UTILISATION OF DAIRY INDUSTRY SOLID WASTE AS AN ORGANIC SOURCE IN SOIL PRODUCTIVITY

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

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2004

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DECLARATION

I hereby declare that this thesis entitled **"Utilisation of dairy industry solid waste as an organic source in soil productivity"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Dedicated to My
Dear Daughter Riya

ACKNOWLEDGEMENT

I humbly bow my head before God Almighty for all the blessings showered upon me to complete this endeavour successfully.

With deep and heart felt gratitude, I express my sincere indebtedness to Dr. Usha Mathew, Assistant Professor (S.S.), Department of Soil Science and Agricultural Chemistry and Chairman of the advisory committee for her timely help, technical advice, inspiring guidance and encouragement for the successful competition of the research work and preparation of the manuscript.

I wish to express my profound thanks and gratitude to Dr. V.K. Venugopal, Professor and Head of Department of Soil Science and Agricultural Chemistry and member of the advisory committee for his timely suggestions and kind help.

The whole hearted co-operation and constructive suggestions given by my advisory committee members Dr. K. Ushakumari, Assistant Professor (S.S.), Department of Soil Science and Agricultural Chemistry and Dr. K.S. Meenakumari, Assistant Professor (S.S.), Department of Plant Pathology during the research work and preparation of thesis is gratefully remembered.

I express my gratitude towards Dr. Sudharmai Devi, Associate Professor, Dr. Manorama Thampatti, Assistant Professor, Dr. Suman Susan Varghese, Assistant Professor and Dr. Thomas George, Assistant Professor of the Department of Soil Science and Agricultural Chemistry for their timely help and suggestions during the chemical analysis. I am grateful to Dr. Suman George, Dr. P.B. Usha, Dr. Komalamma E., Associate Professors of the Department of Soil Science and Agricultural Chemistry, for the utmost help and encouragement rendered during the study period.

I am grateful to Sri. C.E. Ajithkumar, Junior Programmer of Department of Agricultural Statistics for his generous help in the statistical analysis of the data.

My heartiest thanks to all my friends Simi, Sheeba, Neenu, Sekhar, Rekha, Devi and Jyotsna who had sincerely helped me in my work. I am also thankful to Devi chechi, Aparna chechi, Beena chechi, Vineetha, Sunu, Bini, Dhanya, Sreeja and Rini for the help and encouragement rendered during the study period.

I acknowledge all the non teaching staff of the Department of Soil Science and Agricultural Chemistry and casual labourer Sivarajan for the help rendered during my research work.

I am thankful to Jayakumar for his co-operation in taking photographs.

I sincerely acknowledge KAU for the award of Junior Fellowship granted to me.

I am thankful to the Director, CTCRI for permitting me to collect literature.

Thanks to the Director, TRCMPU Ltd., Ambalathara for the co-operation rendered during the study period.

I thank Biju for completing the DTP work in time.

I am thankful to Rosamma, Vikraman Nair and family and Rajan and family for their co-operation and help rendered during my studies.

Personally I thank my husband Biju for his constant encouragement, abundant love and patience that helped me a lot.

Thanks to my daughter, Riya for adjusting with me during my studies.

I am also thankful to my parents and in laws for their moral support.

Finally I thank all those who had directly and indirectly helped me in this venture.

Indu. B.
2001-11-28

CONTENTS

LIST OF ABBREVIATIONS

%	–	Per cent
µg	–	Micro gram
µS	–	Micro seimens
μSm^{-1}	–	Micro siemens per metre
@	–	At the rate of
B:C ratio	–	Benefit – cost ratio
CD	–	Critical difference
cdsw	–	Composted dairy industry solid waste
CEC	–	Cation exchange capacity
cm	–	Centimetre
cmole	–	Centimole
CRD	–	Completely randomised design
cv.	–	Cultivar
dsw	–	Dairy industry solid waste
EC	–	Electrical conductivity
et al.	–	And others
Fig.	–	Figure
fym	–	Farmyard manure
g	–	Gram
g pot^{-1}	–	Gram per pot
ha^{-1}	–	Per hectare
KAU	–	Kerala Agricultural University
kg	–	Kilogram
mg	–	Milligram
Mg m^{-3}	–	Mega gram per cubic metre
mg pot^{-}	–	Milligram per pot
mS cm^{-1}	–	Milli siemens per centimetre
NS	–	Non significant
POP	–	Package of Practices
SE	–	Standard error
t	–	Tonnes
TRCMPU	–	Thiruvananthapuram Regional Co-operative Milk Producing Unit
viz.	–	Namely

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INTRODUCTION

1. INTRODUCTION

Widespread industrial activities and mismanagement of resources have resulted in the uncontrolled dumping of wastes which often lead to pollution of ecosystem. But often wastes from different sources hold a promise for the supply of organic matter and plant nutrients. The idea of conservation and utilization of native agricultural and industrial waste resources which may otherwise cause environmental pollution is gaining momentum in the present day agriculture. Biowastes and wastes from industries have agronomic utility either alone or in combination with fertilizers as sources of nutrients. Recycling of wastes regularly will result in considerable improvement in human health and sanitation, crop yields and soil health. Organic wastes can be converted to good quality organic manure by efficient, economically viable, environmentally sound and socially acceptable processes. Microbes and earthworms play a special role in decomposition of wastes. If waste becomes a resource it is like 'getting gold from garbage and silver from sewage'. Hence recycling of wastes is essential for sustaining agricultural production to meet the needs of growing population without harming the soil resource base.

Technological growth has enhanced accumulation of wastes and its disposal has assumed serious dimensions. Different methods of waste management are land filling, incineration, aerobic digestion, composting etc. Water pollution resulting from the discharge of waste water into surface water, air pollution caused by the incineration of wastes and the scarcity of suitable sites for land fill operations have prompted the search for alternative means of waste disposal. Moreover the ever increasing price of chemical fertilizers and also the concern for efficient utilization of natural resources have generated greater interest in the search of alternatives. Urban and industrial organic wastes and their processed products, judged from their nutritional and organic composition, have many beneficial uses, but there are certain constraints in their use in agriculture. These constraints are the presence of heavy metals, toxic organic compounds, pathogens and eutrophication. Composting is one of the methods for minimizing the impact of toxic compounds and pathogens. Composting is an ecofriendly and cost effective method in recycling.

All the available organic materials can be converted into value added organic manure by adopting suitable biodegradation process. The róle of earthworms as biological agent in the degradation of organic waste is already recognized. Pretreated solid and urban wastes, dairy wastes, wastes from distilleries, hatcheries, sewage sludge, agricultural wastes etc. can be effectively managed by vermiculture biotechnology (Kale *et al.*, 1982). Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites which are found to influence the yield and quality of diverse crops. Application of vermicompost not only adds plant nutrients but also increase soil water retention, microbial population and organic carbon content of soil.

Dairy industry is one of the major industries which generates large volume of liquid waste with very high organic load. Biological oxidation of the liquid waste discharges a sludge which is hard when dry. The source of organics in the wastes are derived from spills, leaks and washings in various operations of dairy industry. It contains suspended solids, nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc and sodium in different quantities. There were no heavy metals like nickel, chromium, copper, cadmium and lead in the effluent. The dry solid waste output is 1000 kg per month in a dairy unit where the daily milk input is 1.5 lakh litres. Even if the quantum output of wastes on dry basis is low, unless it is recycled and reused, in course of time it will accumulate as a pollutant. As a waste management strategy, studies on the feasibility of using dairy industry waste in crop production assumes importance.

In the light of recent literature on the use of dairy sludge on the productive capacity of soil, the present investigation was carried out at College of Agriculture, Vellayani. The main objectives of the study were

1. To characterize the physico-chemical and microbiological properties of dairy industry solid waste.
2. To monitor the changes in physico-chemical and microbiological properties of soil treated with dairy industry solid waste under aerobic conditions.
3. To study the extent of partial substitution of fym and fertilizer nitrogen using composted dairy solid waste in the test crop amaranthus.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rapid population growth accompanied by industrialization and urbanization gave birth to large amount of wastes. Conservation and utilization of native agricultural and industrial waste resources, which may otherwise cause environmental pollution is the prime need of the present day agriculture of our country. Reutilisation of waste through recycling become essential for environmental safety, economic stability and ecological sustainability. Different methods of waste management include landfill, incineration, aerobic digestion, composting etc. Among the various methods, composting is more eco-friendly and more important method of recycling in improving soil productivity. Microbes and earthworms play a special role in composting process.

Industries are the major consumers of earth's natural resources and also the biggest contributor to the pollution of air and water and piling of solid wastes in the land. The effluents of many industries contain essential nutrients or have properties, which can be used to increase the productivity of soils, if proper treatments to these wastes are provided and proper eco-friendly technology is adopted for their management in agricultural land. Dairy industry is one of the major developing industries in India, which generates large volume of liquid waste rich in organic load and many plant nutrients at different concentration. Many studies have dealt with the effect of different agricultural and industrial wastes on soils and crops, but only very few reports are available on the influence of dairy sludge on the productive capacity of soil. Hence the available literature on utilization of different agricultural and industrial wastes for the improvement of soil productivity is reviewed here.

2.1 UTILIZATION OF AGRICULTURAL AND INDUSTRIAL WASTES IN IMPROVING SOIL PRODUCTIVITY

Industrial organic wastes could be used safely and effectively with proper precaution to increase soil productivity. Application of industrial waste material improved physical and chemical properties of soil (Larson *et al.*, 1975; Ravikumar and Krishnamoorthy, 1980).

Effluents from the sugar factory, fertilizer factory and paper industry are rich in plant nutrients and can be applied to soil after proper treatment (Sivaramakrishnan, *et al.*, 1983).

Kumaresan, *et al.* (1984) reported that various agricultural and industrial wastes like groundnut shell, rice husk and water hyacinth had significant effect on yield of groundnut and availability of N, P and K in soil.

Several studies have reported the enhanced nutrient uptake by crops grown in pressmud treated soils. Increased uptake of N, P and K by greengram grown in pressmud treated soil was observed by Borde *et al.* (1984).

Myhre *et al.* (1990) reported that application of phosphogypsum, a byproduct obtained during production of phosphoric acid by the wet process to citrus increased juice and calcium content of citrus fruits.

Krishnamurthi *et al.* (1994) reported that the dairy effluent can be used for growing vegetables and forage crops. The various elements present in the effluent were within the standard limits recommended for crop production and there was no heavy metals like cadmium, nickel, chromium, copper and lead in the effluent.

An increased plant height and dry matter production was reported in rice following the application of partially decomposed coirpith in sandy clay loam soils (Thilagavathi and Mathen, 1995).

Rathinasamy and Narasimhan (1998) reported that increased yields were obtained when sugar factory effluent was used for irrigating bhendi with proper dilution.

Distillery effluent irrigation increased seed yield and quality of groundnut (Singh *et al.*, 2003).

Diluted rubber factory effluent favoured seedling growth in *Vigna radiatus*. Length of root system, shoot system and number of lateral roots were increased by low concentration of effluent (Augusthy and Mani, 2001).

Singh *et al.* (2001) reported that irrigation with textile industrial water resulted in increase in EC and percentage organic matter in soil. Tree species like *Acacia spp., Albizea lebbock, Azadirachta indica* etc. can be established successfully using textile industrial waste water.

Organicmeals, a value added manure prepared from KCPL (Kerala Chemicals and Proteins Ltd.) effluent slurry, when used in combination with inorganic fertilizers improved the growth and yield of rice crop. (Thomas and Gopinathan, 2001).

Jothimani *et al.* (2002) reported that at lower concentrations the dyeing factory effluent favoured the seed germination and growth of seedlings of maize and cowpea.

Sugarcane plant gave better results when irrigated with treated wastewater of oil refinery (Ahmad *et al.*, 2003).

Addition of distillery and paper mill effluents to the soil significantly increased the growth and yield of rice (Chatterjee *et al.*, 2003).

2.2 PHYSICOCHEMICAL AND BIOLOGICAL CHARACTERISTICS OF BIODEGRADABLE WASTES

Devarajan *et al.* (1994) reported that the treated distillery effluent was fairly high in nitrogen (1800 ppm), phosphorus (420 ppm), potassium (11,500 ppm), Calcium (1,050 ppm), magnesium (2,200 ppm) and sulphate (2,440 ppm). It also contained appreciable amounts of micronutrients viz. zinc (8 ppm), Mn (5 ppm), Fe (85 ppm) and Cu (6 ppm). It was neutral to alkaline in pH (7.6) and dark brown in colour with a BOD of 5000 ppm.

Krishnamurthi *et al.* (1994) reported that the dairy effluent contained high amounts of total suspended solids. It contained chlorides, sulphates, ammoniacal nitrogen, calcium, magnesium, iron, zinc, potassium and sodium. There was no heavy metals like nickel, chromium, copper, cadmium and lead. The effluent was alkaline in pH.

Sayed (1997) reported that dairy effluent contained 2010 mg l^{-1} total solids of which 1360 mg l^{-1} was dissolved and 650 mg l^{-1} was suspended solids.

Pressmud, an organic waste material from sugar industries contained about 33 per cent organic carbon, 0.8 per cent nitrogen, 2 per cent phosphorus, 1.1 per cent potassium, 4.45 per cent calcium, 1.12 per cent magnesium, 3100 ppm iron, 80 ppm copper, 150 ppm zinc and 80 ppm manganese with a C: N ratio of 41:1 (Palaniappan and Annadurai, 1999).

Physico chemical and biological properties of dyeing factory effluent revealed that it was alkaline in pH with TSS of 3500 mg l^{-1}. It contained total N (49 mg l^{-1}), total P (17 mg l^{-1}), calcium (240 mg l^{-1}), magnesium 73 (mg l-1), sodium, potassium, chlorides and sulphates. It contained 56 x 10^6 mg^{-1} bacteria, 14.5 x 10^3 mg^{-1} fungi and 2.5 x 10^4 ml^{-1} (Jothimani *et al.*, 2002).

