6.74	19.44^{c}	26.10^{fg}	12.09^{g}	17.24^{bcde}	26.97^{cde}	27.59^{bcd}	19.5
Sludge 2g FC	6.02	29.49^{a}	96.00^{a}	47.12^{a}	19.60^{bcde}	34.72^{b}	34.45^{ab}	38.2
Sludge 4g FC	6.84	19.20^{c}	85.50^{b}	34.02^{b}	25.74^{b}	42.78^{a}	36.27^{a}	35.8
Sludge 1g WL	6.92	10.49^{def}	23.85^{fgh}	17.97^{efg}	18.70^{bcde}	19.69^{fghi}	20.51^{defgh}	16.9
Sludge 2g WL	6.84	6.12^{gh}	61.50^{c}	24.18^{de}	25.40^{bc}	22.17^{defg}	18.15^{fgh}	23.5
Sludge 4g WL	6.78	4.98^{h}	79.50^{b}	26.51^{cd}	20.23^{bcde}	29.21^{bc}	26.08^{cde}	27.6
Control 1 50 FC	7.01	10.82^{def}	18.60^{ghij}	16.98^{fg}	12.81^{cde}	11.85^{j}	15.73^{gh}	13.4
Control 2 FC	6.98	8.54^{efgh}	19.50^{ghij}	12.94^{g}	11.70^{de}	11.18^{j}	14.80^{gh}	12.2
Control 3 WL	6.01	5.03^{h}	16.79^{ghij}	10.46^{g}	11.45^{e}	12.77^{ij}	19.22^{defgh}	11.68
CD (P=0.05)	NS	3.59	8.31	5.84	10.98	5.61	6.51	

Table 4.10. Overall effect of source, level and moisture regime on available P (ppm) at different periods of incubation

Source	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP	6.67	9.13^{b}	22.90^{b}	25.80^{b}	10.86^{b}	18.68^{b}	17.22^{b}	15.9
Sludge	6.75	19.0^{a}	59.42^{a}	31.23^{a}	23.68^{a}	29.05^{a}	27.95^{a}	28.2
CD	NS	1.2	2.77	1.92	3.66	1.87	2.17	
Level								
1 g P	6.79	13.91	24.72^{c}	28.37^{ab}	16.01	20.15^{b}	24.14	19.2
2 g P	6.56	14.18	46.45^{b}	30.12^{a}	19.26	25.53^{a}	21.16	23.3
4 g P	6.77	14.11	52.30^{a}	27.06^{b}	16.54	25.90^{a}	22.46	23.6
CD	NS	NS	3.39	2.38	NS	2.29	NS	
Moisture regime								
50 FC	6.87	17.85^{a}	35.05^{b}	33.04^{a}	19.78	23.72^{b}	23.89^{a}	22.9
FC	6.68	17.38^{a}	43.05^{a}	27.37^{b}	15.76	27.44^{a}	25.17^{a}	23.3
WL	6.58	6.96^{b}	45.37^{a}	25.14^{b}	16.27	20.43^{c}	18.70^{b}	19.0
CD	NS	1.47	3.39	2.38	NS	2.29	2.66	
Control								
50 FC	7.01	10.82	18.60	16.98	12.81	15.84	15.73	16.9
FC	6.98	8.54	19.50	12.94	11.70	15.18	14.79	15.7
WL	6.01	5.03	16.79	10.46	11.45	12.78	19.22	13.10

corresponding with the level of application. The mean release at 4 g, 2 g and 1 g P being 23.6, 23.3 and19.2 ppm respectively.

Maximum release of P occurred at field capacity (23.3 ppm) followed by 50 per cent level (22.9 ppm). In the initial stage of incubation water logging decreased the available P content but it gradually increased with advancing period of incubation. In the waterlogged situation the available P at 15 days was only 6.96 ppm and it was inferior to that at 50 per cent field capacity (17.85 ppm) and at field capacity level (17.38 ppm). But at 30 days the release under waterlogged situation increased to 45.37 ppm and was on par with field capacity level (43.05 ppm).

Interaction between source and level of P, source and moisture regime and between level of P and moisture regime were significant at certain periods of incubation. Higher rate of release of P was observed on 30th day of incubation with all the levels of application. With 4 g P the released P was 52.30 ppm followed by 2 g P and 1 g P with respective values of 46.45 ppm and 24.72 ppm (Table 4.10). In general, this trend of release was maintained throughout the incubation except for 45th day where the highest level, 4 g P was inferior to other levels. Both sludge and rock phosphate released more P at field capacity than under waterlogged condition.

4.1.3.4. Available calcium

Table 4.11 suggest that the mean available calcium content of incubated medium varied from 689.3 ppm in control to 1040 ppm in MRP 4 g P at 50 per cent field capacity. The available Ca content increased up to 60 days, decreased at 90 days and further increased at 120 days of incubation. The peak was observed at 60 days irrespective of treatments. Among the treatments rock phosphate at 4 g 50 field capacity followed by water logging and at field capacity were significantly superior. It was followed by sludge 4 g at field capacity, 50 field capacity and sludge 2 g at 50 field capacity. The mean values of released calcium by 4 g P MRP treatments were 1040, 1025 and 1007 ppm and by sludge 953.6, 941.8 and 929.6 ppm respectively for the three treatments.

Initially the two sources were on par in contributing available calcium, but towards the later period rock phosphate was superior to sludge. From 60th day of incubation onwards the MRP stood significant over the sludge with a value of 1056.2 ppm and 997.1 ppm, respectively. It reached 1068.33 ppm and 992.33 ppm respectively at 120th day of incubation (Table 4.12).

With increase in level of P also there was significant increase in the release of calcium. 4 g P maintained highest values always and it ranged from 813 ppm to 1164 ppm during 15th to 120th day of incubation. The mean values were 982.67, 869.22 and 782.65 ppm respectively for 4, 2 and 1 g P.

Moisture regimes also exerted significant influence on release of available calcium especially towards the later stages of incubation. Field capacity level of moisture was more favourable for the release of calcium at 45th and 60th day of incubation with respective values of 1021.83 ppm and 1089.67 ppm. Later on 50 per cent field capacity level was found superior. Water logged condition was always inferior to other two levels.

Interaction between source and level was significant at 45, 60 and 120 days while that between level of added P and moisture regime was significant at 30, 45 and 120 days. Interaction between source and moisture regime was non-significant.

Table 4.11. Influence of treatments on the available Ca content of soil (ppm) at different periods of incubation

Treatment combination	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP 1g 50 FC	526.7	729	756^{ghi}	880^{i}	924^{efgh}	770^{fghij}	825^{ghi}	772.9
MRP 2g 50 FC	528.4	881	980^{bcdef}	898hi	938^{efgh}	980^{ab}	1218^{b}	917.6
MRP 4g 50 FC	528.4	863	1050^{bcde}	1026^{cd}	1260^{b}	1050^{a}	1503^{a}	1040
MRP 1g FC	530.6	730	840^{efgh}	894^{hi}	966^{efg}	840^{cdefgh}	896^{fgh}	813.8
MRP 2g FC	532.4	652	756^{ghi}	980^{def}	1036^{def}	994^{ab}	829^{ghi}	825.6
MRP 4g FC	524.6	528	1106^{bc}	1288^{a}	1428^{a}	910^{bcde}	1267^{b}	1007
MRP 1g WL	529.4	679	728^{ghi}	754^{j}	798^{h}	748^{ghij}	816^{hi}	721.7
MRP 2g WL	527.4	763	756^{ghi}	917^{ghi}	1036^{def}	918^{bcd}	949^{defg}	838.1
MRP 4g WL	525.6	959	1148^{b}	1157^{b}	1120^{cd}	956^{abc}	1312^{b}	1025
Sludge 1g 50 FC	531.2	728	868^{defgh}	943^{fgh}	910^{efgh}	798^{efghi}	1057^{cd}	833.6
Sludge 2g 50 FC	529.7	876	994^{bcde}	1040^{c}	1050^{de}	924^{bcd}	1094^{c}	929.6
Sludge 4g 50 FC	530.6	748	1015^{bcde}	1050^{c}	1274^{b}	952^{abc}	1023^{cdef}	941.8
Sludge 1g FC	528.4	698	770^{ghi}	879^{i}	924^{efgh}	658^{j}	917^{efgh}	767.8
Sludge 2g FC	524.4	715	1050^{bcde}	959^{efg}	938^{efgh}	812^{defghi}	1002^{cdef}	857.2
Sludge 4g FC	528.4	886	1078^{bcd}	1131^{b}	1246^{bc}	938^{abc}	868^{ghi}	953.6
Sludge 1g WL	530.2	704	784^{fghi}	899^{hi}	854^{gh}	811^{defghi}	919^{efgh}	785.8
Sludge 2g WL	530.1	807	868^{defgh}	900^{hi}	910^{efgh}	876^{bcdef}	1039^{cde}	847.1
Sludge 4g WL	536.8	894	1358^{a}	978^{def}	868^{gh}	848^{cdefg}	1012^{cdef}	927.8
Control 1 50 FC	525.6	622	824^{cdefg}	924^{ghi}	896^{fgh}	728^{hij}	748^{i}	752.5
Control 2 FC	528.2	539	603^{i}	805^{i}	906^{efgh}	700^{ij}	744^{i}	689.3
Control 3 WL	524.4	610	672^{hi}	823^{hi}	962^{efgh}	703^{ij}	719^{i}	716.2
CD (P=0.05)	NS	NS	184.7	44.68	125.8	104.3	114.8	

Table 4.12. Overall effect of source, level and moisture regime on available calcium content (ppm) at different periods of incubation

Source	Period (days)							
	0	15	30	45	60	90	120	Mean
MRP	528.17	753.83	902.22^{b}	977.06	1056.20^{a}	907.33^{a}	1068.3^{a}	884.73
Sludge	529.97	784.06	976.11^{a}	975.44	997.10^{b}	846.33^{b}	992.3^{b}	871.62
CD	NS	NS	61.56	NS	41.94	34.78	38.28	
Level								
1 g P	529.42	711.42	791.00^{c}	874.83^{c}	896.00^{c}	770.83^{b}	905.08^{c}	782.65
2 g P	528.73	782.33	900.67^{b}	949.00^{b}	984.67^{b}	917.33^{a}	1021.83^{b}	869.22
4 g P	529.07	813.08	1125.83^{a}	1104.92^{a}	1199.33^{a}	942.33^{a}	1164.08^{a}	982.67
CD	NS	NS	75.40	18.24	51.36	42.60	46.88	
Moisture regime								
50 FC	529.17	804.17	943.83	972.83^{b}	1059.33^{a}	912.33^{a}	1119.92^{a}	905.94
FC	528.13	701.67	933.33	1021.83^{a}	1089.67^{a}	858.67^{b}	963.17^{b}	870.92
WL	529.92	801.0	940.33	934.08^{c}	931.00^{b}	859.50^{b}	1007.92^{b}	857.68
CD	NS	NS	NS	18.24	51.36	42.60	46.88	
Control								
50 FC	525.6	622.0	824.0	924.0	896.0	728.0	748.0	752.51
FC	528.2	539.0	603.0	805.0	906.0	700.0	744.0	689.31
WL	524.4	610.0	672.0	823.0	962.0	703.0	719.0	716.2

4.2. Standardisation of formulation techniques of organic meals

Different techniques were employed to prepare organic meals from the spent slurry as well as the sludge as described under item 3.2. The formulated organic meals are depicted in Plates 21 and 22. The results of these trials are summarised below:

4.2.1. Organic meals from spent slurry

4.2.1.1. Physical properties

The physical properties of organic meals produced from spent slurry are provided in Table 4.13. It can be seen that organic meals as well as the filtered spent slurry were odourless, and innocuous. Except for colour, all other characters were same for both of the materials as well as the three forms namely dried, dried and powdered and dried and pelletised organic meals. The colour of organic meals was light brown to black. It was white to light grey in filtered spent slurry.

4.2.1.2. Major nutrients

Table 4.14 reveals the major nutrient contents of organic meals. Among the major nutrients, the N content varied from 1.36 to 1.92 per cent. Maximum N content of 1.92 and 1.91 per cent were observed in meal No.3 and 17 respectively. The trend observed was that meals containing neem cake had higher N content. Majority of meals had an N content above 1.7 per cent. Meal 9 had the lowest N (1.36 %) followed by meal 11 (1.53 %) and meal 12 (1.59 %).

In case of P maximum content of 9.06 per cent was recorded in meal No.1. It was followed by meal 17 (8.98 %), meal 16 (8.78 %) and meal 3 (8.34 %) in that

Table 4.13. Physical properties of organic meals and spent slurry

Property	Dried	Dried and powdered	Dried and pelletised
Organic meals			
Odour	No odour, innocuous	No odour, innocuous	No odour, innocuous
Colour	Light brown to black	Light brown to black	Light brown to black
Appearance	Irregular, uneven, crumbs of various size	Fine to small particles	Uniform, bead like, attractive
Consistency	Non sticky, rigid, difficult to handle	Friable, powdered and difficult to handle	Perfected solid form, easy to handle
Filtered spent slurry			
Odour	Same as above	Same as above	Same as above
Colour	White to light grey	White to light grey	White to light grey
Appearance	Same as in organic meals	Same as in organic meals	Same as in organic meals
Consistency	Same as in organic meals	Same as in organic meals	Same as in organic meals

Plate 21 Formulated organic meals from spent slurry

Plate 22 Organic meal produced from open heap composting techniqude

order. All the meals had a P content above 7 per cent. As in the case of N meals with neem cake was comparatively superior to meals containing coir pith and poultry manure as additives.

The calcium content varied from 15.27 to 19.53 per cent. Meal No.17, 1 and 16 were significantly superior with 19.53, 19.2 and 19.1per cent Ca. Meal 2, 7, 14 and 18 also contained around 18 per cent calcium. Calcium content was the lowest in meal 12 (15.27 %) and meal 11 (15.70 %) respectively.

The K, Mg and S content of meals ranged from 0.27 to 0.32, 0.28 to 0.34 and 0.27 to 0.37 per cent respectively. There was no wide variation with respect to the content of above three nutrients.

Thus among the different organic meals, meal No.17 (SS+5NC+10CP+5MRP) recorded significantly higher contents of N, P, K, Ca, Mg, S with respective values of 1.91, 8.98, 0.30, 19.53, 0.34 and 0.35 per cent. This was closely followed by meal No.1 (SS+5NC+5MRP) with respective values of 1.80, 9.06, 0.30, 19.20, 0.32 and 0.35 per cent. All other meals had lower values in general, for these nutrients.

4.2.1.3. Minor nutrients

With regard to micronutrients, no such generalisation could be drawn and in fact they differed significantly from each other. But there was in general an increase in micro nutrient contents with the increase in doses of additives.

The Fe content varied from 706.5 ppm in meal No.13 to 832.4 ppm in meal No.4 and meal No.16 respectively. Meals containing neem cake, poultry manure and higher levels of coir pith as additives exhibited an increased Fe content of more than 800 ppm. Meal No.7, 8 and 9 with 5, 10 and 20 per cent coir pith were significantly

Table 4.14. Major nutrient content (%) of organic meals from spent slurry

Meal No.	Treatments	N	P	K	Ca	Mg	S
1	SS+5NC + 5MRP	1.80^{bcd}	9.06^{a}	0.30^{abc}	19.20^{b}	0.32^{abc}	0.35^{abc}
2	SS+10NC +5MRP	1.87^{ab}	8.04^{ef}	0.30^{abc}	18.60^{c}	0.32^{abc}	0.37^{a}
3	SS+15NC +5MRP	1.92^{a}	8.34^{c}	0.31^{ab}	16.93^{gh}	0.31^{bc}	0.37^{a}
4	SS+5PM + 5MRP	1.79^{bcd}	7.64^{i}	0.28^{bc}	17.17^{efg}	0.34^{a}	0.34^{bc}
5	SS+10PM +5MRP	1.82^{abcd}	7.40^{i}	0.29^{abc}	16.80^{h}	0.33^{ab}	0.36^{ab}
6	SS+15PM +5MRP	1.87^{ab}	8.06^{ef}	0.28^{bc}	16.50^{i}	0.31^{bc}	0.36^{ab}
7	SS+5CP + 5MRP	1.75^{cde}	8.16^{de}	0.27^{c}	18.69^{c}	0.31^{bc}	0.33^{c}
8	SS+10CP + 5MRP	1.65^{fg}	7.93^{fg}	0.31^{ab}	17.23^{def}	0.34^{a}	0.35^{abc}
9	SS+20CP + 5MRP	1.36^{i}	7.98^{f}	0.31^{ab}	17.00^{fgh}	0.34^{a}	0.29^{de}
10	SS+30CP + 5MRP	1.65^{efg}	7.50^{i}	0.32^{a}	16.11^{j}	0.30^{c}	0.30^{d}
11	SS+40CP + 5MRP	1.53^{h}	8.20^{d}	0.32^{a}	15.70^{k}	0.30^{c}	0.34^{bc}
12	SS+50CP + 5MRP	1.59^{gh}	7.02^{l}	0.28^{bc}	15.27^{l}	0.28^{d}	0.27^{e}
13	SS+5CD + 5MRP	1.72^{def}	7.78^{h}	0.29^{abc}	17.23^{def}	0.33^{ab}	0.35^{abc}
14	SS+10CD +5MRP	1.75^{cd}	8.15^{de}	0.28^{bc}	18.50^{c}	0.31^{bc}	0.34^{bc}
15	SS+15CD +5MRP	1.82^{abcd}	8.24^{cd}	0.27^{c}	17.33^{de}	0.34^{a}	0.37^{a}
16	SS+5NC+5CP + 5MRP	1.86^{ab}	8.78^{b}	0.30^{abc}	19.10^{b}	0.34^{a}	0.36^{ab}
17	SS+5NC +10CP + 5MRP	1.91^{a}	8.98^{a}	0.30^{abc}	19.53^{a}	0.34^{a}	0.35^{abc}
18	SS+5PM +10CP + 5MRP	1.84^{abc}	7.84^{gh}	0.29^{abc}	18.70^{c}	0.31^{bc}	0.37^{a}
19	SS+10CD +10CP + 5MRP	1.79^{bcd}	7.98^{fg}	0.31^{ab}	17.23^{def}	0.30^{c}	0.34^{bc}
20	SS+5NC +20CP + 5MRP	1.85^{abc}	7.24^{k}	0.30^{abc}	17.50^{d}	0.33^{ab}	0.35^{abc}
	CD (P=0.05)	0.091	0.128	0.03	0.256	0.02	0.025

Table 4.15. Minor nutrient content (ppm) of organic meals from spent slurry

Meal No.	Treatments	Fe	Mn	Zn	Cu
1	SS+5NC + 5MRP	815.6^{e}	102.7^{j}	118.6^{o}	8.33^{a}
2	SS+10NC +5MRP	804.8^{g}	104.8^{h}	120.4^{n}	8.20^{ab}
3	SS+15NC +5MRP	818.6^{c}	107.6^{cd}	117.5^{p}	8.20^{bc}
4	SS+5PM + 5MRP	832.4^{a}	107.5^{de}	170.8^{g}	8.06^{bc}
5	SS+10PM +5MRP	812.6^{f}	103.2^{i}	182.6^{d}	8.04^{bc}
6	SS+15PM +5MRP	802.5^{h}	108.5^{b}	178.4^{e}	8.01^{c}
7	SS+5CP + 5MRP	784.4^{j}	110.9^{a}	165.6^{i}	7.84^{d}
8	SS+10CP + 5MRP	742.3^{n}	106.6^{f}	170.4^{g}	7.83^{d}
9	SS+20CP + 5MRP	757.8^{k}	107.8^{c}	170.4^{g}	7.83^{d}
10	SS+30CP + 5MRP	816.5^{d}	110.9^{a}	182.5^{d}	7.83^{d}
11	SS+40CP + 5MRP	801.7^{i}	108.7^{b}	208.5^{b}	7.80^{d}
12	SS+50CP + 5MRP	823.4^{b}	105.6^{g}	212.7^{a}	7.74^{de}
13	SS+5CD + 5MRP	706.5^{p}	103.2^{i}	132.8^{k}	7.63^{ef}
14	SS+10CD +5MRP	717.8^{o}	103.4^{i}	130.4^{l}	7.62^{ef}
15	SS+15CD +5MRP	743.5^{m}	108.7^{b}	126.5^{m}	7.58^{ef}
16	SS+5NC + 5CP + 5MRP	832.4^{a}	106.4^{f}	154.8^{j}	7.56^{f}
17	SS+5NC +10CP + 5MRP	757.8^{k}	108.6^{b}	165.6^{i}	7.50^{fg}
18	SS+5PM +10CP + 5MRP	750.2^{l}	104.6^{h}	171.5^{f}	7.36^{g}
19	SS+10CD +10CP + 5MRP	784.7^{j}	101.4^{k}	168.6^{h}	7.12^{h}
20	SS+5NC +20CP + 5MRP	743.8^{m}	107.3^{e}	184.5^{c}	7.04^{h}
	CD (P=0.05)	0.775	0.24	0.48	0.148

inferior. Similarly meals containing cow dung 5 CD, 10 CD and 15 CD also had significantly lower value. The Mn content was highest in meal No.7 and 10 with 110.9 ppm. It was followed by meal 11 (108.7 ppm), meal 15 (108.7 ppm), meal 17 (108.6 ppm) and meal 6 (108.5 ppm) in that order. Meal No.1 had the lowest value of 102.7 ppm.

The Zn content of meals was in the range of 117.5 to 212.7 ppm. Meals containing higher levels of coir pith 50 and 40 per cent level were significantly superior with 212.7 and 208.5 ppm respectively. Meals containing neem cake alone and cow dung alone had comparatively lower Zn level. Poultry manure as additive also increased the Zn content. It was 182.6 ppm in 10 PM and 178.4 ppm in 15 PM.

The Cu content ranged from 7.04 to 8.33 ppm. Meal number 1 to 6 containing neem cake and poultry manure as additives at different levels were significantly superior to rest of organic meals with Cu content above 8 ppm. But the meals containing both neem cake and coir pith (meal 17) or poultry manure and coirpith (meal 18) had significantly lower content.

4.2.1.4. pH, organic carbon and neutralizing value

Details of the above characters are given in Table 4.16. All the meals had an alkaline pH range above 7.0 without significant difference between meals. The pH varied in the range of 7.1 to 7.6.

The organic carbon content of all the meals studied was above 20 per cent. Highest content of 23.83 % was observed in meal 11 followed by 23.7 in meal 12 and 23.4 % in meal 6. Lower values of 21.57, 21.17 and 21.79 % were recorded in meals containing cow dung at 5, 10 and 15 per cent respectively.

Table 4.16. pH, organic carbon and neutralizing value of organic meals from spent slurry

Meal No.	Treatments	pH	Organic carbon (%)	C/N ratio	Neutralizing value
1	SS+5NC + 5MRP	7.2	21.80^{jk}	12.04^{l}	68.7^{a}
2	SS+10NC +5MRP	7.3	22.43^{fghi}	11.93^{lm}	66.4^{e}
3	SS+15NC +5MRP	7.3	22.60^{fg}	11.73^{n}	59.4^{l}
4	SS+5PM + 5MRP	7.2	22.20^{ghij}	12.50^{ij}	62.3^{i}
5	SS+10PM +5MRP	7.1	22.57^{fgh}	12.73^{g}	61.8^{j}
6	SS+15PM +5MRP	7.1	23.40^{bc}	12.53^{hi}	64.6^{f}
7	SS+5CP + 5MRP	7.3	21.40^{kl}	12.40^{j}	67.4^{c}
8	SS+10CP + 5MRP	7.5	22.80^{def}	14.81^{d}	66.5^{e}
9	SS+20CP + 5MRP	7.6	22.17^{hij}	16.30^{a}	62.6^{h}
10	SS+30CP + 5MRP	7.5	23.00^{cde}	14.13^{e}	57.8^{n}
11	SS+40CP + 5MRP	7.5	23.83^{a}	15.56^{b}	56.5^{o}
12	SS+50CP + 5MRP	7.5	23.70^{ab}	15.12^{c}	55.5^{p}
13	SS+5CD + 5MRP	7.3	21.57^{k}	12.58^{hi}	53.5^{r}
14	SS+10CD +5MRP	7.4	21.17^{l}	12.45^{ij}	52.8^{s}
15	SS+15CD +5MRP	7.4	21.79^{jk}	12.04^{l}	54.8^{q}
16	SS+5NC + 5CP + 5MRP	7.2	22.18^{hij}	11.93^{n}	66.9^{d}
17	SS+5NC +10CP + 5MRP	7.4	22.13^{ij}	11.61^{o}	68.5^{b}
18	SS+5PM +10CP + 5MRP	7.2	23.13^{cd}	12.63^{gh}	64.2^{g}
19	SS+10CD +10CP + 5MRP	7.2	23.12^{cd}	13.10^{f}	58.2^{m}
20	SS+5NC +20CP + 5MRP	7.2	22.60^{efg}	12.23^{k}	59.9^{k}
CD (P=0.05)		NS	0.369	0.116	0.165

There was variation in C/N ratio between the different meals with lowest ratio of 11.61 in meal 17 followed by 11.73 in meal 3, 11.93 in meal 16 and meal 2 respectively. Higher ratios were observed in meal 9 (16.3), meal 11 (15.56) and meal 12 (15.12).

The neutralizing value ranged from 52.8 in meal 14 to 68.7 in meal No.1. The meal 17 closely followed the meal No.1 with a value 68.5. All other meals were significantly different with respect to neutralizing value. .

4.2.2. Open heap method of composting

As a quick and cost effective technique of organic meal formulation the KCPL sludge with suitable additives as described under item 3.2.4.2.was subjected to aerobic composting and the results are given below:

4.2.2.1. Compost maturity parameters: Temperature

The variations in temperature due to different levels of enrichment and composting techniques of organic meals pooled at weekly interval for a period of 13 weeks from the date of incubation till maturity of compost is given in Table 4.17. The general trend in temperature variation was a sudden hike from 41°C at the beginning to around 65°C on the second day itself. It further increased to 70°C in the second and fourth week. The temperature maintained around 65°C for the fifth and sixth week. A gradual decrease was observed from the seventh week and it stabilised around 31°C towards 12th week and thereafter.

The treatments differed significantly with respect to temperature. Majority of treatments attained peak value (70°C) during the second week. The peak value ranged from 69.17 to 72.27°C. The organic meal formulation No.7 (S+5NC+20CP+ 5MRP+1U) was significantly superior in maintaining high temperature peak. Moreover meals containing coir pith performed better than the rest in attaining high temperature. Irrespective of formulations, the composting process was completed in 13 weeks time. But the temperature decrease was at a faster pace in formulation 1 and 7.

With respect to method of covering there was no significant difference between the treatments except during sixth, tenth and eleventh week. During the sixth week gunny covered heaps had a temperature of 66.28°C followed by the open covered heaps (66.25°C). The plastic covered heap was significantly inferior (65.09°C). But during the tenth and eleventh week plastic covered heaps were significantly superior with temperatures of 36.01 and 34.72°C respectively. The mean temperature observed in all the three methods was also almost similar with temperature around 51°C.

4.2.2.2. pH

The pH of compost heaps observed for three months period at 15 days interval is given in Table 4.18. Initially all the meals had a pH around 7.2. It increased to a maximum value of above 8 during the second week. Meal No.4 recorded the highest value of 8.35 closely followed by meal No.1 and meal No. 6 with respective values of 8.29 and 8.22. A decrease in pH was observed from the 8th week onwards. At maturity all the meals except meal No.2 had a pH value of below 7.0. The treatment containing poultry manure (meal No. 2) recorded the highest pH of 7.05 at maturity while those with coir pith as additive had significantly lower pH values. There was

Table 4.17. Observations on the temperature of compost heaps (°C) at weekly interval

Meal No.	Treatments	Period (weeks)														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
1	S + 5NC +5MRP+1U	40.27	64.79^{d}	69.19^{d}	62.08^{b}	69.51^{ab}	69.77^{a}	67.39^{a}	56.51^{ab}	48.08^{a}	40.95^{bc}	34.53^{b}	34.07^{abc}	31.53^{abc}	30.53^{b}	48.96
2	S + 5PM +5MRP+1U	41.32	68.47^{b}	69.91^{cd}	62.16^{b}	68.55^{bc}	67.45^{bc}	64.57^{b}	58.52^{a}	50.28^{a}	42.38^{ab}	34.22^{b}	33.92^{abc}	31.87^{a}	30.90^{ab}	51.75
3	S + 5CD +5MRP+1U	40.18	66.31^{c}	69.17^{d}	63.48^{b}	67.70^{c}	65.62^{d}	63.58^{b}	57.83^{a}	47.77^{ab}	42.87^{a}	32.15^{c}	32.33^{c}	31.15^{bc}	30.98^{ab}	50.79
4	S + 5NC+ 5CP+5MRP+ 1U	41.17	66.88^{c}	70.0^{bcd}	63.88^{b}	70.08^{ab}	67.95^{b}	67.24^{a}	53.5^{b}	43.25^{c}	39.73^{c}	36.73^{a}	33.90^{abc}	31.73^{ab}	31.37^{a}	51.24
5	S + 5NC + 10CP+5MRP +1U	41.32	66.50^{c}	70.27^{bc}	66.75^{a}	69.53^{ab}	69.7^{a}	67.88^{a}	54.45^{b}	45.18^{bc}	41.33^{abc}	37.25^{a}	32.87^{bc}	31.62^{abc}	30.98^{ab}	51.83
6	S + 10CD+ 10CP+5MRP +1U	41.30	70.29^{a}	70.89^{b}	67.35^{a}	70.18^{ab}	65.92^{cd}	63.52^{b}	53.08^{b}	43.60^{c}	40.87^{bc}	37.0^{a}	34.85^{a}	31.20^{abc}	31.18^{ab}	51.56
7	S + 5NC + 20CP+5MRP +1U	41.03	67.87^{b}	72.27^{a}	66.51^{a}	70.65^{a}	67.48^{bc}	66.96^{a}	53.73^{b}	48.22^{a}	41.92^{ab}	35.52^{ab}	34.20^{ab}	30.97^{c}	30.57^{b}	52.83
8	Control+1U	40.0	59.20^{e}	61.30^{e}	59.80^{c}	60.60^{c}	60.91^{d}	51.21^{c}	49.82^{c}	44.20^{c}	38.61^{c}	34.21^{b}	33.20^{abc}	31.43^{abc}	30.00^{b}	46.75
CD (P=0.05)		NS	0.86	0.84	1.74	1.67	1.638	1.545	3.11	2.66	1.48	1.65	1.61	0.62	0.62	
Covering:	Open	40.62	65.66	70.38	64.49	69.59	68.09	66.25^{a}	54.39	46.92	41.87	35.36^{ab}	33.06^{b}	31.72	31.12	51.39
	Plastic	41.82	68.11	70.41	64.35	69.85	67.38	65.09^{b}	55.91	46.29	41.40	36.01^{a}	34.72^{a}	31.30	30.85	51.68
	Gunny	40.81	68.15	69.94	64.97	68.92	67.63	66.28^{a}	55.83	46.67	41.04	34.66^{b}	33.43^{b}	31.30	30.82	51.46
CD (P=0.05)		NS	NS	NS	NS	NS	NS	1.04	NS	NS	NS	1.113	1.086	NS	NS	
Mean		41.08	67.31	70.24	64.60	69.45	67.70	65.87	55.37	46.63	41.44	35.34	33.84	31.44	30.94	

Table 4.18. Variation in pH of compost heaps at different intervals

Meal No.	Treatments	Period (days)						
		0	15	30	45	60	90	Mean
1	S + 5NC +5MRP + 1U	7.22^{c}	8.29^{a}	8.02^{a}	7.75^{ab}	7.10^{e}	6.97^{b}	7.56
2	S + 5PM+5MRP + 1U	7.58^{a}	8.02^{d}	7.92^{b}	7.77^{ab}	7.50^{a}	7.05^{a}	7.64
3	S + 5CD +5MRP +1U	7.43^{b}	8.13^{c}	8.02^{a}	7.83^{a}	7.45^{ab}	6.88^{c}	7.62
4	S + 5NC + 5CP + 5MRP + 1U	7.25^{c}	8.35^{a}	7.92^{b}	7.73^{b}	7.35^{bc}	6.46^{e}	7.51
5	S + 5NC + 10CP + 5MRP + 1U	7.18^{c}	8.18^{bc}	7.88^{bc}	7.78^{ab}	7.15^{de}	6.73^{d}	7.48
6	S +10CD +10CP + 5MRP + 1U	7.48^{ab}	8.22^{b}	7.80^{c}	7.52^{c}	7.25^{cd}	6.73^{d}	7.50
7	S + 5NC + 20CP + 5MRP + 1U	7.42^{b}	8.05^{d}	7.92^{b}	7.82^{ab}	7.18^{de}	6.77^{d}	7.53
8	Control + 1U	7.00^{d}	7.75^{e}	7.80^{bc}	7.50^{c}	7.10^{e}	6.70^{d}	7.31
CD (P=0.05)		0.12	0.065	0.085	0.076	0.108	0.076	
Covering: Open		7.37^{a}	8.11^{c}	7.91^{a}	7.76^{ab}	7.31^{a}	6.86^{a}	7.55
Plastic		7.37^{a}	8.19^{b}	7.91^{a}	7.76^{a}	7.28^{a}	6.80^{ab}	7.56
Gunny		7.36^{a}	8.24^{a}	7.95^{a}	7.71^{b}	7.26^{a}	6.76^{b}	7.55
CD (P=0.05)		NS	0.044	NS	0.05	NS	0.05	
Mean		7.37	8.18	7.92	7.74	7.28	6.80	

not much variation in pH due to covering techniques. In all the methods the organic meals registered mean pH around 7.55.