Sewage biosolids contained nitrogen (3.62%), phosphorus (1.46%), potassium (2.53%), zinc (2360 mg kg^{-1}), iron (39220 mg kg^{-1}), manganese (1780 mg kg^{-1}), copper (2680 mg kg^{-1}), lead (5720 mg kg^{-1}), cadmium (932 mg kg^{-1}), chromium (2740 mg kg^{-1} and nickel (3460 mg kg^{-1}) (Chitdeswari *et al.*, 2002).

Patil and Chaudhari (2002) reported that spent wash contained organic matter (7.45%), nitrogen (336 mgl^{-1}), phosphorus (500 mgl^{-1}) potassium (9300 mgl^{-1}), calcium, magnesium, iron, manganese, zinc and copper.

N, P, K and Na content of paper mill effluent were 50, 1.5, 74 and 546 mg l^{-1}respectively. BOD of the effluent was 68 mg l^{-1} (Chatterjee *et al.*, 2003).

2.3 COMPOSTING AS A TOOL FOR DEGRADING BIOWASTES

Kale *et al.* (1982) reported that the earthworm species *Perionyx excavatus, Eudrillus eugeniae* and *Eisenia foetida* could degrade organic wastes and convert into nutrient rich manure.

Bano *et al.* (1987) suggested that earthworms can be successfully employed in biodegradation and found that wormcast produced by *Eudrillus eugeniae* can replace composts and to some extent the costly chemical fertilizers.

Tomati *et al.* (1985) discussed the feasibility of vermiculture as an economic option in organic waste recovery for agricultural purposes, with particular emphasis on sludge and solid urban wastes. They found that earthworms could consume all the organic wastes and reduce their volume by 40 – 60 per cent. As a result castings with a high fertility value could be produced.

Kavian *et al.* (1991) reported that effective bio management of dairy effluent could be done using cultures of red earthworms *Lumbricus rubellus.*

Utilizing earthworm *Eudrillus eugeniae* vegetable garbage can be successfully converted to nutrient rich organic manure (Zachariah, 1995).

Gunathilagraj and Ravigranam (1996) reported that sericulture wastes could be converted into nutrient rich vermicompost using *Perionyx excavatus.* The earthworms feed actively on semi decomposed sericultural wastes and produced wormcasts in a short span of 4 – 5 weeks. The vermicompost was rich in plant nutrients containing 1.9 per cent N, 0.6 per cent P_2O_5 and 1 per cent K_2O besides various micronutrients like, Zn, Fe and Cu. (Das *et al.*, 1996).

Kavian *et al.* (1996) reported that using a culture of red American earthworm *Lumbricus rubellus* bio management of paper mill sludge can be successfully carried out.

Fresh tea waste could be converted into vermicompost in five months time. *Eisenia foetide* was found to be the better species than other local specie of earthworms (Haridas, 1996).

Singh and Rai (1996) found that *Eudrillus eugeniae* was good for vermicomposting garbage, especially kitchen waste mixed with cattle dung.

Suharban *et al.* (1997) reported the biodegradation of coirpith using oyster mushroom *Pleurotus sajor-çaju.*

Coirpith can be converted into value added bio fertilizers using *Lumbricus rubellus* (Kavian, *et al.*, 1998).

Vermicomposting is an effective technique for recycling of animal wastes, crop residues and agro industrial wastes using low energy. (Kale, 1998).

Anand *et al.*(1998) reported that coirpith can be made more responsive to the attack of *Pleurotus* by using coirpith treated with lime @ 5 kg t^{-1} and by using amendments such as rock phosphate @ 20 kg t^{-1} and organic additives such as cowdung and garden weeds @ 100 kg t^{-1}.

Ramaswami (1999) reported that by mixing pressmud and distillery effluent in the ratio 1: 2.5 a humus rich organic manure, bio-compost can be prepared. Enrichment of bio-compost with rock phosphate, $FeSO_4$, $ZnSO_4$ and bio fertilizers improved the nutritive value of bio-compost.

Enriched coir dust based compost was prepared with organic additives like Cowdung, garden weeds, green manure (sun hump) and inorganic additives like rock phosphate and micronutrients along with fungal inoculum *Pleurotus sajor-caju* (Kadalli *et al.,* 2000).

Saha and Hajra (2001) prepared phosphonitroso compost using rock phosphate, water hyacinth, poultry manure, dung slurry, iron pyrite and urea along with microbial cultures.

Banu *et al.* (2001) reported that *Eisenia foetida* proved to be the best worm for bio-management of paper mill sludge.

Gajalakshmi *et al.* (2001) reported that water hyacinth can be suitably vermicomposted with *Eudrillus. eugeniae.*

Sewage bio-solid compost was prepared by mixing sewage sludge with coir pith and green leaf manure (*Glyricidia* sp.) at 2: 1 ratio and composted for 75 days (Chitdeswari *et al.*, 2002).

Sugarcane trash can be efficiently composted by adopting bioconversion technology in which the chopped pieces of trash treated with *Pleurotus sajor-caju* and *Trichoderma* (Talashilkar *et al.*, 2002).

Good quality manure was obtained from sugar factory wastes by composting pressmud with flyash and fym. Enrichment of compost was done with biofertilizers like *Azospirillum* and *Azotobactor* (Krishnamurthy, 2002).

A low cost composting technique for large-scale vermicomposting of coconut wastes was standardized at Central Plantation Crops Research Institute, Kasaragod, using a local species of epigamic earthworm belongs to *Eudrillus* sp. which is very efficient in degrading the lignin rich biomass (Thomas *et al.*, 2003).

2.4 EFFECT OF COMPOSTING ON PHYSIOCHEMICAL AND MICROBIOLOGICAL PROPERTIES OF BIOWASTE

Ponomareva (1953) found an increase in the number of actinomycetes, pigmented bacteria and other bacteria of *Bacillus cereus* group, after passage through the earthworm intestine. The number of bacteria in the earthworm faeces was observed to be 13 times higher than that in the surrounding soil.

Vermicompost contains significant quantities of available nutrients, a large beneficial microbial population and biologically active metabolites particularly gibberellins, cytokines, auxins and vitamins (Bano *et al.*, 1987).

Das (1988) found that composting of plant rich garbage showed increase in humic acid content and CEC. He recorded the CEC of 70 meq $100g^{-1}$, C: N ratio of 13 and nitrogen content of more than two per cent in composted material.

Harinikumar *et al.* (1991) found that mycorrhizal propagules in earthworm cast varied from 2 – 54 per cent per gram.

Vermicomposting experiment was conducted at CPCRI, vital, using cocoa leaves, cocoa pod husk and areca leaves. *Eudrillus eugeniae* was used for composing. Organic carbon content decreased from 47 to 24.4 in cocoa leaves and from 44.2 to 23.1 in areca leaves, C: N ratio also considerably decreased N, P, K, Cu, Mn, Fe and Zn content increased during vermicomposting (Bopaiah *et al.*, 1996).

Sunitha and Varghese (1996) reported that oil palm wastes can be vermicomposted. C: N ratio decreased to 20: 1 from 60: 1 during vermicomposting. Nutrient content of waste increased through vermicomposting.

Ushakumari *et al.* (1996) reported that vermicompost produced from banana waste and cattle manure in the ratio 8:1 had an average of 1.4, 0.4 and 1.8 per cent NPK respectively.

Das *et al.* (1996) found that vermicompost obtained from sericultural farm wastes was rich in micronutrients like Fe, Zn and Cu.

Indira *et al.* (1996) reported that population of beneficial organisms like phosphorus solubilizing bacteria, nitrogen fixing organism and entomophagus fungi were in the range of 10^5 to 10^6 in vermicompost. Amongst the phosphorus solubilising organisms, species belonging to *Bacillus* and *Aspergillus* genus were prominent. While species belonging to *Azotobacter, Azospirillum* and *Rhizobium* were prominent in the nitrogen fixing organism group.

Earthworm casts of *Eudrillus eugeniae* were rich in rock phosphate solubilizing microbes and had high rockphosphate solubilizing capacity (Mba, 1997).

Nair (1999) reported that total number of bacteria, fungi and actiomycetes in vermicompost were more towards latter half of the composting process. Number of bacteria, fungi and actinomycetes isolated from vermicompost produced by *Eudrillus eugeniae* were to the extent of 11.9×10^6 (on 30 day), 11.2×10^4 (on 45 day) and 49.7×10^4 (on 60 day) respectively. The number of nitrogen fixing bacteria (8.9×10^3) was more on 30 day. The number of phosphate solubilizing bacteria (3.1×10^6) was maximum on 15 days of composting.

Vermicompost prepared using *Eisenia foetida* increased N, P and K content of paper mill sludge (Banu *et al.*, 2001).

Vermicomposting of coirpith using a local earthworm *Eudrillus* spp yielded a granular vermicompost with 1.2 per cent nitrogen and a C: N ratio of 6.7.1 in two months (Prabhu and Thomas, 2002).

Bhat (2003) reported that vermicomposting can be successfully done in arecanut and cocoa wastes using earthworm viz. *Eisenea foetida* and *Eudrillus eugeniae.* The average nutrient composition of the vermicompost recovered was N (1.38%), P (0.35%), K (0.98%), organic carbon (33.1%), C:N ratio (23.98) and many micronutrients in arecanut and N (1.65%), P (0.19%), K (0.32%), organic carbon (24.4%), C: N ratio (14.78) and many of the micronutrients in cocoa. Number of bacteria and fungi in vermicompost produced from arecanut was 24 – 30 millions each per gram of sample. Bacteria and fungi in cocoa samples accounted for 17 and 6 millions per gram of sample respectively. Actinomycetes and P solubilizers were also high in vermicompost samples.

2.5. EFFECT OF BIOWASTES AND COMPOSTS ON SOIL PROPERTIES

2.5.1 Physical Properties

Application of 10 – 15 t ha^{-1} rice husk to an alkali soil having low water permeability brought about significant increase in its infiltration rate (Khosla, 1976).

Khaleel *et al.*, (1981) observed increased water retention when organic wastes such as animal manure, municipal wastes and sewage sludge were added to soil.

Fresh crop residues have been found to bring about more favourable physical improvements in soil than composted materials. Incorporation of rice straw and sorghum stalks in a degraded soil had significantly better effect on soil aggregation than when these materials were added after being composted for three months (Kaurav and Verma, 1982).

Lei-Wang *et al.* (1984) reported that when mushroom spent compost was applied to a fine sandy loam soil at varying doses, the bulk density decreased proportionately as the dose increased.

Sewage application of decreased bulkdensity and hydraulic conductivity of soil. It also improved the aggregate stability, capillary porosity and total porosity of soil (Nair, 1987).

Hernado *et al.* (1989) reported that addition of municipal refuse compost improved soil structure and water holding capacity of soil

Application of wheat straw to rice and rice straw to wheat for four years brought about significant improvement in bulkdensity and water holding capacity of a sandy loam soil (Sidhu and Beri, 1989).

Piccolo and Mbagwa (1990) observed that city refuse compost when applied exerted a positive influence on some soil physical properties such as porosity, aggregate stability, water holding capacity and bulkdensity.

Badanur *et al.* (1990) from their study concluded that incorporation of sorghum stubbles and safflower stalks significantly raised the infiltration rate over the fertilizer treatment.

Loganathan (1990) reported that application of organic amendments viz. saw dust, groundnut shell powder, coir dust and fym improved the soil physical characteristics like infiltration rate, total porosity and hydraulic conductivity of red soil.

Bhagat and Verma (1991) showed that fym and rice straw incorporation resulted in higher porosity.

Pagleai and Antsari (1993) reported increased porosity in the topsoil by the addition of organic wastes like livestock effluents and composts from sewage sludge and urban refuse.

Vijayalakshmi (1993) reported that soil physical properties such as porosity, soil aggregation, soil transmission, conductivity and dispersive power of worm cast fertilized soil were improved when compared with no worm cast amended soil.

More (1994) noticed decreased bulk density of a sodic vertisol upon addition of farm wastes and organic manures.

Sarawad *et al.* (1996) reported that physical properties of vertisol was improved with vermicompost application.

Application of vermicompost had considerable effect on soil structural indices such as mean weight diameter and percentage stable aggregates. Water holding capacity, hydraulic conductivity and infiltration rate increased with vermicompost application (Rajalekshmi, 1996).

Application for vermicompost increased soil porosity, water stable aggregates, water holding capacity, infiltration rate and hydraulic conductivity and decreased bulkdensity of soil (Reddy and Reddy, 1997).

Bano (1997) reported that due to the granular nature of vermicompost, it improved the texture of clayey soils, with improved percolation and aeration. In sandy soils it aided in retaining the moisture level of soils.

Logamadevi (1997) reported that application of coirpith to soil reduced bulk density and increased water holding capacity of soil.

Gupta *et al.* (2000) reported that fym and crop residue incorporation resulted in decreased bulkdensity and increased water holding capacity of soil.

Long term paper mill sludge application increased soil aggregation and moisture holding properties of soil (Zibilske *et al.*, 2000).

Urban organic refuse application to soil increased soil structure and soil aggregation (Carvaca *et al.*, 2001).

Application of dairy factory effluent increased soil pH and unsaturated hydraulic conductivity (Sparling *et al.*, 2001).

Sewage irrigation at 7.5 cm ha^{-1} reduced bulk density and increased hydraulic conductivity and pore space of soil (Bhatia *et al.*, 2001).

Long-term addition of lantana residue in rice field increased water stable aggregates, total porosity and reduced bulk density of soil (Bhagat *et al.*, 2003).