4.2.2.3. Microbial count

The microbial count taken during three stages of composting viz., (initial) mesophillic, (mid) thermophilic and maturity stage is given in Table 4.19. Maximum load of all the three microbes under study was observed during the thermophilic stage (1st to 6th week). The population decreased towards the maturity phase. Load of microbes was lowest at the mesophilic stage. Between the treatments, meal No.7 recorded the highest microbial count at the thermophilic stage. The respective count of bacteria, actinomycetes and fungi were 309.63 x 10^5, 158.20 x 10^5 and 49.53 x 10^5CFU. It was closely followed by meal 6 with respective values of 310.1 x 10^5, 154.18 x 10^5, and 49.52 x 10^5CFU.

At the thermophilic stage the population of bacteria ranged from 278.5 (meal 3) to 310.1 (meal 6), actinomycetes from 145.65 (meal 1) to 158.2 (meal 7) and fungi from 41.92 (meal 1) to 49.53 (meal 7) respectively. In the mesophilic stage it was 45.93 to 51.49 bacteria, 5.47 to 6.92 actinomycetes and 34.67 to 37.22 fungi respectively. At maturity stage the peak values of bacteria, actinomycetes and fungi were in the order 84.34 (meal 3), 48.07 (meal 1) and 43.01 (meal 1).

Method of covering did not show any wide variation in the microbial count. But open heap method of covering was superior to other methods at certain stages.

4.2.2.4. C/N ratio

The C/N ratio of the compost heaps recorded at monthly interval is given in Table 4.20. There was a gradual decrease in the C/N ratio towards maturity phase. At

Table 4.19. **Observations on microbial population (10^5CFU) in the compost heaps at intervals**

Meal No	Treatments	Bacteria			Actinomycetes			Fungi		
		Mesophilic	Thermophilic	Maturity	Mesophilic	Thermophilic	Maturity	Mesophilic	Thermophilic	Maturity
1	S+5NC+ 5MRP+1U	51.49^{a}	299.6^{b}	82.07^{b}	5.47^{e}	145.65^{e}	48.07^{a}	34.67^{c}	41.92	43.01^{a}
2	S+5PM+ 5MRP+1U	50.53^{ab}	284.0^{bc}	78.03^{c}	5.80^{d}	146.93^{e}	41.71^{c}	37.19^{a}	44.92	33.72^{e}
3	S+5CD+ 5MRP+1U	48.84^{b}	278.5^{c}	84.34^{a}	5.70^{d}	150.73^{cd}	37.55^{d}	37.22^{a}	48.18	42.28^{ab}
4	S + 5NC + 5CP + 5MRP + 1U	50.17^{ab}	299.3^{b}	74.13^{d}	6.17^{c}	151.89^{bc}	42.13^{c}	37.14^{a}	47.40	36.83^{d}
5	S + 5NC + 10CP + 5MRP + 1U	45.93^{c}	304.5^{ab}	74.48^{d}	6.92^{a}	149.37^{d}	41.91^{c}	36.37^{b}	44.55	36.67^{d}
6	S + 10CD + 10CP + 5MRP + 1U	50.18^{ab}	310.1^{a}	80.78^{b}	6.03^{c}	154.18^{b}	41.72^{c}	37.01^{ab}	49.52	40.83^{c}
7	S + 5NC + 20CP + 5MRP + 1U	49.90^{ab}	309.6^{a}	81.90^{b}	6.36^{b}	158.20^{a}	45.08^{b}	37.15^{a}	49.53	41.17^{bc}
8	Control + 1U	35.67^{d}	282.4^{bc}	80.40^{b}	5.3^{e}	130.40^{f}	33.40^{e}	31.40^{d}	38.20	30.40^{f}
CD (P=0.05)		1.64	8.42	1.43	0.186	0.122	2.301	0.695	NS	1.31
Covering:	Open	50.23	300.9^{a}	81.26^{a}	6.06	151.97^{a}	42.92	36.52	45.59	40.36^{a}
	Plastic	49.27	298.0^{b}	78.60^{b}	6.05	149.39^{b}	42.23	36.82	44.74	38.64^{b}
	Gunny	49.25	294.9^{c}	78.32^{b}	6.09	151.62^{a}	42.62	36.69	45.10	38.64^{b}
CD (P=0.05)		NS	2.74	0.934	NS	1.54	NS	NS	NS	0.86

all periods meal No.3 had higher C/N ratio compared to other meals. The C/N ratio at maturity phase was 17.52. Meal No.1, 2, 4 and 7 were significantly on par with each other with a C/N ratio around 13. Lowest ratio of 11.71 was recorded in meal No.5. The control treatment also recorded significantly higher C/N at all periods of study.

The mean C/N ratio of gunny covered heaps was 16.43 followed by 15.72 in plastic heap and 15.52 in open heap in that order. But the differences between methods were not significant.

4.2.2.5. Nutrient content

The nutrient content of the compost heaps at maturity phase is given in Table 4.21. The N content of composts ranged from 1.32 to 1.91 percent. Perusal of data showed that the organic meal formulation No.5 had the highest N content of 1.91 per cent followed by meal 2 (1.84 %) and meal 1 (1.79 %) which were significantly on par. The organic meals 3 and 6 recorded significantly lower N content of 1.32 and 1.38 respectively.

Maximum P content of 9.05 per cent was recorded in meal No.1 at maturity phase. This was closely followed by meal No.5 (8.96 %) and meal No.4 (8.93 %). Lowest value of 7.71 per cent was recorded in meal No.2

The K content varied from 0.26 (meal No.4) to 0.29 per cent in meal No.3 and 6. All the other meals were on par with a value around 0.28 per cent.

Higher calcium content was observed in meal 5 (17.05 %) and meal 1 (16.96 %). It was closely followed by meal 7 (16.42 %) and meal 4 (16.35 %). Meals containing poultry manure and cow dung as additives recorded significantly lower content.

Table 4.20. Variation in C/N ratio of compost heaps at intervals

Meal No.	Treatments	Period (days)				
		0	30	60	90	Mean
1	S + 5NC +5MRP + 1U	18.4	15.41^{bc}	13.24^{cd}	12.51^{cd}	14.89
2	S + 5PM +5MRP + 1U	18.6	15.62^{bc}	13.11^{cd}	12.89^{cd}	15.06
3	S +5CD + 5MRP +1U	19.2	18.71^{a}	17.84^{a}	17.52^{a}	18.32
4	S + 5NC + 5CP + 5MRP + 1U	18.4	16.09^{b}	14.14^{c}	13.04^{cd}	15.42
5	S + 5NC + 10CP + 5MRP +1U	18.8	14.87^{c}	12.26^{d}	11.71^{d}	14.41
6	S +10CD + 10CP + 5MRP + 1U	19.0	16.34^{b}	15.01^{ab}	15.99^{b}	16.84
7	S +5NC +20CP + 5MRP + 1U	18.7	17.40^{ab}	14.24^{bc}	13.42^{c}	15.94
8	Control + 1U	19.2	18.40^{a}	16.01^{ab}	16.64^{ab}	17.56
CD (P=0.05)		NS	1.21	1.86	1.264	
Covering: Open		18.2	15.98	14.26	13.64	15.52
Plastic		18.4	16.21	14.84	13.44	15.72
Gunny		18.8	17.20	15.21	14.52	16.43
CD (P=0.05)		NS	NS	NS	NS	
Mean		18.47	16.46	14.77	13.87	

The Mg content of meals ranged from 0.31 to 0.34 per cent. Meals No.1 to 5 had a higher content of above 0.32 per cent and all these were significantly on par. While meal No.6 and 7 were significantly inferior.

There was no wide variation in the S content of organic meals. All the meals except meal No.4 had S content around 0.35 per cent. Meal No.4 had a significantly lower value of 0.34 per cent.

In terms of micronutrients there was no wide variation between the different organic meal formulations. But meal No.4 and 6 were significantly superior to the rest in maintaining higher content of Fe, Mn, Zn and Cu. The Fe content of the meals varied from 653 ppm to 883.5 ppm, Mn from 103.62 to 108.23 ppm, Zn from 113.3 to 214.1 ppm and Cu from 7.28 to 7.74 ppm respectively.

The method of covering of heaps did not exert a significant influence on the nutrient content of heaps. Only with respect to P the open heaps proved superior to gunny or plastic covered heaps.

4.2.2.6. Moisture content, organic carbon, neutralizing value

The details of the above characters are given in Table 4.22. Moisture content of meals ranged from 35.25 per cent in meal No.3 to 44.35 per cent in meal No.6. Meals with coir pith as additive had significantly higher moisture compared to other meals. The control had moisture of 36.04 per cent. Composting reduced the moisture content over the basic material. Method of covering did not influence the moisture content of compost heaps.

There was no wide variation among the different organic meals with respect to organic carbon content. All the meals maintained an organic carbon of around

Table 4.21. Nutrient content (%) of compost heaps at maturity stage

Meal No.	Treatments	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
1	S + 5NC+5MRP+1U	1.79^{abc}	9.05^{a}	0.28^{b}	16.96^{a}	0.325^{ab}	0.357^{a}	883.5^{b}	103.62^{c}	113.3^{d}	7.71^{a}
2	S + 5PM+ 5MRP+1U	1.84^{ab}	7.71^{e}	0.28^{b}	15.22^{c}	0.338^{a}	0.350^{a}	832.5^{b}	105.17^{bc}	180.5^{b}	7.56^{ab}
3	S + 5CD+ 5MRP+1U	1.32^{d}	8.51^{d}	0.29^{a}	15.92^{c}	0.342^{a}	0.355^{a}	653.0^{d}	105.82^{abc}	129.5^{c}	7.74^{a}
4	S +5NC+5CP+5MRP +1U	1.77^{bc}	8.93^{ab}	0.26^{c}	16.35^{b}	0.327^{ab}	0.340^{b}	848.0^{b}	108.23^{a}	165.5^{b}	7.55^{ab}
5	S + 5NC + 10CP + 5MRP + 1U	1.91^{a}	8.96^{ab}	0.28^{b}	17.05^{a}	0.335^{ab}	0.350^{a}	746.5^{c}	108.18^{a}	165.5^{b}	7.55^{ab}
6	S + 10CD + 10CP +5MRP + 1U	1.38^{d}	8.53^{c}	0.29^{a}	15.78^{c}	0.313^{c}	0.358^{a}	848.8^{b}	107.20^{ab}	209.0^{a}	7.28^{b}
7	S + 5NC + 20CP +5MRP + 1U	1.71^{c}	8.87^{b}	0.28^{b}	16.42^{b}	0.320^{bc}	0.350^{a}	877.6^{b}	105.27^{bc}	214.1^{a}	7.58^{ab}
8	Control +1U	1.42^{d}	7.43^{e}	0.28^{b}	17.08^{a}	0.310^{c}	0.340^{b}	952.5^{a}	105.07^{bc}	128.6^{c}	7.78^{a}
CD (P=0.05)		0.12	0.147	0.03	0.334	0.015	0.008	52.88	2.65	15.34	0.338
Covering: Open		1.67	8.72^{a}	0.28	15.71	0.324	0.350	802.3	105.49	163.7	7.49
Plastic		1.71	8.60^{b}	0.28	15.82	0.329	0.353	801.7	106.94	168.1	7.55
Gunny		1.63	8.45^{c}	0.28	15.93	0.330	0.351	834.4	106.21	161.9	7.59
CD (P=0.05)		NS	0.099	NS	NS	NS	NS	NS	NS	NS	NS
Mean		1.67	8.59	0.28	15.82	0.327	0.351	812.8	106.21	164.6	7.54

Table 4.22. Moisture content, organic carbon and neutralizing value of compost heaps at maturity

Meal No.	Treatments	Moisture content (%)	Organic carbon (%)	Neutralizing value
1	S + 5NC + 5MRP + 1U	36.80^{c}	22.38^{b}	71.22^{a}
2	S + 5PM + 5MRP + 1U	36.03^{cd}	23.57^{a}	60.73^{c}
3	S + 5CD + 5MRP + 1U	35.25^{d}	22.97^{ab}	62.33^{c}
4	S + 5NC +5CP +5MRP + 1U	43.43^{a}	22.98^{ab}	67.27^{b}
5	S+5NC+10CP+5MRP + 1U	44.12^{a}	22.60^{ab}	67.47^{b}
6	S+10CD+10CP+5MRP + 1U	44.35^{a}	22.15^{b}	55.67^{d}
7	S+5NC+20CP+5MRP + 1U	41.45^{b}	22.63^{ab}	69.75^{ab}
8	Control + 1U	36.04^{cd}	23.08^{a}	54.50^{d}
CD (P=0.05)		1.2	0.88	3.49
Covering: Open		40.35	22.42^{b}	65.13
Plastic		40.29	22.69^{ab}	64.56
Gunny		39.98	23.15^{a}	65.07
CD (P=0.05)		NS	0.592	NS
Mean		40.21	22.75	64.92

22 per cent. Only meal No.2 had a high value of 23.57 per cent. With respect to covering gunny covered heaps had the highest organic carbon of 23.15 per cent followed by plastic heap (22.69 %) and open heap (22.42 %) in that order.

Neutralizing value was highest in meal 1 (71.22) followed by meal 7 (69.75). It was the lowest in meal 6 (55.67). The formulated meals had a higher neutralizing value compared to the basic material with no significant difference between the covering methods.

4.2.3. Pit method of composting

The same treatments were also tried in pit system of composting and results are narrated in Tables 4.23 to 4.25.

4.2.3.1. Compost maturity indices

The observations on temperature from the start of incubation to 15 weeks were pooled at weekly interval. In contrast to the heap method of composting temperature in the compost pits did not rise to expected levels. In the beginning the temperature was around 30°C. Irrespective of treatment differences the temperature in general was around 37°C signalling the failure of composting technique. Even in the thermophilic phase of second to sixth week there was hardly any hike in temperature. Only in organic meal No.5 the temperature rose to at least 40°C. Throughout the period of incubation the temperature level maintained around 35-37°C. There was no significant variation in temperature between the different organic meal treatments during the entire period of investigation.

Table 4.23. Temperature (°c) of compost in pit method at weekly interval

Meal No	Treatments	Period (weeks)															
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	S + 5NC + 5MRP + 1U	30	37.0	36.4	36.5	35.5	35.8	35.1	36.0	35.7	35.1	35.1	35.7	35.1	34.6	33.2	33.2
2	S +5PM + 5MRP + 1U	30	38.1	37.4	36.5	35.7	35.7	35.1	35.2	36.1	35.4	35.3	36.1	35.1	35.1	33.4	33.8
3	S +5CD + 5MRP + 1U	30	36.2	36.1	36.1	35.5	35.2	36.1	37.1	37.1	36.1	36.1	35.4	35.4	34.8	33.5	33.1
4	S + 5NC + 5CP+5MRP+ 1U	30	37.0	37.0	37.0	36.5	36.2	36.7	37.2	37.2	36.7	36.8	35.4	35.4	34.6	33.8	33.4
5	S +5NC + 10CP+5MRP + 1U	30	40.4	39.5	39.6	38.7	38.0	37.1	37.1	37.4	36.2	36.4	35.1	35.1	34.4	33.1	33.1
6	S + 10CD + 10CP+5MRP + 1U	30	37.4	36.4	36.1	36.2	36.2	36.2	37.2	37.3	36.3	36.2	35.8	35.8	34.5	34.5	33.1
7	S +5NC + 20CP+5MRP + 1U	30	37.0	36.7	36.7	36.1	35.7	36.1	36.1	36.5	36.2	36.2	35.4	35.1	34.1	34.1	33.8
CD (P=0.05)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.2.3.2. Nutrient content

Due to failure of temperature rise to expected levels the nutrient and other related observations were recorded only at the end of the 15th week (Table 4.24). There was significant difference between organic meals with respect to N, P, K and Ca content. The N content varied from 1.54 to 1.82 per cent. Meal No.5 contained the highest N (1.82 %) followed by meal No.1 (1.76 %). The same trend was observed in P also. The P content in meal 5 was 8.83 per cent and in meal 1 it was 8.68 per cent. All the other organic meals were significantly on par.

With respect to K meal 5, 6 and 7 recorded higher values (0.31 %) than the rest of the meals (0.27-0.28 %). Calcium content was highest in meal 5 (18.2 %) followed by meal 3 (18.19 %). Meal 7 contained significantly lower Ca content (15.82 %). Generally meal No.5 was superior to the rest in terms of N, P, K and Ca. The Mg content of meals ranged from 0.32 to 0.34 per cent and S content from 0.34 to 0.36 per cent. Due to failure in the composting technique the organic meals were not analysed for either micronutrient or heavy metal content.

4.2.3.4. Moisture, pH, organic carbon and neutralizing value

Moisture played an important role in the pit method of composting. The moisture content of pits ranged from 50.6 per cent to 57.53 per cent. There was no reduction in moisture content due to composting. Moisture content was maximum in meal No.5 and meal No.6 (57.53 %). Irrespective of treatment differences all the meals contained more than 50 per cent moisture.

Highest pH value of 7.67 was found in meal No.1. Meal No.3 and 7 and the other set meal 4, 5 and 6 were on par each other within the group.

Table 4.24. Observations on the major nutrient content (%) of compost in pit method

No	Treatments	N	P	K	Ca	Mg	S
1	S+ 5NC + 5MRP + 1U	1.76^{a}	8.68^{a}	0.28^{b}	16.98^{b}	0.34	0.35
2	S+ 5PM + 5MRP + 1U	1.68^{b}	7.82^{b}	0.27^{b}	16.11^{bc}	0.33	0.36
3	S+ 5CD + 5MRP + 1U	1.64^{b}	7.67^{b}	0.28^{b}	18.19^{a}	0.32	0.35
4	S+ 5NC+ 5CP + 5MRP +1U	1.68^{b}	7.90^{b}	0.28^{b}	16.37^{bc}	0.34	0.34
5	S+ 5NC + 10CP + 5MRP +1U	1.82^{a}	8.83^{a}	0.31^{a}	18.20^{a}	0.34	0.36
6	S+ 10CD + 10CP + 5MRP +1U	1.54^{c}	7.58^{b}	0.30^{a}	16.04^{bc}	0.33	0.35
7	S+ 5NC + 20CP + 5MRP + 1U	1.56^{c}	8.02^{b}	0.31^{a}	15.82^{c}	0.32	0.35
CD (P=0.05)		0.22	0.52	0.017	0.88	NS	NS

Table 4.25. Observations on moisture content, pH, organic carbon and neutralizing value of compost in pit method

No	Treatments	Moisture content (%)	pH	Organic carbon (%)	C/N ratio	Neutralizing value
1	S+ 5NC+5MRP + 1U	50.80^{c}	7.67^{a}	32.81^{b}	18.64	59.63^{ab}
2	S+ 5PM +5MRP + 1U	56.40^{ab}	7.23^{c}	33.73^{a}	20.07	56.63^{bc}
3	S+ 5CD + 5MRP + 1U	53.93^{b}	7.43^{b}	32.11^{bcd}	19.58	58.17^{abc}
4	S+ 5NC + 5CP + 5MRP + 1U	54.13^{b}	7.23^{c}	31.30^{d}	18.63	55.57^{c}
5	S + 5NC+ 10CP +5MRP + 1U	57.53^{a}	7.17^{c}	31.90^{cd}	17.52	60.40^{a}
6	S+10CD + 10CP + 5MRP + 1U	57.53^{a}	7.27^{c}	32.61^{bc}	21.17	59.33^{ab}
7	S+ 5NC +20CP + 5MRP + 1U	50.60^{c}	7.43^{b}	32.28^{bc}	20.69	56.67^{bc}
CD (P=0.05)		2.48	0.112	0.779	NS	3.32

The organic carbon content of meals ranged from 31.30 to 33.73 per cent. All the meals had a value of above 30 per cent. The organic carbon level failed to decrease below the initial value. Lowest content was recorded in meal 4.

All the organic meals had a C/N ratio of above 17.5. Highest ratio was found in meal 6 (21.17) followed by meal 7 (20.69) and meal 2 (20.07). Compared to the heap method the organic meals produced by pit method had a higher C/N ratio.

The neutralizing value was highest in meal No.5 (60.4) closely followed by meal 1 (59.63) and meal 6 (59.33). All the meals had a neutralizing value of above 55.

4.3. Pot culture study

Exploratory pot culture study was conducted with the selected organic meal to gather indicative information on its suitability as organic fertilizer. Being a new material adverse influence at higher doses were also needed to be assessed before taking it to the field. Results of the exploratory trial are presented below:

4.3.1. Growth attributes

The observations on plant height and number of tillers as influenced by organic meal addition are given in Table 4.26. Application of organic meal recorded significantly higher plant height compared to control. At all stages, the lower levels of organic meal application produced shorter plants and higher levels the taller ones. With 20 g OM, the plant height rose from the lowest value of 46.58 cm at the tillering phase to 66 cm at the harvest stage. The plant height increased progressively with the level of application of organic meal and the tallest plants were produced by the treatment 320 g OM. In this treatment the plants were tallest during the tillering phase to harvest stage with respective values of 58.46 cm and 80.92 cm. The mean plant height was 71.18 cm. This treatment was closely followed by 240 g OM and 400 g OM in that order but the differences were, in general, insignificant.

Tiller production also showed an almost comparable trend with that of the plant height. It increased linearly with time in all cases. Maximum number of tillers was produced in 320 g OM (9.8) followed by 160 g OM (9.3) at panicle initiation stage. The other two higher levels viz. 240 g and 400 g followed these treatments with comparable values. At lower doses of 20 g OM and 40 g OM the tiller production significantly decreased, the tiller number being 6.3 and 6.5 respectively and it was comparable to the control (5.0).

4.3.2. Yield attributes

The number of productive tillers, filled grains per panicle, thousand grain weight was significantly higher with organic meal addition as compared to the control (Table 4.27.). As in the case of growth characters addition of increased doses of organic meal significantly increased the yield attributes also up to 320 g OM. Similarly there was also a slight drop in all the characters at the highest level, 400 g OM.

Application of organic meal at doses of 160 g OM and above produced more number of ear heads compared to lower doses. Highest number of 8.7 was observed in 320 g OM followed by 7.7 in 240 g OM and 7.5 in 160 g OM and these were on par. 320 g OM was significantly superior to the rest in production of maximum number of filled grains per panicle (77.7) but it was statistically on par with 160 g OM (69.4), 240 g OM (71.66) and 400 g OM (70.93). Application at lower doses of

Table 4.26. Exploratory pot culture study with selected organic meal –observations on plant height and tiller count

No.	Dose of OM (g/pot)	Plant height (cm)					Number of tillers			
		Tillering	PI	Flower -ing	Harvest	Mean	Tillering	PI	Flower -ing	Mean
1	20	46.58^{d}	51.58^{d}	58.14^{c}	66.00^{b}	55.58	4.83	6.3^{bc}	6.0^{bc}	5.71
2	40	51.21^{c}	54.00^{d}	62.30^{c}	66.58^{b}	58.52	6.00	6.5^{bc}	6.1^{bc}	6.20
3	80	54.42^{bc}	60.08^{c}	67.92^{bc}	72.58^{ab}	63.75	6.00	7.4^{abc}	6.8^{abc}	6.73
4	160	56.59^{ab}	62.33^{bc}	70.42^{ab}	73.53^{ab}	65.72	6.70	9.3^{a}	7.8^{ab}	7.93
5	240	57.25^{ab}	65.08^{ab}	75.17^{ab}	78.25^{a}	68.94	7.00	7.8^{ab}	7.8^{ab}	7.53
6	320	58.46^{a}	68.50^{a}	76.83^{a}	80.92^{a}	71.18	6.25	9.8^{a}	9.0^{a}	8.35
7	400	56.00^{ab}	63.92^{bc}	73.83^{ab}	76.96^{a}	67.68	7.75	8.5^{ab}	8.0^{ab}	8.08
8	Control	34.08^{e}	38.86^{e}	49.06^{d}	55.20^{c}	44.30	4.67	5.0^{c}	5.2^{d}	4.96
CD (P=0.05)		3.79	4.05	7.60	8.39		1.38	2.48	1.54	

Table 4.27. Exploratory pot culture study with selected organic meal – observations on yield attributes

No.	Dose of OM (g/pot)	No. of productive tillers	Panicle length (cm)	Filled grains per panicle	1000 grain weight(g)	Grain yield g/pot	Straw yield g/pot
1	20	5.00^{cd}	18.20	62.63^{c}	21.96^{a}	21.30^{c}	24.55^{c}
2	40	5.76^{bc}	18.40	66.60^{bc}	21.70^{a}	27.07^{b}	34.53^{b}
3	80	6.40^{abc}	18.01	68.93^{bc}	22.41^{a}	36.80^{a}	39.30^{ab}
4	160	7.50^{abc}	18.74	69.40^{abc}	22.53^{a}	42.00^{a}	50.07^{a}
5	240	7.70^{ab}	18.62	71.66^{ab}	21.97^{a}	42.46^{a}	49.60^{a}
6	320	8.70^{a}	18.40	77.70^{a}	21.98^{a}	35.53^{ab}	49.20^{a}
7	400	7.40^{abc}	18.24	70.93^{abc}	21.52^{a}	34.76^{ab}	49.43^{a}
8	Control	4.40^{d}	18.01	52.17^{d}	20.04^{b}	17.13^{c}	18.50^{c}
CD (P = 0.05)		2.57	NS	8.7	1.27	8.71	14.97

80 g OM and below were inferior to the higher levels in terms of filled grains. The thousand grain weight did not differ statistically between the different treatments except for control.

The grain yield in the pot culture study ranged from 17.13 in control to 42.46 g per pot in 240 g OM. This was followed by 42 g in 160 g OM and 36.8 g in 80 g OM and these were statistically on par. Yield obtained at the lowest dose of 20 g OM (21.3 g) was comparable to control (17.13 g). There was a progressive increase in yield with levels up to 240 g OM and thereafter, the yield declined.

Higher levels of organic meal at 160 g OM and above were significantly superior to control and lower doses in increasing straw yield. Maximum yield of 50.07 g per pot was obtained with 160 g OM. This was followed by 49.6 g in 240 g OM, 49.43 g in 400 g OM and 49.2 g per pot in 320 g OM and these were statistically on par.

4.3.3. Nutrient uptake

The nutrient analysis of both grain and straw were carried out separately for all the major and minor nutrients. The data are furnished in Tables 4.28, 4.29, 4.30 and 4.31. With regard to major nutrient contents there was significant difference between control and treated plots. With different levels of meal the difference was significant more in straw than in grain and especially with higher levels of meals. The N content of straw varied from 0.87 per cent to 1.04 per cent among the treated pots. These values were 0.17 to 0.21 per cent for P, 0.82 to 1.19 per cent for K, 0.69 to 1.04 per cent for Ca and 0.0174 to 0.019 for Mg. The values for the control pot were in general lower and significantly inferior.

The nitrogen content of grain in treated pots was centered around the comparable range 1.3 to 1.50 per cent against the significantly low value of 1.09 in control. Similarly the P, K, Ca and Mg content of grain treated with meals was respectively in the range of 0.24 to 0.29 per cent, 0.26 to 0.28 per cent, 0.18 to 0.29 and 0.018 to 0.0194 per cent (Table 4.28)

In case of micronutrients also there was significant difference between the different treatments. The Fe content of straw varied from 667.7 to 926.7 ppm among the treated pots. The corresponding range of values for Mn, Zn and Cu were 48.33 to115.3 ppm, 20.67 to 38.33 ppm and 2.67 to 3.67 ppm, respectively.

There was no significant difference between the treatments with respect to Zn and Cu content of grain. The Fe content of grain was maximum in 400 g OM (149 ppm) and Mn content in 240 g OM (52.67 ppm). The Fe content varied from 98.67 to 149 ppm, Mn content from 33.77 to 52.67 ppm, Zn from 25 to 28 ppm and Cu content from 2.67 to 4.67 ppm in treated pots (Table 4.29).

There existed significant difference between treatments in the uptake pattern of nutrients by straw and grain. Increasing the levels of organic meal increased the uptake of nutrients. The N uptake of grain ranged from 0.27 to 0.63 g, P uptake from 0.051 to 0.118 g, K from 0.26 to 0.28 g, Ca from 0.18 to 0.29 g and Mg uptake from 0.0038 to 0.0079 g per pot. The uptake pattern in control pot was comparatively lower and significantly inferior to treated pots.