2.5.2 Soil Fertility

The key role of earthworms in improving soil fertility is known since long (Darwin, 1881).

Terman *et al.* (1973) reported that urban waste compost improved the productivity of agricultural land.

Gaur and Mukherjee (1979) reported that wheat straw applied at 5 t ha^{-1} significantly increased pod yield of groundnut.

Khan *et al.* (1981) reported that city compost raised the Zn and Fe content of plants from deficiency to sufficiency level.

Addition of *Ipomoea cornea* to soil at the rate of 10 t ha^{-1} a week before transplanting of rice contributed 40 kg N ha^{-1} to the rice crop (Mirza *et al.*, 1982).

Earthworm casts have been reported to contain more soil exchangeable cations (Lal and Akinene, 1983.).

Gallardo-Lara and Nogales (1987) reported that domestic composts are valuable liming material for acid soils due to their high content of calcium and provide organic phosphorus and large quantities of organic matter.

Marchesini *et al.* (1988) reported that city refuse compost improved the humus content, pH, buffering capacity and CEC of soil.

Badanur *et al.* (1990) reported that incorporation of sorghum stubbles and safflower stalks increased the available N content of a vertisol.

Sulphitation presumud increased electrical .conductivity of clay loam soil (Yaduvanshi and Yadav, 1990).

Dhillon and Dhillon (1991) obtained significant increase in wheat yield and contents of available P and K of soil due to incorporation of groundnut residue.

Connel *et al.* (1993) found that the composted municipal solid waste application in soil increased the available N content.

More (1994) reported that addition of farm wastes and organic manures increased the status of organic carbon, available nitrogen, phosphorus and potassium of soil.

Application of organic manure in the form of vermicompost in soil increased the availability of N, P, K, Ca and Mg in soil (Rajalekshmi, 1996).

Bijulal (1997) reported that vermicompost influenced almost all electro chemical properties of soil significantly compared to other organic manures. Available N, P, K, Ca and Mg increased in soil when vermicompost was applied to soil.

Bano (1997) reported that vermicompost application raised pH of acidic soils. It also improved nitrate and phosphate levels in soils.

Sewage irrigation @ 75 cm ha^{-1} increased N, P, K and organic carbon content of soil (Bhatia *et al.*, 2001).

Sharma (2001) reported that incorporation of wheat residue resulted in an increase in organic carbon, total N, available P and available K content of soil.

Application of dairy factory effluent increased organic carbon, N and P status of soil (Sparling *et al.*, 2001).

Spent wash irrigation increased organic matter content and electrical conductivity of soil (Sukanya *et al.*, 2002).

Treated sewage irrigated soils showed relatively low pH and EC but higher organic carbon, available nitrogen, phosphorus, potassium and magnesium in comparison to tube well irrigated soils (Tiwari *et al.*, 2003).

Irrigation with treated paper mill effluent had increased the soil pH, EC, organic carbon, available N, P, K, exchangeable Na, Ca and K. (Udayasoorian and Prabhu, 2003).

2.5.3. Soil Biology

Soil biological component is favourably influenced by the addition of composts (Gaur and Prasad, 1970).

Compost contains very large population of bacteria, actinomycetes and fungi and stimulate those already present in the soil. The application of organics help microorganism to produce polysaccharides, which build up better soil structure. Nitrogen fixation and phosphorus solubilization are also increased due to improved microbiological activity (Balasubramaniam *et al.*, 1972).

Vermicompost application enhanced the activity of selected microbes in the soil system. The count of nitrogen fixers were about 3.48×10^3 per gram of soil in treated plot, while it was only 2.16×10^3 per gram in control plots (Prasad and Singhania, 1989)

Significant increase in soil microbial numbers has been reported even when crop residues are used as surface mulch (Singh, 1991).

After the crop residues are incorporated into the soil, a lot of heterotrophic microorganisms bring about mineralization of carbon and other elements contained in the residue. This is accompanied by a large increase in soil microbial populations and evolution of CO_2 from the residue treated soil (Sedha *et al.*, 1991).

Kale *et al.* (1982) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in nitrogen fixation and phosphate solubilization leading to higher nutrient uptake by plants.

Rapid increase in microbial biomass following incorporation of cereal and legume residues was reported by Goyal *et al.* (1994).

Incorporation of residues of *Lantana camara, Ipomoea cornea*, water hyacinth, Karanj leaves (*Pongamia glabra*), subabul leaves, lentil straw, maize stover and rice straw in acid clay loam soil significantly increased the population of aerobic, non symbiotic, nitrogen fixing, phosphate solubilizing and sulphur oxidizing microorganisms (Lal *et al.*, 2000).

Vermicompost and fym application increased the growth of microbial population and improved the rate of mineralization of nutrients (Tiwari *et al.*, 2000).

Addition of municipal solid waste compost increased the microbial biomass and soil respiration (Bhattacharya *et al.*, 2001).

Sewage irrigation at7.5 cm ha^{-1} increased bacterial and fungal population in soil resulting in higher microbial activity (Bhatia *et al.*, 2001).

Sparling *et al.* (2001) reported that application of dairy factory effluent increased soil microbial population.

Application of urban organic waste compost increased microbial activity in soil (Ros *et al.*, 2003).

2.6 EFFECT OF COMPOST ON CROPS

2.6.1 Growth and Yield

Pain (1961) reported that compost prepared from mulberry leaves was as efficient as cattle manure in increasing the yield of mulberry leaves.

Lei-Wang *et al.* (1984) reported that yield of cucumber and soyabean increased as the rate of mushroom spent compost increased.

In watermelon, vigorous growth and increased number of flowers are observed when treated with vermicompost (Ismail *et al.*, 1991).

Shuxin *et al.* (1991) observed 30 to 50 per cent increase in plant growth and nitrogen uptake and 10 per cent increase in height and effective tillering of sugarcane when vermicompost was applied.

Vadiraj *et al.* (1992) observed significant increase in height, number of roots per plant, length of root, fresh and dry weight of cardamom seedlings when vermicompost was used as potting mixture.

Gowda *et al.* (1992) studied the effect of municipal waste compost with or without recommended dose of fertilizers on the grain and straw yield of finger millet crop. The combined application of mineral fertilizers and municipal waste compost was found to be more efficient than the use of fertilizer alone.

Ismail *et al.* (1993) conducted a comparative evaluation of vermicompost, fym and fertilizers on yields of bhindi and watermelon and observed an increase in yield in all cases with vermicompost.

More (1994) suggested that the treatment fym and pressmud was the best for increasing yields of rice and wheat grown on sodic vertisol.

In turmeric also the effect of vermicompost was pronounced. The varieties Armour and surome when treated with vermicompost had 30 per cent increase in plant height and 70 per cent increase in leaf area over the control (Vadiraj *et al.*, 1996).

In rice, grain yields were significantly high in the treatments applied with vermicompost prepared from sugarcane trash, ipomoea, parthenium, neem leave, banana peduncles and NPK at recommended levels than in the treatments with NPK alone (Vasanthi and Kumaraswamy, 1996).

Chilli yield was increased by 12 per cent by application of vermicompost over Package of Practices Recommendation with fym and inorganic fertilizer (Rajalekshmi, 1996).

Mean fruit weight and girth of tomato fruits were significantly increased by vermicompost application (Pushpa, 1996).

Vermicompost along with Package of Practices Recommendation of inorganic fertilizers increased yield by 21.2 per cent and 16 per cent in bitter gourd and cowpea respectively (Jiji *et al.*, 1996).

Composted coirpith increased the yield and crude protein content in soyabean and cowpea (Logamadevi, 1997).

Suharban *et al.* (1997) in a pot culture experiment with bhindi reported that the treatment with coirpith compost gave maximum yield.

Vermicompost prepared using sugarcane trash and coirpith increased growth attributes like plant height, root length, dry matter production and yield in soyabean (Thanunathan and Arulmurugan, 1997).

In some of the field experiments conducted with rice, grass, maize sugarcane, pulses, groundnut etc. coirpith compost added plots recorded 10 to 30 per cent higher yield than inorganic fertilizers alone (Ramaswami, 1999).

Application of vermicompost showed significant positive effect on yield and dry matter production in green gram (Rajkhowa *et al.*, 2000).

Sewage biosolid compost application enhanced the green biomass yield of amaranthus and the highest yield was observed with compost of sewage biosolid plus coirpith. Increasing levels of sewage biosolid addition increased the yield of amaranthus (Chitdeswari *et al.*, 2002).

Vermicompost prepared using banana leaves and pseudostem enriched with rock phosphate increased yield and quality of cowpea (Sailajakumari and Ushakumari, 2002).

Vermicompost application increased growth and yield of paddy (Thangavel *et al.*, 2003).

When poultry droppings composted with plant materials were used in wheat field increased grain yield was obtained (Toppo *et al.*, 2003).

2.6.2 Crop Quality

Tomati *et al.* (1990) reported that incorporation of vermicompost increased the protein synthesis in lettuce and radish by 24 and 32 per cent respectively.

Sabrah *et al.* (1995) reported the beneficial effect of town refuse compost in enhancing protein content of maize.

Pushpa (1996) reported that protein and carbohydrate content of tomato fruits were more due to application of vermicompost than fym.

Organic manures like fym, compost, oil cakes, green leaf, poultry manure etc. improved the quality of vegetables. Increase in ascorbic acid content of tomato, pyruvic acid in onion and minerals in gourds were reported due to application of organic manures to vegetable crops (Rani *et al.*, 1997).

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

Joseph (1998) reported that when vermicompost was used as source of nutrients in snake gourd, it produced fruits with more shelf life and content of phosphorus and potassium over fym and poultry manure.

Starch content of sweet potato tuber was maximum when vermicompost was applied on N equivalent basis (Sureshkumar, 1998).

Use of vermicompost in amaranthus resulted in high content of vitamin C and protein and low content fibre (Arunkumar, 2000).

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

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

2.7 EFFECT OF COMPOSTS ON NUTRIENT ECONOMY

Phospho compost application increased the phosphorus use efficiency of green gram (12.9%) and wheat (20.48%) over single super phosphate (Mishra *et al.*, 1982).

Sarawad *et al.* (1996) reported that application of one tonne of vermicompost could substitute 25 to 50 per cent recommended dose of fertilizers.

Yield of radish, spinach and green peas were better with 50 per cent dose of NPK through chemical fertilizers and the rest through vermicompost (Jambhakar, 1996).

Seed coating with vermicompost in cowpea along with half recommended N produced 30 per cent increase in yield over Package of Practices Recommendations. Quantity of fertilizer can be reduced to half when vermicompost was used as seed inoculant (Meera, 1998).

By using vermicompost as organic manure in sweet potato, it is possible to bring down the use of chemical fertilizers. Vermicompost with ½ or ¾of recommended NPK produced highest yield (Sureshkumr, 1998).

Phosphorus recommendation for cowpea can be reduced to half by priming vermicompost with rock phosphate (Sailajakumari, 1999).

Mohanty and Sharma (2000) reported that use of locally available organic materials such as chopped straw, fym, water hyacinth compost, azolla and green manure *in situ* with sunhemp and daincha can substitute N fertilizer up to 50 per cent of total crop requirement in rice-rice cropping system in the acid laterite soils.

Application of enriched coir dust based compost @10 t ha-1 saved 50 per cent recommended NPK fertilizers for maize crop (Kadalli *et al.*, 2000).

Phosphocompost application to groundnut @ 2.5 t ha^{-1} saved 50 per cent recommended NPK fertilizers (Saha and Hajra, 2001).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Utilization of dairy industry solid waste as an organic source in soil productivity" was carried out at College of Agriculture, Vellayani during 2002 – 2004. The experiment consisted of four parts.

3.1 Characterization of dairy industry solid waste.

3.2 Vermicomposting of dairy industry solid waste (dsw).

3.3 Incubation study to monitor the changes in physicochemical and microbiological properties of soil treated with dsw under aerobic conditions.

3.4 Pot culture experiment to study the influence of compost of dairy solid waste (cdsw) on Amaranthus.

The materials used and methods adopted for the study are briefly described in this chapter.

3.1 CHARACTERIZATION OF DAIRY INDUSTRY SOLID WASTE

Dairy solid waste was collected from TRCMPU Ltd. at Ambalathara, Thiruvananthapuram. The waste was powdered, air dried and used for chemical analysis.

3.1.1 Physico-chemical Analysis of Dairy Solid Waste

Estimation of pH, EC, organic carbon, N, P, K Ca, Mg, Fe, Mn, Zn and Cu in dairy solid waste was done using the procedures given in Table 1.

Table 1. Analytical procedures followed in the analysis of dairy solid waste and vermicompost

Sl. No.	Parameter	Methods	References
1	Organic carbon	Loss on Ignition method	Jackson (1973)
2	pH	pH meter	Jackson (1973)
3	Electrical conductivity	Conductivity meter	Jackson (1973)
4	Nitrogen	Microkjeldahl distillation after digestion in sulphuric acid	Jackson (1973)
5	Phosphorus	Volumetric ammonium phosphomolybdate method	FAI (1986)
6	Potassium	STPB method	FAI (1986)
7	Calcium	Nitric-perchloric acid (9:4) digestion and versanate titration with standard EDTA	Tandon (1993)
8	Magnesium	Nitric-perchloric acid (9:4) digestion and versanate titration with standard EDTA	Tandon (1993)
9	Fe, Mn, Cu, Zn	Nitric-perchloric acid (9:4) digestion and atomic absorption spectrometry	Jackson (1973)

3.1.2 Microbial Analysis of Dairy Solid Waste

Number of bacteria, actinomycetes and fungi in dsw were determined by serial dilution plate method (Timonin,1940). The medium used for isolation of different groups of microorganism (Appendix I) are given below:

Organism	Dilution	Medium
Bacteria	10^8	Nutrient Agar
Fungi	10^4	Potato Dextrose Agar
Actinomycetes	10^4	Kauster's Agar

3.2 VERMICOMPOSTING OF DAIRY INDUSTRY SOLID WASTE.

3.2.1 Collection of Composting Materials

In addition to dsw, other materials collected were cowdung and kitchen waste. Cowdung was collected from the Department of Animal Husbandry at College of Agriculture, Vellayani. Vegetable waste was collected from hostels and canteens at College of Agriculture, Vellayani.

Dry dsw was slightly moistened and ground using a wooden mallet. It was then mixed with cowdung and vegetable waste in the ratio 3:1:5. A sample was taken from the mixture, dried, powdered, sieved and analysed for the content of organic carbon, N, P, K, Ca, Mg, Fe, Mn, Cu and Zn. C:N ratio of the mixture was also worked out.

3.2.2 Preparation of Vermicompost

Vermicompost was prepared according to Package of Practices Recommendation of Kerala Agricultural University (KAU, 2002). Vermicomposting was carried out in pits of size 1m x 0.5m x 0.5m using the mixture of dairy solid waste, cowdung and kitchen waste by the activity of earthworm *Eudrillus eugeniae*. Adult earthworms were introduced (250 nos.) into 80 kg of the mixture and it was kept for composting for 60 days. Number of earthworms was recorded after 45 and 60 days of composting. C: N ratio of the mixture was determined after 60 of composting. After 60 days compost was collected from the compost pit and worms were separated. The compost was air dried in shade, sieved and stored in plastic sacks for further investigations.

3.2.3 Chemical Analysis of Vermicompost

Content of organic carbon, N, P, K, Ca, Mg, Fe, Mn, Cu and Zn in air dried compost were determined using procedures given in Table 1.

3.2.4 Microbial Analysis of Compost

The number of bacteria, actinomycetes and fungi in the vermicompost was determined by serial dilution plate method (Timonin,1940). The medium used for isolating different groups of microorganism (Appendix I) are given below.

Organism	Dilution	Medium
Bacteria	10^6	Vermicompost extract agar (Nair *et al.*, 1997)
Fungi	10^4	Martin's rose Bengal agar (Martin, 1950)
Actinomycetes	10^4	Kauster's Agar

3.3 INCUBATION STUDY

The incubation study was conducted in the laboratory for three months during January to March 2003 to monitor the nutrient release pattern and changes in physico chemical properties and microbilogical population in soil.

3.3.1 Soil

Soil for incubation study was collected from Instructional Farm at College of Agriculture, vellayani. The soil belongs to the Vellayani series (Rhodic Haplustult). The surface soil collected was thoroughly mixed air dried and sieved through a 2 mm sieve. Basic physiochemical properties of the soil used for incubation study are given in Table 2.

Table 2. Physico-chemical properties of soil used for incubation study

A. Physical properties	
1. Particle density	2.86 Mg m^{-3}
2. Bulk density	1.45 Mg m^{-3}
3. Water holding capacity	27 %
B. Chemical properties	
1. pH	5.3
2. EC	152.4 μS m^{-1}
3. CEC	3.2 cmol kg^{-1}
4. Organic carbon	0.58 %
5. Available N	235.83 kg ha^{-1}
6. Available P	83.46 kg ha^{-1}
7. Available K	178.50 kg ha^{-1}
8. Exchangeable Ca	0.98 cmol kg^{-1}
9. Exchangeable Mg	0.63 cmol kg^{-1}
C. DTPA extractable micronutrients	
1. Iron	25.33 mg kg-1
2. Manganese	1.65 mg kg-1
3. Copper	0.98 mg kg-1
4. Zinc	2.4 mg kg-1

Two kg of soil was taken in plastic containers of uniform size and incubated at 60 per cent field capacity for three months after application of treatments at room temperature. The moisture level was maintained throughout the study period by replenishing the moisture loss by evaporation. The details of the experiment are presented below.

Design: CRD

Number of replication: 3

Number of treatments: 7

Treatments:

T_0 : Absolute control (2 kg soil alone)

T_1 : Soil + 25 g fym

T2 : Soil + 25 g dsw

T_3 : Soil + 12 ½ g fym + 12 ½ g dsw

T_4 : Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 : Soil + 12 ½ g cdsw

T_6 : Soil + 6 ¼ g cdsw

Soil samples were drawn at periodical intervals of 1, 2, 4, 6, 8 and 12 weeks and analysed for the available status of major and micronutrients, bulk density and water holding capacity following standard analytical procedures given in Table 4.

3.3.2 Microbial Analysis of Soil

The number of bacteria, fungi and actinomycetes, in soil was determined by serial dilution plate method. The media used for isolation of different groups of microorganisms (Appendix I) are given below,

Organism		
Bacteria	10^6	Soil extract Agar
Fungi	10^4	Rose Bengal agar
Actinomycetes	10^6	Kenknight's medium

3.4 POT CULTURE EXPERIMENT

The pot culture experiment was undertaken to study the influence of compost of dairy industry solid waste on growth, yield and quality of amaranthus.

3.4.1 Season

The study was conducted during December 2003 to March 2004. Weather conditions during entire cropping season were recorded from Meteorological observatory attached to Department of Agronomy, College of Agriculture, Vellayani and presented in Appendix II.

3.4.2 Crop and Variety

The red amaranthus cultivar Arun which is more popular in homesteads of southern Kerala was used for the experiment. The seeds were purchased from the Instructional Farm, College of Agriculture, Vellayani.

3.4.3 Nursery

A small area adjacent to the experimental site was cleared, dug well, stubbles removed, clods broken and fine nursery bed was prepared. Amaranthus seeds were sown and Sevin 50 per cent WP was sprinkled round the border of the bed to prevent the attack of ants. The nursery bed was then covered with coconut fronds. Sprinkling of water was carried out at regular intervals. By third day after sowing, complete germination was observed and then coconut fronds were removed. Regular weeding of nursery was also done. After 25 days seedlings were ready for transplanting.

3.4.4 Pot Culture

A pot culture experiment was carried out in the experimental field of the Instructional Farm at College of Agriculture, Vellayani. Red soil (Rhodic Haplustult) collected from Instructional Farm Vellayani was used for pot culture experiment. Surface soil (0-15 cm) free from plant

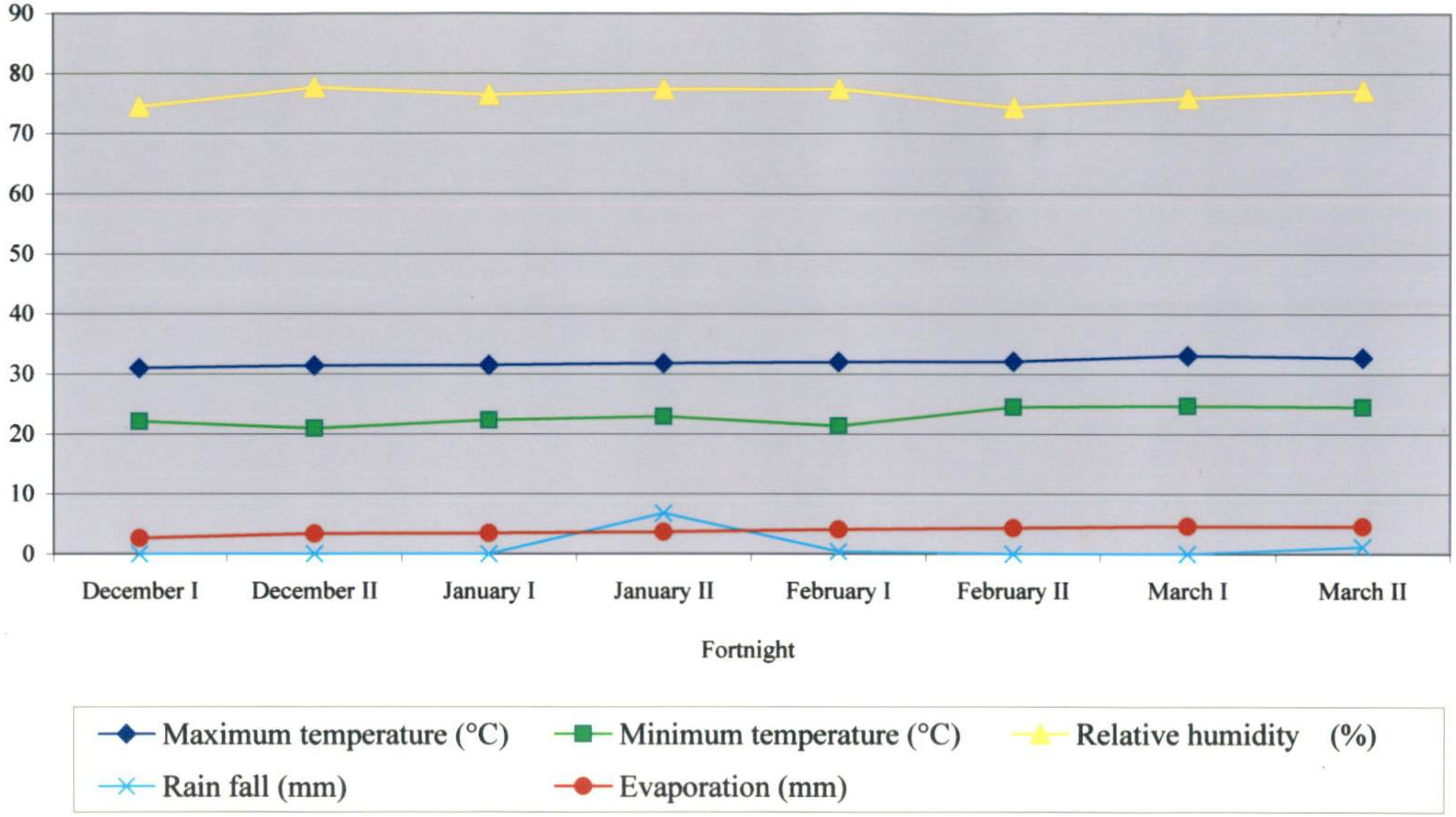

Fig. 1 Weather parameters during the cropping period (December 2003 –March 2004)

debris collected from Instructional Farm, Vellayani was used for the pot culture experiment. Important physico chemical properties of soil are given in Table 3. Earthen pots of 25 cm diameter were filled with 5 kg of the soil and the following treatments were replicated thrice in completely randomized design. Lay out of the experiment is given in figure 2

Treatments

T_0 : Absolute control

T_1 : POP Fertilizers + fym 50 t ha^{-1}

T_2 : POP Fertilizers + cdsw 50 t ha^{-1}

T_3 : POP Fertilizers + fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_4 : POP Fertilizers+ fym 25 t ha^{-1} +cdsw 12 ½ t ha^{-1}

T_5 : 2/3 N and PK of POP+ fym25 t ha^{-1} +cdsw 25 t ha^{-1}

T_6 : 2/3 N and PK of POP+ fym 25 t ha^{-1} +cdsw 12 ½ t ha^{-1}

T_7 : 1/2 N and PK of POP +fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_8 : 1/2 N and PK of POP+ fym 25 t ha^{-1} +cdsw 12 ½ t ha^{-1}

3.4.5 Manures and Fertilizers

fym (0.6% N, 0.2% P, 0.5% K), cdsw (3.12% N, 1.97% P, 1.82% K) urea (46 % N) single super phosphate (18 % P_2O_5) and muriate of potash (60 % K_2O) were used for the pot culture experiment.

At the time of filling the pots fym and cdsw were applied. Fertilizers were given as per package of practices recommendations of Kerala Agricultural University (KAU,2002). ½ N, full P and K were applied as basal. ½ N was given as top dressing. Pots were arranged in the field at a spacing of 20 x 20 cm. Two seedlings were transplanted in each plot. Pots were irrigated daily.

N

Replication I	Replication II	Replication III
T_8	T_5	T_2
T_0	T_1	T_4
T_6	T_7	T_0
T_5	T_3	T_8
T_4	T_6	T_1
T_2	T_8	T_5
T_3	T_0	T_7
T_1	T_4	T_3
T_7	T_2	T_6

Fig. 2 Layout plan of the pot culture experiment

Table 3. Physico-chemical properties of the soil used for pot culture experiment

A. Physical properties	
1. Coarse sand	29.3 %
2. Fine sand	22.8 %
3. Silt	26.5 %
4. Clay	19.6 %
5. Texture	Sandy loam
6. Particle density	2.84 Mg m^{-3}
7. Bulk density	1.42 Mg m^{-3}
8. Water holding capacity	29 %
C. Chemical properties	
1. pH	5.2
2. EC	154.6 µS m^{-1}
3. CEC	3.3 cmol kg^{-1}
4. Organic carbon	0.59 %
5. Available P	80.56 kg ha^{-1}
6. Available K	196.35 kg ha^{-1}
7. Available N	230.5 kg ha^{-1}
8. Exchangeable Ca	1.05 cmol kg^{-1}
9. Exchangeable Mg	0.60 cmol kg^{-1}
DTPA extractable micronutrients	
10. Iron	24.8 mg kg-1
11. Manganese	1.69 mg kg-1
12. Copper	1.02 mg kg-1
13. Zinc	2.42 mg kg-1

3.4.6 Plant Protection

Dithane M-45 was sprayed at the concentration of 0.4 per cent in cowdung water suspension at two weeks after transplanting to prevent incidence of leaf blight.

3.4.7 Harvesting

First harvest was done at 30 days after transplanting and subsequent harvests were done at two weeks interval.

3.4.8 Observation

Observations were made on important parameters associated with growth, yield and quality of amaranthus.