The uptake by straw was generally higher than by grain. Increase in levels of organic meal significantly increased the uptake by straw over control. The uptake pattern of N in straw varied from 0.21 g to 0.50 g. The respective uptake pattern for P,

Table 4.28. Exploratory pot culture study with selected organic meal – major nutrient content (%) of grain and straw

No.	Dose of OM (g/pot)	N		P		K		Ca		Mg	
		Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
1	20	0.87	1.27^{ab}	0.17^{a}	0.24^{a}	0.82^{c}	0.26	0.75^{bc}	0.18^{b}	0.0174^{a}	0.0180^{a}
2	40	0.97	1.32^{ab}	0.20^{a}	0.26^{a}	0.87^{bc}	0.27	0.88^{ab}	0.19^{a}	0.0176^{a}	0.0182^{a}
3	80	0.95	1.32^{ab}	0.18^{a}	0.27^{a}	0.84^{bc}	0.26	0.76^{bc}	0.21^{a}	0.0182^{a}	0.0186^{a}
4	160	0.99	1.51^{a}	0.20^{a}	0.28^{a}	0.84^{bc}	0.28	0.75^{bc}	0.20^{a}	0.0184^{a}	0.0190^{a}
5	240	0.98	1.37^{a}	0.20^{a}	0.28^{a}	0.98^{abc}	0.27	0.69^{bc}	0.25^{a}	0.0180^{a}	0.0188^{a}
6	320	1.04	1.41^{a}	0.21^{a}	0.29^{a}	1.08^{ab}	0.28	0.84^{ab}	0.27^{a}	0.0188^{a}	0.0192^{a}
7	400	1.01	1.54^{a}	0.21^{a}	0.29^{a}	1.19^{a}	0.28	1.04^{a}	0.29^{a}	0.0190^{a}	0.0194^{a}
8	Control	0.87	1.09^{b}	0.13^{b}	0.18^{b}	0.75^{c}	0.25	0.61^{c}	0.13^{b}	0.0104^{b}	0.0120^{b}
CD (P=0.05)		NS	0.239	0.056	0.054	0.226	NS	0.054	0.054	0.005	0.0064

Table 4.29. Exploratory pot culture study with selected organic meal – minor nutrient content (ppm) of grain and straw

No.	Dose of OM (g/pot)	Fe		Mn		Zn		Cu	
		Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
1	20	847.3^{a}	98.67^{d}	48.33	33.77^{c}	20.67^{c}	25.00	2.67	3.33
2	40	667.7^{b}	107.3^{cd}	86.67	34.00^{c}	25.00^{bc}	25.33	3.67	2.67
3	80	901.3^{a}	126.5^{b}	63.00	37.33^{bc}	23.00^{bc}	25.00	3.33	3.00
4	160	921.0^{a}	131.7^{b}	79.00	45.67^{abc}	23.33^{bc}	25.00	3.33	3.33
5	240	840.7^{a}	132.7^{b}	88.33	52.67^{a}	25.00^{bc}	28.00	3.67	4.00
6	320	926.7^{a}	147.0^{a}	92.33	48.00^{ab}	38.33^{a}	25.00	3.00	4.67
7	400	808.0^{a}	149.0^{a}	115.3	48.00^{ab}	33.00^{ab}	26.00	3.33	4.33
8	Control	543.3^{c}	120.7^{bc}	126.3	39.67^{abc}	30.33^{b}	25.00	2.67	2.33
CD (P=0.05)		118.9	13.45	NS	12.38	7.33	NS	NS	NS

Table 4.30. Exploratory pot culture study with selected organic meal – uptake pattern of major nutrients (g/pot)

No	Dose of OM (g/pot)	N			P			K			Ca			Mg		
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
1	20	0.27^{c}	0.21^{cd}	0.48	0.051^{d}	0.042^{bc}	0.093	0.26	0.196^{de}	0.456	0.18^{b}	0.163^{c}	0.343	0.0038^{b}	0.0043^{b}	0.0081
2	40	0.35^{bc}	0.34^{bc}	0.69	0.071^{c}	0.069^{ab}	0.140	0.27	0.293^{cd}	0.563	0.19^{a}	0.307^{b}	0.497	0.0050^{ab}	0.0062^{b}	0.0111
3	80	0.48^{ab}	0.38^{ab}	0.86	0.100^{b}	0.071^{ab}	0.171	0.26	0.333^{cd}	0.593	0.21^{a}	0.307^{b}	0.517	0.0068^{a}	0.0072^{a}	0.0140
4	160	0.63^{a}	0.50^{a}	1.13	0.116^{a}	0.064^{ab}	0.180	0.28	0.420^{bc}	0.700	0.20^{a}	0.377^{ab}	0.577	0.0079^{a}	0.0092^{a}	0.0171
5	240	0.58^{a}	0.49^{a}	1.07	0.118^{a}	0.063^{ab}	0.181	0.27	0.483^{ab}	0.753	0.25^{a}	0.333^{b}	0.583	0.0079^{a}	0.0089^{a}	0.0168
6	320	0.50^{ab}	0.49^{a}	0.99	0.100^{b}	0.101^{a}	0.201	0.28	0.516^{ab}	0.796	0.27^{a}	0.403^{ab}	0.673	0.0068^{a}	0.0092^{a}	0.0160
7	400	0.55^{a}	0.49^{a}	1.04	0.104^{b}	0.101^{a}	0.205	0.28	0.581^{a}	0.861	0.29^{a}	0.510^{a}	0.800	0.0067^{a}	0.0094^{a}	0.0161
8	Control	0.19^{c}	0.17^{d}	0.36	0.031^{e}	0.023^{c}	0.054	0.25	0.140^{e}	0.390	0.13^{b}	0.113^{c}	0.243	0.0020^{bc}	0.0019^{c}	0.0040
CD (P=0.05)		0.173	0.145	-	0.005	0.038	-	NS	0.155	-	0.054	0.134	-	0.002	0.0022	-

Table 4.31. Exploratory pot culture study with selected organic meal – uptake pattern of minor nutrients (mg/pot)

No	Dose of OM (g/pot)	Fe			Mn			Zn			Cu		
		Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
1	20	2.09^{b}	20.72^{bc}	22.81	0.719	1.17	1.89	0.533^{cd}	0.505^{d}	1.038	0.071^{bc}	0.067^{b}	0.138
2	40	2.89^{b}	22.93^{bc}	25.82	0.920	3.01	3.93	0.686^{bcd}	0.872^{cd}	1.558	0.072^{bc}	0.126^{a}	0.198
3	80	4.65^{a}	35.39^{ab}	40.04	1.373	2.45	3.82	0.920^{abc}	0.902^{cd}	1.822	0.110^{ab}	0.129^{a}	0.239
4	160	5.58^{a}	45.97^{a}	51.55	1.918	3.94	5.86	1.050^{ab}	1.165^{bc}	2.215	0.139^{a}	0.166^{a}	0.305
5	240	5.64^{a}	41.82^{a}	47.46	2.236	4.26	6.49	1.190^{a}	1.223^{bc}	2.413	0.169^{a}	0.184^{a}	0.353
6	320	5.08^{a}	46.59^{a}	51.67	1.705	4.56	6.27	0.880^{abc}	1.867^{a}	2.747	0.166^{a}	0.138^{a}	0.304
7	400	5.26^{a}	39.49^{a}	44.75	1.668	5.75	7.42	0.903^{abc}	1.617^{ab}	2.520	0.151^{a}	0.165^{a}	0.316
8	Control	2.09^{b}	9.99^{c}	12.08	0.679	2.36	3.04	0.428^{d}	0.562^{d}	0.990	0.057^{bc}	0.049^{b}	0.106
CD (P = 0.05)		1.18	15.19	-	0.48	2.12	-	0.421	0.483	-	0.054	0.054	-

K, Ca and Mg were in the range of 0.042 to 0.101 g, 0.196 to 0.581g, 0.163 to 0.51 g and 0.0043 to 0.0094 g per pot respectively (Table 4.30)

As in the case of major nutrients there was significant difference in uptake pattern of micronutrients by straw and grain (Table 4.31). The uptake of Fe by grain varied from 2.09 mg in 20 g OM to 5.64 mg per pot in 240g OM. The Mn uptake ranged from 0.719 to 2.236 mg, Zn uptake from 0.533 to 1.19 mg and Cu uptake from 0.071 to 0.169 mg per pot in the same treatments as that of Fe. In case of straw the Fe uptake centered around 20.72 to 46.59 mg per pot. The control pot had a significantly low value of 9.99 mg per pot. The Mn uptake was the highest in 400 g OM with 5.75 mg per pot. The Zn uptake was around 0.505 to 1.867 mg per pot and Cu uptake ranged from 0.067 to 0.184 mg per pot.

4.4. Field studies

Field experiments were conducted as detailed under item 3.4.2 to study the direct and residual influence of organic meal as well as its efficacy under on farm situation. Results on crop growth components and yield attributes are presented below.

4.4.1. Plant height and number of tillers

Observations on the plant height and tiller production at different stages for two seasons Mundakan and Puncha are given in Table 4.32 and 4.33 respectively. Plant height increased progressively with advancing age of crop irrespective of treatments in both seasons. Plant height recorded was more during Mundakan season compared to Puncha. This effect was more pronounced during tillering and panicle initiation stages.

Application of organic meal produced taller plants at all the growth stages in both the seasons. During the Mundakan season organic meal treated plots produced plants of comparable height with those grown under the recommended practice (Control 1). There was not much difference due to different levels of organic meals though maximum height of 151.37 cm was recorded in OM 20 NPK at flowering stage. Application of OM at 5 tons (142.9 cm) was also on par with the recommended practice (145.5 cm). While in the Puncha season tendency to produce taller plants increased with the addition of organic meal and it was even significantly superior to those grown under recommended dose of nutrients. OM 20¾ NPK recorded the maximum height in all stages with a height of 158.53 cm at harvest. It was followed by OM 10 NPK (149.97) and OM 15 ½ NPK (149.9 cm) at the same stage. In all the stages OM 5 NPK was comparable to the recommended practice-control 1. Here the plant height varied from 57.8 cm to 134.93 cm and from 61 to 133.6 cm respectively in control 1 and lowest level of organic meal treated plots.

The tiller production also increased with the age up to panicle initiation stage, thereafter there was a slight decline. Season did not exert any influence on the tiller production. In both seasons analysis of variance showed significant difference between the treatments. Tillering increased markedly with the application of organic meal. In both seasons maximum tillers were produced on application of 20 t organic meal in combination with inorganic fertilizer.

In the Mundakan season at panicle initiation stage maximum tillers were produced in OM 10¾ NPK (15.67) followed by OM 20¾ NPK (15.55) while during

Table 4.32. Plant height and number of tillers at different stages of the crop during mundakan season

No.	Treatments	Plant height (cm)					Number of tillers			
		Tillering	PI	Flower-ing	Harvest	Mean	Tillering	PI	Flower-ing	Mean
1	OM 5 NPK	72.60^{ab}	113.72^{abcd}	142.90^{a}	147.97	119.29	14.53	12.22^{b}	11.22^{abc}	12.66
2	OM 10 ½ NPK	67.87^{abc}	107.06^{abcd}	143.50^{a}	144.83	115.82	14.53	14.0^{ab}	12.44^{ab}	13.66
3	OM 10 ¾ NPK	71.27^{ab}	112.98^{abcd}	143.57^{a}	144.60	118.11	13.40	15.67^{a}	10.88^{abc}	13.32
4	OM 10 NPK	69.60^{abc}	114.28^{abc}	145.93^{a}	149.97	119.95	13.53	14.55^{ab}	9.66^{cd}	12.58
5	OM 15 ½ NPK	65.93^{bc}	102.04^{d}	138.20^{a}	141.10	118.82	12.13	13.00^{b}	9.83^{cd}	11.65
6	OM 15 ¾ NPK	70.13^{abc}	109.99^{abcd}	136.83^{a}	143.90	115.22	14.53	13.87^{ab}	11.54^{abc}	13.31
7	OM 15 NPK	70.27^{abc}	118.69^{a}	147.57^{a}	149.37	121.48	15.33	14.11^{ab}	10.20^{bcd}	13.21
8	OM 20 ½ NPK	66.73^{bc}	103.55^{cd}	139.37^{a}	146.97	114.16	12.93	13.78^{ab}	10.77^{abc}	12.49
9	OM 20 ¾ NPK	69.53^{abc}	116.56^{ab}	146.53^{a}	148.23	120.21	16.13	15.55^{a}	12.98^{a}	14.82
10	OM 20 NPK	74.40^{a}	111.74^{abcd}	151.37^{a}	155.23	123.18	14.73	13.78^{ab}	11.76^{abc}	13.42
11	Control I	74.47^{a}	119.11^{a}	145.50^{a}	148.10	121.79	12.53	12.07^{b}	10.89^{abc}	11.83
12	Control II	63.47^{c}	90.53^{e}	105.80^{b}	108.43	92.06	10.73	8.89^{c}	8.12^{d}	9.25
CD (P=0.05)		5.98	11.49	22.07	NS	-	NS	2.01	1.97	-

Table 4.33. Plant height and number of tillers at different stages of the crop during Puncha season

No.	Treatments	Plant height (cm)					Number of tillers			
		Tillering	PI	Flowering	Harvest	Mean	Tillering	PI	Flowering	Mean
1	OM 5 NPK	61.00^{bcd}	92.83^{de}	132.93^{c}	133.60^{b}	105.08	12.47^{bc}	12.50^{bcd}	11.27^{abc}	12.08
2	OM 10 ½ NPK	61.87^{abcd}	108.97^{a}	149.27^{ab}	149.50^{ab}	117.40	15.07^{ab}	11.56^{cd}	9.70^{bc}	12.11
3	OM 10 ¾ NPK	58.87^{cd}	88.63^{ef}	131.33^{c}	132.43^{b}	102.82	15.33^{ab}	11.27^{d}	8.87^{c}	11.82
4	OM 10 NPK	65.23^{ab}	105.47^{ab}	147.77^{ab}	149.97^{ab}	117.11	12.43^{bc}	13.17^{bcd}	11.97^{ab}	12.52
5	OM 15 ½ NPK	64.10^{abc}	106.00^{ab}	140.70^{bc}	149.90^{ab}	115.17	14.23^{ab}	13.80^{abc}	13.33^{a}	13.79
6	OM 15 ¾ NPK	62.30^{abcd}	96.10^{cde}	134.93^{c}	136.80^{b}	107.53	14.03^{ab}	13.80^{abc}	12.07^{ab}	13.30
7	OM 15 NPK	62.10^{abcd}	103.53^{abc}	139.47^{bc}	142.63^{ab}	111.93	13.37^{ab}	13.93^{ab}	12.40^{ab}	13.23
8	OM 20 ½ NPK	61.47^{bcd}	97.63^{bcde}	130.97^{c}	142.90^{ab}	108.24	16.07^{a}	13.50^{abcd}	12.77^{ab}	14.11
9	OM 20 ¾ NPK	67.37^{a}	109.60^{a}	153.07^{a}	158.53^{a}	122.14	14.43^{ab}	15.60^{a}	14.40^{a}	14.81
10	OM 20 NPK	60.33^{bcd}	101.20^{abcd}	140.70^{bc}	142.27^{ab}	111.12	14.53^{ab}	13.70^{abc}	12.47^{ab}	13.57
11	Control I	57.80^{d}	90.67^{ef}	134.60^{c}	134.93^{b}	104.30	10.33^{c}	11.90^{bcd}	8.50^{c}	10.24
12	Control II	51.87^{e}	82.67^{f}	116.40^{d}	118.30^{c}	92.31	8.6^{c}	8.47^{e}	7.00^{d}	8.02
CD (P=0.05)		5.19	8.25	9.57	10.22	-	2.67	2.02	2.79	-

flowering it was maximum in OM 20¾ NPK followed by OM 10½ NPK, the tiller production being 12.98 and 12.44 tillers respectively. At all stages OM 5 NPK (12.22) was on par with recommended practice (12.07).

In Puncha crop the best treatment at tillering was OM 20 ½ NPK with 16.07 tillers followed by OM 10 ¾ NPK (15.33). At panicle initiation and flowering stages maximum tillers were seen in OM 20 ¾ NPK with respective values of 15.60 and 14.40. It was followed by OM 15 NPK (13.93) at panicle initiation and OM 15 ½ NPK (13.33) at flowering stage.

The application of different levels of inorganic fertilizer was on par with respect to tiller production in both the seasons. The tillers produced in OM 10 ½ NPK was 14.0, in OM 10 ¾ NPK 15.67 and OM 10 NPK 14.55 tillers during the Mundakan season at panicle initiation stage. The corresponding values during Puncha were 11.56, 11.27 and 13.17 respectively. While in absolute control and NPK alone treated plots the tiller production at tillering stage was 8.89 and 12.07 respectively in Mundakan season. OM 20 ¾ NPK treatment recorded the highest value of 16.13 during Mundakan crop at tillering stage. This treatment also maintained highest values both at PI and flowering stages. During Puncha also this treatment produced better values, which were comparable to other organic meal treated plots at higher levels.

4.4.2. Leaf Area Index

Leaf area index was more in the Puncha crop as compared to Mundakan (Table 4.35 and 4.34). In general organic meal treated plots were comparable to recommended practice (Control I) and significantly different from Control II in Mundakan while it significantly increased the leaf area compared to both control in

Puncha season. There was no great significant difference between the different doses of organic meal addition. In both seasons OM 20 ¾ NPK was the best in terms of increased leaf area index. In Mundakan second best treatment was OM 20 NPK with 8.53 value in tillering and it was on par with OM 20 ¾ NPK at panicle initiation stage (12.74). In Puncha season OM 20 ¾ NPK recorded a leaf area of 9.49 at tillering and 13.13 at panicle initiation and in Mundakan it was 8.90 and 12.62 respectively. The above treatment was followed by OM 15 NPK at panicle initiation (12.59) in Puncha.

4.4.3. Dry matter production

Dry matter accumulation increased with the growth of the crop in both seasons (Table 4.34 and 4.35). Though season did not exert a major influence on dry matter production slight increase was recorded in the Mundakan crop. In this season though there was significant difference between the fertilizer applied plots and Control II, no difference was observed within the fertilized treatments at tillering stage. But significant effects were seen at the flowering stage. Maximum dry matter was produced in OM 20 NPK (10.66t/ha) followed by OM 20 ¾ NPK (10.62 t), OM 15 ¾ NPK (10.42 t) and OM 10 ¾ NPK (9.44 t) in that order. OM 5 NPK and Control I was statistically on par at both stages. Respective values were 5.82 and 8.7 t in Control I and 5.29 and 8.25 t/ha in OM 5 NPK (Table 4.34).

Dry matter production increased with increasing levels of organic meal in both stages during Puncha season (Table 4.35). Application of 20 t organic meal along with different rates of fertilizer was significantly superior to rest of the levels of organic meal and to both controls. Of this maximum dry matter was accumulated in OM 20 NPK (9.67 t/ha). It was closely followed by OM 20 ¾ NPK (9.55 t) and OM 20 ½ NPK (9.13 t). Application of 15 t of organic meal was on par with 20 t. OM 5

Table 4.34. Leaf area index and dry matter production (t/ha) at different stages of crop during Mundakan season

No.	Treatments	LAI		DMP (t/ha)	
		Tillering	Panicle Initiation	Tillering	Flowering
1	OM 5 NPK	6.83^{bcd}	9.24^{c}	5.29^{a}	8.25^{d}
2	OM 10 ½NPK	5.83^{cd}	9.62^{bc}	6.20^{a}	8.17^{d}
3	OM 10 ¾NPK	6.24^{cd}	9.41^{bc}	6.16^{a}	9.44^{bc}
4	OM 10 NPK	6.03^{cd}	9.28^{c}	5.73^{a}	9.28^{cd}
5	OM 15 ½NPK	5.23^{d}	9.76^{bc}	5.53^{a}	8.25^{d}
6	OM 15 ¾NPK	6.73^{bcd}	10.01^{bc}	5.69^{a}	10.42^{ab}
7	OM 15 NPK	7.90^{ab}	10.46^{b}	5.45^{a}	8.34^{cd}
8	OM 20 ½NPK	6.13^{cd}	11.25^{ab}	5.99^{a}	8.52^{cd}
9	OM 20 ¾NPK	8.90^{a}	12.62^{a}	6.01^{a}	10.62^{a}
10	OM 20 NPK	8.53^{a}	12.74^{a}	6.24^{a}	10.66^{a}
11	Control I	7.40^{abc}	10.04^{ab}	5.82^{a}	8.70^{cd}
12	Control II	5.37^{d}	7.42^{d}	4.04^{b}	6.70^{e}
CD (P = 0.05)		1.49	1.71	1.05	1.002

Table 4.35. Leaf area index and dry matter production (t/ha) at different stages of crop during Puncha season

No	Treatments	LAI		DMP (t/ha)	
		Tillering	Panicle Initiation	Tillering	Flowering
1	OM 5 NPK	8.12^{ab}	9.97^{cd}	4.89^{d}	8.23^{abc}
2	OM 10 ½NPK	8.81^{a}	10.35^{bcd}	5.01^{cd}	8.35^{abc}
3	OM 10 ¾ NPK	9.10^{a}	9.55^{d}	5.52^{bc}	8.5^{abc}
4	OM 10 NPK	7.44^{ab}	11.95^{ab}	5.11^{cd}	8.59^{abc}
5	OM 15 ½ NPK	9.33^{a}	12.35^{a}	5.81^{ab}	8.52^{abc}
6	OM 15 ¾ NPK	9.18^{a}	11.99^{ab}	5.65^{ab}	8.46^{abc}
7	OM 15 NPK	8.08^{ab}	12.59^{a}	5.69^{ab}	8.80^{abc}
8	OM 20 ½ NPK	7.77^{ab}	10.40^{bcd}	6.16^{a}	9.13^{ab}
9	OM 20 ¾ NPK	9.49^{a}	13.13^{a}	6.15^{a}	9.55^{a}
10	OM 20 NPK	7.79^{ab}	11.69^{abc}	6.11^{a}	9.67^{a}
11	Control I	5.83^{bc}	10.06^{bcd}	4.92^{d}	7.94^{bc}
12	Control II	4.59^{c}	6.23^{e}	3.69^{e}	6.11^{d}
CD (P= 0.05)		2.59	1.73	0.499	1.318

NPK (4.89 t), OM 10 ½ NPK (5.01 t) and OM 10 NPK (5.11 t) were comparable to control I (4.92 t) at tillering and on par with other higher levels at flowering stage.

4.4.4. Days to 50 per cent flowering

Season exerted influence on days to 50 per cent flowering. The crop raised during Puncha took a longer time of 102 days to attain 50 per cent flowering (Table 4.37) while during Mundakan it was only 72 days (Table 4.36). There was no significant difference due to treatments in both the seasons.

4.4.5. Number of productive tillers

Season did not affect the productive tiller count significantly while fertilizer treatments did. The effective ear heads were maximum in OM 20 ¾ NPK followed by OM 20 NPK in both seasons. In Mundakan season the earhead count for the above treatments were 10.87 and 10.74, respectively (Table 4.36). These treatments produced 11.43 and 10.07 tillers during the Puncha season (Table 4.37). In Mundakan, even lower levels of organic meal in combination with inorganic fertilizer produced good number of productive tillers with values being 9.93, 9.47 and 10.07 respectively for OM 5 NPK, OM 10 ½ NPK and OM 10 ¾ NPK. All the above treatments were comparable to Control I, the NPK alone treated plot (9.39). But in Puncha crop higher levels of organic meal were in general, significantly superior to lower levels of organic meal and control treatments.

4.4.6. Panicle length

The panicle length ranged from 22.79 in Control II (no manure treated plot) to 26.19 cm in OM 20 ¾ NPK during Mundakan (Table 4.36) and from 22.04 in

OM 10 NPK to 25.67 cm in OM 20 ¾ NPK in Puncha (Table 4.37). There was no significant difference between different treatments in increasing panicle length. The treatment OM 20 ¾ NPK had the longest panicle (26.19cm) followed by OM 10 ¾ NPK (26.17cm) in Mundakan.

4.4.7. Number of filled grains per panicle

Application of organic meal in combination with inorganic fertilizers exerted a favourable effect on the production of filled grains. In the Mundakan season maximum number of filled grains was observed in OM 15 ¾ NPK (147.07), followed by OM 10 ½ NPK (142.43), OM 20 ¾ NPK (140.73) and OM 5 NPK (140.5) (Table 4.36) while in Puncha crop OM 10 ¾ NPK produced significantly higher number of filled grains (141.67). It was followed by OM 15 NPK (137.13) and OM 20 ¾ NPK (135.97). OM 5 NPK produced 129 filled grains and it was also on par with the above best treatments (Table 4.37).

4.4.8. Thousand grain weight

The thousand grain weight was comparable in both seasons. No significant difference between different treatments was observed in Mundakan (Table 4.36). But in Puncha the seed weight was highest in OM 15 NPK (23.09 g) followed by OM 10 ¾ NPK (22.58 g) and OM 10 ½ NPK (21.65 g). The thousand grain weight in OM 5 NPK (20.06) was on par to control I (20.22), the recommended practice of crop nutrition (Table 4.37).

4.4.9. Grain and straw yield

The grain and straw yield obtained during Mundakan and Puncha season is given in Tables 4.36 and 4.37 respectively. The grain yield ranged from 2.59 t to 5.01t/ha in Mundakan and from 2.41 t to 4.25 t/ha during Puncha. Higher grain yield was recorded during Mundakan season in all the treatments compared to Puncha. In Mundakan season higher the level of application of organic meal higher was the increase in yield. Maximum yield of 5.01 t was obtained from OM 20 ¾ NPK followed by OM 20 NPK (4.92 t) and OM 15 NPK (4.79 t) and OM 10 ½ NPK (4.39 t). OM 5 NPK produced similar yield (4.33 t) to that of recommended practice- control 1 (4.37 t).

In the Puncha season, the NPK alone treated plot (control I) produced only 3.53 t and addition of organic meal at 5 t was on par with it (3.48 t). Maximum yield of 4.25 t was recorded in OM 20 ¾ NPK followed by 4.2 t in OM 15 ½ NPK. Similarly OM 20 ½ NPK (4.13 t) produced comparable yield to OM 20 NPK (3.75 t). Also the yield obtained at OM 10 t in combination with different levels of fertilizer was comparable to each other.

The straw yield also increased during the Mundakan season. Increasing the levels of organic meal and inorganic fertilizer significantly increased the straw yield. This effect was more pronounced during Mundakan season. In both season organic meal treated plots significantly increased the straw yield over the control. In Mundakan season maximum yield was attained in OM 15 ¾ NPK (5.76 t) closely followed by OM 20 ¾ NPK (5.64 t) and OM 20 NPK (5.64 t) while in Puncha season maximum straw yield was recorded in OM 20 ¾ NPK (5.42 t) closely followed by OM 15 NPK (5.33 t) and OM 15 ½ NPK (5.18 t).

Table 4.36. Yield and yield components of crop during Mundakan season

No.	Treatments	No. of productive tillers	Days to 50 per cent flowering	Panicle length (cm)	No. of filled grains per panicle	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
1	OM 5 NPK	9.93^{ab}	72.67	24.53^{ab}	140.50^{a}	22.57	4.33^{bcd}	4.82^{ab}
2	OM 10 ½ NPK	9.47^{ab}	71.67	25.41^{a}	142.43^{a}	22.03	4.39^{ab}	5.02^{ab}
3	OM 10 ¾ NPK	10.07^{ab}	72.46	25.99^{a}	139.87^{ab}	22.73	4.07^{cd}	4.83^{ab}
4	OM 10 NPK	8.77^{ab}	72.00	26.17^{a}	136.10^{abc}	21.87	3.90^{d}	5.28^{ab}
5	OM 15 ½ NPK	7.97^{bc}	72.33	24.76^{ab}	121.53^{c}	21.70	4.29^{bcd}	5.38^{ab}
6	OM 15 ¾ NPK	10.43^{a}	71.67	26.13^{a}	147.07^{a}	21.57	4.30^{bcd}	5.76^{a}
7	OM 15 NPK	9.37^{ab}	72.33	25.17^{a}	130.20^{abc}	22.13	4.79^{ab}	5.48^{ab}
8	OM 20 ½ NPK	9.90^{ab}	72.00	24.14^{ab}	120.73^{c}	22.43	4.65^{abc}	5.41^{ab}
9	OM 20 ¾ NPK	10.87^{a}	72.33	26.19^{a}	140.73^{a}	22.03	5.01^{a}	5.64^{a}
10	OM 20 NPK	10.74^{a}	72.40	24.63^{ab}	122.08^{c}	23.00	4.92^{ab}	5.64^{a}
11	Control I	9.39^{ab}	72.30	24.62^{ab}	128.40^{abc}	21.70	4.37^{bcd}	4.59^{b}
12	Control II	6.41^{c}	72.00	22.79^{b}	82.67^{d}	21.27	2.59^{e}	3.52^{c}
CD (P=0.05)		1.92	NS	1.57	18.85	NS	0.556	0.875

Table 4.37. Yield and yield components of crop during Puncha season

No.	Treatments	No. of productive tillers	Days to 50 per cent flowering	Panicle length (cm)	No. of filled grains per panicle	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
1	OM 5 NPK	8.42^{bcd}	102.67	24.14^{abc}	129.0^{abc}	20.06^{cd}	3.48^{bc}	4.27^{abc}
2	OM 10 ½ NPK	8.33^{cd}	102.67	24.29^{ab}	123.27^{bc}	21.65^{abc}	3.69^{ab}	5.05^{ab}
3	OM 10 ¾ NPK	9.42^{bc}	104.00	23.49^{bcd}	141.67^{a}	22.58^{ab}	3.96^{ab}	5.05^{ab}
4	OM 10 NPK	8.27^{cd}	102.67	22.04^{d}	123.17^{bc}	21.38^{bc}	3.83^{ab}	4.16^{abc}
5	OM 15 ½ NPK	9.13^{bcd}	103.00	23.87^{abc}	121.03^{bc}	21.52^{bc}	4.20^{ab}	5.18^{a}
6	OM 15 ¾ NPK	7.67^{d}	102.33	24.08^{abc}	114.93^{c}	19.56^{d}	3.33^{c}	4.27^{abc}
7	OM 15 NPK	8.87^{bcd}	102.33	23.34^{bcd}	137.13^{ab}	23.09^{a}	4.02^{ab}	5.33^{a}
8	OM 20 ½ NPK	8.80^{bcd}	102.33	24.31^{ab}	125.73^{abc}	19.61^{d}	4.13^{ab}	4.75^{ab}
9	OM 20 ¾ NPK	11.43^{a}	102.00	25.67^{a}	135.97^{ab}	21.20^{bc}	4.25^{a}	5.42^{a}
10	OM 20 NPK	10.07^{ab}	102.33	24.09^{abc}	123.57^{bc}	21.40^{bc}	3.75^{ab}	4.46^{abc}
11	Control I	8.20^{cd}	102.33	24.51^{ab}	123.90^{bc}	20.22^{cd}	3.53^{bc}	3.82^{bc}
12	Control II	5.20^{e}	102.00	22.42^{cd}	95.13^{d}	18.79^{d}	2.41^{d}	3.26^{c}
CD (P=0.05)		1.49	NS	1.55	15.25	1.41	0.79	1.103

4.4.10. Nutrient uptake

The uptake of major nutrients viz., N, P, K, Ca and Mg and that of the micronutrients viz. Fe, Mn, Zn and Cu were studied at stage wise and crop wise. For the sake of brevity and ease in comprehension the values at maturity are furnished here. Tables 4.38.to 4.41.contain the content of nutrients of the test crop, season wise.

Irrespective of season and treatment differences the N and P content decreased at the maturity phase. While K content was maximum in the harvest stage. The Ca content increased towards maturity in Mundakan but a definite pattern could not be observed during Puncha. Mg content was almost uniform throughout. N and P content was more in grain while straw contained more K, Ca and Mg.

Though significant difference was observed between fertilizer treated plots and Control II the different levels of organic meal did not influence the nitrogen content. In the Mundakan season OM 15 ¾ NPK with 1.45 and 2.57 per cent in straw and grain respectively was superior to other treatments. In the Puncha crop OM 20 ¾ NPK was significantly superior at all stages. The straw and grain content were 1.39 and 1.77 per cent respectively.

There was not much variation in the P content due to application of different levels of organic meal. But absolute control was significantly inferior. In the Mundakan season the maximum P content was observed in OM 20 ¾ NPK, the grain and straw content being 0.31 and 0.27 per cent respectively. The P content in grain and straw was highest in OM 15 ½ NPK during Puncha with respective values of 0.32 and 0.19 per cent.

Even with respect to K content the various levels of organic meal did not differ significantly. The content of K in straw was highest in OM 15 ¾ NPK (1.66) followed by OM 10 ¾ NPK (1.65) treated plots during Mundakan. The respective treatments also recorded higher content of K in grain but the differences between treatments were not significant. In Puncha a maximum of 1.8 per cent K in straw was recorded in OM 10 ½ NPK and OM 10 ¾ NPK. OM 15 ¾ NPK and OM 20 ½ NPK accumulated 0.33 per cent K in the grain.

In the Mundakan season the different treatments did not vary significantly with respect to Ca content. A maximum of 1.86 per cent was observed in OM 15 ¾ NPK at maturity in straw while OM 20 ½ NPK treated plot had a high content of 0.73 per cent Ca in grain. The above treatments were closely followed by OM 5 NPK with 0.71 and 1.79 per cent in grain and straw respectively.

In the Puncha crop though increasing levels of organic meal had increased the Ca content it was not significant between levels. Absolute control was significantly inferior. OM 20 ¾ NPK had the highest Ca content of 1.59 per cent in straw followed by OM 15 ¾ NPK (1.28 %) and OM 15 NPK (1.24 %). The grain content was maximum in OM 10 ¾ NPK, OM 15 ½ NPK and OM 15 NPK with 0.41 per cent. These treatments were also on par with other levels.

The Mg content varied from 0.018 to 0.02 per cent in both the seasons. There was no significant difference either in grain or straw content between the different treatments in both seasons.

Among the micronutrients, Fe, Zn and Cu content decreased towards maturity while Mn content increased. Fe and Mn were higher in straw while Zn and Cu content during Puncha was more or less uniform in grain and straw. During Mundakan the grain had higher Cu content.

The Fe content at maturity phase was comparatively higher in Mundakan than Puncha crop. It varied from 1219 to 2588 ppm in straw and from 195 to 607.7 ppm in grain during Mundakan. Corresponding content during Puncha ranged from 1151 to 1972 ppm and from 65 to 141 ppm respectively in straw and grain.

The Mn content during Mundakan ranged from 96 to 199.3 ppm in straw and from 27.33 to 41 ppm in grain in organic meal treated plots. In the case of straw the contents at lower levels of organic meal were comparable to that of the NPK treated plots and superior to absolute control. But the content at higher levels of meal were significantly inferior. In Puncha season it varied from 196.3 ppm to 320 ppm in straw and from 44 to 76.67 ppm in grain. But the differences between treatments were not significant.