3.4.8.1 Height of Plant

Height of the plants were recorded at three growth stages *viz.*, 30^{th}, 45^{th} and 60^{th} days after transplanting. The height was measured from the ground level to the topmost leaf buds. Mean values were computed and expressed in cm.

3.4.8.2 Number of Branches

Number of branches for each plant were counted and the mean worked out for each plant at three growth stages.

3.4.8.3 Internodal Length

Internodal length for each plant was calculated and mean was found out for each plant and expressed in cm at three stages of growth.

3.4.8.4 Number of Cuts

Three harvests were done for all treatments at 30^{th}, 45^{th} and 60^{th} days after transplanting.

3.4.8.5 Days to Flowering

Number of days taken for flowering after transplanting was recorded for each plant and mean value was worked out.

3.4.8.6 Yield per Harvest

Total weight of leaf and stem portion from each pot were recorded at the time of harvest and expressed as g pot^{-1}.

3.4.8.7 Total Dry Matter Production

Dry matter production was obtained by summing up the dry weight of all plant parts in each pot and expressed as g pot^{-1}.

3.4.8.8 Leaf Stem Ratio

Leaf stem ratio was recorded at the time of harvest by dividing the weight of leaves by the weight of stem.

3.4.8.9 Quality Characters

3.4.8.9.1 Beta Carotene

Beta carotene content of fresh leaves at each harvest was estimated according to the method proposed by Sadasivam and Manickam (1992).

3.4.8.9.2 Nitrates

The nitrate content of plant was estimated by method suggested by Humphries (1956).

3.4.9 Benefit Cost Ratio

The economics of cultivation of amaranthus were worked out and benefit cost ratio was calculated as follows.

$$\text{Benefit cost ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.4.10 Chemical Analysis

3.4.10.1 Soil Analysis

Soil samples for chemical analysis were taken after final harvest. They were air dried , passed through 2mm sieve and were used for the

Table 4. Analytical methods followed in soil analysis

Sl. No.	Parameters	Methods	References
1	Mechanical composition	International Pipette Method	Piper (1944)
2	Particle density	Pycnometer method	Black *et al.* (1965)
3	Bulk density	Undisturbed core sample	Black *et al.* (1965)
4	Waterholding capacity	Keen Razkozky Box method	Piper (1944)
5	Hydraulic conductivity	Undisturbed core sample	Black *et al.* (1965)
6	pH	pH meter	Jackson (1973)
7	Electrical conductivity	Conductivity meter	Jackson (1973)
8	Cation exchange capacity	Ammonium saturation using neutral normal ammonium acetate	Jackson (1973)
9	Organic carbon	Walkley and Black chromic acid wet digestion method	Walkley and Black (1934)
10	Available N	Alkaline potassium permanganate method	Subbiah and Asija (1956)
11	Available P	Bray No. 1 extraction and photoelectric colorimetry	Jackson (1973)
12	Available K	Neutral normal ammonium acetate extraction and Flame photometry	Stanford and English (1949)
13	Exchangeable Ca and Mg	Neutral normal ammonium acetate extraction and titration with EDTA (Versenate titration)	Hesse (1971)
14	Fe, Mn, Cu, Zn	DTPA extraction and atomic absorption Spectro photometer	Lindsay and Norvell (1975)

Table 5. Analytical methods followed in plant analysis

Sl. No.	Element	Methods	References
1	Nitrogen	Microkjeldahl distillation after digestion in sulphuric acid .	Jackson (1973)
2	Phosphorus	Nitric-perchloric acid (9:4) digestion and colorimetry making use of vanado molybdo phosphoric yellow colour method	Jackson (1973)
3	Potassium	Nitric-perchloric acid (9:4) digestion and flame photometry	Jackson (1973)
4	Calcium	Nitric-perchloric acid (9:4) digestion and versenate titration with standard EDTA	Tandon (1993)
5	Magnesium	Nitric-perchloric acid (9:4) digestion and versenate titration with standard EDTA	Tandon (1993)
6	Fe, Mn, Zn, Cu	Nitric-perchloric acid (9:4) digestion and atomic absorption spectrophotometry	Jackson (1973)
7	Nitrate	Colorimeteric method	Humphries (1956)
8	Beta carotene	Acetone-hexane extraction and colorimetry	Sadasivam and Manickam (1992)

analysis of pH, EC, organic carbon, N, P, K, Ca, Mg, Fe, Mn, Zn and Cu using standard procedures given in Table 4.

3.4.10.2 Plant Analysis

Plant samples were collected at each harvest. The samples were oven dried at 70^0C, powdered and used for estimation of N, P, K, Ca, Mg, Fe, Mn, Zn and Cu. Standard procedures adopted are given in Table 5.

3.4.11 Statistical Analysis

Data generated from the experiments were subjected to statistical analysis applying analysis of variance technique and significance tested by F-test (Cochran and Cox 1965). In cases where the effects were found to be significant, CD was calculated by using standard techniques.

RESULTS

4. RESULTS

An investigation was carried out at College of Agriculture, Vellayani during 2002-2004 to study the suitability of dairy industry solid waste as an organic source in soil productivity. The data on various observations were statistically analysed and are presented in this chapter.

4.1 CHARACTERIZATION OF DAIRY INDUSTRY SOLID WASTE

Physico-chemical and microbiological properties of dsw are presented in Table 6. From the data it can be seen that dsw had a near neutral pH (6.5). EC of dsw was 2.75 mS cm^{-1}. It contained 37.5 per cent organic carbon, 5.8 per cent N, 2.04 per cent P, 0.71 per cent K, 1.69 per cent Ca, 1.58 per cent Mg, 1.71 per cent Fe, 159 mg kg^{-1} Mn and 1084 mg kg^{-1} Zn. Copper was present only in traces .It contained 38.6 percent moisture and 9.5 percent inert materials. It also contained microbes like bacteria, fungi and actinomycetes. Population of bacteria, fungi and actinomycetes in dsw were 13.3×10^6, 11.6×10^4 and 1.3×10^4 respectively.

4.2 VERMICOMPOSTING OF DAIRY INDUSTRY SOLID WASTE

Data given in Table 7 indicate the nutrient composition and microbiological properties of biowaste mixture (dsw, vegetable waste and cowdung in 3:5:1 ratio) and the compost and the biomass potential of earthworms after 45 days and 60 days of composting.

Vermicomposting of biowaste mixture resulted in increased content of N, P, K, Ca, Mg and micronutrients. Through composting, the C:N ratio was brought down to 11.17 from 33.20 and organic carbon content reduced to 34.87 per cent from 44.50 per cent. pH increased to 6.9 from

Table 6 Characteristics of dairy industry solid waste

pH	6.5
EC	2.75 mS m^{-1}
Organic carbon	37.50 %
N	5.80 %
P	2.04 %
K	0.71 %
Ca	1.69 %
Mg	1.58 %
Fe	1.71 %
Mn	159 mg kg^{-1}
Zn	1084 mg kg^{-1}
Cu	–
Moisture	38.6 %
Inert materials	9.5 %
Microbial population (per gram of dsw) Bacteria	13.3×10^6
Fungi	11.6×10^4
Actinomycetes	1.3×10^4

Table 7. Physico-chemical and microbiological properties of biowaste mixture and compost

Parameter	Biowaste mixture	Compost
pH	5.8	6.9
EC	4.83 mS m^{-1}	7.43mS m^{-1}
CEC	15.5 cmol (p^+) kg^{-1}	38.8 cmol (p^+) kg^{-1}
Organic carbon (per cent)	44.50	34.87
C : N ratio	33.20	11.17
N (per cent)	1.34	3.12
P (per cent)	1.29	1.97
K (per cent)	0.98	1.81
Ca (per cent)	1.22	2.05
Mg (per cent)	1.94	3.55
Fe (per cent)	0.53	0.80
Mn (mg kg^{-1})	140	230
Zn (mg kg^{-1})	273	408
Cu (mg kg^{-1})	28	44
Moisture(per cent)	36	48
Inert materials (percent)	17.4	9.2
Microbial population per gram of compost Fungi	14.6 x 10^4	38.6 x 10^4
Bacteria	9.3 x 10^6	42.6 x 10^6
Actinomycetes	3.3 x 10^4	21.3 x 10^4
Number of earthworm introduced	250	-
Number of worms at 45 days of composting	-	420
Number of worms at 60 days of composting	-	510

5.8. The vermicompost contained 3.12 per cent N, 1.97 per cent P, 1.81 per cent K, 2.05 per cent Ca, 3.55 per cent Mg, 0.80 per cent Fe, 230 mg kg^{-1} Mn, 408 mg kg^{-1} Zn and 44 mg kg^{-1} Cu. Moisture content of compost was 48 per cent and it contained 9.2 percent inert materials . Microbial population also increased through vermicomposting. Number of bacteria, fungi and actinomycetes in the compost at maturity stage was 42.6 x 10^6, 38.6 x 10^4 and 21.3 x 10^4 respectively. The number of worms at 45 days of composting was 420. At 60 days of composting, the number of worms was 510.

4.3 INCUBATION STUDY

The data on various parameters during the period of incubation are presented in Tables 8 to 19.

4.3.1 **Available Nitrogen** (Table 8)

Statistical analysis of the data revealed that the available N in soil was significantly influenced by the treatments. Availability was in the medium range for all treatments except T_0 for which it was low. Availability increased with increasing periods of incubation upto 6-8 weeks and then declined.

Upto six weeks available N was maximum in T_5 which received cdsw at higher dose. The highest value of available N (356.4 Kg) was recorded in T_5 at six weeks of incubation. At eight and twelve weeks, availability was maximum in T_1.

4.3.2 **Available P** (Table 9)

Analysis of the data indicated a gradual increase in available P content of soil upto fourth week followed by a decline towards the end of incubation period for treatments T_5 and T_6. Treatments T_1, T_2, T_3 and T_4

Table 8.Influence of dairy industry solid waste on available N (kg ha^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	238.3	248.4	251.9	248.8	243.8	241.7
T_1	292.7	318.8	341.8	351.2	355.4	346.0
T_2	278.1	286.4	311.3	318.8	316.7	306.3
T_3	286.4	308.5	323.0	333.5	340.8	323.4
T_4	273.9	284.3	310.4	318.8	328.2	321.1
T_5	300.0	323.2	343.7	356.4	330.6	308.8
T_6	280.2	307.3	339.6	346.3	318.8	305.2
SE	1.93	2.88	4.35	1.71	2.21	1.52
CD(0.05)	5.87	8.75	13.19	5.16	6.70	4.60

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Table 9. Influence of dairy industry solid waste on available P (kg ha^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	86.8	88.9	86.8	87.5	85.4	84.0
T_1	100.2	103.6	109.2	109.9	108.5	106.6
T_2	100.8	103.6	106.6	107.1	105.0	101.5
T_3	97.3	100.1	105.9	109.2	107.1	103.0
T_4	95.2	98.7	102.2	108.5	105.0	102.2
T_5	106.4	111.3	121.1	116.9	116.2	112.1
T_6	100.1	105.7	112.8	110.6	106.1	100.5
SE	1.18	1.56	0.76	1.66	1.78	2.09
CD(0.05)	3.58	4.74	2.33	5.05	5.39	6.35

T_0 Absolute control
T_1 Soil + 25 g fym
T_2 Soil + 25 g dsw
T_3 Soil + 12 ½ g fym + 12 ½ g dsw
T_4 Soil + 12 ½ g fym + 6 ¼ g dsw
T_5 Soil + 12 ½ g cdsw
T_6 Soil + 6 ¼ g cdsw

showed increased P availability upto sixth week. After six weeks, availability of P decreased.

The highest available P (121.1 kg ha^{-1}) was recorded in T_5 at four weeks of incubation. Throughout the period of incubation T_5 recorded maximum value for available P.

4.3.3 Available K (Table 10)

The effect of treatments on available K was significant. In cdsw applied treatments, available K increased upto four weeks and then it declined. T_1, T_2, T_3 and T_4 recorded a gradual increase in available K status upto six weeks followed by a decline towards the end of incubation period.

At first and second weeks the highest value was recorded by T_5 followed by T_6 and T_1. At fourth week also T_5 recorded the maximum value followed by T_1 and T_6.

The highest value of available K was 249.2 Kg ha^{-1}. It was recorded in T5 and T1 at 4 and 6 weeks respectively.

Effect of dsw and cdsw on K availability were significantly superior to fym in the initial periods of incubation. However it was reverse after 4-6 weeks. At eight and twelve weeks, T_1 showed maximum availability followed by T_3, T_5 and T_4. T_0 showed lowest value for available K throughout the incubation period.

4.3.4 Available Fe (Table 11)

It was found that available content of Fe in soil was significantly influenced by the treatments. In T_2, availability of Fe increased upto four weeks and then decreased. For T_1, T_3 and T_4, T_5 and T_6 Fe content

Table 10. Influence of dairy industry solid waste on available K (kg ha^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	164.3	158.1	151.8	143.2	137.6	132.2
T_1	199.2	209.1	235.8	249.2	234.9	225.1
T_2	207.2	211.7	214.6	219.7	211.9	208.1
T_3	198.3	203.7	218.3	234.2	227.8	219.9
T_4	197.6	201.8	209.1	230.3	218.4	209.1
T_5	208.1	226.6	249.2	233.1	225.1	217.7
T_6	200.2	217.9	227.8	219.8	211.9	208.5
SE	2.09	1.29	1.63	1.86	2.08	1.61
CD(0.05)	6.36	3.94	4.94	5.64	6.32	4.89

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw .

increased gradually upto six weeks followed by a gradual decline towards the end of incubation period.

At first, second and fourth and six weeks, the highest value of 30.9, 32.2, 34.4 and 38.3 mg kg^{-1} was recorded by T_5 followed by T_1 and T_6.