The Zn content in straw was highest in OM 15 ¾ NPK 31 ppm followed by 29.67 ppm in OM 15 NPK treated plot during Mundakan season. The content in grain varied from 21.33 to 24 ppm in treated plots but the difference was not significant. In Puncha also there was no significant difference between treatments in the content in straw. But with regard to grain the Zn content was significantly superior in organic meal treated plots than the rest. The treatments OM 15 ¾ NPK and OM 20 ½ NPK had the highest Zn content of 29.67 ppm. These were followed by OM 15 ½ NPK (29.3 ppm), OM 10 ¾ NPK (29 ppm) and OM 20 ¾ NPK (29 ppm) treated plots.

There was not much variation in the Cu content between treatments in both the seasons. The Cu content was comparatively higher in Puncha season. During Mundakan the Cu content in straw varied from 1.33 to 4.67 and in grain from 1.0 to 6.0 ppm in treated plots. Corresponding values during Puncha were 4.33 to 8.0 ppm and 4.67 to 7.73 ppm in straw and grain respectively.

Table 4.38. Effect of treatments on the major nutrient content (%) during Mundakan season

No	Treatments	N		P		K		Ca		Mg	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	OM 5 NPK	2.05^{bc}	1.09^{abc}	0.28^{a}	0.24^{a}	0.29	1.31^{bc}	0.71^{a}	1.79^{ab}	0.0184	0.0204
2	OM 10 ½ NPK	2.12^{abc}	1.18^{abc}	0.30^{a}	0.23^{a}	0.30	1.25^{c}	0.68^{ab}	1.18^{de}	0.0181	0.0208
3	OM 10 ¾ NPK	1.98^{bc}	1.33^{ab}	0.30^{a}	0.24^{a}	0.33	1.65^{a}	0.54^{abcd}	1.61^{abc}	0.0186	0.0312
4	OM 10 NPK	2.06^{bc}	1.17^{abc}	0.25^{a}	0.25^{a}	0.27	1.59^{ab}	0.43^{cd}	1.59^{bc}	0.0191	0.0206
5	OM 15 ½ NPK	2.15^{ab}	1.03^{bc}	0.27^{a}	0.23^{a}	0.31	1.40^{abc}	0.47^{bcd}	1.62^{abc}	0.0182	0.0204
6	OM 15 ¾ NPK	2.57^{a}	1.45^{a}	0.26^{a}	0.24^{a}	0.34	1.66^{a}	0.45^{bcd}	1.86^{a}	0.0176	0.0212
7	OM 15 NPK	2.10^{abc}	1.32^{ab}	0.31^{a}	0.24^{a}	0.30	1.54^{abc}	0.49^{abcd}	1.56^{bc}	0.0181	0.0214
8	OM 20 ½ NPK	2.06^{bc}	1.13^{abc}	0.25^{a}	0.26^{a}	0.29	1.36^{abc}	0.73^{a}	1.20^{de}	0.0182	0.0221
9	OM 20 ¾ NPK	2.24^{ab}	1.26^{ab}	0.31^{a}	0.27^{a}	0.29	1.58^{ab}	0.69^{ab}	1.42^{cd}	0.0174	0.0212
10	OM 20 NPK	2.18^{ab}	1.15^{abc}	0.30^{a}	0.25^{a}	0.33	1.42^{abc}	0.56^{abcd}	1.77^{ab}	0.0182	0.0208
11	Control I	2.25^{ab}	1.03^{bc}	0.32^{a}	0.24^{a}	0.33	1.33^{bc}	0.62^{abc}	1.69^{ab}	0.0186	0.0204
12	Control II	1.65^{c}	0.87^{c}	0.16^{b}	0.12^{b}	0.27	0.95^{d}	0.37^{d}	1.10^{e}	0.0184	0.0208
CD (P=0.05)		0.49	0.37	0.076	0.054	NS	0.27	0.214	0.239	NS	NS

Table 4.39. Effect of treatments on the micronutrient content (ppm) of crop during Mundakan season

No	Treatments	Fe		Mn		Zn		Cu	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	OM 5 NPK	195.0^{c}	1352	37.00	199.3^{a}	22.30	22.67^{cd}	1.33^{c}	4.67^{a}
2	OM 10 ½ NPK	607.7^{a}	2331	36.67	178.7^{ab}	24.00	25.00^{c}	1.00^{c}	3.00^{ab}
3	OM 10 ¾ NPK	336.0^{bc}	1431	31.33	170.3^{abc}	22.00	24.00^{cd}	1.33^{c}	2.00^{b}
4	OM 10 NPK	384.7^{abc}	1298	39.00	107.7^{d}	22.00	25.30^{c}	5.00^{ab}	1.33^{b}
5	OM 15 ½ NPK	492.0^{ab}	2076	41.00	113.0^{cd}	23.00	25.67^{c}	3.00^{abc}	1.67^{b}
6	OM 15 ¾ NPK	278.7^{bc}	2588	34.67	131.0^{bcd}	21.33	31.00^{a}	6.00^{a}	1.33^{b}
7	OM 15 NPK	390.0^{abc}	1558	27.67	132.7^{bcd}	23.67	29.67^{ab}	4.00^{abc}	1.33^{b}
8	OM 20 ½ NPK	408.0^{abc}	1641	37.33	96.0^{d}	21.67	26.33^{bc}	2.33^{bc}	2.67^{b}
9	OM 20 ¾ NPK	417.7^{abc}	1932	34.67	105.7^{d}	22.00	25.33^{c}	4.00^{abc}	1.33^{b}
10	OM 20 NPK	257.0^{bc}	1219	27.33	107.3^{d}	22.67	22.33^{cd}	3.33^{abc}	1.33^{b}
11	Control I	326.0^{bc}	1323	53.67	183.3^{ab}	23.33	26.33^{bc}	3.67^{abc}	1.33^{b}
12	Control II	239.0^{bc}	1334	26.67	137.0^{bcd}	21.67	20.67^{d}	2.33^{bc}	1.33^{b}
CD (P=0.05)		225.9	NS	NS	55.34	NS	3.58	3.07	1.89

Table 4.40. *Effect of treatments on the major nutrient content (%) during Puncha season*

No	Treatments	N		P		K		Ca		Mg	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	OM 5 NPK	1.43^{d}	1.11^{bcd}	0.19^{a}	0.15^{ab}	0.30^{ab}	1.39^{e}	0.34^{a}	1.05^{a}	0.0200	0.0184
2	OM 10 ½ NPK	1.48^{cd}	1.38^{ab}	0.27^{a}	0.18^{a}	0.28^{ab}	1.80^{a}	0.36^{a}	1.17^{a}	0.0180	0.0182
3	OM 10 ¾ NPK	1.51^{cd}	1.02^{cd}	0.22^{a}	0.19^{a}	0.26^{b}	1.80^{a}	0.41^{a}	1.00^{a}	0.0180	0.0194
4	OM 10 NPK	1.52^{cd}	1.11^{bcd}	0.21^{a}	0.21^{a}	0.29^{ab}	1.69^{ab}	0.39^{a}	1.14^{a}	0.0187	0.0186
5	OM 15 ½ NPK	1.55^{cd}	1.15^{bcd}	0.32^{a}	0.19^{a}	0.28^{ab}	1.60^{bc}	0.41^{a}	0.95^{a}	0.0186	0.0184
6	OM 15 ¾ NPK	1.54^{cd}	1.04^{cd}	0.27^{a}	0.19^{a}	0.33^{a}	1.51^{cd}	0.39^{a}	1.28^{a}	0.0182	0.0214
7	OM 15 NPK	1.58^{bc}	0.99^{d}	0.23^{a}	0.19^{a}	0.29^{ab}	1.57^{c}	0.41^{a}	1.24^{a}	0.0188	0.0208
8	OM 20 ½ NPK	1.70^{a}	1.04^{cd}	0.31^{a}	0.19^{a}	0.33^{a}	1.54^{cd}	0.37^{a}	1.16^{a}	0.0186	0.0214
9	OM 20 ¾ NPK	1.77^{a}	1.39^{a}	0.28^{a}	0.19^{a}	0.26^{b}	1.52^{cd}	0.37^{a}	1.59^{a}	0.0184	0.0208
10	OM 20 NPK	1.68^{ab}	1.31^{abc}	0.24^{a}	0.18^{a}	0.28^{ab}	1.60^{bc}	0.40^{a}	1.18^{a}	0.0188	0.0214
11	Control I	1.48^{cd}	1.01^{cd}	0.22^{a}	0.20^{a}	0.28^{ab}	1.43^{de}	0.39^{a}	1.07^{a}	0.0196	0.0226
12	Control II	1.28^{e}	0.88^{d}	0.19^{b}	0.13^{b}	0.20^{c}	1.01^{f}	0.22^{b}	0.66^{b}	0.0178	0.0181
CD (P=0.05)		0.110	0.273	0.079	0.016	0.054	0.107	0.076	0.288	NS	NS

Table 4.41. Effect of treatments on the micronutrient content (ppm) of crop during Puncha season

No	Treatments	Fe		Mn		Zn		Cu	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	OM 5 NPK	79.0^{d}	1529^{abc}	76.67	210.3	22.00^{c}	24.30	5.00^{b}	4.33^{bc}
2	OM 10 ½ NPK	110.7^{abc}	1151^{c}	49.33	266.7	26.7^{abc}	29.00	5.00^{b}	7.33^{a}
3	OM 10 ¾ NPK	121.7^{ab}	1361^{bc}	50.67	212.0	29.00^{a}	26.00	4.67^{b}	7.00^{ab}
4	OM 10 NPK	126.7^{a}	1289^{bc}	63.67	196.3	27.67^{ab}	29.00	5.67^{ab}	7.00^{ab}
5	OM 15 ½ NPK	141.0^{a}	1278^{bc}	65.00	223.7	29.30^{a}	29.00	6.00^{ab}	6.67^{ab}
6	OM 15 ¾ NPK	93.7^{bcd}	1385^{bc}	74.00	203.7	29.67^{a}	27.67	5.67^{ab}	8.00^{a}
7	OM 15 NPK	126.0^{a}	1492^{bc}	50.67	202.3	26.7^{abc}	27.00	7.33^{a}	8.00^{a}
8	OM 20 ½ NPK	126.0^{a}	1301^{bc}	61.67	320.0	29.67^{a}	28.00	6.33^{ab}	8.00^{a}
9	OM 20 ¾ NPK	117.0^{ab}	1502^{bc}	44.00	210.3	29.00^{a}	29.67	6.00^{ab}	6.33^{ab}
10	OM 20 NPK	115.3^{ab}	1203^{bc}	50.00	214.3	28.00^{ab}	29.00	7.73^{a}	6.67^{ab}
11	Control I	83.67^{cd}	1672^{ab}	55.33	146.7	23.30^{bc}	25.00	4.67^{b}	5.3^{abc}
12	Control II	65.0^{d}	1972^{a}	56.33	217.3	25.7^{abc}	25.33	5.00^{b}	2.67^{c}
CD (P=0.05)		26.91	431.9	NS	NS	4.56	NS	1.61	2.62

4.4.11. Nutrient status of soil

The soil samples were analysed for pH, organic carbon, major and minor nutrients at the beginning and end of each crop. The details for the two seasons are presented in Tables 4.42, 4.43 and 4.44 respectively.

The pH of the soil varied from 5.33 to 5.93 during Mundakan and from 5.43 to 6.0 in Puncha season in the treated plots. Addition of organic meal raised the soil pH from 5.4 to 6.0 in OM 20 NPK during Puncha season. In all the treatments there was a slight increase in pH over the initial value (5.40). During both seasons OM 20 NPK and OM 20 ¾ NPK were significantly superior to all other levels.

The organic carbon content of soil increased from 2.08 to 3.10 per cent in OM 5 NPK in Mundakan and from 2.02 to 3.21 per cent in OM 10 NPK in Puncha. During Mundakan the organic carbon content of treated plots were superior to recommended practice of crop nutrition but in Puncha there was no difference between the different treatments. Irrespective of season the value at harvest was higher than the initial ones in all the treatments.

The available N status of the soil improved with organic meal application. The increase was from 310 to 370 ppm in OM 10 ½ NPK in Mundakan and from 314 to 413 ppm in OM 5 NPK in Puncha. N content of soil after harvest was comparatively higher during Puncha crop. Maximum content of 370 ppm was recorded in OM 10 ½ NPK, OM 15 ¾ NPK and OM 20 ¾ NPK during Mundakan crop. These were statistically on par with lower level of OM 5 NPK (320 ppm) as well as recommended practice of crop nutrition (330 ppm). In the Puncha crop the available N at harvest was highest in OM 5 NPK (413 ppm) and OM 10 NPK (413 ppm). These were followed by OM 10 ½ NPK (412 ppm) and OM 15 NPK (411 ppm). In general organic meal in combination with full recommended dose of NPK registered higher available N content compared to ½ and ¾th levels. The absolute control showed a slight decrease in content from the initial level.

Available P content of soil at harvest varied from 8 ppm to 20 ppm in Mundakan and from 15 to 27 ppm in Puncha in treated plots. During Mundakan season available P content of soil increased with increase in organic meal levels. The maximum content of 20 ppm was recorded in OM 20 NPK followed by 18 ppm in OM 20 ¾ NPK and 17 ppm in OM 10 ½ NPK. The content recorded at lower level of 5 NPK, OM 10 ¾ NPK, OM 10 NPK and OM 15 ½ NPK were significantly on par with that of recommended practice of nutrition. In Puncha season there was a slight decrease in available P with increase in organic meal. Maximum content of 27 ppm was obtained in OM 10 ¾ NPK followed by 23 ppm in OM 10 ½ NPK. These were also comparable to Control I (23 ppm). During both seasons the Control II, the no manure added plot was significantly inferior.

There was not much variation in the K content at harvest during both seasons. During Mundakan crop maximum K was recorded in OM 20 ½ NPK (72 ppm) and in Puncha it was in OM 20 NPK (68 ppm). But these were on par to other levels and also to the recommended practice. All the treatments registered a slight increase in K content at harvest compared to initial K status of soil. This trend was observed during both seasons.

Table 4.42. Effect of treatments on the available major nutrient content of soil at harvest in mundakan season

Treatments	pH	Organic carbon (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg (ppm)
Initial	5.40	2.08	310	3.5	50	1880	84
OM 5 NPK	5.40^{bcd}	3.10^{a}	320^{abcd}	11^{de}	57^{bc}	2030^{de}	32^{cd}
OM 10 ½ NPK	5.70^{abc}	2.81^{abcd}	370^{a}	17^{abc}	55^{c}	2270^{bc}	44^{bcd}
OM 10 ¾ NPK	5.50^{bcd}	2.80^{bcd}	330^{abcd}	12^{cde}	58^{bc}	2070^{de}	32^{cd}
OM 10 NPK	5.33^{d}	3.09^{a}	360^{ab}	11^{de}	62^{abc}	2270^{bc}	88^{ab}
OM 15 ½ NPK	5.83^{a}	3.04^{ab}	340^{abe}	8^{def}	60^{abc}	2300^{bc}	68^{abcd}
OM 15 ¾ NPK	5.73^{ab}	2.79^{bcd}	370^{a}	13^{bcd}	57^{bc}	1890^{f}	24^{d}
OM 15 NPK	5.40^{cd}	2.76^{bcd}	360^{ab}	14^{bcd}	57^{bc}	2150^{cd}	36^{bcd}
OM 20 ½ NPK	5.50^{bcd}	2.83^{abcd}	290^{cd}	13^{bcd}	72^{a}	2520^{a}	60^{abcd}
OM 20 ¾ NPK	5.90^{a}	2.95^{abc}	370^{a}	18^{ab}	70^{a}	2480^{a}	84^{abc}
OM 20 NPK	5.93^{a}	2.72^{cd}	350^{ab}	20^{a}	68^{ab}	2410^{ab}	108^{a}
Control I	5.47^{bcd}	2.63^{d}	330^{abcd}	7^{ef}	60^{abc}	1950^{ef}	36^{bcd}
Control II	5.20^{d}	2.08^{e}	280^{d}	4^{f}	51^{c}	1880^{f}	73^{abcd}
CD (P=0.05)	0.28	0.262	50	5	11	169	53

Table 4.43. Effect of treatments on the available major nutrient content of soil at harvest in Puncha season

Treatments	pH	Organic carbon (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg (ppm)
Initial	5.40	2.02	314	3.6	53	1790	33
OM 5 NPK	5.43^{cd}	2.91^{a}	413^{a}	15^{d}	55^{b}	1610^{c}	24
OM 10 ½ NPK	5.46^{bc}	3.02^{a}	412^{a}	23^{b}	55^{b}	1700^{abc}	16
OM 10 ¾ NPK	5.63^{bc}	2.98^{a}	357^{bc}	27^{a}	60^{ab}	1620^{bc}	28
OM 10 NPK	5.63^{bc}	3.21^{a}	413^{a}	22^{b}	58^{ab}	1840^{a}	36
OM 15 ½ NPK	5.80^{ab}	3.18^{a}	384^{ab}	22^{b}	57^{ab}	1810^{ab}	40
OM 15 ¾ NPK	5.83^{ab}	3.11^{a}	320^{cd}	19^{bcd}	62^{ab}	1770^{abc}	28
OM 15 NPK	5.83^{ab}	2.93^{a}	411^{a}	19^{bcd}	60^{ab}	1720^{abc}	20
OM 20 ½ NPK	5.88^{ab}	2.95^{a}	403^{ab}	22^{b}	62^{ab}	1740^{abc}	24
OM 20 ¾ NPK	5.90^{a}	3.17^{a}	384^{ab}	17^{cd}	65^{ab}	1860^{a}	32
OM 20 NPK	6.00^{a}	2.85^{a}	395^{ab}	19^{bc}	68^{a}	1860^{a}	20
Control I	5.47^{cd}	2.89^{a}	349^{ab}	23^{b}	58^{b}	1750^{abc}	26
Control II	5.27^{cd}	2.02^{b}	310^{c}	4.9^{e}	52^{c}	1780^{ab}	16
CD (P=0.05)	0.22	0.505	50	3.9	10	169	NS

The available Ca content after harvest of crop showed a slight increase in the Mundakan season. The trend was not uniform in Puncha. Ca content of soil increased with organic meal application. The highest content of 2520 ppm was recorded in OM 20 ½ NPK during Mundakan. It was followed by OM 20 ¾ NPK (2480 ppm). The Ca content recorded at lower levels of organic meal was also superior to that of recommended practice. In Puncha also OM 20 ¾ NPK and 20 NPK were significantly superior with 1860 ppm calcium. These were statistically on par with OM 10 NPK (1840 ppm) and OM 15 ½ NPK (1810 ppm). All the other levels were on par to each other.

The available Mg content of soil after harvest of the crop decreased in certain treatments while it was maintained around the initial level in others. This trend was seen in both the seasons of study. During Mundakan it ranged from 24 to 108 ppm and in Puncha it was from 16 to 40 ppm. There was not much difference in the Mg content between the different levels of organic meal. In Mundakan maximum value of 108 ppm was recorded in OM 20 NPK. The Mg content at lower levels was comparable to that in Control I. The absolute control also recorded higher content of 73 ppm. In Puncha there was no significant difference between the different treatments.

The Fe, Mn, Zn and Cu content of soil at harvest of the Mundakan crop was in the range of 91.4 to 97.27 ppm, 8.6 to 12.55 ppm, 0.64 to 0.913 ppm and 2.16 to 2.71 ppm respectively in the treated plots. The Fe, Mn and Zn content increased while Cu content decreased at harvest. In Puncha the Fe content varied from 103.1 to 115.4 ppm, Mn from 8.69 to 13.03 ppm, Zn from 0.55 to 0.99 ppm and Cu from

Table 4.44. Effect of treatments on the available micronutrient content of soil at harvest in Mundakan and Puncha season

Treatments	Fe (ppm)		Mn (ppm)		Zn (ppm)		Cu (ppm)	
	Mundakan	Puncha	Mundakan	Puncha	Mundakan	Puncha	Mundakan	Puncha
Initial	86.5	88.6	7.28	7.28	0.62	0.64	3.24	3.32
OM 5 NPK	92.27^{b}	103.1^{c}	8.75^{def}	11.68^{abc}	0.773^{ab}	0.59^{d}	2.16^{b}	3.26^{cde}
OM 10 ½ NPK	94.64^{ab}	115.2^{a}	11.89^{abc}	9.09^{bcd}	0.90^{a}	0.90^{ab}	2.69^{a}	3.37^{bcd}
OM 10 ¾ NPK	97.27^{a}	107.4^{b}	9.93^{de}	8.69^{cd}	0.640^{b}	0.55^{d}	2.58^{ab}	3.40^{bcd}
OM 10 NPK	92.77^{ab}	108.8^{b}	10.64^{bcd}	9.89^{abcd}	0.640^{b}	0.99^{a}	2.58^{ab}	3.46^{abc}
OM 15 ½ NPK	95.70^{ab}	108.9^{b}	10.15^{cde}	13.03^{a}	0.653^{b}	0.77^{abcd}	2.55^{ab}	3.47^{abc}
OM 15 ¾ NPK	95.43^{ab}	115.4^{a}	12.55^{a}	12.04^{ab}	0.74^{ab}	0.67^{cd}	2.35^{ab}	3.47^{abc}
OM 15 NPK	96.97^{a}	107.3^{b}	8.98^{def}	12.93^{a}	0.84^{ab}	0.71^{bcd}	2.27^{ab}	3.55^{ab}
OM 20 ½ NPK	91.40^{bc}	113.3^{a}	12.03^{ab}	12.98^{a}	0.77^{ab}	0.88^{abc}	2.65^{a}	3.53^{ab}
OM 20 ¾ NPK	93.72^{ab}	107.5^{b}	8.60^{ef}	12.24^{ab}	0.913^{a}	0.89^{ab}	2.53^{ab}	3.21^{de}
OM 20 NPK	95.16^{ab}	109.3^{b}	9.41^{de}	12.63^{a}	0.753^{ab}	0.75^{bcd}	2.71^{a}	3.57^{ab}
Control I	93.95^{ab}	113.0^{a}	8.68^{ef}	7.86^{d}	0.893^{a}	0.63^{d}	2.38^{ab}	3.68^{a}
Control II	87.84^{c}	101.3^{c}	7.39^{f}	7.56^{d}	0.633^{b}	0.55^{d}	2.16^{b}	3.08^{e}
CD (P=0.05)	3.99	3.67	1.701	2.93	0.186	0.2004	0.415	0.207

3.21 to 3.57 ppm in organic meal treated plots. Fe, Mn and Zn increased while copper remained almost the same during Puncha.

4.5. Residual effect of organic meal

Field experiments were conducted during two successive seasons (Puncha and Virippu) to arrive at the residual effects, if any following the main experiments in the same plots of experiment No.1. The plots were prepared as described under item 3.4.2 and P was skipped in those plots, which received organic meal during the main experiment season. The results are presented below:

4.5.1. Growth characters

In the first season Puncha, the plant height differed significantly except during the initial stage (Table 4.45). Organic meal treated plots in the absence of added P in general, produced taller plants over the NPK treated control, though these were on par to each other at all stages of plant growth. Of the different levels, OM 20 ¾ NPK treated plot produced the tallest plants with a height of 158.57 cm. It was followed by OM 15 NPK (157.4 cm) and OM 10 NPK (156.53 cm) treated plots. Whereas in the control NPK treated plot, the plant height at final stage was around 150 cm which was also on par with the majority of the P skipped and previously organic meal treated plots.

In the second crop Virippu also, the residual influence of the organic meal was significant as reflected in the growth of the test variety Matta Triveni, a well adapted Puncha season high yielding variety. The plant height increased from 46.5 cm at tillering to a maximum height of 86.9 cm in previous OM 10 NPK treated plot at

Table 4.45. Growth attributes of the residual crop var. Chemeen during Puncha season

Treatments	Plant height (cm)				No. of tillers		
	Tillering	PI	Flower-ing	Harvest	Tillering	PI	Flower-ing
OM 5 NPK	59.83	114.23^{bc}	150.77^{ab}	154.60^{a}	10.13^{d}	10.87^{b}	10.67
OM 10 ½ NPK	60.17	115.17^{ab}	143.47^{abc}	150.13^{a}	13.07^{bc}	12.87^{ab}	12.70
OM 10 ¾ NPK	61.43	121.20^{ab}	147.67^{abc}	153.50^{a}	12.60^{c}	11.07^{b}	9.87
OM 10 NPK	61.73	115.63^{ab}	146.60^{abc}	156.53^{a}	13.00^{bc}	12.43^{ab}	9.40
OM 15 ½ NPK	60.80	120.17^{ab}	139.50^{bc}	149.03^{a}	13.00^{bc}	14.63^{a}	10.90
OM 15 ¾ NPK	62.13	120.17^{ab}	156.30^{a}	155.63^{a}	14.33^{abc}	13.80^{a}	12.37
OM 15 NPK	64.37	123.73^{ab}	157.87^{a}	157.40^{a}	15.07^{ab}	13.97^{a}	11.57
OM 20 ½ NPK	61.20	118.93^{ab}	136.10^{c}	147.23^{a}	15.07^{ab}	14.67^{a}	9.87
OM 20 ¾ NPK	62.60	128.5^{a}	157.43^{a}	158.57^{a}	15.27^{a}	15.00^{a}	11.30
OM 20 NPK	61.90	122.0^{ab}	150.70^{ab}	155.73^{a}	15.00^{ab}	13.87^{a}	10.13
Control I	59.83	121.63^{ab}	150.83^{a}	150.87^{a}	9.80^{d}	10.93^{b}	10.40
Control II	55.03	102.90^{c}	121.87^{d}	129.33^{b}	7.56^{e}	7.23^{c}	7.13
CD (P=0.05)	NS	11.51	12.85	11.64	1.88	2.41	NS

Table 4.46. Growth attributes of the residual crop var. Matta Triveni during Virippu season

Treatments	Plant height (cm)				No. of tillers		
	Tillering	PI	Flowering	Harvest	Tillering	PI	Flowering
OM 5 NPK	45.7^{abc}	59.8^{c}	79.3^{abc}	78.7	6.67^{cd}	7.20^{ab}	7.27
OM 10 ½ NPK	38.8^{d}	57.3^{d}	74.3^{c}	74.5	6.33^{d}	6.63^{a}	6.57
OM 10 ¾ NPK	40.9^{cd}	58.9^{cd}	78.4^{bc}	82.8	7.50^{ab}	8.13^{a}	7.13
OM 10 NPK	46.5^{abc}	59.9^{cd}	82.3^{ab}	86.9	7.20^{abc}	7.63^{ab}	7.40
OM 15 ½ NPK	39.4^{d}	58.8^{cd}	80.6^{ab}	80.9	7.17^{abc}	7.07^{ab}	6.87
OM 15 ¾ NPK	49.1^{a}	65.6^{a}	84.8^{a}	84.3	7.83^{a}	8.57^{a}	7.87
OM 15 NPK	47.5^{ab}	60.9^{bcd}	83.4^{ab}	85.2	7.37^{abc}	8.20^{a}	7.47
OM 20 ½ NPK	42.2^{bcd}	67.2^{a}	84.1^{ab}	84.8	7.57^{ab}	7.80^{ab}	7.23
OM 20 ¾ NPK	46.2^{abc}	64.4^{ab}	82.6^{ab}	84.6	7.60^{ab}	8.60^{a}	7.73
OM 20 NPK	45.7^{abc}	59.7^{cd}	81.6^{ab}	85.0	6.97^{bcd}	7.23^{ab}	7.47
Control I	45.4^{abc}	62.2^{abc}	83.3^{ab}	80.5	7.47^{ab}	8.57^{a}	8.27
Control II	36.9^{d}	53.3^{e}	68.6^{d}	69.4	5.60^{e}	5.67^{c}	5.43
CD (P=0.05)	5.11	3.82	5.11	NS	0.70	1.02	NS

harvest (Table 4.46). This increased height was observed in all the erstwhile organic meal treatments. In the early stages OM 20 ½ NPK and OM 15 ¾ NPK produced taller plants with 67.2 and 65.6 cm respectively and these were also on par with other higher levels of previous organic meal treatments and NPK treated plot. Always the plants in the absolute control plots were significantly inferior over the rest of the treatments.

With regard to the tiller counts also the influence of pre-treated organic meal plots was significant. As in the case of plant height these treatments were always significantly superior to the absolute control and in general were on par with the NPK treated Control I. During Puncha season the variety Chemeen produced maximum number of 15 tillers in previous OM 20 ¾ NPK at panicle initiation stage followed by OM 20 ½ NPK (14.67) and OM 15 ½ NPK (14.63) treated plots. Lower levels of OM application viz. 5 (10.87) and 10 (11.07) had only lower residual effects and were comparable to Control I (10.93) (Table 4.45).

While in Virippu crop there was not much variation in tiller count between the previously organic meal applied plots and Control I, the NPK treated plots (Table 4.46). Maximum number of tillers were produced as residual influence of OM 20 ¾ NPK (8.6) and OM 15 ¾ NPK (8.57) and these were comparable to Control 1 (8.57). This trend was observed in all the stages of growth of the crop.

4.5.2. Grain and Straw yield

The grain and straw yield obtained for the two residual crops are given in Table 4.47. In the first residual crop there did not exist significant difference between the plots treated with different levels of fertilizer and organic meal in grain yield. The yield obtained in all the plots treated previously was comparable to NPK regularly treated plot (Control I) and significantly superior to absolute control (II). Maximum yield of 5 t was observed in OM 20 ¾ NPK followed by 4.89 t in Control I and 4.88 t in OM 20 ½ NPK. In the second residual crop also there existed significant difference in yield between the different treatments. However, those plots that previously received high doses of organic meal viz., OM 20 ¾ NPK, OM 10 ¾ NPK were on par with Control I under regular NPK with a yield of 3.33 t/ha. OM 15 NPK followed these with 3.28 t and OM 20 ½ NPK with 3.06 t. Comparatively poorer yields were obtained in OM 5 NPK (2.61) and OM 10 ½ NPK (2.67).

As in grain yield no difference existed between the pre-treated plots of organic meal with respect to straw yield during Puncha season. Maximum yield of 5.33 t was produced in OM 15 NPK and OM 20 NPK followed by 5.2 t in OM 10 NPK and OM 20 ½ NPK.

In Virippu the treatment OM 15 ½ NPK produced maximum straw yield of 4.33 t followed by Control I (4.27) and OM 15 NPK (4.03). There did not exist much variation in the straw yield between plots, which previously received higher levels of organic meal and recommended fertilizer doses. But in those plots, which received lower levels of organic meal OM 5 NPK and OM 10 ½ NPK, straw yield decreased significantly.

4.5.3. Soil nutrient contents

The details of the major and minor nutrient status at harvest of residual crops grown during Puncha and Virippu is presented in Tables 4.48, 4.49 and 4.50 respectively.

Table 4.47. Grain and straw yield (t/ha) of residual crops during Puncha and Virippu season

Treatments	Puncha season Var. Chemeen		Virippu season Var. Matta Triveni	
	Grain yield	Straw yield	Grain yield	Straw yield
OM 5 NPK	4.11^{a}	4.53^{a}	2.61^{c}	3.47^{cd}
OM 10 ½ NPK	4.11^{a}	4.80^{a}	2.67^{c}	3.60^{bcd}
OM 10 ¾ NPK	4.28^{a}	4.80^{a}	3.33^{a}	4.00^{abc}
OM 10 NPK	4.50^{a}	5.20^{a}	2.95^{abc}	3.70^{abc}
OM 15 ½ NPK	4.11^{a}	4.73^{a}	2.78^{bc}	4.33^{a}
OM 15 ¾ NPK	4.55^{a}	5.00^{a}	2.89^{abc}	3.67^{abc}
OM 15 NPK	3.72^{a}	5.33^{a}	3.28^{ab}	4.03^{abc}
OM 20 ½ NPK	4.88^{a}	5.20^{a}	3.06^{abc}	3.73^{abc}
OM 20 ¾ NPK	5.00^{a}	5.07^{a}	3.33^{a}	3.77^{abc}
OM 20 NPK	4.55^{a}	5.33^{a}	2.89^{abc}	3.87^{abc}
Control I	4.89^{a}	5.04^{a}	3.33^{a}	4.27^{ab}
Control II	2.23^{b}	2.80^{b}	1.94^{d}	3.00^{d}
CD (P = 0.05)	1.25	0.72	0.45	0.59

The pH of the soil in the Puncha crop varied from 5.67 to 6.0 in previously organic meal treated plots. These were comparable to that in NPK treated plot (Control I)(5.73). In the Virippu crop also there was not much variation between the different levels of organic meal. In both seasons the absolute control was significantly inferior.

There was a decrease in the organic carbon content of soil at the end of Puncha crop in all the treatments. Maximum content of 2.52 per cent was recorded in OM 20 ¾ NPK but it was on par to that at lower levels and also to recommended practice. When compared to Puncha an increase was recorded at the end of Virippu. Highest content of 2.88 per cent was in OM 10 NPK. Among the different levels OM 10 was significantly superior at all levels of inorganic fertilizer. OM 5 NPK recorded 2.76 per cent organic carbon and it was significantly superior to recommended practice of crop nutrition (2.39 %).

The available N status of soil improved at the end of Puncha crop while a slight decrease was observed in Virippu. This trend was observed in all the treatments. Maximum N content of 390 ppm was recorded in OM 10 ½ NPK, OM 10 ¾ NPK, OM 15 NPK and OM 20 NPK in Puncha. There was not much difference between the different levels but lower levels of previously OM treated plots also had significantly higher N values. In the Virippu season OM 15 NPK and OM 20 NPK with 380 ppm N was superior followed by 360 ppm in OM 10 ½ NPK. The N per cent in OM 5 NPK and control I was comparable with a content of 300 ppm and 310 ppm respectively. All the other levels were also on par with each other.

The available residual P content of soil ranged from 16 to 32 ppm during Puncha. Corresponding values in Virippu were 1.6 to 9.9 ppm respectively. In Puncha season OM 15 NPK had a high content of 32 ppm. But the P content at OM 5 NPK (28 ppm) was also on par with OM 20 NPK (28 ppm) and also OM 10 ½ NPK (27 ppm). OM 20 ¾ NPK had a low value of 17 ppm. But the P content in previously OM treated plot was superior to both control treatments. Higher the level of organic meal added to previous Mundakan season crop, higher was the available P at the end of Virippu crop. The treatments OM 15 NPK and all levels of OM 20 was significantly superior to all other treatments with a P content around 9 ppm. The lower levels of OM 5 NPK, OM 10 ½ NPK were comparable to Control I. The available P status of soil reduced significantly by the end of Virippu crop.

The available K content in plots treated with lower levels of organic meal recorded an increase in Puncha while it decreased in Virippu from the initial status. The reverse pattern was seen in plots, which previously received higher levels of organic meal. The available K content in OM 10 NPK was 77 ppm and it decreased to 57 ppm by the end of Virippu crop. While in OM 20 ½ NPK the content increased from 52 ppm in Puncha to 75 ppm towards the harvest of Virippu crop.

The available Ca content of soil decreased from the initial level at the end of both crops. In Puncha maximum content of 1830 ppm was noticed in OM 20 ½ NPK and OM 20 ¾ NPK. The previously OM treated plots were significantly superior to recommended practice of crop nutrition. In the Virippu season also there was no appreciable difference between the different levels of organic meal but previously treated plots were significantly superior to recommended practice. The available Mg content in Puncha ranged from 16 to 64 ppm and in Virippu from 16 to 76 ppm.

Table 4.48. Effect of treatments on the available major nutrient content of soil at harvest of residual crop in Puncha season

Treatments	pH	Organic carbon (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg (ppm)
OM 5 NPK	5.87^{ab}	2.23^{ab}	370^{ab}	28^{b}	57^{bcd}	1710^{ab}	64
OM 10 ½ NPK	5.67^{bc}	2.19^{ab}	390^{a}	27^{bc}	50^{de}	1650^{ab}	44
OM 10 ¾ NPK	5.70^{abc}	2.28^{ab}	390^{a}	18^{e}	67^{ab}	1750^{ab}	76
OM 10 NPK	5.83^{ab}	2.38^{ab}	370^{ab}	16^{e}	77^{a}	1590^{b}	56
OM 15 ½ NPK	5.87^{ab}	2.18^{ab}	380^{ab}	18^{e}	60^{bcd}	1630^{b}	24
OM 15 ¾ NPK	5.77^{ab}	2.34^{ab}	330^{bc}	25^{cd}	60^{bcd}	1720^{ab}	28
OM 15 NPK	5.70^{abc}	2.40^{ab}	390^{a}	32^{a}	65^{abc}	1640^{ab}	20
OM 20 ½ NPK	5.77^{ab}	2.43^{ab}	350^{ab}	24^{d}	52^{de}	1830^{a}	16
OM 20 ¾ NPK	5.93^{ab}	2.52^{a}	360^{ab}	17^{e}	60^{bcd}	1830^{a}	28
OM 20 NPK	6.00^{a}	2.44^{ab}	390^{a}	28^{b}	62^{bcd}	1670^{ab}	28
Control I	5.73^{ab}	2.43^{ab}	350^{ab}	10^{f}	48^{de}	1160^{c}	20
Control II	5.40^{c}	2.03^{b}	290^{c}	4.3^{g}	42^{e}	850^{d}	16
CD (P=0.05)	0.32	0.414	45	2.3	12	169	NS

Table 4.49. Effect of treatments on the available major nutrient content of soil at harvest of residual crop in Virippu season

Treatments	pH	Organic carbon (%)	Available N (ppm)	Available P (ppm)	Available K (ppm)	Available Ca (ppm)	Available Mg (ppm)
OM 5 NPK	6.00^{a}	2.76^{ab}	300^{cd}	2.6^{de}	53^{cd}	1020^{b}	36
OM 10 ½ NPK	5.97^{a}	2.87^{a}	360^{abc}	2.4^{de}	57^{bcd}	1000^{b}	20
OM 10 ¾ NPK	6.07^{a}	2.77^{ab}	320^{bc}	2.0^{ef}	60^{bcd}	1070^{ab}	36
OM 10 NPK	6.00^{a}	2.88^{a}	330^{abc}	1.6^{ef}	57^{bcd}	1140^{ab}	24
OM 15 ½ NPK	6.23^{a}	2.59^{bc}	330^{abc}	4.4^{c}	67^{abc}	1220^{a}	32
OM 15 ¾ NPK	6.17^{a}	2.33^{c}	260^{d}	6.0^{b}	63^{abcd}	1040^{ab}	16
OM 15 NPK	5.90^{ab}	2.69^{ab}	380^{a}	8.9^{a}	70^{ab}	1130^{ab}	20
OM 20 ½ NPK	6.10^{a}	2.83^{ab}	320^{bc}	9.6^{a}	75^{a}	1030^{ab}	24
OM 20 ¾ NPK	6.23^{a}	2.78^{ab}	340^{abc}	9.1^{a}	65^{abc}	1010^{b}	20
OM 20 NPK	6.13^{a}	2.81^{ab}	380^{a}	9.9^{a}	62^{abcd}	1050^{ab}	40
Control I	5.97^{a}	2.39^{c}	310^{cd}	3.4^{cd}	50^{d}	790^{c}	60
Control II	5.60^{b}	2.16^{d}	280^{e}	1.0^{f}	32^{e}	650^{c}	20
CD (P=0.05)	0.33	0.212	55	1.1	12	169	NS

Table 4.50. **Effect of treatments on the available micronutrient content of soil (ppm) at harvest of residual crops in Puncha and Virippu season**

Treatments	Fe		Mn		Zn		Cu	
	Puncha	Virippu	Puncha	Virippu	Puncha	Virippu	Puncha	Virippu
OM 5 NPK	102.76^{ab}	105.89^{abc}	12.27^{bcd}	10.77^{cd}	0.94^{ab}	0.94^{cd}	3.30^{cd}	2.68^{c}
OM 10 ½ NPK	93.63^{bc}	107.66^{ab}	13.10^{ab}	12.61^{abc}	0.94^{ab}	0.95^{cd}	3.36^{cd}	3.16^{a}
OM 10 ¾ NPK	102.22^{ab}	108.54^{a}	13.68^{a}	10.93^{cd}	0.83^{ab}	0.84^{cde}	3.1^{de}	2.94^{b}
OM 10 NPK	101.42^{ab}	108.05^{ab}	10.85^{fg}	10.31^{d}	0.84^{ab}	0.70^{efg}	3.83^{e}	2.97^{b}
OM 15 ½ NPK	97.84^{abc}	105.69^{abc}	13.57^{a}	13.32^{ab}	0.92^{ab}	0.81^{def}	3.12^{de}	2.98^{b}
OM 15 ¾ NPK	104.71^{a}	106.69^{ab}	12.90^{abc}	11.79^{abcd}	1.03^{ab}	1.51^{b}	3.38^{cd}	2.70^{c}
OM 15 NPK	107.15^{a}	102.19^{c}	11.26^{def}	11.46^{bcd}	0.93^{ab}	1.23^{b}	3.58^{bc}	2.74^{c}
OM 20 ½ NPK	109.80^{a}	102.24^{c}	11.13^{ef}	13.56^{a}	1.04^{a}	0.82^{def}	4.18^{a}	2.81^{bc}
OM 20 ¾ NPK	103.96^{a}	104.47^{bc}	11.93^{cde}	10.78^{cd}	0.93^{ab}	1.16^{a}	3.37^{cd}	2.91^{b}
OM 20 NPK	106.37^{a}	104.67^{bc}	9.94^{g}	11.03^{cd}	0.95^{ab}	0.97^{c}	3.83^{ab}	2.92^{b}
Control I	103.95^{a}	107.76^{ab}	12.61^{abc}	11.36^{cd}	1.09^{a}	1.88^{a}	2.86^{e}	2.71^{c}
Control II	88.96^{c}	98.13^{d}	8.64^{h}	8.39^{e}	0.64^{b}	0.65^{g}	2.75^{e}	2.54^{c}
CD (P=0.05)	8.51	3.41	0.985	1.74	0.355	0.131	0.397	0.194

There was no significant difference between the different treatments in both seasons. Compared to initial Mg status, the content decreased at the end of each crop.

The Fe content in previously OM treated plot varied from 93.63 to 109.8 ppm in Puncha but the differences were not significant. The Fe content at all the levels were comparable to recommended practice. In Virippu the content ranged from 102.19 to 108.54 ppm. The content was comparatively more at lower levels of 5 and 10 OM. OM 15 NPK and OM 20 ½ NPK had lower content around 102 ppm. The Fe content increased at the end of Puncha crop and the same content was more or less maintained at the end of Virippu.

The Mn content of soil decreased with increasing levels of OM in previous crop. Maximum content of 13.68 ppm was registered in OM 10 ¾ NPK followed by 13.57 ppm in OM 15 ½ NPK during Puncha. In Virippu OM 20 ½ NPK recorded a high of 13.56 ppm. But all other treatments were statistically on par. There was no appreciable difference in Zn content of soil between different treatments at the end of Puncha. In Virippu crop, the lower levels had significantly lower content of Zn. In both seasons highest content of 1.09 and 1.88 ppm was recorded in Control I. The Cu content increased at Puncha and then decreased at the end of Virippu crop. Maximum of 4.18 ppm was recorded in OM 20 ½ NPK in Puncha and 3.16 ppm in OM 10 ½ NPK at end of Virippu. The Cu content in the meal treated plots was higher to control.

4.6. On farm trial

On farm observational trials were conducted in the Muriyad kole lands of Irinjalakuda block in Thrissur district during Puncha season of 1999 on variety Jyothi

Table 4.51. Grain and straw yield (t/ha) under on farm trial in Muriyad Kole lands

Levels	Locations	Grain yield (t/ha)	Straw yield (t/ha)
OM 1.25 t/ha	1	5.50	5.60
	2	5.25	5.80
	3	5.50	5.90
	4	6.00	5.95
	5	5.50	5.75
	Mean	5.55	5.80
OM 2.5 t/ha	1	6.25	6.40
	2	6.00	6.25
	3	5.80	6.10
	4	6.00	6.15
	5	6.10	6.30
	Mean	6.03	6.24
Control	1	5.50	6.00
	2	5.75	6.00
	3	5.50	5.75
	4	5.00	5.50
	5	5.50	6.00
	Mean	5.45	5.85

using the same organic meal selected in field study as described under item 3.4.2.4. The grain and straw yield obtained is presented in Table 4.51.

The grain yield in plots supplied with 1.25 t OM ranged from 5.25 to 6.00 tonnes. The corresponding values for straw was 5.60 to 5.95 tonnes. The mean grain and straw yield were 5.55 and 5.80 t respectively. Similarly in plots supplied with higher level of 2.5 t the grain and straw yield varied from 5.80 to 6.25 tonnes and from 6.15 to 6.40 tonnes respectively. The mean grain and straw yield at 2.5 t OM was 6.03 and 6.24 respectively. In the plots with recommended practice of crop nutrition (control) the mean grain and straw yield were 5.45 and 5.85 t respectively.

Discussion

Chapter 5

DISCUSSION

The results of the various experiments on the properties of the study material and the formulation and evaluation of organic meals from KCPL effluent slurry described under chapter 4 are discussed in this chapter.

5.1. Basic properties of KCPL effluent sludge

The physico-chemical properties of KCPL effluent sludge was studied in detail and the results on the basic properties described under section 4.1 in tables 4.1 to 4.4 and appendices 7a to 7p are discussed below. The KCPL sludge has got a light to deep grey colour with an offensive, irritating odour. This is understandable since the sludge, a bone based organic material is usually left open and thereby subjected to various stages of uncontrolled putrefaction processes.

As revealed from Table 4.1 the consistency of the sludge is more or less semi-solid with plasticity level varying around non-plastic to slightly plastic. The consistency is a composite expression of those cohesive and adhesive forces characteristic to the fineness of the particles as well as the relative content of moisture at a given point of time (Brady, 1988). The semi-solid stature of the sludge is explainable as the entire samples under study showed an almost uniform particle size distribution, with dominance of fine particles in the range of 0.002-0.02 mm (59.92%) and practically fewer particles above 0.02 mm (9.88%). This showed that the sludge is in a highly pulverised form. Relatively good amount of ultra fine particles of below 0.002 mm (30.19%) further adds to this property. This fineness together with moisture content in the range of 50-60 percent explains well for the semi-solid state of the sludge available in the form of cobbled flakes a characterization of the platy nature, predominantly along the horizontal axis (Hillel, 1982; Brady, 1988).

The material was neutral in reaction with a pH around 6.75 (Table 4.2). This is suggestive of the fact that the neutralization treatment given to the sludge prior to its disposal is satisfactory and as per the stipulations prescribed (Gopinathan, 1996). The near neutrality of the study material can be taken as a criterion for considering it as safe material for soil enrichment.

Being a bone based material and further calcium treated as per the processes involved for production of the end product, gelatin (Appendix 1) the high contents of Ca and P are expected and understandable as the inherent content of these elements in raw bone itself is around 31 per cent and 22 per cent respectively (Gaur *et al.*, 1971). These components therefore, provides the study material the status of a good organic source of calcium and phosphorus. Appreciably good content of nitrogen (1.86%), which is even higher to that of good quality farmyard manure or compost (0.5%) further adds to the acceptability of the study material as an excellent organic nutrient source. The almost uniform contents of all major and minor nutrients throughout the study period as well as at different sampling interval within each month as provided in appendixes 7a to 7p are expressions that the source material and the treatment processes tends to be generally homogenous. As a result the byproduct, the study material also inherit uniform properties, a very desirable character for a material to be recognized as a known nutrient source.

Industrial byproducts are often associated with undesirable traits and properties (Eghball *et al.*, 1997). The major one of this nature being the content of heavy metals. The status of KCPL sludge in this aspect is also important to consider as a soil amendment as it is basically an industrial byproduct. As evident from Table 4.4 the contents of heavy metals under investigation are far below or near to the permissible level and hence a chemically safe material.

The neutralizing value as revealed from Table 4.2 is around 57. This property being proportional to the potential base ion release pattern of the source material (Brady, 1988) the high content of calcium of the sludge comes as a comfortable point for explaining this character. It can be concluded that the KCPL sludge is a chemically safe, nutrient rich uniform organic source of material for fertilizing the soil. Because of its high calcium content and neutralizing value, it can also be a good soil conditioner

5.2. Incubation Study

The results of the incubation study with sludge and mussorie rock phosphate (MRP) as target P sources provided under section 4.1.3. in Tables 4.5 to 4.12 are discussed below.

As seen from Table 4.5 and Fig. $\overset{3}{4}$ the pH in general increased to a peak value (7.1) on 15th day of incubation and later on decreased and in general stabilized towards the fag end of incubation to around 6.5. Both of the P sources always had higher value over control.

Soil reaction is an outstanding default characteristic of soil and is mainly influenced by the inherent soil colloidal properties and pH dependent soil solution factors. The changes in pH observed were more prominent in treated soils than in the control. This is indicative that both the sources of P namely KCPL sludge and MRP were

Fig3 Incubation study - change in pH at different stages

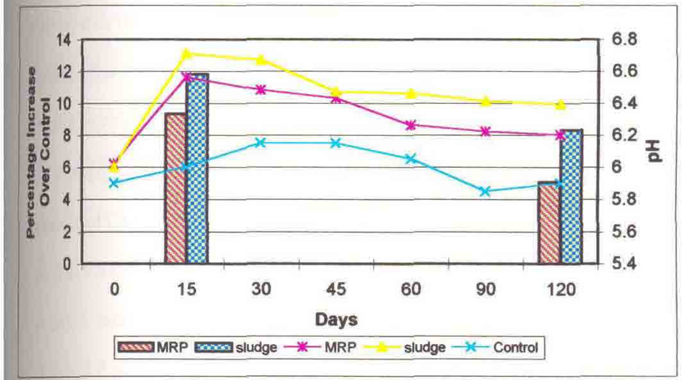
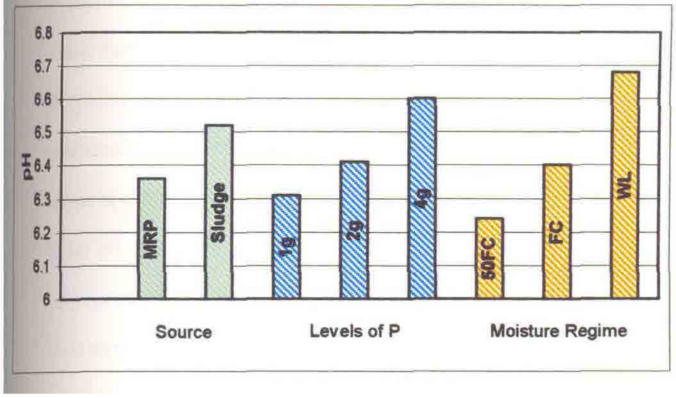


Fig4 Incubation Study - combined influence of source, levels and moisture regimes on pH



able to add significantly to the pH dependent soil solution factors as the permanent soil factors, since the electrostatic forces resulting from isomorphic substitution within the clay crystals (Brady, 1988) were same to all the treatments as same soil medium was used for the incubation. With both of the P sources pH showed an increase over the control signifying the fact that pH dependent soil factors were prominent in deciding the pH change. It can be recollected that both the KCPL sludge and MRP contain good amount of Ca and Mg (Table 4.2) and Appendix 3. It is established that metallic cations such as Ca and Mg have more direct impact on the hydroxyl ion concentration of the soil solution exerting corresponding increase in soil pH. The observed differences with different P sources over the control can therefore, be explained.

Several other mechanisms also are involved in pH change associated with flooded soil situation. As observed by Islam (1993) the largest increase in pH of acid soils occurs during the first two weeks of flooding. The H^+ ions may participate in various redox systems thereby causing lesser concentration of these ions in soil solution. Moreover the development of reduction condition on submergence causes anaerobic decomposition of organic matter, which releases OH^- ions consuming H^+ ions and hence increase the soil pH (Ponnamperuma, 1965). Similarly the accumulated ammonia released by anaerobic mineralisation of organic matter and smaller amounts of ammonia resulting from the release of entrapped ammonium ions from the clay minerals may also help to maintain a higher pH during incubation. The pH increase may also be due to the ion exchange between organic acids and hydroxyl groups of Al or Fe hydroxides (Hue, 1992). All these aspects are helpful to explain the observed pH hike in the flooded situation charged with respective sources of P as that of the present study.

The decrease in pH after the initial peak and subsequent stabilisation can be attributed to the classical trend of submerged soil system (Ponnamperuma, 1972). Also in a soil system of moderate to weak acid as in the present study the adsorbed H^+ ions makes its contribution in the soil solution over time. Some of the H^+ ions, which have been held tenaciously through covalent bonding by organic complex particles and clay minerals will also get released to the soil solution. Similarly production of weak acids like carbonic acid and traces of inorganic acid through microbial action may also contribute for the observed pH reduction in soil condition (Jenny, 1968). The observed trend of pH reduction and consequent stabilisation around 6.5 can also be emphasised through comparable observations made by Singh *et al.*, 1981 in a similar study with compost. Ponnamperuma (1972) also reported that soils high in organic matter attained stabilized pH value of 6.5 within a few weeks of submergence.

As observed in Fig.4 and Table 4.6, judged through the combined influence of all the variables, KCPL sludge is found to be slightly superior in the stabilised pH value around the comfortable level of 6.5. Being a pre-treated, highly pulverised organic P source rich in calcium this source would have provided all the favourable environment factors for the observed stabilisation trend in soil reaction. The pH is also getting more pronounced towards the comfortable level with increase in levels of P and moisture. With the highest P level (4gP) and moisture level (WL) stabilised pH value of 6.7, further add strength to the characteristic trend of soil reaction under submergence with organic additives.

5.2.1. Nutrient release

Mineralisation and nutrient release pattern of major nutrients N, P and Ca in KCPL sludge in comparison with MRP are provided in Tables 4.7 to 4.12 and illustrated in figures 5 to 10 Under improved conditions of soil reaction as described previously the stimulatory effect of micro-organisms and micro site environment for mineralisation of organic and inorganic forms of nutrients attain their peak forms which are properly reflected in the illustrations.

5.2.1.1. Nitrogen

The highest rate of release of N (213.7 ppm) was observed at 45th day of incubation from KCPL sludge at 4 g P level at field capacity closely followed by the same source at waterlogged condition (209.7 ppm). Thereafter it gradually declined and the level and trend of nitrogen availability was the same as that of other source (MRP) and control. More details are furnished in Tables 4.7 and 4.8.

It is established that nitrogen release from any source is at larger quantities and faster rate in anaerobic condition than in aerobic reactions. It is more so in case of organic source. The process of mineralisation of organic matter to release fixed or immobilised nitrogen is largely controlled by the availability of oxygen. However, under the anaerobic conditions of submergence availability of oxygen can be critical, nitrogen mineralisation can only proceed at a slower rate than in aerobic soil (Alexander, 1975). Anaerobes in the submerged soil even though are less efficient and derive only much less energy for growth and activities from a given amount of organic matter mineralised, release more N into available pool since the rate of mineralisation of N under such condition is comparatively very low (Abichandani and Patnaik, 1958; Broadbent and Nakashima, 1970).

Fig.5 Incubation Study - Changes in available N at different stages

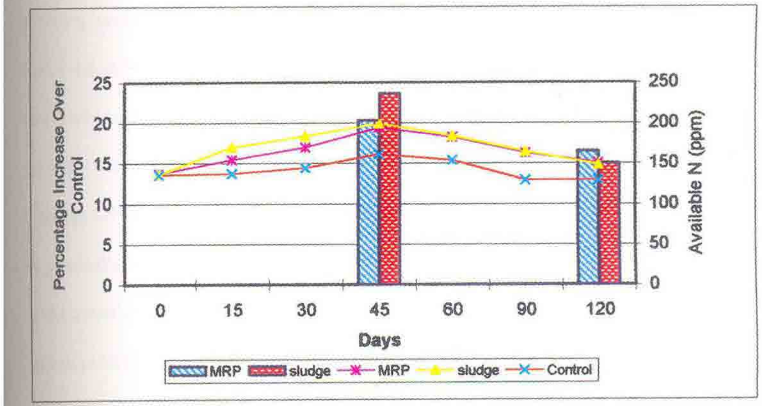
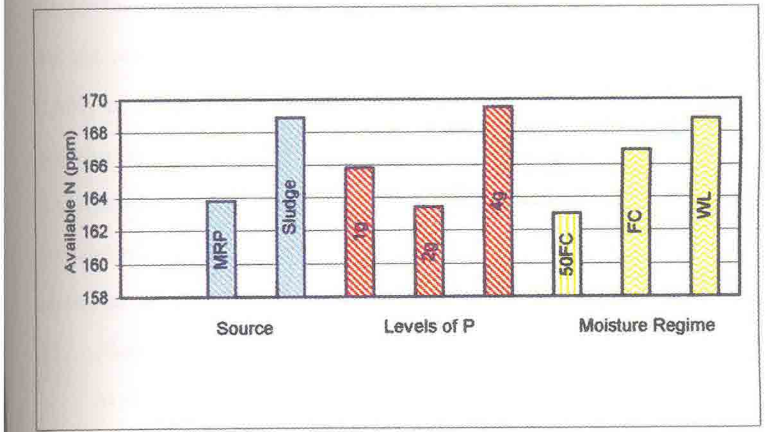


Fig.6.Incubation Study-Combined influence of source, levels and moisture regimes on available N



Together with this high available N pool, the capability of KCPL sludge in releasing N over the other source MRP, can be viewed as a peculiarity of KCPL sludge in providing favourable C/N ratio as revealed from Table 4.2. KCPL sludge is an organic P source rich in N (1.86%) and with a narrow C/N ratio of 18.00. The immobilisation of microbially released N from an organic source is predominantly determined by C/N ratio, the wider the ratio greater will be the net immobilisation and vice versa (IRRI, 1964). Since the C/N ratio of KCPL sludge is even lower than the ideal value of 20:1 there will be practically no locking up of nitrogen and whatever N mineralised will be contributed to the available pool and hence the observed superiority in N release by the sludge is understandable.

It is also observed that addition of P increased the available N pool. Though the exact mechanism for increased rate of N mineralisation due to P addition was not clear the increased biological activity geared up by this facilitating nutrient is widely considered as a synergistic factor for N mineralisation (IRRI, 1964; Tisdale *et al.*, 1993). The high content of P (8.44%) in combination with reasonably good amount of N (1.86%) of KCPL sludge comes as a complimentary combination for lesser immobilisation. Since mineralisation is a microbially activated process it is also logical that it should proceed at faster pace under conditions of adequate moisture as observed in field capacity and water logged condition of study. Hence the observed increase in N release with increase in P levels and moisture is explainable.

5.2.1.2. Phosphorus

As illustrated in Fig.7 and reflected through Table 4.9 and 4.10 under section 4.1.3.3, the pronounced trend is peak release of P at 30th day of incubation and detectably high availability throughout the incubation period with the KCPL sludge.

P availability is affected by various reactions that the element undergoes in soils. It is to a great extent determined by the mineralisation of organic P and solubilisation of inorganic phosphates brought about by the biological and chemical process mediated and controlled predominantly by soil reaction or pH. The peak content of P was observed during the 4th week of incubation and after attaining maximum value it tended to decrease. But the values were still higher than the initial concentration. In the waterlogged situation the higher available P in the early stages of incubation might be due to enhanced chemical and biological reactions consequent to flooding. Ponnamperuma (1965) demonstrated that in soil available P increased during the first 3-4 weeks of flooding and then decreased with time of submergence.

In the present study at 30th day the pH assumes a range of 6.4-6.8, a most ideal level for release of P into the available pool (Table 4.6). It is established that the immediate result of addition of any source of P to soil is its net insolubility. The basic iron and aluminium phosphates [$Al(OH)_2H_2PO_4$, $Fe(OH)_2H_2PO_4$], the hydrous oxides formed under acid range has a minimum solubility around pH 4-5. Towards higher pH some of the P thus fixed is released and precipitation of insoluble calcium salts begins and at pH above 7 even more insoluble compounds such as apatite are formed. Maximum availability of P is obtained where the pH range is maintained around 6-7. The observed trend of P peak and its continued increased availability despite the sources and the absence of any added P as in control clearly emphasize and go well with the concept of ideal pH range in controlling phosphorus solubility (Brady 1988).

With time, changes take place in reaction products of soluble phosphates mainly in the reduction of their surface area, increase in crystal size and intrusion of soluble components into the oxide particles. These insolubility factors, which are characteristics of ageing get stabilized over time and reflect correspondingly to the labile P pool.

Between sources, the KCPL sludge released more available P compared to MRP (Fig.9). At the peak period of 30 days the per cent increase in available P from sludge was 61% over MRP and 71.8% over control (Fig.7). Superiority of this sludge in providing soluble fractions to the P pool was also maintained throughout the period of incubation. Addition of sludge might have initiated the decomposition process and the organic acids produced helped in the conversion of insoluble P to more soluble forms by interacting with P binding cations and clay minerals. Application of organic phosphate source significantly reduces the fixation of added as well as native P making P more available to plants (Gosh *et al.*, 1981). Organic form has got a profound influence in mobilising the P in the available pool from the insoluble form of P. Singh and Sarkar (1986) reported increased availability of P due to farm yard manure application and explained it to be the deactivation of sesquioxides through chelation and action of blocking agents present in manure in blocking the fixation spots on clay. Increased trend of phosphorus availability from KCPL sludge can therefore be attributed to its organic origin and peculiarities as evident from Table 4.2 and Appendix 1.The sludge is a rich organic source containing N (1.86 %), P (8.44 %) and organic carbon (33.49 %).

For mineralisation to occur, soil organic amendments must contain at least 0.2% total P and a C: N: P ratio of 20:1:100 otherwise net immobilisation may occur (Tisdale *et al.*, 1993). Here the target material sludge has a CNP ratio of 33:1.8:8 (Table 4.2), a stage, which is more ideal for net mobilisation further substantiate this point.

Comparatively low availability of P from MRP might be due to strong apatite bond and greater crystalinity characteristic to calcium containing P sources. The lesser

Fig.7. Incubation Study - Changes in available P at different stages

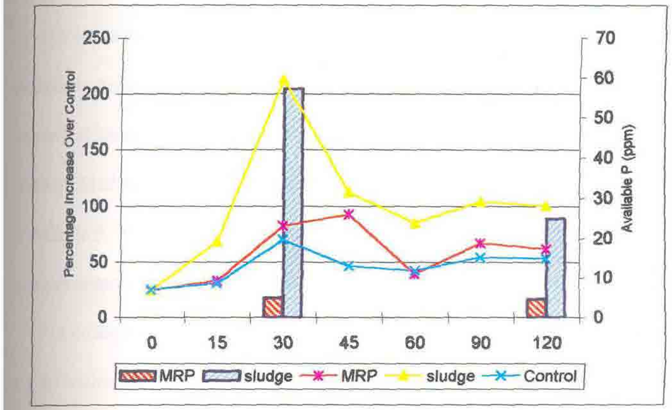
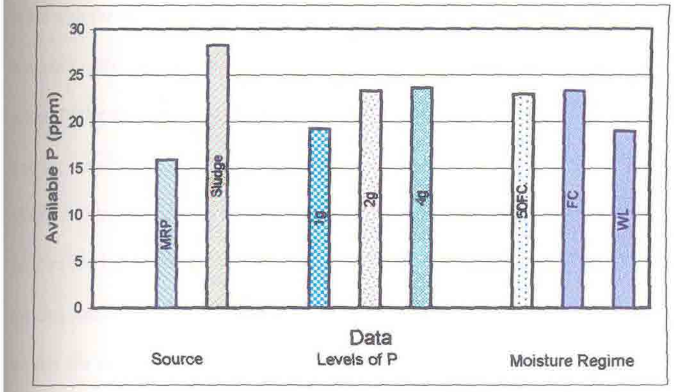


Fig.8 Incubation Study-Combined influence of source, levels and moisture regimes on available P



available P initially may also be due to water insoluble nature. As incubation proceeded the solubility increased and hence it equalled sludge at later stages.

Even in the absence of added P the content of available P in this soil increased on incubation. This may be due to increased content of saloid P and enhanced solubility of iron and aluminium phosphates brought about by reduction reactions as a result of flooding. In addition mineralisation of organic P would also have contributed to the pool of available P. The relatively high content of available P in laterite soil was attributed to its higher content of total P and enhanced rate of reduction reactions occurring in the soil.

Coming to interaction when the levels of P application was increased from 2 g to 4 g the additional increase in available P recovered was less. That is because only a constant level of P out of the added P can be retained in the available form and further increase in rate of application results in retention of P in the unavailable pool in soil. This is in agreement with the study of Mathews and Jose (1984).