From sixth week onwards, maximum content of available Fe was showed by T_5 and this trend continued till the end of incubation period. The effect of cdsw and fym are significantly superior to dsw on available Fe in soil.

4.3.5 Available Mn (Table 12)

The results given in Table 12 indicate that the effect of treatments on available Mn content in soil was significant. Available Mn content increased upto six weeks in T_1, T_2, T_3 and T_4 and then decreased. In T_5 and T_6 which received cdsw, there was an increase upto four weeks and then declined.

The highest available Mn content was showed by T_5 upto four weeks and it was in the range of 1.93 to 3.27 mg kg^{-1} followed by T_6 and T_1 which were on par.

At eight weeks, the highest value of 2 .4 mg kg^{-1} was showed by T_1 which received fym followed by T_5 and T_3 which were on par. This trend continued till the end of incubation period. Lowest value was recorded by absolute control throughout the incubation period.

4.3.6 Available Zn (Table 13)

Statistical analysis of the data in Table 13 revealed that the available Zn content of soil was significantly influenced by the treatments. It increased in T_1, T_2, T_3 and T_4 upto six weeks and then decreased. In T_5

Table 11. Influence of dairy industry solid waste on available Fe (mg kg^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	22.5	20.6	20.6	19.0	19.0	17.5
T_1	29.6	31.6	33.1	36.4	35.4	30.3
T_2	28.7	28.2	30.3	27.4	24.6	20.4
T_3	25.9	28.7	30.6	32.6	28.2	22.5
T_4	25.4	27.2	28.2	30.6	27.2	20.6
T_5	30.9	32.2	34.4	38.3	31.7	27.5
T_6	26.7	28.7	31.6	34.4	26.7	25.1
SE	0.48	0.51	0.39	0.58	0.57	0.58
CD(0.05)	1.47	1.56	1.20	1.76	1.75	1.76

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Table 12. Influence of dairy industry solid waste on available Mn (mg kg^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	1.64	1.63	1.62	1.63	1.63	1.62
T_1	1.83	1.92	2.43	2.45	2.40	2.02
T_2	1.62	1.67	1.66	1.76	1.64	1.53
T_3	1.72	1.87	2.05	2.24	2.17	1.69
T_4	1.64	1.72	1.73	1.87	1.73	1.68
T_5	1.93	2.54	3.27	3.23	2.20	1.88
T_6	1.83	1.89	2.39	2.35	1.88	1.67
SE	0.014	0.017	0.079	0.107	0.059	0.028
CD(0.05)	0.043	0.054	0.240	0.327	0.182	0.054

T_0 Absolute control
T_1 Soil + 25 g fym
T_2 Soil + 25 g dsw
T_3 Soil + 12 ½ g fym + 12 ½ g dsw
T_4 Soil + 12 ½ g fym + 6 ¼ g dsw
T_5 Soil + 12 ½ g cdsw
T_6 Soil + 6 ¼ g cdsw

and T_6 availability of Zn increased only upto four weeks and then it showed a declining trend.

In the first week, Zn content of soil was not significantly influenced by the treatments. In the second week, T_1 which received fym, recorded the highest value and it was on par to T_5, T_6 and T_3.

The highest content of available Zn was 8.76 mg Kg^{-1} · It was noticed in T_5 at four weeks which received cdsw at higher dose. T_5 was followed by T_6 and T_1. At six weeks, maximum value of 7.78 mg kg^{-1} was showed by T_1 followed by T_3 and T_5 and this trend continued upto eight weeks.

At twelve week, T_1 showed the highest value which was on par with T_3 which received fym and dsw. Throughout the incubation period T_0 recorded the lowest value.

4.3.7 Available Cu (Table 14)

Data given in the Table 14 showed that the effect was significant on available Cu in soil. In T_1, T_3 and T_4 available Cu content increased upto eight weeks followed by a gradual decline towards the end of incubation period.

In T_5 which received cdsw at higher dose, available Cu recorded a gradual increase upto four weeks and thereafter it remained steady upto eight weeks and then declined till the end of incubation period and it was in the range of 0.72 to 0.81 mg kg^{-1}.

Maximum content of available Cu was observed in T_1 throughout the incubation period and it was in the range of 0.82 to 1.56 mg kg^{-1}. The effect of all other treatments on available Cu content was significantly inferior to T_1.

Table 13. Influence of dairy industry solid waste on available Zn (mg kg^{-1}) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	2.56	2.67	2.83	2.80	2.56	2.37
T_1	2.83	4.69	6.44	7.78	7.64	5.83
T_2	2.81	3.24	4.45	4.82	4.67	4.84
T_3	2.85	4.43	6.34	6.82	6.56	5.71
T_4	2.66	3.86	5.83	5.85	4.80	4.58
T_5	2.99	4.65	8.76	6.64	4.82	4.28
T_6	2.67	4.25	7.76	5.83	4.78	4.19
SE	-	0.176	0.153	0.123	0.143	0.124
CD(0.05)	NS	0.534	0.463	0.374	0.434	0.376

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Table 14. Influence of dairy industry solid waste on available Cu ($mg\ kg^{-1}$) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	0.67	0.63	0.67	0.66	0.68	0.68
T_1	0.82	1.13	1.25	1.33	1.56	1.53
T_2	0.66	0.71	0.71	0.66	0.71	0.67
T_3	0.68	0.71	0.73	0.73	0.74	0.74
T_4	0.69	0.71	0.78	0.81	0.86	0.82
T_5	0.72	0.75	0.81	0.81	0.81	0.78
T_6	0.67	0.67	0.71	0.71	0.72	0.71
SE	0.008	0.021	0.010	0.07	0.025	0.014
CD(0.05)	0.054	0.016	0.031	0.024	0.071	0.043

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ gdsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

4.3.8 Bulk Density (Table 15)

Bulk density of soil was significantly affected by the treatments. Treatment in which cdsw was applied, showed the lowest bulk density throughout the incubation period and was in the range of 1.22 to 1.32 Mg m^{-3}. T_5 was followed by T_1 and they were statistically on par. All treatments except T_0 showed a decrease in bulk density upto six weeks followed by a gradual increase in bulk density towards the end of incubation period.

4.3.9 Water Holding Capacity (Table 16)

Effect of treatments on water holding capacity of soil was significant upto eight weeks and after that it was not significant. Treatment that received cdsw at higher dose showed the highest water holding capacity upto six weeks followed by T_6 and T_1 which were on par.

At eighth week, highest water holding capacity (33.3 per cent) was noticed in T_1 that received fym and it was on par with T_5 (32.8 per cent). Absolute control showed the lowest water holding capacity throughout the period of incubation which was in the range of 26.6 to 27.5 per cent.

4.3.10 Microbial Population

Microbial population in soil was significantly influenced by the treatments. The count was the highest for bacteria and the lowest for actinomycetes.

4.3.10.1 Fungi (Table 17)

Fungal count increased upto sixth week in all treatments except T_0 followed by a gradual decline till the end of incubation period.

Table 15. Influence of dairy industry solid waste on bulk density (Mg m^{-3}) of soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	1.45	1.48	1.48	1.46	1.48	1.48
T_1	1.30	1.29	1.28	1.24	1.28	1.35
T_2	1.38	1.36	1.35	1.32	1.33	1.40
T_3	1.36	1.30	1.30	1.26	1.29	1.37
T_4	1.34	1.30	1.30	1.28	1.33	1.37
T_5	1.28	1.26	1.25	1.22	1.28	1.32
T_6	1.35	1.32	1.30	1.29	1.30	1.37
SE	0.020	0.027	0.018	0.016	0.013	0.011
CD(0.05)	0.060	0.082	0.054	0.048	0.042	0.034

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Table 16. Influence of dairy industry solid waste on water holding capacity (%) of soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	26.6	26.8	26.6	27.3	27.5	27.5
T_1	29.4	31.2	32.7	33.3	33.3	30.5
T_2	29.8	30.4	31.6	31.8	31.6	27.6
T_3	28.5	30.6	31.5	31.5	31.8	28.1
T_4	28.3	30.5	31.7	31.7	31.7	27.6
T_5	32.8	33.5	34.6	35.6	32.8	30.2
T_6	30.3	31.4	32.6	33.2	30.4	28.5
SE	0.38	0.66	0.57	0.68	0.76	-
CD	1.15	2.02	1.74	2.06	2.31	NS

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Treatments that received cdsw showed more fungal population compared to other treatments.

Upto six week, the highest fungal count was noticed in T_5 followed by T_6.

In the eighth week, maximum fungal population of 20.33 was recorded by T_1 and it was followed by T_5 and T_3 in which the fungal count was 15.66 and 15.00 respectively. T_5 and T_3 were statistically on par.

At twelve weeks, the treatment effect was non-significant. T_0 recorded the lowest fungal population throughout the incubation period.

4.3.10.2 Bacteria

Bacterial population increased upto sixth week in all treatments except T_0 and then decreased till the end of incubation. T_5 in which cdsw applied at higher dose showed the highest bacterial count throughout the incubation period. In the first week, bacterial count in T_5 was 17.66. It increased to 27.33 in six weeks. It was followed by T_6 and T_1 throughout the incubation period.

The bacterial count at first week was 14.60 in T_6. It increased to 22.66 at six weeks. In T_1 it was 13.33 and 21.33 in the first and sixth week respectively. T_6 was on par to T_1 at six, eight and twelve weeks. Lowest bacterial count was seen in T_0.

4.3.10.3 Actinomycetes (Table 19)

The effect of treatment was non-significant with respect to actinomycete population upto sixth week. The highest actinomycete population of 5.66 was recorded by T_5 at eight weeks and it was significantly superior to other treatments. T_5 was followed by T_1, T_3, T_6

Table 17. Influence of dairy industry solid waste on fungal population (dilution factor 10^4) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	5.00	6.33	8.00	5.33	6.00	4.66
T_1	8.33	9.66	15.33	20.66	20.33	7.66
T_2	6.33	7.33	9.66	11.66	9.66	5.66
T_3	7.00	8.00	12.33	15.66	15.00	8.00
T_4	5.00	6.66	11.66	13.00	9.66	6.33
T_5	13.00	17.66	20.66	23.33	15.66	9.33
T_6	9.00	14.66	16.33	21.66	13.33	7.00
SE	0.678	0.745	0.786	0.925	1.015	-
CD(0.05)	2.058	2.261	2.386	2.808	3.081	NS

T_0 Absolute control
T_1 Soil + 25 g fym
T_2 Soil + 25 g dsw
T_3 Soil + 12 ½ g fym + 12 ½ g dsw
T_4 Soil + 12 ½ g fym + 6 ¼ g dsw
T_5 Soil + 12 ½ g cdsw
T_6 Soil + 6 ¼ g cdsw

Table 18. Influence of dairy industry solid waste on bacterial population (dilution factor 10^6) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	6.33	6.33	8.00	8.00	7.66	6.33
T_1	13.33	14.66	18.66	21.33	15.66	12.66
T_2	9.66	12.33	16.33	18.33	13.33	11.33
T_3	12.33	14.33	17.33	19.66	14.66	11.66
T_4	12.33	12.66	17.00	19.00	12.33	9.00
T_5	17.66	17.66	22.66	27.33	18.00	14.33
T_6	14.60	15.00	19.00	22.66	16.33	13.00
SE	0.398	0.378	1.154	1.305	1.154	0.519
CD(0.05)	1.208	1.146	3.502	3.957	3.502	1.515

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

Table 19. Influence of dairy industry solid waste on actinomycete population (dilution factor 10^6) in soil at different periods of incubation

Treatments	Period (weeks)					
	1	2	4	6	8	12
T_0	1.33	1.6	2.66	2.66	3.00	3.33
T_1	2.66	3.88	4.33	4.88	5.00	6.33
T_2	2.00	2.99	3.33	3.66	4.00	4.66
T_3	2.33	3.33	4.33	5.00	5.00	5.33
T_4	1.66	2.77	3.66	4.00	4.66	5.00
T_5	3.00	4.33	5.33	5.66	5.66	5.33
T_6	2.33	3.66	4.00	4.33	5.00	5.00
SE	-	-	-	-	0.172	0.810
CD(0.05)	NS	NS	NS	NS	0.522	0.750

T_0 Absolute control

T_1 Soil + 25 g fym

T_2 Soil + 25 g dsw

T_3 Soil + 12 ½ g fym + 12 ½ g dsw

T_4 Soil + 12 ½ g fym + 6 ¼ g dsw

T_5 Soil + 12 ½ g cdsw

T_6 Soil + 6 ¼ g cdsw

and T_2 which were on par. The same trend was seen at twelfth week also. The lowest actinomycetes count was noticed in T_0.

4.4 INFLUENCE OF DAIRY INDUSTRY SOLID WASTE ON AMARANTHUS

A pot culture experiment using amaranthus as a test crop was conducted to study the influence of cdsw on growth, yield and quality . Analysis of nutrient status of soil after the pot culture experiment was also done. The data obtained are presented in Tables 20 to 32.

4.4.1 Growth and Yield Characters

4.4.1.1 First Cut (Table 20)

Analysis of the data revealed that plant height was significantly influenced by the treatments. Treatment which received the highest level of cdsw (T_2) showed maximum plant height of 54.80 cm. It was followed by T_3 and T_5 that were on par. The lowest value for plant height was noticed in T_0 and it was 30.70 cm.

Number of branches was not significantly influenced by the treatments. It ranged from 3.3 in T_0 to 8.3 in T_2.

The highest internodal length (5.20 cm) was noticed in T_2 and was followed by T_3, T_5 and T_7 which were on par. Internodal length was the lowest in T_0 and it was only 3.33 cm.

The leaf stem ratio ranged from 1.26 to 2.35, the highest being recorded by T_0 and the lowest by T_2. T_3 and T_5 were on par to T2.