In the present study, maximum release of P occurred at field capacity. But at the peak release period both field capacity and water logging was statistically on par. This is in line with the study of Singh and Ram (1976). With advance in time the release of P was more under aerobic than under submerged condition. This is due to time lag i.e. ultimately the amount present in aerobic soil exceeded that under submergence and the time lag required to attain this stage was more for less soluble phosphatic materials. Moisture increases the availability of both native and applied P, but efficiency of moisture level vary with the type of soils and increase in soil water content would induce reducing condition in soil and would decrease the values of redox potential. This would increase the available P due to release of P from insoluble form of ferric phosphate as well as hydrolysis of insoluble aluminium phosphate. In contrast to this Iyamuremye and

Dick (1996) mentioned that the decrease in water soluble P with increase in levels of moisture might be attributed to the suboxidation condition which caused iron phosphate precipitation rendering P unavailable. Paul and Delong (1949) suggested that prolonged flooding reduced the amount of easily soluble P especially in presence of an easily decomposable organic matter. The release of P was more at 50% field capacity than under submerged condition in fertilizer treated soils (Roy and Sinha, 1975).

It must also be recalled that the phosphorus fixing power of unlimed soils may reach up to approximately 50 tonnes of super phosphate containing 20% P_2O_5 per acre ferro-slice. In certain plain soils and soils of lateritic origin the phosphorus fixing power can even go up to 125 tonnes (Bear and Toth, 1942). The observed insensitivity in measurable available P at higher levels of applied P - 4 gm P equivalent to 0.64 ton/acre is therefore understandable.

5.2.1.3. *Exchangeable Calcium*

In the incubated soil the exchangeable calcium values increased gradually and reached its peak at 60th day after which it tended to decrease at 90 days and another peak was observed again at 120 days (Fig. 9).

In the case of sludge maximum release was observed at 60 days in sludge 4g 50 FC (1274 ppm) followed by sludge 4g at field capacity (1246 ppm). But for MRP the maximum release was observed in 4g 50 FC at 120 days (1503 ppm) (Table 4.11). Though initially both were on par, from 60th day onwards the release of calcium was more for MRP treated soils and hence the mean release of Ca from MRP was 884.73 and that of sludge was 871.62 ppm (Table 4.12). Both the sources were significantly superior to control.

Fig. 9. Incubation Study - Changes in available Ca at different stages

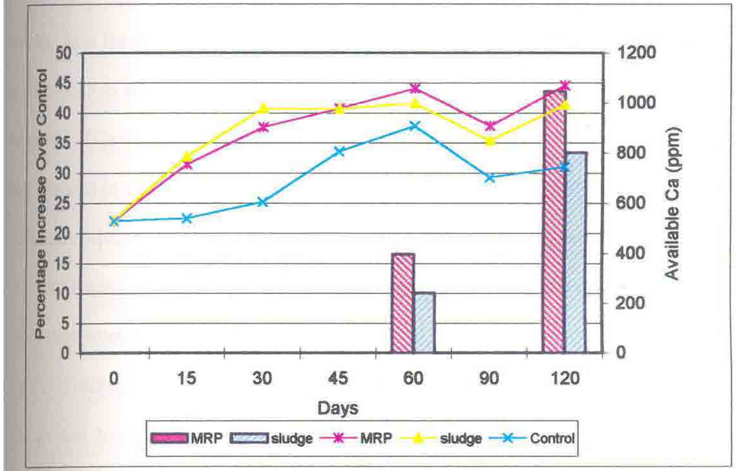
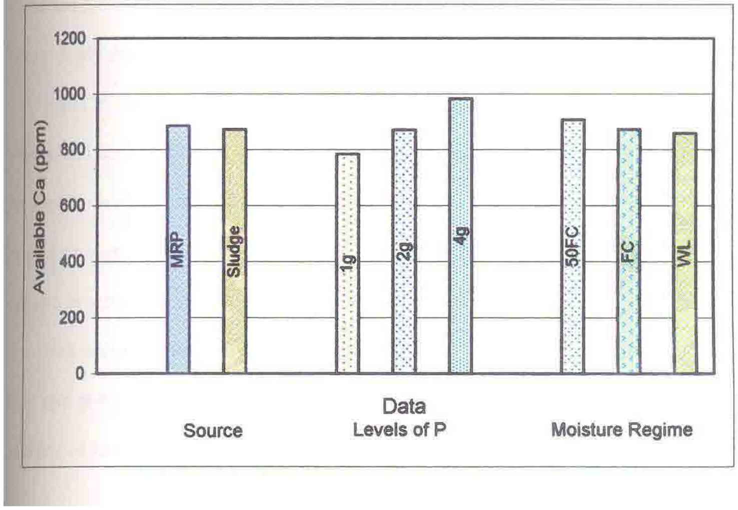


Fig. 10 Incubation Study- Combined influence of source, levels and moisture regimes on available Ca



The peak values of exchangeable calcium availability may be attributed to the increased solubility of Ca compounds in the soil due to combined effect of CO_2 plus soil reaction. As in the case of other major nutrients the availability of calcium is influenced by pH through its effect on solubility of their nutrient compounds. Differential pattern in the content of Ca at different periods may be due to the difference in the total content of these elements in soil solution as well as to the changes in soil reaction and specific conductance which can alter the ionic strength and induce ionic displacement.

MRP was superior to KCPL sludge in releasing greater quantities of calcium. This is due to high amount of calcium present in the material (Table 4.2). According to Tisdale *et al.* (1993) phosphate rocks contain about 35 percent calcium and when applied at high rates to acid tropical soils substantial amount of calcium is released. Banik and Mukhopadhyay (1985) also observed a gradual increase in the amount of exchangeable calcium with time of incubation in rock phosphate treated soils indicating solubilisation of added P source. The peak observed at 120 days may be due to slow dissolution of material and prolonged contact with soil. However release was at faster pace in KCPL sludge probably due to its organic nature.

High Ca^{2+} saturation indicates a favourable pH for microbial activity. According to Mengel and Kirkby (1978) factors which influence the rate of mineralisation of N can also affect the levels of nitrogen and calcium ions. In the present study the maximum release of nitrogen occurred around 45 and 60 days period (Table 4.7). This interaction might also have resulted in increase in exchangeable Ca in the incubated soil.

With increase in level of P also calcium release increased with a mean release of 982.67 ppm at 4g P level (Fig.$\overset{10}{11}$). Actually soil reaction plays an important role in the availability of both Ca and P. With increase in pH above 7, phosphorus is fixed as calcium phosphate and is insoluble. But here in the study the pH of the incubated soil did not rise above 7 and it stabilized around 6.5, which is ideal for P release. Hence there was no precipitation of P as insoluble calcium phosphate. This might also have contributed to exchangeable calcium in the exchange complex.

Moisture regimes also exerted influence on the release of available calcium in the soil. At 45th and 60th day the field capacity level was superior while at later stages more release occurred at 50 percent field capacity. Waterlogging was inferior compared to other two regimes. Kabeerthuma and Patnaik (1982) stated that the availability of calcium increases upon flooding the soil on account of their displacement by action of water through hydration and hydrolysis and also due to their release from exchange sites. But Kawaguchi and Kawachi (1969) opined that increased calcium eluviation in flooded soils of reduced condition is due to exchange of calcium ions by ferrous ion and this might be the reason for the corresponding decrease in exchangeable calcium under waterlogged condition.

Thus it can be concluded that KCPL sludge with pH around 6.5, N (1.86%), P (8.44%), Ca (20.34%) and organic carbon (33.49%) is a good nutrient source which is significantly superior to mussoriephos and could be effectively utilized both under aerobic and waterlogged condition. With respect to pattern of release, the peak release of all nutrients occurred within the 60 days period ie. N at 45 days, P at 30 days and Ca at 60 days. Hence it could be effectively utilized in crop production as an organic P source.

5.3. Standardisation of formulation techniques of organic meals

5.3.1. Organic meals from spent slurry

Standardisation of different techniques for formulating organic meals from spent slurry and physico-chemical properties of promising organic meals are provided under section 4.2.1.and in Tables 4.13 to 4.16. As revealed from Table 4.13 the odour, appearance and consistency between organic meals and filtered spent slurry did not but for the colour vary much. In the case of organic meal the colour was light brown to black while that for spent slurry it was white to light grey. These similarities as well as slight difference in colour can be explained since the basic substrate for the preparation of organic meal was spent slurry, the by product of KCPL sludge after biomethanation. Through the processes already described (Gopinathan, 1996) it is established that KCPL sludge can be converted to an odourless and innocuous material with nutrient enrichment as compared to base substrate. The small variation in colour to the organic meal prepared from spent slurry can be attributed to the inherent colour characteristics and different shades of the respective additives added for imparting an appealing colour so as to make it an organically enriched material.

Among the different techniques tried to prepare organic meals namely drying, drying and powdering and drying and pelletisation there did not appear much differences in odour and colour, as it was basically a physical process for altering the appearance and fineness for imparting ease in handling. Therefore, by employing the processes of powdering and pelletisation the uneven crumbs like dried spent slurry of irregular shape was converted to fine to small particles of uniform beads. Consequently the consistency of the material was also changed from non-sticky, rigid, difficult to handle nature to something like perfected bead like form, which is easy to handle. All these processes were basically to change the physical properties for imparting an appealing colour and consistency.

Among the different organic meals thus prepared the meal No.17 (spent slurry + 5 per cent neem cake + 10 per cent coir pith + 5 per cent mussorie phosphate) and meal

No.1 (spent slurry + 5 per cent neem cake + 5 per cent mussorie phosphate) were almost comparable to each other with respect to content of all major nutrients but for a small difference in the nitrogen content. All other combinations of organic meals had values, with regard to major nutrients in between those with these two best forms.

Comparing the above two formulations 10 per cent coir pith was the only addition and all other components were same to both of the meals. Though this component could alter some of the nutrient content by and large this form of meal was comparable to that of meals without coir pith. This situation is understandable especially when significant portion of all the organic meals was always spent slurry and not the additives and thereby reflecting the major properties of the composted materials similar to that of the substrate. Therefore, it can be concluded that organic meal formulation No.1 namely spent slurry + 5 per cent neem cake + 5 per cent MRP can be the better option viewed in terms of physical appearance, handling capability and contents of major nutrients.

As evident from Table 4.15 though there was significant variation between meals with regard to minor nutrients namely Fe, Mn, Zn and Cu the organic meal formulation No.1 (SS+5NC+5MRP) also had comparable values with other forms like meal No.17 (SS+5NC+10CP+5MRP). The content and variations of micronutrients revealed through different forms of organic meal can be attributed to the respective variations in the quantities of organic additives. The organic additives are not as uniform as that of present base material spent slurry and they are usually complex materials with combinations of micronutrients in varying proportions. The slight variability observed in micronutrients within different grades of organic meal is hence explainable.

Viewed from the desirability level of pH, content of organic carbon and neutralizing value the organic meal formulation SS+5NC+5MRP proved to be a safer option. The pH of this meal was 7.2, organic carbon 21.8%, C/N ratio 12.04 and neutralizing value 68.7 (Table 4.16). These characters are at comfortable level to treat it as an organic meal and go well with the contents and values of base material, the spent slurry.

Though the organic meals described above had desirable characters and appreciable levels of major and minor nutrients to consider them as good organic meals, basically all of them were prepared from an innocuous base material the spent slurry after biomethanation process. To treat any process or formulation technique as a viable one, it must also be economically profitable as well as technologically simple especially when the end product is an organic manure which has to be used in large quantities for enriching the soil. It must be recalled that spent slurry is the by product of anaerobic fermentation of KCPL sludge subjected to biomethanation (Appendix 4) for making the sludge material into an innocuous form (Gopinathan, 1996).

The processes involved in biomethanation like initial charging with suitable inoculum and starter dose, maintaining a substrate induced environment favourable for entire period of hydraulic retention time, siphoning and safe delivery system for spent slurry disposal, filtration and further processing of spent slurry etc makes this option a technologically complicated one. Similarly the special equipments and structures required for standardising the formulation techniques of KCPL sludge, like fermentation tank, drier, pellatisor etc. as illustrated in Plates 6a to 9b make the preparation of spent slurry and resultant organic meal a costly proposition too.

Considering these disadvantages and difficulties, the accidental finding while heaping of the KCPL sludge in open, different composting options were thoroughly investigated as described under section 3.2.4. The details of these results are discussed below.

5.3.2. Composting Techniques

The results of composting techniques tried with seven promising treatments (section 4.2.2.) both in open heap and pit method are provided in Tables 4.17 to 4.25. The open heaping was also combined with protective covering with gunny bag and polythene sheet. For maintaining clarity and sharpness of understanding of various processes involved in the standardisation techniques the best promising option namely open heaping alone is considered here. The influence of different techniques of composting in comparison with the promising treatment is illustrated in Fig. 11. to 14. Fig.11, 12 and 13 depicts overall influence of temperature, pH and microbial build up during the entire period of composting respectively for open, plastic and gunny covered heaps. Fig.14 is the respective characters in pit method.

It is distinct that all the open heaping techniques were always significant over the pit method. Sudden shooting up of temperature and subsequent coalescing effect closely followed by similar pattern of microbial build up along with the favourable pH seen with all the three cases of open heap clearly tell that composting was so fast and active as compared to pit system wherein, all the above characters were around stagnation.

The composting processes in the open heap technique have started suddenly and achieved peak stages at faster rate as observed in Fig. 11 to 13. It is interesting to note that in all the three composting techniques the performance curves did not show the characteristic inclined trend of the three distinct stages namely mesophilic, thermophilic and maturity stages (Gaur and Sadasivam, 1993; Thampan, 1993). Though definite cut off points between different stages is not so sharp and in as much as one blends into the next while describing the normal processes the trend of an almost low level of temperature and bacterial count in initial mesophilic stage as seen here is something specific and needs detailed explanation.

As composting is a biological process, the nature of substrate as well as environment for the microbes to get themselves flourished to the required level of impact is important. In all the biological decomposition process substrate itself is treated as an environmental factor because it is extrinsic to the microbial population and as such exercises influences on the extent and rate of microbial activity. Here the substrate is already in a most congenial form consequent to pulverisation and pre-acid treatment as discussed under section 5.1. This material therefore when charged with additives and starter dose of nitrogen suddenly favoured the flourishing of microbial count to around 300 x 10^5 CFU within two days of incubation. This was also reflected in the corresponding hike in temperature from 41°C to 70°C in two days. Similarly the maximum bacterial count and temperature (70°C) in the entire process was observed on the 7th day. In short the peak microbial population and resultant temperature hike was observed within one week of incubation and thereby functionally curbing the mesophilic stage. This peculiarity of bacterial decomposition can only be attributed to the nature of the substrate as it is established that capacity of microbes to assimilate a given substrate depend on its ability to synthesize the enzyme involved in breaking down complex compounds into intermediate simpler metabolites for synthesizing new bacterial cellular materials (Gaur and Sadasivam, 1993).

Fig.11. Variations in maturity parameters during composting - Open Heap method

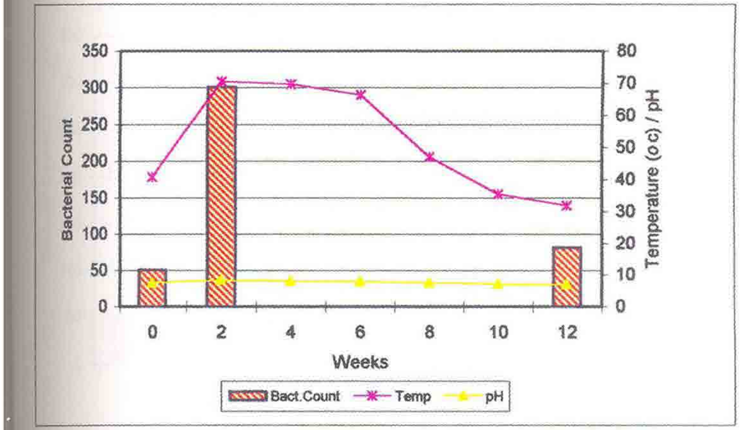


Fig.12. Variations in maturity parameters during composting - Plastic covered heap

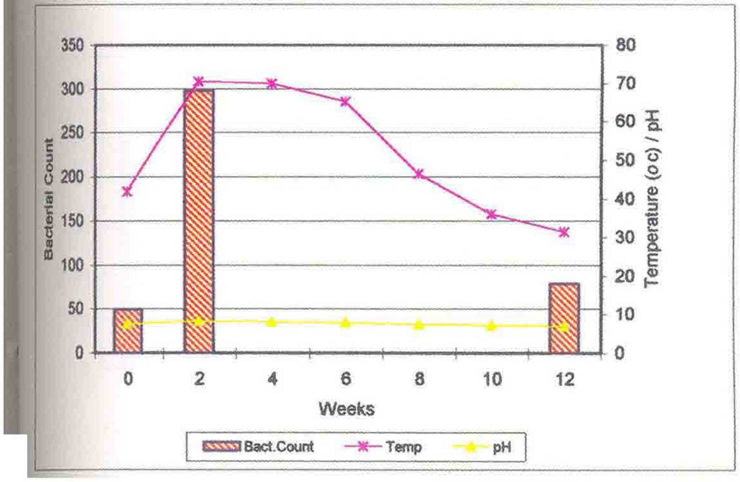


Fig.13. Variations in maturity parameters during composting - *Gunny covered heap*

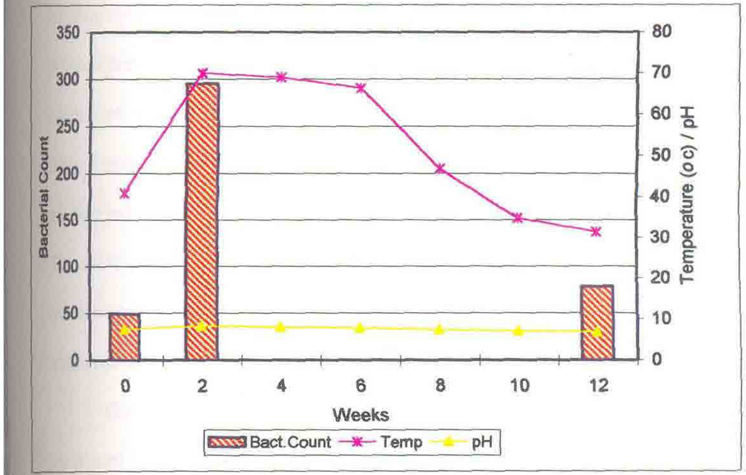
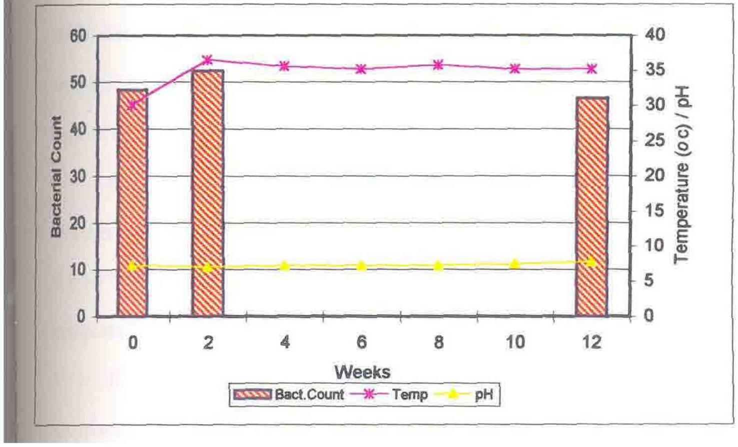


Fig.14 Variations in maturity parameters during composting - Pit method



This unusual trend is also supported by the observed pH fluctuation. Usually in normal mesophilic stage of aerobic composting there is a decrease in pH consequent to building up of organic acids, an intermediary product of biological degradation of starch, proteins and fats (Biddlestone and Grey, 1985) and then a corresponding increase in pH consequent to assimilation of these products and their further conversion to simplified units. Hence there is an intrinsic relationship between temperature and bacterial build up as observed above in the process of biodegradation of complex molecule to simpler ones. The same pattern can also be extended to pH build up, a sensitive environmental character to determine microbial population. The observed variation in pH can also be attributed to the substrate peculiarities.

The KCPL sludge being a highly pulverised and pre-treated substrate as mentioned under section 4.1 this explanation holds good to understand the peculiar changes in the established trend of composting process. Consequent to assumption of thermophilic stage, the maximum level by which a substrate can support the bacterial build up the trend observed in all the open heap techniques resemble to that of established stable maturity phase. From the highest level of bacterial build up in open heap technique it came down to a stabilised value of around 80 x 10^5CFU within 12 weeks period (Table 4.19).

Similarly the temperature also coalesced and attained stable value of around 31°C towards twelfth week (Table 4.17). The pH also showed stabilised trend of around 6.7-6.9 by this time (Table 4.18). Viewed from both of these characters the maturity of composts reached in all the three open heap techniques in twelve weeks after incubation.

In contrast to the processes observed in open heap techniques, the pit method of composting was totally ineffective. Here neither the temperature and bacterial build up nor pH assumed a detectably superior position as compared to open heap technique and all of them were almost static throughout the entire period of composting. The temperature was around 37°C, microbial build up 76.4 x 10^5 CFU and pH 7.0. This shows that pits were not at all active and there was no detectable level of composting processes. This was also evident by the persisting objectionable odour of substrate material throughout the composting period and even after the maturity period in open heaps.

This observed inactivity in pit system could also be well attributed to the inherent peculiarity of substrate characterised by high moisture content (50%) and superfine pattern of particles consequent to pretreating. The fineness of particles coupled with high moisture content imparts compaction when they are charged in pits. This compaction results in corresponding anaerobic environment in the substrate atmosphere since water in excess displaces air. Composting is usually an aerobic process controlled, augmented and supported by variety of microorganisms to oxidize biological products into simple forms. Consequent to compaction and anaerobic condition thus existed in the pit system, aerobic processes inevitable for odourless composting, got stopped.

The observed unpleasant odour in the pit system can be attributed to this reduced stage resulting in formation of mercaptans and short chain fatty acids ranging from acetic to caproic characterised with objectionable odours (Biddlestone and Grey, 1985). Therefore, viewed from the public health and crop safety aspects resulting out of high temperature build up and thermal death point of plants and animal pathogens, aerobic composting can be judged as quick, cost effective and best method of KCPL sludge treatment and organic meal formation.

The organic carbon content decreased from around 32 per cent to around 22 per cent in the open heap technique while there was no decrease in the pit system. The organic carbon was around 32 per cent itself. Hence from the carbon content itself it is understandable that decomposition occurred rapidly in open heap technique while it was stagnant in the pit system.

C/N ratio is another maturity parameter that determines the worth of compost as manure. C/N ratio is the most conventional index, which reflects organic matter decomposition and stabilisation during composting. As composting proceeds, the micro flora use the substrate carbon as energy source and carbonaceous materials are converted into microbial biomass, CO_2, water and humus. N is used for cell building. It is the major nutrient required by microorganisms in the assimilation of carbon compounds in the organic wastes. Decomposition involves the reduction of relative proportion of elements to a point where available carbon has been totally consumed and bacterial activity ceases. In the study the C/N ratio decreased from initial value of 18.4 in base material to 15.41 after 30 days. The ratio continued to decrease albeit less sharply to 13.24 after 60 days and stabilised around 12.51 after 90 days in open heap composting (Table 4.20). Hence the reduction is due to loss of carbon and increase in concentration of N during composting since the N remains in the system while C is lost as CO_2. According to Jimenez and Garcia (1992) C/N ratio of 10-12 is usually considered to be an indicator of stable and decomposed organic matter. The meal No.1 (S+5NC+5MRP+1U) had a C/N ratio of 12.51 and it is around the above-mentioned range and this can be considered as another criteria for selecting S+5NC+5MRP+1U.

In contrast to open heap method the C/N ratio of organic meals in the pit method was around 18-20 (Table 4.25) and it was comparable to that of base material. There has been no change in the C/N ratio and this is another reason to establish that decomposition did not occur in the pit method.

In the matured compost obtained from open heap technique the moisture content was around 36 per cent in meal No.1 (Table 4.22). In meals with coir pith as additive the moisture content increased and it can be attributed to the inherent property of material added. Coir pith has the capacity to absorb large quantities of moisture since its water holding capacity is very high (Savithri and Khan, 1994). Composting reduced the moisture content to an ideal value of around 30-40 per cent.

In the pit system there was no reduction in moisture and it ranged around 50-57 per cent (Table 4.25). For materials with high moisture content in order to provide sufficient oxygen for decomposition, composting is done above ground level so that oxygen will be available from all the sides since it is exposed to air (Gowda, 1996). Hence the failure of the pit system to operate effectively with the highly pulverised substrate is explainable.

Comparing the overall nutrient content meal No.1 (S+5NC+5MRP+1U) was significantly superior with 1.79 % N, 9.05 % P, 0.28 % K, 16.96 % Ca, 0.32 % Mg and 0.36 % S. The Fe, Mn, Zn and Cu content were 883.5, 103.62, 113.33 and 7.71 ppm respectively. It is generally believed that composting of organic materials sharply decreases the C content and the soluble organic matter but increases the content of nutrients on dry weight basis. In this study the organic carbon and N content decreased while P, K and S increased. There was slight decrease in Ca and Mg content compared to the base material. This may not be due to composting but due to addition of additives in the formulation process, which may result in corresponding dilution with regard to these elements.

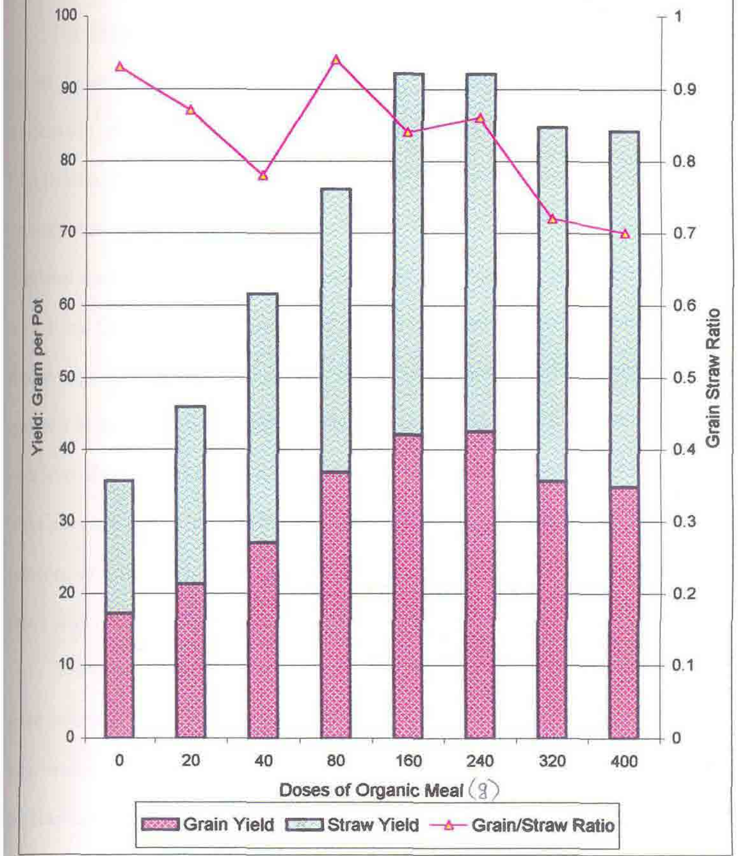
It can be concluded that, aerobic open heap composting is quick, cost effective and the best method of organic meal formation from the KCPL sludge. Judged from maturity parameters and final nutrient contents, the treatment, sludge + 5% neemcake+ 5% mussorie rock phosphate + 1% urea (S+5NC+5MRP+1U) under open heap composting can yield the best organic meal formulation.

5.4. Pot culture study

Based on the ease in formulation technique and favourable physico-chemical properties as described under section 4.2.2, the meal No.1 (sludge + 5 per cent neemcake + 5 per cent mussoriephos + 1 per cent urea) was adjudged superior to rest of the organic meals. But the value of any manurial source cannot be assessed based on nutrient status alone. Its suitability to a crop situation is also especially important. To gather indicative information on these aspects and also to know, being a new material, whether any deleterious effects the meal was subjected to an exploratory pot test as described under section 3.4.1. Seven doses ranging from mild, moderate, high and extra high levels (20 g to 400 g per pot) were tried and the results are discussed below.

As evident from Table 4.26 and 4.27 and Figure 15 organic meal application significantly increased the growth and yield attributes of rice var. Matta Triveni over control. Moreover, the growth and yield attributes also increased progressively with increasing levels of organic meal. It can be recalled that the plant height and tiller count progressively increased from 55.58 cm and 5.71 for the lowest level to 67.68 cm and 8.08 for the highest level. This could possibly be due to the increased availability of plant nutrients at higher levels of organic meals.

Fig.15 Pot culture study - Grain Yield, Straw Yield and Grain/Straw Ratio



With 80 g OM per pot, which is equivalent to 20 t/ha, the potted plants yielded the best. Growth parameters and the yield attributes were also high with this treatment. Both the higher as well as the lower levels to 80 g per pot were not found desirable when judged through the growth parameters and yield attributes.

The percentage increase in grain yield of the best treatment over the control, 20 g and 40 g per pot were 114, 72.7 and 36 per cent respectively. As yield is the manifestation of the complimentary functions of innate genetic constitution (Russell, 1963; Epstein, 1972) and desirable environmental characters, the differences observed in the study can definitely be attributed to the nutritional physiology dependent to the nutritional source, the organic meal. It may be recalled that the study material though rich in P and Ca is poor in the two essential elements N and K. Further their availability through organic meal may also be not as fast as compared to the inorganic sources especially in the absence of inorganic nutrient support. This might have brought about some level of insufficiency of these vital elements and consequent metabolic disturbances in the plant system. The manifestation of visible symptoms such as stunted growth, yellowing or purpling of leaves, lack of vigour (Plate 23a and 23b) coupled with low values of all the growth parameters are reflections of this.

The remarkable difference in the above characters as well as the vigour and lush green nature of the plants at higher levels of organic meal (Plate 24) reiterate that insufficiency stage of these nutrients were renounced and the plants were relieved of the possible nutritional strains described through the classical law of minimum concepts (Liebig, 1862) through higher doses of organic meal. However, this is not a simple linear relationship with successive increments of the target nutrients. As observed (Fig. 15) the treatment 80 g OM recorded the highest grain straw ratio of 0.94. At the highest level of

Plate 23a

Pot culture study – influence of lower levels of organic meal on rice

Plate 23b

Plate 24 Pot culture study – influence of higher levels of organic meal on rice

Plate 25 Pot culture study - growth in the absolute control treatment

320 and 400 g OM the grain straw ratio was 0.72 and 0.70 respectively. Increased levels of organic meal had increased the vegetative growth and hence plant height and also the tiller production (Table 4.26) without corresponding increase in terms of assimilate partitioning towards reproductive sink. This is reflective of the fact that yield depression can also occur even when the limiting nutrient crosses the optimum level.

As Mitscherlich (1947) observed, yield can be increased by each single growth factor even if it is not present in minimum as long as it is present in optimum. And once the optimum level is reached, rate of increase is proportional to the descent from the maximum yield obtainable under most ideal environment. This disproportionality in yield and other attributes with varying levels of organic meal also tells out the observed significance on the interaction of different levels of organic meal. As interaction is the response of unequal influence of two or more factors, the nutrient availability viz. a viz. the quantity of organic meal applied and the corresponding partitioning capability of the plant system to the harvestable assimilates observed with sub-optimal and over optimal levels of input addition are understandable.

In the uptake pattern of major and minor nutrients greater differences between treatments were observed in straw compared to grain. As uptake is a function of the dry matter produced as well as nutrient content in the unit mass of the dry matter, the increased straw yield is responsible for increased nutrient uptake. This effect was more pronounced at higher levels of organic meal. Therefore, the observed variations in total nutrient uptake (Fig.16 and 17) can be well explained as a function of the total dry matter, both straw and grain produced and the respective content of nutrients in them. It may also be noted that there was no environmental factor operating in the pot culture medium which may bring about derangement in the absorption and metabolism of nutrients as the plants were under controlled condition.

Fig. 16 Pot culture study-Uptake Pattern of Major Nutrients

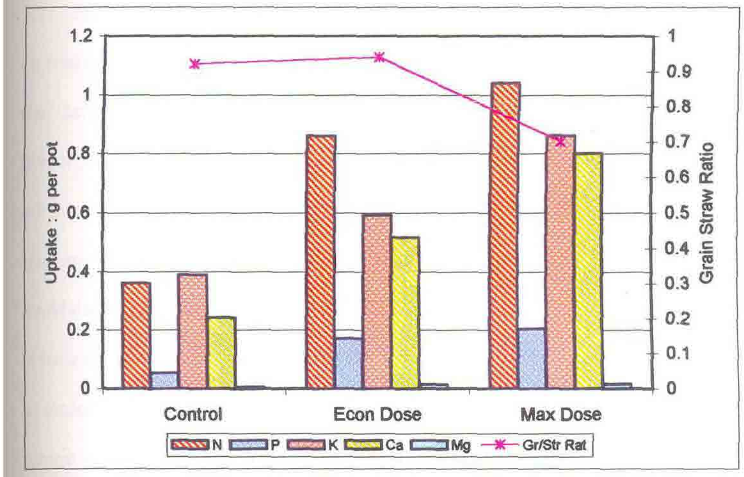
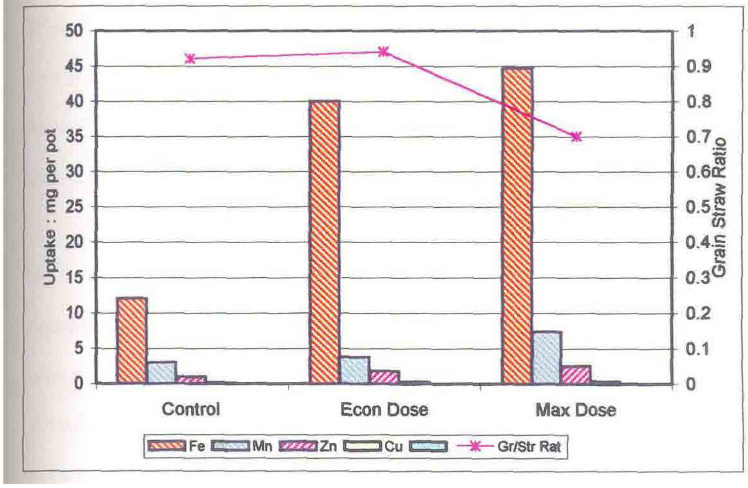


Fig.17 Pot culture study - Uptake Pattern of Minor Nutrients



From the pot culture study, it is clearly evident that the organic meal is suitable for crop and no detrimental effects could be noticed even at very high levels. It is also clear that lower doses will not be able to meet the requirement of the crop. Comfortable level of plant growth and yield was observed at 80 g OM per pot. Even at this level it will come to 20 t/ha an enormous level involving high operational costs for maintaining economic yield. Further, being a P rich material dumping of this much organic meal would also lead to other problems especially non-point source of environmental pollution in due course. This problem could be solved to a certain extent if organic meal is used as an concentrated organic P source in place of mussorie rock phosphate. The content of nutrients in sludge as well as the release pattern of N, P and Ca when compared to rock phosphate is comparatively more from sludge as described in section 5.2. and Table 4.2. Moreover the micro site enrichment by the addition of organic meal will definitely be different in the field where more synergistic and complex factors act in combination than those in the controlled pot culture situation. The interplay between nutrients and over 50 factors (Tisdale *et al.*, 1993) which affect the growth and yield of a crop do operate in union in the field situation.

Therefore, the organic meal in combination with other inorganic fertilizers can help reduce its bulk requirement, besides providing the balanced supply of all nutrients as required by the crop. The residual impact of this organic source also assumes significance under field situation and the subsequent discussion provides those feedback based on plot culture and farm trials with lesser doses of organic meal and other required nutrient support.

5.5. Field study

Being a new material of significant importance exhaustive field studies were undertaken to evaluate and establish the influences of organic meal in the real field situation. It included two seasons study to test the direct influence on paddy, subsequent two season experiment to evaluate residual effects, and finally an on farm trial in cultivator's fields. Needless to say that those efforts had generated a large amount of data, which form the major part of this dissertation. However, a deliberate attempt was made in this discussion part to avoid detailed mentioning of all the growth and yield observations but anchored to the major trends and considerations to enhance brevity and entirety of conclusions.

5.5.1. Direct effect of organic meal on crop

5.5.1.1. Climatic influence

Before going into the influence of test material on crop and soil in the field condition a mention about the climatological condition is required as it is the major uncontrollable factor contributing to the crop performance. As can be pursued from Appendices (6a) to (6c) and Figures (2a) to (2c) that the weather parameters during all the cropping seasons were around the normal trend indicating that the climate did not exert any special effect on the crop growth during the target period of study. The only notable effect worth mentioning on seasonal influence is the comparatively better performance of crop during Mundakan season (Table 4.36 and Fig. 18) and extended duration to bloom (Table 4.37) in Puncha season. The test cultivar chemeen took only 72 days to reach 50 per cent flowering in Mundakan while it was 102 days in Puncha. But even this seasonal influence can be attributed to the photosensitive nature of the locally preferred cultivar, characterised by photoperiodism and temperature sensitivity and not to the climatic peculiarities *per se*.

Yield process develops properly when maximum and minimum temperatures are near or below 34°C and 22°C. The above conditions were satisfied during Mundakan crop (Appendix 6a). Because of this favourable exposure of the cultivar to the optimum extent of photo-thermal requirement, the Mundakan crop had performed better over the Puncha season. In Puncha season, physiological factors controlled by photo-thermal criticalities might have induced reduction in cross sectional area of vascular bundles disturbing the movement of assimilates and absorbed nutrients resulting in corresponding reduction in yield. This again is a varietally induced yield barrier and not a strictly climatological factor. It can therefore be presumed that within the varietal limitations the differences in crop growth and yield are essentially attributable to the test material, the organic meal, as other extraneous factors mainly climate was normal during the investigation period.

5.5.1.2. Growth expressions

Application of organic meal exerted significant influence on the growth characters during both seasons of study. Its application at the highest level of 20 t produced taller plants. In terms of other growth expressions like tiller counts, dry matter production and leaf area index, also, the treatments which received higher levels of organic meal stood first as seen from Tables 4.32 to 4.35 and Figures 18 and 19. It is also interesting to note that between different levels of organic meal in combination with supplementary doses of inorganic fertilizers, the difference in growth expressions were in general insignificant. Even the lowest does of 5 t/ha along with the required level of

Fig. 18. Influence of organic meal on growth characters in Mundakan season

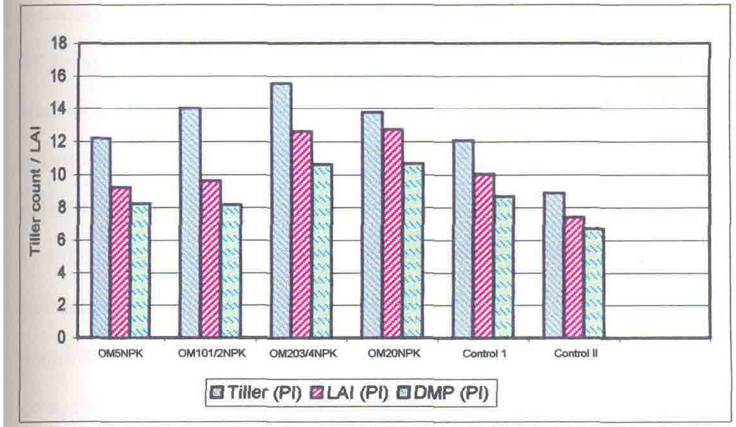
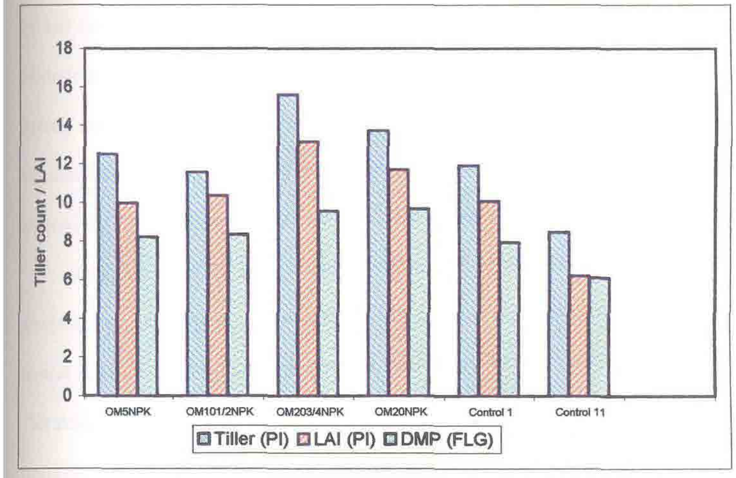


Fig. 19 Influence of organic meal on growth characters in Puncha season



NPK supplement was always comparable with the recommended practice of fertilization, the control I. As seen from Table 4.32 the mean plant height and tiller count in OM 5 NPK during Mundakan season were 119.29 cm and 12.66 while the corresponding values in the recommended practice was 121.79 cm and 11.83 tillers respectively. Similarly the dry matter produced at flowering stage in OM 5 NPK was 8.25 t/ha and it was comparable to control I at 8.7 t/ha (Table 4.34).

Of over 50 external factors affecting the crop growth and their expressions, two major factors establishing the upper limit of growth potential are the amount of available moisture during the growing seasons and adequate supply of mineral nutrient elements (Levitt, 1980). These two factors are so much interlinked, as the growth of plant is proportional to the amount of water present and the assimilable nutrient availability. Right from the first formed stable products of photosynthesis to the complex processes of metabolising carbohydrates, proteins, lipids and other types of compounds, constituents for cell formation, multiplication and cell elongation, water performs both as the substrate as well as a medium for the translocation of nutrients. Among these two biotic factors, since the availability of moisture was assured either through precipitation or irrigation throughout the growing season, the observed variations in growth expressions, between the treatments can entirely be attributed to the nutrient availability.

Application of 20 t/ha of organic meal will itself amount to a situation of providing 358, 1808 and 56 Kg/ha of N, P and K respectively as evident from the nutrient content in Table 4.21, though major portion of this may not be available to the test crop. This along with the supplementary doses of inorganic fertilizers as seen with the selected treatments will definitely tell about heavy fertilization encouraging greater vegetative growth. The inferiority of the absolute control where the imposed nutrient stress was maximum further reiterates this fact. The abundance and availability of nutrients are also reflected in the best index of vegetative growth, the leaf area index (Tables 4.34 and 4.35) an expression of the vegetative development of plant in relation to land area utilized. Consequently the photosynthesising surface had increased resulting in faster dry matter accumulation and associated growth expressions.

5.5.1.3. Yield attributes

As the test of any technology or input for that matter is the yield analysis as to how effectively the influences of growth characters were transmitted to yield and its components this analysis assumes great significance. All the yield components namely number of productive tillers, panicle length, number of filled grains per panicle and thousand grain weight did not differ significantly between the different levels. But the treated plots were comparable to recommended practice and superior to absolute control. As in the case of growth characters the highest yield (5.01t) was also obtained at the highest level of OM (20t/ha) but it was comparable to that of the treatment OM 10½ NPK both during Mundakan and Puncha (Fig 20 and 21).

The yield in general, was low as compared to a high yielding variety because the test variety was photosensitive in nature and low assimilate apportioning capability is a characteristic plant function of such varieties. Application of higher quantities of nutrients will enhance leaf growth and grain yields are depressed because of higher mutual shading. Given this situation, it can logically be assumed that under both of the drastically different levels, the crop was getting sufficient nutrients to express its potential. In other words, even when the quantity of OM was reduced by half from the highest level of 20 t/ha virtually there was no difference in yield. Even 5t/ha was showing

Fig.20 Influence of organic meal on yield in Mundakan season

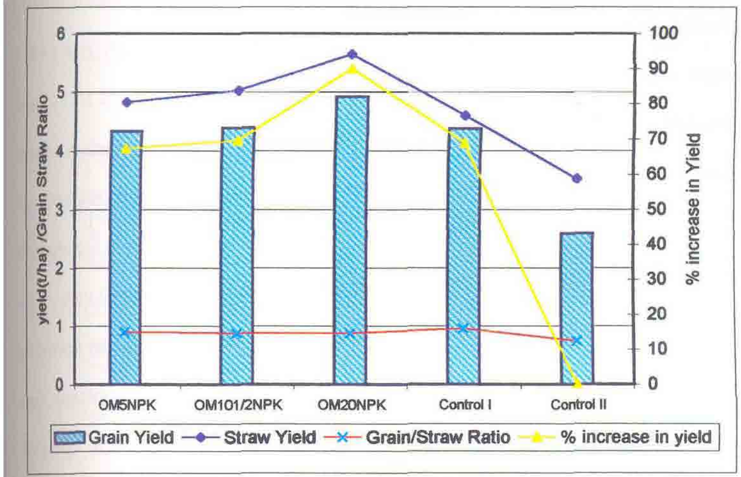
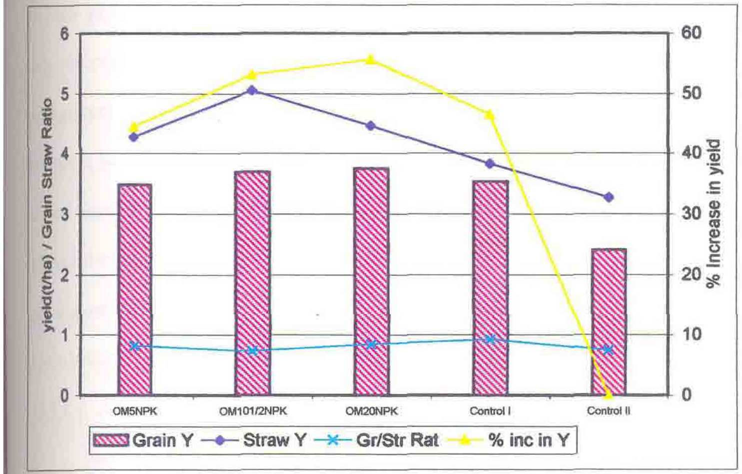


Fig.21 Influence of organic meal on yield in Puncha season



comparable trends in many of the growth and yield attributes (Tables 4.32 to 4.37). This is understandable as we see that the crop was benefited with the nutritional abundance of N (89.5 Kg), P (452 Kg), K (14 Kg), Ca (848 Kg) and Mg (16 Kg) even at the lowest level of OM tried. Insensitiveness in yield in linear positive terms at two to four times increase in the supply of these nutrient elements as seen in treatments T_4 (OM 10t) and T_{10} (OM 20t) might be reflective of the fact that the critical efficiency level of these elements had already crossed at 5t OM.

Any further addition in nutrient availability does not have any significant effect on growth rate and it only leads to wastage of nutrients through accumulation in soil and their consequent loss. This appears to be natural because of the competitive ionic behaviour of elements in soil and plant system and inevitable interaction between cationic Ca and anionic P and/or S, which neutralizes both and creates metabolic unavailability of elements. Similar results have been reported by Senthil *et al.*, 2000 with the same study material in groundnut even with 1-1.5 t/ha. Sreekumar and Potty (2000) also observed increased metabolic unavailability of elements under varied nutrient management systems in pepper. This would also mean that growth and yield attributes are not a simple linear function and additions of each successive increment after the critical level results in a progressively smaller increase in yield. With consequent increased input inefficiency, this being a high nutrient source, results of field experiments are suggestive that realizable yield potential of the test variety is possible even with still more lower levels of OM than the lowest tried level of 5t/ha.

5.5.1.4. Nutrient uptake

Nutrient content of a plant at any point of time is a function of its availability and is a factor for growth whereas nutrient uptake is a function of growth, absorption and accumulation. Due to the basic inherent nature of the crop N and P content was more in grain while K, Ca and Mg in straw. There was no wide variation between the different levels of organic meal with respect to the nutrient content of the crop. As narrated under section 4.4.10, OM10 ½ NPK with 2.12% N in grain was comparable to OM 20 NPK with 2.18% N and OM 5 NPK with 2.05% N. The corresponding values in straw were 1.18,1.15 and 1.09 % respectively in Mundakan season (Table 4.38). Similarly in case of P also the concentration in grains did not increase proportionately to the amount of P applied. The content in straw varied from 0.23-0.27 % in treated plots and from 0.25-0.31% in grain while the absolute control had a low value of 0.12 and 0.16 % in Mundakan season. In Puncha also there was no significant difference between the different levels of organic meals with respect to P content in grain or straw. This trend was observed with respect to almost all major nutrients.

In the case of K the content in grain in Mundakan season varied from 0.27 to 0.34% in treated plots but it was not significant. The content in straw in OM 5 NPK was 1.31%, in OM 10 ½ NPK 1.25 %, OM 15 ½ NPK 1.40 % and OM 20 ½ NPK 1.36 % K and all these were statistically on par to each other. This was the case in Puncha also (Table 4.40).

The Ca content of grain at lower levels of organic meal in Mundakan season was comparable to that at higher levels. OM 5 NPK had 0.71% Ca, OM 10 ½ NPK 0.68 % and these were statistically on par with OM 20 ½ NPK (0.73%) and OM 20 ¾ NPK (0.69%). Similarly the Ca content in straw in OM 5 NPK and OM 20 NPK were comparable, the values being 1.79 and 1.77% respectively. All other levels also had comparable values. The high Ca content result from the high Ca level in the soil solution. This might be due to higher quantum of Ca released from organic meal.

Compared to Ca, the Mg content was comparatively lower in the study. This might be due to the inhibitory effect of high Ca ions. The presence of calcium ions in the root environment can considerably influence the uptake of Mg^{2+} ions by crops (Mengel and Kirkby, 1978). In both seasons of study there was no significant difference between different treatments in Mg content of straw or grain. Cation competition plays a major role in Mg uptake and uptake is seriously affected either by an excess of other cation species especially K^{+}, Ca^{2+} or a combination of these ions.

As in the case of major nutrients there was no great significant difference between the levels of organic meal with respect to micronutrients too (Tables 4.39 and 4.41). The micronutrient Fe was found to be very high at all stages. In Mundakan the Fe content in grain ranged from 195 ppm to 607 ppm and in straw from 1219 ppm to 2588 ppm in treated plots. Under submerged soil solution microbial reduction increased the concentration of ferrous ion in the soil solution and the rice crop absorbs iron easily. The Mn and Zn content also did not vary much between the levels of organic meal. Compared to other micronutrients the Cu availability and uptake is less because humic complexes of copper are highly unavailable and therefore fixation of Cu by organic meal application is a possibility. Over 99 per cent of copper in soil is complexed by soil organic matter.

As already discussed, as the nutrient availability increases the growth rate and nutrient content also increase until the critical input use efficiency level is attained. After this stage, presumably because of the competitive ionic interaction, metabolic unavailability and increased input use inefficiency, the plant system fail to absorb nutrient elements despite the surrounding nourishing environment with abundance of nutrients. Therefore the increased nutrient uptake seen with different stages of crop growth can only be attributed to increased dry matter production at respective stages, a function independent of levels of OM, for reasons explained already.

5.5.1.5. Soil nutrient availability

Results on soil nutrient availability in comparison with their initial status presented in Tables 4.42 to 4.44 and explained in section 4.4.11 tell upon the fact that the organic meal application had positive buffering effect in determining the ionic concentrations of the elements in solution. The desirable pH change from 5.43 to 6.0 in Puncha and organic carbon build up (3.21 %) are in general attributable to numerous physical, chemical and biological processes which controls the availability of plant nutrients. The results and interpretations presented under section 4.1.3 for the incubation study may also be recalled in understanding the trend and fluctuations observed in the field culture.

The soil pH recorded a slight increase from the initial value in almost all the treatments. The increase in pH may be due to the submerged condition as well as the liming effect of organic meal. Several essential elements tend to become available around this desirable level of pH.

There was an increase in organic carbon content of soil at harvest in both the seasons. Even in the lowest dose of OM 5 NPK substantial build up of organic carbon was noticed. Significant variation between the different levels of meals was also noticed. Guisquiani *et al.* 1995 also observed that total organic carbon increased as compost rates were increased but the rise in soil carbon was not proportional to the amount of organic carbon added with compost. Several authors have reported differential build up of organic carbon due to addition of FYM, poultry manure, biogas slurry etc (Srivastava, 1985., Maskina *et al.*, 1988 and Jagdeesh *et al* ., 1994) and therefore the observed effects in organic carbon is understandable.

The available N status of the soil also improved with organic meal application. Naturally with the comfortable C/N ratio of 12.51 of the organic meal (Table 4.20) net mineralisation is expected and increased N availability is explainable. Being a phosphorus rich source the higher available N status at higher level of P might be due to the presence of more quantities of P to meet the needs of soil organisms to effect the mineralisation of nutrients. Higher available N content of soil under higher dose of digested organic matter favours microbial activity and enhanced biomass addition to soil as a result of improved soil physical properties (Muthuvel *et al.*, 1990).

Irrespective of treatments there was an increase in the available P status of soil during both seasons. But the build up was not proportional to quantity added. The build up of available P in soil is understandable since all the P added is not taken up by the crop. Zhang *et al.*1994 reported that combinations of organic manure with fertilizers increased the solubility and mobility of P in paddy soils. However it must be recalled that the immediate result of any form of P addition is net insolubility or immobilization following sorption and desorption processes, precipitation and fixation phenomenon as described under section 5.2.1.2. Phosphorus, therefore is never readily soluble in soil but always add to the total P pool making very little to the available pool. Despite huge quantities of elemental P applied through different levels of OM and other sources the observed trend of very low available P is therefore, explainable.

There was not much difference in available K content of soil between levels though the highest level had the highest content. Slight increase in K content was noticed after harvest of crop. The combined application of both organic meal and inorganic fertilizer might have created favourable physical and chemical conditions in the soil and better availability of nutrients.

There was substantial improvement in Ca content of soil with increase in organic meal application. Even lower levels were superior to recommended practice. But the available Mg content of soil decreased. This might be due to increase in activity of calcium ions in the soil solution consequently increasing its activity on the exchange complex. This decreased the exchangeable Mg. There are reports that application of single super phosphate and rock phosphate also increased the calcium content of soil due to the content present in these materials.

In case of micronutrients, Fe, Mn and Zn content increased while Cu content decreased at harvest. The Fe and Mn content might have increased due to the reduced conditions under submergence. Mn becomes available as the Mn^{++} ion is very soluble. Ferric ion is converted to ferrous forms in the case of iron. The soils applied with organic manure or those, which are naturally high in organic matter are prone to low redox potential due to the fact that organic matter favours the growth and metabolism of anaerobic microorganisms. Low redox potential may lead to a very high Fe^{2+} concentration harmful to rice plant. The organic carbon content is generally positively correlated to available Fe. The decrease in Cu content might be due to fixation of Cu in humic complexes as discussed in the previous section. Swarup (1984) also found that application of farmyard manure enhanced the availability of native micronutrient cations in the soil.

5.5.2. Residual Effect

Since phosphorus does not occur as abundantly in soils as nitrogen and potassium and among all nutrients P is the most susceptible to immobilization to render it less recoverable for short duration crops (De Datta *et al.* 1966; Hollord and Crocket, 1991) as that of rice, residual influence of OM assumes importance. Field experiments were conducted during two successive seasons after the main experiment as described under section 3.4.2 to study the residual influence of organic meal on crop. Details of crop growth and yield for the two seasons Puncha and Virippu is given in Tables 4.45 to 4.47 under section 4.5.

During the successive Puncha season the test cultivar Chemeen of the main experiment is used. To generate information on a high yielding variety and also to avoid the seasonal disadvantage of taking a photosensitive variety in Virippu, the high yielding red variety popular in the locality, Matta Triveni, was used.

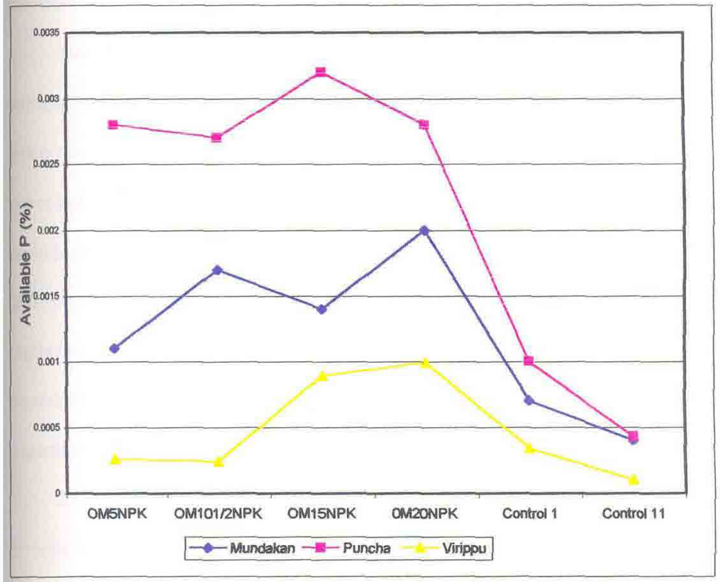
The results were encouraging and they testified that OM could be a good residual P source also. Along with its established direct effect as described under section 4.4 to ensure available P pool buffered by both organic and inorganic P fractions, the soil solution P or the intensity factor during the residual crop periods was also very much pronounced. The significant reflections on agronomic traits viz. tiller counts, productive tillers, plant height and dry matter accumulation in previously OM treated plots over controls were supportive to this (Table 4.45 and 4.46).

In the case of yield and yield components also the treatment, which received the lowest level of OM i.e. 5 t/ha, performed better and it was comparable to the higher OM levels even during the second successive residual crop. This clearly signifies that the concentration of available P in the soil and its consequent absorption by plants was optimum despite the differences in levels of OM as a direct P source or the consecutive skipping of elemental P for two seasons. In both seasons straw yield was higher in plots previously treated with higher levels of organic meal. Since plant height and number of tillers are two contributing factors, which determine the straw yield greater availability of nutrients must have accelerated these vegetative characters and hence straw yield.

During Puncha season in general there was not much difference between the different levels of previously OM treated plots. Maximum yield of 5t was observed in OM 20 ¾ NPK but economic yield of 4.11t was observed even in the lowest dose of OM 5 NPK. In this experiment also OM 10 ½ NPK performed well and produced 4.11t and was on par with OM 5 NPK (Table 4.47). In spite of peculiar seasonal limitations and varietal characters observed during Puncha all the treatments produced more than 4 tonnes and was superior to the first crop during Mundakan.

Coming to the soil status there was significant increase in available P in the second season (Puncha) compared to first season (Mundakan) indicating the residual effect of applied P (Fig.22). This is due to long contact with soil and greater dissolution of P from OM applied in the first season. Hence uptake also increased in the second year and yield increased. Moreover under submerged condition P fixed as iron phosphate is released on reduction of iron from ferric to ferrous state. At the end of Virippu crop the available P reduced drastically at lower levels while upper levels of previously OM treated plots were significantly superior to regular NPK treated plot and absolute control. It may be noted that the quantity of total P in soil has a little or no direct relationship to the availability of P to plants. Instead the interrelationships between various forms of P in soils, the sorption and desorption linked buffering capacity of the clay surface-soil solution interface, microbial immobilization and subsequent mobilization of microbial P etc plays significant role in the intensity factor of mobile ions and their plant availability. However, the inorganic and organic labile P fractions collectively called as quantity factor which is determined either singly or in combination by the inherent, applied or residual P (Tisdale et.al.1993). Here the investigations both under direct and residual influence of OM substantiates the effectiveness of this source to maintain a comfortable

Fig.22 Residual influence of organic meal on P availability



ratio of quantity to intensity factor, which determines the capacity or the ability of the soil to buffer changes in the soil solution P. The observations of Barbarika *et al.*, 1980 and Colacicco (1982) in similar studies that the cumulative agronomic and economic value of organic meal applied to agricultural soils could be more than five times greater in the post application period than the value realized during the year of application are also noteworthy.

Available N increased at the end of Puncha due to greater mineralisation of nutrients. Greater availability of P must have induced microbial activity and hence greater release of nutrients into available pool. The slight decrease in Virippu may be due to crop uptake or also due to leaching effect due to heavy rainfall. In Puncha season the available N content was high even in lower levels of previously OM treated plots (370 ppm) but in Virippu lower levels of OM 5 NPK had lower N content (300 ppm). Higher levels of OM 15 NPK and OM 20 NPK had higher values of available N in soil at the end of both Puncha and Virippu crops. The values being 390 ppm and 380 ppm respectively for both treatments in Puncha and Virippu season (Table 4.48 and 4.49).

There was not much difference between the plots, which received different doses of meals in Puncha and Virippu with respect to K content. The K content ranged from 50-77 ppm in previously OM treated plots in Puncha and from 53-75 ppm in Virippu season. In general, the K content was low. K moves in the ionic form without being involved in the formation of any organic compounds. Because of this fact even the soils with high organic matter showed very low K content (Sobulo and Jaiyeola, 1980).

Both available Ca and Mg decreased at the end of both seasons. The Ca content varied from 1590 ppm to 1830 ppm in previously OM treated plots during Puncha while it was in the range of 1000 ppm to 1220 ppm in Virippu. In both seasons the previously

OM treated plots were significantly superior to recommended practice and absolute control. This might be due to the Ca present in the organic meal. Generally only small amount of Ca is taken up by the crop. Ca and Mg is complexed mainly in the humic and fulvic fractions of organic matter and thereby influence the soil reaction and other chemical properties of soil (Schnitzer and Skinner, 1969). When these two elements released by soil solution are not taken up by crops they are likely to be adsorbed by humus thereby preventing the loss of these nutrients by leaching and hence it become available during successive seasons.

Among the micronutrients there was slight increase in available Fe content at the end of Puncha and it was almost maintained at the end of Virippu (Table 4.50). The Fe content in previously OM treated plots varied from 93.63 ppm to 109.8 ppm in Puncha and from 102.19 to 108.54 ppm in Virippu season. Initially the Fe content increases in flooded soils due to submergence and further becomes stable after a period of time. The increase in available Fe content may also be due to positive interaction between organic carbon and Fe content. Fe may exist as organic form in the form of chelates, which are highly available. The available Mn content was also maintained at the end of successive crops. At high levels of OM treated plots the Mn content decreased. Both Zn and Cu also increased at the end of Puncha and their slight decrease in Virippu as in the case of Mn might be due to crop uptake.

Hence it can be concluded that organic meal has got many beneficial residual influence and it can be used in economizing crop production. Application of P can be skipped even for two seasons at higher levels of 10-20 t/ha of organic meal to sustain high yields. As it was impossible to evaluate residual effect of OM even after the second consecutive season, because of the time compulsion as well as the limited input and management support inherent to a doctoral research programme, the continued beneficial influence (if any) need to be ascertained through subsequent studies.

5.5.3. On farm trial

Coupled with the direct and continued beneficial effects as described above the results of on-farm observational trials conducted in Kole lands of Thrissur even with very low levels compared to the pot and plot culture studies signifies that OM can be a good organic P source, besides its role as a liming material and a micronutrient reserve.

As observed in Table 4.51 in large plots of one- acre size in actual farm field even 1.25 t/ha OM could give better straw and grain yield over the plots which did not receive any OM. Average yield of five locations revealed that there was 11% increase at 2.5 t/ha and the yield at 1.25 t/ha was comparable to control, the recommended practice. The general increase in growth and yield of plant over the plot culture studies even with very low level of OM can be attributed to the positive production environment such as assured irrigation facilities and inherent fertility status of Kole land soils.

But detectable yield increase between the levels definitely tells on the effective manifestations of all positive influences of organic meal in determining the intensity, quantity and capacity factors of respective macro and micronutrients and their resultant availability to plant as described previously. The fact that the customary practice of liming in the range of 600 to 1000 Kg/ha could also be avoided even with 1.25t OM/ha further indicate the possibility of input cost reduction besides the established residual impact in sustaining economic rice culture. However these indicative trends under actual on-farm situations needs to be established through well planned field studies combining direct, ancillary and residual effects at critical and optimum levels and, economic advantages assessed accordingly.

5.6. Economics of organic meal production

Organic meal is the bio-processed and enriched organic material produced from the KCPL effluent sludge, a waste material of the KCPL factory. This bio-processed material is a highly potential organic source as evident through field studies and farm trial. The demand for organic meal will increase and commercial production of it could be a viable option and hence the economics is worked out.