Yield at first cut was significantly influenced by treatments. Yield ranged from 50.50 to 129.86 g pot^{-1}. The yield was the highest in T_2

Table 20. Influence of composted dairy solid waste on growth and yield characters of amaranthus

1st cut

Treatments	Height of plant (cm)	Number of branches	Internodal length (cm)	Leaf stem ratio	Yield (g pot^{-1})
T_0	30.70	3.33	3.33	2.35	50.50
T_1	48.83	5.00	4.40	1.45	119.53
T_2	54.80	8.33	5.20	1.26	129.86
T_3	52.93	7.33	5.03	1.30	125.18
T_4	49.56	5.33	4.40	1.44	118.85
T_5	52.70	7.00	4.73	1.33	120.28
T_6	48.50	6.33	4.45	1.49	115.56
T_7	49.50	6.66	4.63	1.41	118.40
T_8	46.70	5.33	4.27	1.58	115.50
SE	1.14	-	0.24	0.51	3.21
CD(0.05)	3.39	NS	0.71	0.15	9.55

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

followed by T_3 and T_5 which were on par. Absolute control showed the lowest yield of 50.50 g pot^{-1}. .

4.4.1.2 ***Second Cut*** (Table 21)

Maximum height of 52.60 cm was noticed in T_2 followed by T_3 and T_5. It was 50.9 cm and 49.70 cm in T_3 and T_5 respectively and were statistically on par. The lowest plant height was noticed in absolute control (T_0) and was 26.83 cm.

Maximum number of branches was recorded by T_2 and it was 12.66. In T_3 and T_5 it was 12 and 11 respectively. They were on par. Absolute control recorded the lowest value which was only 5.33.

Internodal length was the highest in T_2 and it was 4.43 cm. It was 4.28 and 4.20 cm in T_3 and T_5 respectively. T_2, T_3 and T_5 were significantly superior to other treatments and they were on par. The lowest internodal length (2.83 cm) was noticed in T_0.

Leaf stem ratio ranged between 1.20 and 2.77. The highest leaf stem ratio was recorded by T_0 and the lowest by T_2. In T_1, T_2, T_3 and T_7 it was 1.30, 1.15, 1.20 and 1.32 respectively. They were on par.

The highest yield of 136.93 g pot^{-1} was recorded by T_2 .In T_3 and T_5 the yield was 135.85 and 133.88 g pot^{-1} respectively and were on par.

4.4.1.3 ***Third Cut*** (Table 22)

Maximum height (51.96 cm) was noticed in T_2 followed by $T_3$and T_5 which were on par. The lowest value for plant height was recorded by T_0.

Table 21. Influence of composted dairy solid waste on growth and yield characters of amaranthus

2nd cut

Treatments	Height of plant (cm)	Number of branches	Internodal length (cm)	Leaf stem ratio	Yield (g pot^{-1})
T_0	26.83	5.33	2.83	2.77	36.35
T_1	43.43	9.00	3.83	1.30	122.24
T_2	52.60	12.66	4.43	1.15	136.93
T_3	50.90	12.00	4.28	1.20	135.85
T_4	46.73	8.33	3.83	1.39	126.68
T_5	49.70	11.00	4.20	1.23	133.88
T_6	45.43	8.00	3.76	1.37	120.56
T_7	47.73	8.66	3.80	1.32	127.87
T_8	43.20	8.33	3.56	1.45	117.65
SE	1.17	0.57	0.15	0.08	1.44
CD(0.05)	3.48	1.61	0.47	0.20	4.28

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

Table 22. Influence of composted dairy solid waste on growth and yield characters of amaranthus

3rd cut

Treatments	Height of plant (cm)	Number of branches	Internodal length (cm)	Leaf stem ratio	Yield (g pot^{-1})
T_0	22.63	7.33	2.50	2.81	32.85
T_1	49.93	11.33	3.46	1.38	111.24
T_2	51.96	13.66	4.16	1.28	108.28
T_3	50.53	15.33	4.10	1.22	117.80
T_4	45.80	11.33	3.46	1.30	108.58
T_5	49.76	15.00	3.80	1.34	116.68
T_6	42.93	12.33	3.43	1.47	104.85
T_7	45.13	13.33	3.56	1.41	111.55
T_8	40.50	11.33	3.20	1.90	99.50
SE	1.73	0.91	0.16	0.20	1.20
CD(0.05)	2.76	2.72	0.47	0.59	3.55

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} +cdsw 12 ½ t ha^{-1}

Number of branches was maximum in T_3 and T_5 and it was 15.33. In T_2 it was 13.66. T_3, T_5 and T_2 were statistically on par. It was the lowest in T_0.

T_2 showed the highest internodal length of 4.16 cm followed by T_3 (4.10 cm) and T_5 (3.80 cm) and they were statistically on par. The lowest value of 2.5 cm was noticed in T_0.

Leaf stem ratio ranged from 1.22 to 2.81. The highest value being recorded by T_0 and the lowest by T_3. All treatments except T_8 and T_0 were on par to T_3. All treatments except T_8 and T_0 were on par to T_3.

T_3 recorded the highest yield of 117.80 g pot^{-1}. It was followed by T_5 with a value of 116.68 g pot^{-1}. T_3 and T_5 were statistically on par. The lowest yield was recorded by T_0.

4.4.2 Crop Quality (Table 23)

4.4.2.1 Nitrate

The nitrate content ranged between 0.11 and 0.35 per cent. In the first cut it was the highest in T_2 followed by T_3 and T_1 which on par. The lowest nitrate content was recorded by T_0. It was maximum in the first cut in all treatments.

In the second cut, nitrate content in plants was lower than the first cut. Here also the highest value was recorded by T_2 followed by T_3 and T_1 and were on par. Lowest value (0.08 per cent) was noticed in T_0.

Nitrate content showed a decreasing trend in third cut also. T_2 showed highest nitrate content (0.26 per cent). T_2 was on par to T_3, T_1, T_5 and T_7. T_0 showed the lowest value of 0.04 per cent.

Table 23. Influence of composted dairy solid waste on nitrate and beta carotene content of amaranthus

Treatments	Nitrate (%)			Beta carotene (μg $100g^{-1}$)		
	1st cut	2nd cut	3rd cut	1st cut	2nd cut	3rd cut
T_0	0.11	0.08	0.04	2956	2432	2192
T_1	0.29	0.28	0.20	5810	5946	5390
T_2	0.35	0.32	0.26	6560	7027	5481
T_3	0.31	0.28	0.22	6226	6937	5363
T_4	0.23	0.20	0.14	5462	5676	5298
T_5	0.28	0.24	0.19	6182	6847	5420
T_6	0.21	0.18	0.13	5307	5335	5280
T_7	0.23	0.20	0.16	6045	6617	5335
T_8	0.19	0.16	0.10	5129	5330	5196
SE	0.01	0.01	0.04	57.32	72.27	242.93
CD(0.05)	0.04	0.05	0.12	171.54	214.75	721.82

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw12 ½ t ha^{-1}

T_7 ½ N + full PK of POP +fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

4.4.2.2 Beta Carotene

At first cut, beta carotene values ranged from 2956 to 6560 μg 100 g^{-1}. The highest value was recorded by T_2. It was significantly superior to other treatments. T_2 was followed by T_3 and T_5 with values 6226 and 6182 μg 100 g^{-1} respectively. T_3 and T_5 were statistically on par. The lowest beta carotene content of 2956 μg 100 g^{-1} was noticed in T_0.

In the second cut, beta carotene content increased in all treatments except T_0. The highest value was recorded by T_2 followed by T_3 and T_5 with values 7027, 6937 and 6847 μg 100 g^{-1} respectively and were on par. Here also T_0 recorded the lowest beta carotene content.

In the third cut, beta carotene content decreased in all treatments. The highest value of 5481 μg 100 g^{-1} recorded by T_2 which was on par to other treatments except T_0. The lowest value was noticed in T_0. In general, beta carotene content was maximum in the second cut and minimum in the third cut.

4.4.3 Nutrient Content

4.4.3.1 N, P, K, Ca and Mg

4.4.3.1.1 **First Cut** (Table 24)

Analysis of the data revealed that cdsw application significantly increased the N content of plant. The values ranged from 1.96 to 3.59 per cent. The highest value was recorded by T_2 and was significantly superior to other treatments. It was followed by T_3, T_5, T_7 and T_1. They were statistically on par.

Table 24. Influence of composted dairy solid waste on content of macronutrient in amaranthus

1st cut

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_0	1.96	0.27	1.75	1.66	0.52
T_1	3.10	0.38	2.21	2.41	0.76
T_2	3.59	0.48	2.64	2.89	0.93
T_3	3.28	0.43	2.45	2.56	0.86
T_4	3.00	0.40	2.18	2.44	0.65
T_5	3.20	0.42	2.25	2.52	0.85
T_6	2.90	0.40	2.07	2.24	0.73
T_7	3.18	0.42	2.20	2.48	0.81
T_8	2.60	0.39	2.09	2.35	0.73
SE	0.04	0.01	0.07	0.10	0.05
CD(0.05)	0.12	0.03	0.23	0.32	0.16

T_0 Absolute control

T_1 Fertilizers + fym per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym t ha^{-1} +cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym t ha^{-1}+ cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP +fym t ha^{-1} + cdsw 12 ½ t ha^{-1}

The P content of plant was significantly influenced by different treatments. T_2 recorded the highest value of 0.48 per cent and it was significantly superior to others. T_2 was followed by T_3, T_5 and T_7 which were on par. T_0 showed the lowest value (0.27 per cent). The range of per cent P content was 0.38 to 0.43 in the treatments other than T_2 and T_0.

The highest K content of 2.64 per cent was noticed in T_2 followed by T_3 (2.45 per cent) and T_5 (2.25 per cent) which were on par. The lowest value of 1.75 per cent was noticed in T_0.

Application of cdsw significantly influenced calcium content of plant. The highest Ca content of 2.89 per cent was observed in T_2 and it was significantly superior to other treatments. T_2 was followed by T_3, T_5 and T_7. In these treatments per cent Ca content was in the range of 2.48 to 2.56 and were statistically on par.

The Mg content was the highest (0.93 per cent) in T_2 which was on par to T_3, T_5 and T_7 with values 0.86, 0.85 and 0.81per cent respectively. T_0 showed the lowest value and it was 0.52 per cent.

4.4.3.1.2 Second Cut (Table 25)

In the second cut, the highest N content of 3.9 per cent was recorded by T_3 followed by T_5, T_7 and T_1. They were statistically on par. T_0 showed the lowest N content and it was only 1.8 per cent, while in other treatments it was in the range of 3.1 to 3.7 per cent.

The P content ranged from 0.24 to 0.44 per cent. The highest value was observed in T_2 and the lowest in T_0. T_2 was on par to T_1, T_3, T_5 and T_7 with values 0.43, 0.43, 0.42 and 0.41 per cent respectively.

T_3 recorded the highest K content of 2.80 per cent. T_3 was significantly superior to other treatments. The lowest K content was noticed in T_0 and was 1.43 per cent.

Table 25. Influence of composted dairy waste on content of macronutrient in amaranthus

2nd cut

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_0	1.80	0.24	1.43	1.67	0.37
T_1	3.40	0.43	1.80	2.42	0.83
T_2	3.60	0.44	2.23	2.88	0.82
T_3	3.90	0.43	2.80	2.52	0.86
T_4	3.30	0.38	1.67	2.26	0.68
T_5	3.70	0.42	1.73	2.47	0.82
T_6	3.20	0.36	1.67	2.25	0.73
T_7	3.60	0.41	1.87	2.50	0.85
T_8	3.10	0.34	1.65	2.20	0.70
SE	0.13	0.01	0.07	0.10	0.04
CD(0.05)	0.39	0.04	0.23	0.32	0.13

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym t ha^{-1}+cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

Application of cdsw significantly influenced the calcium content. The highest Ca content of 2.88 per cent was observed in T_2 and the lowest value was observed in T_0 (1.67 per cent). T_2 was significantly superior to other treatments. It was followed by T_3, T_5, T_7 and T_1 were statistically on par.

The highest Mg content of 0.86 per cent was recorded by T_3 and was on par to T_1, T_2, T_5 and T_7. The lowest value was recorded by T_0 which was only 0.37 per cent.

4.4.3.1.3 Third Cut (Table 26)

N content was significantly influenced by the treatments. It ranged from 1.5 to 2.8 per cent. The highest N content was observed in T_1 followed by T_2, T_3 and T_5 and were statistically on par. The lowest N content was recorded by T_0.

The highest P content was showed by T_2 followed by T_1 and they were on par T_2 and T_1 were significantly superior to other treatments. The lowest value of 0.18 per cent was showed by T_0.

The content of K ranged from 0.72 to 1.1 per cent. T_1 showed the highest K content of 1.1 per cent. T_1 was on par with T_3, T_5 and T_7. The lowest K content was noticed in T_0

The highest Ca content of 2.30 per cent was showed by T_2 followed by T_3. They were on par to other treatments except T_0. The calcium content was the lowest in T_0 and it was 1.57 per cent.

Mg content ranged from 0.25 to 0.77 per cent. The highest Mg content was recorded by T_1 and the lowest by T_0. T_1 was on par to other treatments except T_0.