Cost of production of one tonne of organic meal:

Organic meal = sludge + 5% neemcake + 5% mussorie rock phosphate + 1% urea

1. Cost of enrichers 50 kg NC, 50 kg MRP and 10 kg Urea (NC @ Rs.5/- per kg; MRP @ Rs.2/- per kg and urea @ Rs.5/- per kg)	=	400.00
2. Processing charge – 1 tonne substrate requires 3 mandays @ Rs.100/man	=	300.00
3. Packing and other charges	=	300.00
Total	=	1000.00

The cost of production of one tonne of organic meal at the present price level is estimated as Rs.1000/-. Sludge is taken as a no cost material since presently it is a waste product with serious disposal problems. As the acceptance level of organic meal increases the sludge material may also cost and economics at that time.

It can be safely concluded that through activated composting technique and with further organic enrichment, the KCPL sludge, a hither to objectionable industrial waste can be converted into a value added manure called organic meal (OM). The formulation No.1 (S+5NC+5MRP+1U) is the best organic meal. It is odourless, light brown to black in colour and a rich source of both major and minor nutrients. It contained 1.79 % N, 9.05 % P, 0.28 % K, 16.96 % Ca, 0.32 % Mg and 0.36 % S. The Fe, Mn, Zn and Cu contents were 883.5, 103.62, 113.3 and 7.71 ppm respectively. The pH of this meal was 6.97, organic carbon 22.38%, C/N ratio12.51 and neutralizing value71.22. Pot culture, plot culture and farm trials had revealed that this new manure is a potential P and Ca source with no deleterious effect either on crop or soil even at higher dose of 20 t/ha. The desirable direct as well as residual effect of organic meal were manifested even with doses in the range of 1.25 to 5 t/ha.

Summary and Conclusion

Chapter 6

SUMMARY and CONCLUSION

The studies on the formulation and evaluation of organic meals from KCPL effluent slurry were conducted at KCPL factory site and at College of Horticulture from May, 1997 to December, 1999. The experiments included study of the basic properties of the KCPL effluent sludge, formulation techniques of organic meals, evaluation of their physico-chemical properties and the influence and residual effect of the best selected organic meal on crop and soil. An on-farm trial was also conducted in the Kole lands of Thrissur district to test the field level acceptability of the organic meal. Observations on growth, yield attributes, uptake of nutrients and soil nutrient status were taken at regular intervals and the salient findings of the study are summarized below.

- The KCPL effluent sludge is a bone based industrial waste, which is light to deep grey in colour with an offensive, irritating and nauseating odour. It is semi-solid in consistency and available as wet cobbled flakes, with homogenous properties.
- The material is near neutral in reaction with a pH of 6.75. It contained 1.86 % N, 8.44 % P, 0.28 % K, 20.34 % Ca, 0.42 % Mg, 0.34 % S, 1654 ppm Fe, 125.5 ppm Zn, 106.8 ppm Mn and 8 ppm Cu. The heavy metal contents of Ni, Cr, Pb and Cd were 17.3, 12, 13.3, and 3 ppm respectively and these were well within the permissible limit. The mean neutralizing value of sludge was 57.7, organic carbon 33.49 % and moisture content 57.2 %.
- The incubation study to understand the pattern and nature of nutrient mineralisation of KCPL sludge in comparison with mussorie rock phosphate at

171748

different levels of phosphorus and moisture regimes showed that KCPL sludge was superior to rock phosphate in the release of nutrients. It maintained a significantly higher pH (6.52) as compared to rock phosphate (6.36). Among the different treatments KCPL sludge 4gP under water logged condition was superior in stabilized pH values. Application of different levels of P and water logged condition significantly increased the soil pH.

- N release from KCPL sludge under water stagnation was superior with a mean value of 175.1 ppm. The release of N from sludge was more during the initial period (45 days) while greater release occurred from rock phosphate during later period of study (120 days).
- Maximum release of available P occurred at 30 days of incubation thereafter P decreased. KCPL sludge registered higher release through out the incubation period, the highest being 59.42 ppm at 30 days while rock phosphate could touch only at 25.8 ppm (45 days). P release was more at field capacity than under waterlogged condition.
- Rock phosphate was superior to KCPL sludge with respect to Ca release, the mean values being 884.73 ppm and 871.62 ppm respectively. Release was more at field capacity level.
- In general KCPL sludge could be effectively utilized both under aerobic and water logged condition. It could serve as an efficient organic source since the peak release of all nutrients occurred within the 60 days period. N at 45 days, P at 30 days and Ca at 60 days. Addition of different levels of P significantly increased the release of all nutrients under study.

- Among the different formulation techniques of organic meals the organic meals produced from spent slurry were odourless and in innocuous form, light brown to black in colour. The odour, appearance and consistency of all forms of meal namely dried, dried and powdered and dried and pelletised were same to both organic meals as well as spent slurry. The consistency of the material was changed from non-sticky, rigid, difficult to handle nature to a perfected bead like attractive form, which is easy to handle.
- The organic meal No.1 namely Spent slurry + 5 per cent neem cake + 5 per cent rock phosphate with respective values of 1.8 % N, 9.06 % P, 0.3 % K, 19.2 % Ca, 0.32 % Mg, 0.35 % S, pH 7.2, Organic carbon 21.8%, C/N ratio 12.04 and neutralizing value 68.7 is considered as the best formulation viewed in terms of physical appearance, handling capability and contents of major nutrients.
- With regard to micronutrient content the different organic meals differed from each other. The Fe content ranged from 706.5 to 832.4 ppm, Mn from 101.4 to 110.9 ppm, Zn from 117.5 to 212.7 ppm and Cu from 7.04 to 8.33 ppm.
- The production of organic meals from spent slurry was found to be technology complicated and costly procedure since number of processes and equipments were involved in the bio-methanation of KCPL sludge as well as in the subsequent processing of spent slurry.
- Signaled from an accidental observation, principle of activated composting was employed to evolve a more viable technique to produce organic meals. Aerobic open heap composting was found to be quick, cost effective and the

best feasible technology for the production of organic meal from KCPL sludge within 90 days.

- Among the compost maturity parameters maximum microbial population of bacteria (310.10 x 10^5 CFU), actinomycetes (158.2 x 10^5) and fungi (49.53 x10^5) were in the thermophilic stage. Temperature (70°C) and pH (8) also attained maximum values at this stage. C/N ratio also decreased towards the maturity phase and stabilized around 12.51 after 90 days. Composting also reduced the moisture content over the base material. All the meals maintained an organic carbon around 22 per cent.
- Based on the ease in formulation technique and favourable physico-chemical properties the meal No. 1 namely Sludge + 5 % neem cake + 5 % mussorie phosphate + 1 % urea was adjudged superior to other meals. It contained 1.79 % N, 9.05 % P, 0.28 % K, 16.96 % Ca, 0.32 % Mg and 0.36 % S. The Fe, Mn, Zn and Cu content were 883.5, 103.62, 113.3 and 7.71 ppm respectively. The pH of this meal was 6.97, organic carbon 22.38 %, C/N ratio 12.51 and neutralizing value 71.22.
- The pit system of composting was not effective. Irrespective of treatment differences the temperature hardly rose to 37°C and thereby preventing the build up of thermophilic environment essential for activated composting. There was no change in the moisture content or in the C/N ratio even after 90 days in the pit system.
- Rapid pot culture trials with meal No. 1 (S + 5NC + 5MRP + 1U) showed that in general the growth and yield characters increased with the addition of

increased doses of organic meal up to 320 g OM. Economic dose for better plant growth and yield was 80 g OM which is equivalent to 20 t/ha.

- Increasing the levels of organic meal had increased the uptake of nutrients. The N uptake of grain ranged from 0.27 to 0.63 g, P uptake from 0.051 to 0.118 g, K from 0.26 to 0.28 g, Ca from 0.18 to 0.29 g and Mg uptake from 0.0038 to 0.0079 g per pot. In case of micronutrients the Fe uptake of grain varied from 2.09 to 5.64 mg, Mn from 0.719 to 2.236, Zn from 0.533 to 1.19 mg and Cu from 0.071 to 0.169 mg in treated pots.
- Field investigations with the organic meal during two seasons Mundakan and Puncha showed that the organic meal when used in combination with inorganic fertilizers improved the growth and yield of rice crop, helped to reduce the bulk requirement besides providing balanced supply of all nutrients as required by the crop.
- There was no significant variation between the different levels of organic meal with respect to either growth or yield components. The highest yield of 5.01t was recorded in OM 20 ¾ NPK but difference was not significant. OM 10 ½ NPK also produced higher yields during both seasons. With respect to both growth and yield characters the lowest dose of 5 t/ha was always comparable to the recommended package of practices. The optimum dose was fixed as 5t/ha.
- Even with respect to nutrient content there was no wide variation between the different levels of organic meal. Thus the uptake was not in proportion to the quantity applied, which proved that there was a biological limit for unit conversion of nutrients to harvestable produce.

- The soil productivity status was also improved by the organic meal application. There was substantial build up of soil organic carbon even at the lowest dose of OM 5 NPK. The major and minor nutrient status of soil also improved at the end of the crop.
- Residual study during two successive seasons Puncha and Virippu following the main experiments proved that organic meal can also be a good residual P source. The growth and yield components at the lowest level of OM 5 t/ha was comparable to higher OM levels even during second successive residual crop. In Puncha, first residual crop though maximum yield of 5t was observed in OM 20 ¾ NPK economic yield of 4.11t was observed even in the lowest dose of OM 5 NPK.
- Soil P status also improved in the second season (Puncha) compared to direct crop (Mundakan) which indicates the residual effect of applied P. At the end of Virippu crop the available P reduced at lower levels while upper levels were significantly superior. This shows that organic meal has got beneficial residual influence and it can be used in economizing crop production. Application of P can be skipped for two seasons at higher levels of 10-20 t/ha and this can sustain higher yields.
- The on-farm observational trials conducted in Kole lands of Thrissur showed that organic meal can be a good organic P source even at very low levels of 1.25 t/ha when used in combination with inorganic fertilizer, besides being a liming material as well as a micro nutrient source.
- The KCPL sludge could also be utilized as an organic P source and substitute for mussorie rock phosphate. By this the rate of application of organic meal could be further reduced and addition of huge quantities of nutrients into soil prevented.

Future line of work

- Organic meal a bio-processed industrial waste rich in calcium, phosphorus and with considerable quantities of other plant nutrients is a highly potential organic source for crop production. This dissertation was restricted to production of meal, study of its properties and its use under submerged condition on rice. Being a new material it should be tried in different situations and hence offers scope for further studies.
- The nutrient release pattern from the incubation study clearly revealed that organic meal could be utilized as an organic source both under aerobic and submerged conditions. Hence its suitability under moisture stress and upland situations could be further ascertained by conducting field studies in these situations.
- The use of this material could also be diversified to other important crops like banana, vegetables, tuber crops, floriculture and especially calcium loving crops like groundnut and other oilseeds and pulses.
- Studies on its feasibility as an starter organic enricher source along with potting mixture in high-tech farming like commercial floriculture as rosemeal, orchid meal etc at very low application rates will find ways for commercial utilisation of organic meal.
- Since organic meal is a form of concentrated organic-cum-fertilizer source extensive field trials could be conducted at very low doses of less than one tonne to use it as an organic P fertilizer similar to rockphosphate. By this, accumulation of nutrients into soil could be prevented.

- Extensive field trials to determine the heavy metal build up in the soil over a period of time needs to be thoroughly investigated.
- On-farm exploratory trial with organic meal in farmer's fields in kole lands has revealed the possibility of popularising it for bulk utilisation in rice. Because of its appreciable neutralising value the meal could be easily popularised in major rice growing tracts like kole, Kuttanad and parts of Palakkad region. Well conducted onfarm trials are needed for substantiating this.

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* Original not seen

Appendices

Appendix 1. Processes involved in KCPL effluent slurry production.

The Kerala Chemicals and Proteins Ltd. (KCPL) is a joint sector company promoted by Kerala State Industrial Development Corporation Ltd. in collaboration with two Japanese companies viz. M/s. Mitsubishi Corporation and Nita gelatine Inc. The company produces ossein, an intermediate product in the manufacture of gelatine and dicalcium phosphate from crushed animal bones through hydrochloric acid (HCl) and hydrated lime ($Ca(OH)_2$) treatment. During this process about 15 t of effluent sludge diluted to an approximate volume of 100 m^3 is produced. The combined effluent from various sources in the plant, bone charging section, ossein washing section, DCP filtration system and siphoning system are collected and subjected to different treatments to separate sediment sludge and clear overflow. The overflow is let out into Chalakudy river at pH 7 – 7.2 and sediment sludge is left in the open for sun drying. About 7 – 10 t of filtered sediment sludge is produced daily, for which no effective disposal system is in vogue. The sludge is causing environmental problems also. Due to uncontrolled putrefaction processes, the sludge is emitting nauseating and asphyxiant smell to surrounding atmosphere and restricts clean and pleasant air to the nearby inhabitants (KCPL, 1996).

Appendix 2. Physico-chemical properties of KCPL effluent sludge

Properties	Value
1. Colour and appearance	Light to deep grey, wet cobbled / flakes form
2. Bulk density (g/cm^3)	0.61
3. Particle density (g/cm^3)	1.30
4. pH	6.60
5. Nitrogen (%)	1.13
6. Phosphorus (%)	5.60
7. Potassium (%)	0.31
8. Calcium (%)	21.30
9. Magnesium (%)	0.51
10. Sulphur (%)	0.40
11. Organic carbon (%)	14.3.
12. Moisture content (%)	53.8

(Source: Gopinathan, 1996)

Appendix 3 Chemical properties of mussorie rock phosphate

Property	**Content (%)**
Nitrogen	-
Phosphorus (P_2O_5)	20 – 25
Potassium	0.21
Calcium	35
Iron	1.2
Magnesium	0.31

Appendix 4. Processes and properties of KCPL spent slurry

Gopinathan, 1996 reported that KCPL slurry could be a good renewable clean energy source with a potential of 5-12 m^3 of high quality methane gas per m^3 of slurry and the spent slurry obtained can be used as a manure.

Processes of spent slurry production

The thickner slurry of 10-12 percent TSC (Total Solid Concentration) at standardised pH 6.8-7.0, temperature 29-30°C and at HRT (Hydraulic Retention Time) of 40 days is kept for methanogenesis in suitable digestion tanks. Gas production starts from 2nd day of fermentation and reaches a peak value around 24-28 days and this continues for 46-56 days. The methane evolved is utilized in the factory. The spent slurry from the digester contains about 90 percent moisture and poses problems for on-farm use. Hence it is filtered into a semi-solid sludge for free handling.

Properties of spent slurry

Properties	Value
1. Colour	White to light grey,
2. Odour	No odour, innocuous
3. Nitrogen %	1.2
4. Phosphorus %	6.4
5. Potassium %	0.31
6. Calcium %	20.5
7. Magnesium %	0.34
8. Sulphur %	0.35
9. Moisture content %	90
10. pH	6.7

Appendix 5 Soil characteristics of the experimental sites.

Particulars	KCPL factory site 1	KCPL factory site 2
1. pH	5.4	5.4
2. Organic carbon %	2.08	2.02
3. Available N %	0.031	0.0314
4. Available P %	0.00035	0.00036
5. Available K %	0.005	0.0053
6. Available Ca %	0.188	0.179
7. Available Mg %	0.0084	0.0033
8. Available Fe (ppm)	86.3	88.6
9. Available Mn (ppm)	7.28	7.28
10. Available Zn (ppm)	0.62	0.64
11. Available Cu (ppm)	3.24	3.32

Appendix 6a. Weekly weather data for the period from October 1997 to January 1998 (Mundakan crop)

Std. Week	Dates	Rainfall (mm)	Relative Humidity (%)		Temperature (0°C)		Sunshine (hrs/day)
			07.30 hrs.	14.30 hrs.	Max.	Min.	
October 1997							
40	1-7	12.0	88.6	67.1	29.6	23.5	7.00
41	8-14	44.0	88.6	61.4	32.2	23.9	5.60
42	15-21	100.3	86.9	63.7	32.2	23.9	6.10
43	22-28	116.6	84.1	69.4	32.5	23.0	5.00
44	29-4	41.9	91.7	67.4	30.9	23.2	5.80
November 1997							
45	5-11	51.7	88.9	66.3	28.1	22.8	7.30
46	12-18	26.3	92.4	44.6	30.8	26.0	4.00
47	19-25	78.4	93.1	81.9	28.1	22.9	5.10
48	26-2	16.2	87.1	72.9	29.4	22.6	7.90
December 1997							
49	3-9	3.8	90.9	77.4	32.7	22.4	4.50
50	10-16	40.4	90.3	66.6	33.2	22.6	6.70
51	17-23	131.2	90.3	63.1	32.5	23.0	5.90
52	24-31	-	88.1	65.3	33.1	21.8	9.40
January 1998							
1	1-7	-	90.7	62.9	33.6	20.1	8.70
2	8-14	-	91.3	59.7	34.2	18.5	9.50
3	15-21	-	77.0	53.4	33.6	19.4	7.10
4	22-28	-	89.4	49.7	34.9	22.6	-
5	29-04	-	87.3	51.5	35.4	21.6	-

Appendix 6b. Weekly weather data for the period from January 1998 to June1998 (Puncha Crop)

Std. Week	Dates	Rainfall (mm)	Relative Humidity (%) 07.30 hrs.	Relative Humidity (%) 14.30 hrs.	Temperature (0°C) Max.	Temperature (0°C) Min.	Sunshine (hrs/day)
January 1998							
1	1-7	-	90.7	62.9	33.6	20.1	8.70
2	8-14	-	91.3	59.7	34.2	18.5	9.50
3	15-21	-	77.0	53.4	33.6	19.4	7.10
4	22-28	-	89.4	49.7	34.9	22.6	-
5	29-4	-	87.3	51.5	35.4	21.6	-
February 1998							
6	5-11	-	75.9	51.5	35.1	20.6	-
7	12-18	-	83.7	48.8	35.0	21.8	-
8	19-25	-	88.7	58.2	35.4	21.7	-
9	26-4	-	88.6	52.3	35.5	22.4	-
March 1998							
10	5-11	-	92.6	50.6	35.5	22.3	9.8
11	12-18	-	88.1	52.4	35.5	22.4	9.1
12	19-25	-	88.1	53.6	35.5	22.2	-
13	26-1	-	88.0	54.0	36.9	23.0	-
April 1998							
14	01-17	-	81.9	56.0	36.7	25.1	9.23
15	08-14	-	97.7	55.4	36.9	26.0	7.08
16	15-21	5.6	87.7	54.1	36.4	25.6	7.20
17	22-28	30.9	87.6	54.3	36.3	25.1	8.13
May 1998							
18	29-05	19.8	89.6	58.6	36.8	23.7	8.47
19	06-12	10.5	90.4	77.1	36.1	25.2	5.35
20	13-19	55.2	90.0	72.5	34.6	24.5	3.17
21	20-26	-	93.9	66.4	34.6	24.5	7.53
22	27-02	5.0	92.7	62.0	35.0	24.9	8.14
June 1998							
23	03-09	73.3	91.6	79.0	33.9	23.1	5.26
24	10-16	130.2	93.7	79.1	30.4	19.6	2.14
25	17-23	194.8	94.9	91.1	29.7	22.1	2.30
26	24-30	200.6	95.4	91.1	27.5	22.1	-

Appendix 6c Weekly weather data for the period from June 1998 to September 1998 (Virippu Crop)

Std. Week	Dates	Rainfall (mm)	Relative Humidity (%) 07.30 hrs.	Relative Humidity (%) 14.30 hrs.	Temperature (0°C) Max.	Temperature (0°C) Min.	Sunshine (hrs/day)
June 1998							
23	3-9	73.3	91.6	79.0	33.9	23.1	5.26
24	10-16	130.2	93.7	79.1	30.4	19.6	2.14
25	17-23	194.8	94.9	91.1	29.7	22.2	2.30
26	24-30	200.6	95.4	91.1	27.5	22.1	-
July 1998							
27	1-7	178.5	93.4	90.7	23.4	18.9	4.58
28	8-14	277.9	93.7	90.9	28.4	20.9	2.30
29	15-21	135.2	93.1	91.6	29.9	21.8	5.40
30	22-28	116.5	94.9	74.4	28.9	21.8	2.90
August 1998							
31	29-04	125.5	93.7	74.9	25.3	22.4	4.63
32	05-11	88.0	94.3	87.4	25.2	22.3	2.60
33	12-18	54.4	93.1	87.8	28.9	23.7	4.19
34	19-25	140.5	96.4	83.8	29.7	18.3	3.50
35	26-01	14.5	89.9	87.3	30.5	21.0	6.23
September 1998							
36	2-08	30.6	80.0	88.0	32.4	21.0	1.95
37	9-15	32.7	94.2	86.0	30.5	21.0	6.30
38	16-22	21.7	92.5	83.1	30.1	21.7	3.35
39	23-29	20.8	86.3	85.8	28.5	20.8	8.60

Appendix 7a. N content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	1.72	1.72	1.79	1.74^{b}
June 97	1.88	1.84	1.94	1.89^{a}
July 97	1.85	1.82	1.73	1.79^{b}
August 97	1.83	1.89	1.97	1.89^{a}
September 97	1.94	1.88	1.92	1.92^{a}
October 97	2.01	1.82	1.91	1.91^{a}
Mean	1.87^{a}	1.83^{a}	1.87^{a}	

Appendix 7b. P content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	7.84	8.11	7.86	7.93^{b}
June 97	8.54	8.24	9.02	8.60^{a}
July 97	8.56	8.64	8.92	8.71^{a}
August 97	7.66	8.58	8.14	8.12^{b}
September 97	8.67	8.82	8.34	8.61^{a}
October 97	8.72	8.34	9.04	8.69^{a}
Mean	8.33^{a}	8.45^{a}	8.55^{a}	

Appendix 7c. K content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	0.26	0.27	0.29	0.273^{d}
June 97	0.29	0.28	0.28	0.286^{b}
July 97	0.28	0.29	0.28	0.284^{b}
August 97	0.30	0.31	0.29	0.30^{a}
September 97	0.28	0.28	0.27	0.28^{c}
October 97	0.29	0.29	0.26	0.284^{b}
Mean	0.282^{b}	0.288^{a}	0.281^{c}	

Appendix 7d. Ca content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	20.73	20.53	21.13	20.80^{ab}
June 97	19.45	20.40	20.87	20.24^{b}
July 97	19.20	19.50	20.07	19.59^{c}
August 97	20.2	20.13	20.63	20.32^{ab}
September 97	21.2	20.27	21.33	20.93^{a}
October 97	19.7	19.9	21.03	20.21^{b}
Mean	20.08^{b}	20.12^{b}	20.84^{a}	

Appendix 7e. Mg content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	0.42	0.41	0.41	0.42
June 97	0.44	0.42	0.41	0.42
July 97	0.44	0.41	0.42	0.42
August 97	0.41	0.41	0.44	0.42
September 97	0.40	0.44	0.40	0.41
October 97	0.44	0.41	0.44	0.43
Mean	0.42	0.42	0.42	

Appendix 7f. Sulphur content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	0.32	0.36	0.31	0.33
June 97	0.32	0.31	0.35	0.33
July 97	0.40	0.31	0.35	0.35
August 97	0.36	0.31	0.40	0.35
September 97	0.37	0.31	0.35	0.34
October 97	0.36	0.34	0.37	0.35
Mean	0.36	0.32	0.36	

Appendix 7g. Fe content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	1032.3	1157.7	1113.6	1101.0^{e}
June 97	1712.1	1738.2	1708.8	1719.7^{c}
July 97	1897.7	1852.1	1901.8	1882.9^{a}
August 97	1547.5	1566.13	1547.5	1553.7^{d}
September 97	1867.5	1797.5	1825.6	1830.2^{b}
October 97	1817.1	1847.2	1853.2	1839.2^{b}
Mean	1645.2^{a}	1659.8^{a}	1658.3^{a}	

Appendix 7h. Mn content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	108.30	105.63	106.83	106.92^{b}
June 97	106.95	104.63	102.63	104.74^{c}
July 97	107.37	106.53	105.77	106.56^{b}
August 97	110.10	108.43	108.47	109.00^{a}
September 97	105.97	108.17	107.17	107.10^{b}
October 97	106.33	107.02	106.13	106.49^{b}
Mean	107.50^{a}	106.74^{ab}	106.17^{b}	

Appendix 7i. Zn content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	120.47	120.33	120.70	120.50^{d}
June 97	132.73	128.50	125.53	128.92^{a}
July 97	125.47	127.93	129.03	127.48^{ab}
August 97	122.37	124.27	122.80	123.14^{cd}
September 97	124.07	123.90	126.77	124.91^{bc}
October 97	129.37	127.43	128.47	128.42^{a}
Mean	125.74^{a}	125.39^{a}	125.55^{a}	

Appendix 7j. Cu content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	7.74	8.75	7.52	8.00^{b}
June 97	7.99	7.87	8.10	7.99^{b}
July 97	7.94	7.71	8.09	7.91^{b}
August 97	7.63	8.23	8.93	8.26^{a}
September 97	7.57	8.08	7.75	7.79^{b}
October 97	7.61	7.62	8.76	7.99^{b}
Mean	7.75^{b}	8.04^{a}	8.19^{a}	

Appendix 7k. Ni content of KCPL sludge (ppm).

Month of sampling	10th day	20th day	30th day	Mean
May 97	18.29	18.05	17.67	18.00^{a}
June 97	16.88	17.34	17.71	17.31^{b}
July 97	16.44	18.03	17.94	17.47^{ab}
August 97	17.49	17.31	16.99	17.26^{b}
September 97	17.13	16.38	16.46	16.66^{c}
October 97	17.04	17.04	16.89	16.99^{bc}
Mean	17.21^{a}	17.36^{a}	17.27^{a}	

Appendix 7l. Cr content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	12.07	11.55	11.99	11.87^{a}
June 97	11.45	11.97	11.82	11.75^{ab}
July 97	11.10	11.86	11.69	11.55^{b}
August 97	12.02	11.97	11.43	11.81^{ab}
September 97	11.84	11.81	11.95	11.87^{a}
October 97	11.28	11.79	11.75	11.61^{ab}
Mean	11.63^{a}	11.83^{a}	11.77^{a}	

Appendix 7m. Pb content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	11.51	11.11	11.52	11.38^{d}
June 97	13.23	11.95	13.38	12.85^{c}
July 97	14.20	13.79	13.37	13.78^{b}
August 97	14.32	14.03	14.34	14.23^{ab}
September 97	14.24	14.22	14.42	14.29^{ab}
October 97	14.64	14.51	14.30	14.48^{a}
Mean	13.69^{a}	13.27^{a}	13.55^{a}	

Appendix 7n. Cd content of KCPL sludge (ppm)

Month of sampling	10th day	20th day	30th day	Mean
May 97	2.99	3.10	2.97	3.02^{a}
June 97	2.90	2.86	2.97	2.91^{bc}
July 97	3.03	2.77	2.71	2.84^{c}
August 97	3.00	2.95	2.76	2.90^{bc}
September 97	3.10	2.89	2.92	2.97^{ab}
October 97	2.92	3.01	2.84	2.92^{bc}
Mean	2.99^{a}	2.93^{a}	2.86^{b}	

Appendix 7o. Neutralizing value of KCPL sludge

Month of sampling	10th day	20th day	30th day	Mean
May 97	58.07	57.23	57.17	57.49^b
June 97	55.87	54.5	54.93	55.10^c
July 97	56.47	57.7	57.67	57.28^b
August 97	59.47	58.67	57.77	58.63^a
September 97	60.33	59.03	58.43	59.27^a
October 97	59.4	58.5	58.4	58.78^a
Mean	58.27^a	57.61^b	57.39^b	

Appendix7p. Organic carbon content of KCPL sludge (%)

Month of sampling	10th day	20th day	30th day	Mean
May 97	32.01	30.97	31.37	31.45^b
June 97	34.96	33.45	34.58	34.33^a
July 97	34.10	34.04	32.56	33.58^a
August 97	32.11	34.84	33.99	33.64^a
September 97	33.69	35.17	34.17	34.35^a
October 97	33.84	33.29	33.75	33.62^a
Mean	33.45^a	33.63^a	33.40^a	

FORMULATION AND EVALUATION OF ORGANIC MEALS FROM KCPL EFFLUENT SLURRY

By
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ABSTRACT OF A THESIS

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requirement for the degree of

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ABSTRACT

The study on the formulation and evaluation of organic meals from KCPL effluent slurry was conducted at KCPL (Kerala Chemicals and Proteins Ltd.) factory site and at College of Horticulture, Vellanikkara during May, 1997 to December, 1999. Being a new material sequential steps involving the study of the basic properties of KCPL sludge, standardisation of formulation techniques of organic meals, analyzing of physico-chemical properties of the organic meals, direct and residual effect of selected organic meal on crop and soil were conducted during the period.

Drawing composite samples three times every month at 10 days interval for a period of six months from May, 97 to October, 97 the basic properties were evaluated. An incubation study was conducted to understand the availability and release pattern of nutrients. The sludge along with mussorie rock phosphate was incubated for 120 days at three levels of 1g, 2g and 4g P per five kilogram of soil at three moisture regimes 50FC, FC and water logging, drawing samples at 30 days interval for analysis. Various formulation techniques were tried to develop organic meals in a quick and cost effective manner. Organic meals were produced from spent slurry obtained after biomethanation of KCPL sludge. Signaled from an accidental observation principles of activated composting was employed to evolve a cost effective and quick method for preparing organic meals. Exhaustive pot culture and field experiments besides on farm trial in farmers field (Kole lands of Thrissur) were conducted to test the manurial quality and acceptability of the organic meals.

From the basic properties evaluation studies it was confirmed that KCPL sludge is a nutrient rich uniform organic source containing 1.86 % N, 8.44 % P, 20.34 % Ca and appreciable quantities of other major and minor nutrients. The heavy metal contents were below the permissible limit rendering it chemically safe for fertilizing the soil.

Because of its high Ca and neutralizing value it can also be a good soil conditioner. From the incubation study it was found that KCPL sludge was superior to rock phosphate in the release of major nutrients. More over peak release of all nutrients occurred within the 60 days period and it could be successfully used as an organic source both under aerobic and waterlogged situation.

The principle of aerobic composting was standardized as the best formulation technique for the production of organic meals. Good quality composts could be produced within a period of 90 days by the open heap method. Among the compost maturity parameters maximum microbial population were in the thermophilic stage. Temperature (70°c) and pH (8) also attained maximum values at this stage. C/N ratio stabilized around 12.51 after 90 days. There was not much variation in the above characters due to the covering techniques. But the pit system of composting failed to achieve the required level of thermophilic environment for composting

Based on ease in formulation technique and favourable physico-chemical properties the meal No.1 (sludge + 5% neem cake + 5% mussorie rock phosphate + 1% urea) was adjudged superior over the rest of seven formulations. It contains 1.79 % N, 9.05 % P, 0.28 % K, 16.96 % Ca, 0.32 % Mg and 0.36 % S. The Fe, Mn, Zn and Cu content are 883.5, 103.62, 113.3 and 7.71 ppm respectively. pH of this meal is 6.97, organic carbon 22.38 %, C/N ratio 12.51and neutralizing value 71.22.

From the pot culture study it was inferred that organic meals even at higher levels were not harmful to the crop, but lower doses of meal alone will not be able to meet the nutrient demand of the crop.

Field investigations with organic meal showed that it improved the growth and yield of rice crop when used in combination with inorganic fertilizers besides providing the balanced supply of all nutrients as required by the crop. In general there was no significant variation between the different levels of organic meal with respect to either growth or yield components. The highest yield of 5.01t was obtained from OM 20 ¾ NPK. With respect to both growth and yield characters the lowest dose of 5 t/ha was always comparable to the recommended practice of crop nutrition.

Residual study proved that organic meal could serve as a good residual P source. The growth and yield components at the lowest level of OM 5 t/ha was comparable to higher levels even during second successive residual crop. Economic yield of 4.11 t was observed in OM 5 NPK. Moreover soil P status also improved in the successive seasons. Application of P can be skipped for two seasons at higher levels of 10-20 t/ha and this can sustain higher yields.

The on-farm trials also showed that organic meal could be a good organic P source even at very low levels of 1.25 t/ha when used with inorganic fertilizers. The desirable direct as well as residual effects of organic meal were manifested continuously for two seasons even with doses in the range of 1.25 to 5 t/ha of organic meal.