Table 26. Influence of composted dairy waste on content of macronutrient in amaranthus

3rd cut

Treatments	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
T_0	1.50	0.18	0.72	1.57	0.25
T_1	2.80	0.35	1.10	2.26	0.77
T_2	2.60	0.36	0.98	2.30	0.61
T_3	2.50	0.31	1.05	2.28	0.71
T_4	2.10	0.28	0.82	2.25	0.56
T_5	2.50	0.29	1.01	2.23	0.73
T_6	2.10	0.26	0.85	2.16	0.64
T_7	2.40	0.30	1.06	2.24	0.71
T_8	1.90	0.25	0.88	2.09	0.65
SE	0.117	0.018	0.040	0.112	0.071
CD(0.05)	0.348	0.053	0.121	0.334	0.211

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP +fym 25 t ha^{-1} +cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP +fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

4.4.3.2 Fe, Mn, Zn and Cu

4.4.3.2.1 First Cut (Table 27)

Data given in Table 27 revealed that application of cdsw had a significant effect on content of micronutrients in plant.

In the case of Fe, the highest value of 649.1 mg kg^{-1} was recorded by T_2 which was significantly superior to others. The content of Fe in T_3, T_5 and T_7 was 636.1, 635.5 and 638.1 mg kg^{-1} respectively and they were statistically on par. The lowest Fe content was noted in T_0 and it was 455.8 mg kg^{-1}.

The highest Mn content of 28.7 mg kg^{-1} was showed by T_2 which was significantly superior to others. T_2 was followed by T_3, T_5, T_7 and T_1 with values 24.3, 23.6, 23.9 and 22.6 mg kg^{-1} respectively and they were statistically on par. The lowest Mn content of 20.60 mg kg^{-1} was showed by T_0.

The Zn content ranged from 55.5 to 78.5 mg kg^{-1}. The highest being noted in T_2 and it was followed by T_3 and they were on par.

The Cu content ranged from 4.6 and 11.9 mg kg^{-1}. It was the highest in T_1 and the lowest in T_0. In other treatments it was in the range of 8.0 to 10.2 mg kg^{-1}. It was found that Cu content was lower in treatments receiving cdsw than fym.

4.4.3.2.2 Second Cut (Table 28)

The iron content was in the range of 393.2 to 602.6 mg kg^{-1}. The highest being recorded by T_1 and it was significantly superior to other treatments. In T_2 and T_3 it was 589.8 and 580.7 mg kg^{-1} respectively. The lowest value was noticed in T_0.

Table 27. Influence of composted dairy waste on content of micronutrient in amaranthus

1st cut

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
T_0	455.8	20.6	55.5	4.6
T_1	618.9	22.6	69.6	11.9
T_2	649.1	28.7	78.5	9.3
T_3	636.1	24.3	75.7	10.2
T_4	623.8	21.6	66.1	8.4
T_5	635.5	23.6	71.7	10.1
T_6	618.7	20.5	67.9	8.0
T_7	638.1	23.9	74.6	9.9
T_8	618.3	22.6	67.5	7.9
SE	3.67	0.63	1.32	0.67
CD(0.05)	10.91	1.88	3.94	1.98

T_0 Absolute control
T_1 Fertilizers + fym as per POP
T_2 POP fertilizers + 50 t ha^{-1} cdsw
T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}
T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}
T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}
T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}
T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}
T_8 ½ N + full PK of POP +fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

Table 28. Influence of composted dairy waste on content of micronutrient in amaranthus

2^{nd} cut

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
T_0	393.2	14.4	46.3	4.3
T_1	602.6	21.1	64.3	12.0
T_2	589.8	17.4	60.3	10.7
T_3	580.7	16.3	62.8	10.3
T_4	561.1	15.5	54.8	9.12
T_5	578.5	17.6	60.5	10.3
T_6	564.4	16.3	55.5	8.6
T_7	579.2	15.5	59.6	10.1
T_8	566.5	13.7	53.5	8.1
SE	1.17	1.12	2.00	0.88
CD(0.05)	3.50	3.33	5.94	2.63

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

Mn content ranged from 14.4 to 21.1 mg kg^{-1}. The highest being recorded by T_1 and the lowest by T_0. T_1 was significantly superior to other treatments.

The highest Zn content was noticed in T_1 (64.3 mg kg^{-1}) followed by T_3, T_5 and T_7 with values 62.8, 60.5 and 59.6 mg kg^{-1} respectively. T_0 showed the lowest value and it was 46.3 mg kg^{-1}.

Content of Cu ranged from 4.3 to 12 mg kg^{-1} and it was the highest in T_1 and the lowest in T_0. In other treatments it was in the range of 8.1 to 10.7 mg kg^{-1} and they were on par. The lowest value was recorded by T_0.

4.4.3.2.2 Third Cut (Table 29)

At third cut, Fe content ranged from 294.1 to 467.4 mg kg^{-1}. The highest value being recorded by T_1 and it was followed by T_3, T_5, T_2 and T_4 with values 457.6, 453.9, 447.5 and 446.2 mg kg^{-1} respectively.

The Mn content ranged from 12.7 to 18.6 mg kg^{-1}. The highest Mn content was noticed in T_1. In T_3 and T_5 it was 15.7 and 15.6 mg kg^{-1} respectively and were statistically on par. The lowest Mn content was recorded by T_0.

The highest Zn content was noticed in T_1 (58.6 mg kg^{-1}) followed by T_3, T_5 and T_1 with values 58.3, 55.4 and 54.5 mg kg^{-1} respectively. The lowest value was noticed in T_0.

Content of Cu was the highest in T_1 and it was 12.3 mg kg^{-1}. T_1 was significantly superior to others. In T_5, T_7 and T_3 it was 10.5, 10.2 and 10.1 mg kg^{-1} respectively.

Table 29. Influence of composted dairy waste on content of micronutrient in amaranthus

3rd cut

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
T_0	294.1	12.7	35.7	3.8
T_1	467.4	18.6	58.6	12.3
T_2	447.5	14.4	52.6	8.8
T_3	457.6	15.7	58.3	10.1
T_4	446.2	13.3	48.6	9.5
T_5	453.9	15.6	55.4	10.5
T_6	437.9	14.8	48.6	8.8
T_7	421.1	12.4	54.5	10.2
T_8	426.2	12.05	43.6	8.1
SE	7.78	1.60	2.64	0.57
CD(0.05)	23.12	2.98	7.84	1.72

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers +fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP +fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

4.4.4 Total Yield, Dry Matter Production, Days to flowering and B : C Ratio (Table 30)

Total yield was the highest in T_3 (378.8 g pot^{-1}) followed by T_2 (375 g pot^{-1}) and T_5 (370.8 g pot^{-1}) and they were on par. The lowest yield was recorded by T_0. Total yield ranged from 119.7 to 378.8 g pot^{-1}.

T_3 recorded highest dry matter production of 67.3 g pot^{-1} followed by T_2 (66.7 g pot^{-1}) and T_5 (64.7 g pot^{-1}) and they were on par. T_3, T_2 and T_5 were significantly superior to other treatments. The lowest production of dry matter was noticed in T_0.

Days to flowering was maximum in T_3 (49.6) followed by T_5 (49) and T_7 (48.3) and they were on par. Early flowering was noticed in T_0

B:C ratio ranged from 0.60 to1.85. The highest being recorded by T_3 and the lowest by T_0. T_3 was followed by T_2 and T_5 with values 1.81 and 1.80 respectively. They were on par. T_3, T_2 and T_5 were significantly superior to other treatments.

4.4.5 Physico-chemical Properties of Soil after Pot Culture Experiment (Table 31)

Properties of the soil used in pot culture after the experiment is presented in Table 31

From the data it can be seen that T_2 recorded the maximum value for pH (6.2) and it was significantly superior to other treatments. It was followed by T_3 and then by T_5 and T7 and were on par. Treatments T_1, T_4 T_6 and T_8 were also on par. The lowest value was noticed in T_0.

Table 30.. Influence of composted dairy waste on total yield, total dry matter, days to flowering and B:C ratio

Treatments	Total yield (g pot^{-1})	Total dry matter (g pot^{-1})	Days to flowering	B : C ratio
T_0	119.7	19.5	34	0.60
T_1	353.0	54.6	43.3	1.73
T_2	375.0	66.7	47.3	1.81
T_3	378.8	67.3	49.6	1.85
T_4	354.1	55.2	44	1.73
T_5	370.8	64.7	49	1.80
T_6	340.9	53.5	45.6	1.67
T_7	357.6	56.3	48.3	1.74
T_8	332.6	51.9	45.3	1.63
SE	2.69	1.04	0.86	0.02
CD(0.05)	8.00	3.10	2.56	0.05

T_0 Absolute control

T_1 Fertilizers + fym as per POP

T_2 POP fertilizers + 50 t ha^{-1} cdsw

T_3 POP fertilizers +fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_4 POP fertilizers + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_5 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_6 2/3 N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

T_7 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}

T_8 ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}

Table 31. Physico-chemical properties of soil used for pot culture after the experiment

Parameters	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	SE	CD	Before experiment
pH	5.0	5.5	6.2	5.8	5.4	5.6	5.3	5.7	5.3	0.09	0.28	5.2
EC (μS m^{-1})	112.1	124.7	134.3	132.2	115.8	130.5	118.8	128.4	120.5	1.40	4.16	138.6
Organic carbon (%)	0.33	0.93	0.97	0.92	0.86	0.92	0.84	0.92	0.85	0.004	0.012	0.69
Available N (kg ha^{-1})	215.3	351.7	330.8	340.5	321.5	338.8	318.6	330.6	315.4	12.9	38.5	220.5
Available P (kg ha^{-1})	60.5	92.2	102.6	98.3	89.2	95.2	86.4	94.3	85.6	0.87	2.60	68.4
Available K (kg ha^{-1})	176.5	287.5	268.8	276.3	260.3	275.8	258.5	278.5	259.8	1.41	4.21	203.6
Exchangeable Ca (cmol kg^{-1})	1.04	1.56	2.08	1.82	1.48	1.79	1.40	1.80	1.43	0.012	0.038	1.2
Exchangeable Mg (cmol kg^{-1})	0.46	0.78	0.62	0.68	0.58	0.72	0.56	0.71	0.58	0.018	0.054	0.54
DTPA extractable micronutrients												
Fe (mg kg^{-1})	18.6	29.6	36.3	33.6	28.90	34.2	30.2	32.8	28.6	0.67	2.01	24.2
Mn (mg kg^{-1})	1.49	1.82	1.75	1.68	1.58	1.70	1.60	1.73	1.55	0.03	0.08	1.69
Zn (mg kg^{-1})	2.15	5.80	5.09	5.23	4.80	5.16	4.60	5.08	4.8	0.025	0.076	2.42
Cu (mg kg^{-1})	1.02	1.55	1.23	1.37	1.18	1.38	1.08	1.35	1.10	0.010	0.029	1.32

Electrical conductivity ranged from 112.1 to 134.3 μSm^{-1} the highest being rerecorded by T_2 followed by T_3 and T_5 which were statistically on par. T_0 showed the lowest value.

The highest organic carbon was noticed in T_2 and it was significantly superior to other treatments. Second highest value was recorded by T_1 and it was on par with T_3, T_5 and T_7. The lowest organic carbon content was seen in T_0.

Analysis of the data revealed that T_1 recorded the highest value of available N (351.7 kg ha^{-1}) and was significantly superior to other treatments. T_1 was followed by T_3, T_5, T_7 and T_2 and were statistically on par. The lowest available N was recorded by T_0 (215.3 kg ha^{-1}). Available N was in the medium range in all treatments except in T_0 where it was low.

Available P was maximum in T_2 (102.6 kg ha^{-1}) and minimum in T_0 (60.5 kg ha^{-1}). T_2 was followed by T_3, T_5 and T_7 which were statistically on par.

Effect of treatments on available K was significant. Available K was the highest in T_1(287.5 kg ha^{-1}). In T_7, T_3 and T_5 it was 278.5, 276.3 and 275.8 kg ha^{-1} respectively. T_3, T_5 and T_7 were statistically on par. T_0 showed the lowest value (196.5 kg ha^{-1}).

The highest exchangeable calcium (2.08 cmol kg^{-1}) was noticed in T_2 and it was significantly superior to others. T_2 was followed by T_3, T_5 and T_7 and were statistically on par. The lowest value (1.04 cmol kg^{-1}) was recorded by T_0.

Exchangeable Mg was the highest in T_1 (0.78 cmol kg^{-1}) and it was significantly superior to other treatments. Second highest value was showed by T_5 followed by T_7 and T_3 which were statistically on par. Lowest available Mg was noticed in T_0.

Fe availability was maximum in T_2 (36.3 mg kg^{-1}) followed by T_3 and T_7 with values 33.6 and 32.8 mg kg^{-1} respectively. The lowest available Fe was recorded by T_0.

Available Mn was the highest in T_1 (1.82 mg kg^{-1}) followed by T_2 (1.75 mg kg^{-1}) and were statistically on par. The lowest available Mn was noticed in T_0.

Zn availability was maximum in T_1 (5.8 mg kg^{-1}) which was significantly superior to others. T_1 was followed by T_3 and T_5 and were on par. It was the lowest in T_0 .

Availability of Cu was the highest in T_1 (1.55 mg kg^{-1}) followed by T_5, T_3 and T_7 and they were statistically on par. T_0 showed lowest value (1.02 mg kg^{-1}).

DISCUSSION

5. DISCUSSION

The important results of the experiment carried out to investigate the feasibility of utilising dsw as an organic source in soil productivity presented in the preceding chapter are discussed in the light of fundamental principles and evidences from published literatures, keeping in view the objectives proposed in the study.

5.1 CHARACTERISATION OF DAIRY INDUSTRY SOLID WASTE

Organic wastes from industries are less commonly used to improve soil conditions and fertility. In recent years worldwide awareness of the need to use renewable forms of energy has revived the use of organic materials to improve environmental conditions and public health and the need to reduce costs of fertilizing crops. The literature contains many references to the quantities of organic materials available in the world for recycling and their vast potential for supplying plant nutrients.

Dairy industry is one of the major industries which generates large volume of liquid waste rich in organic load which after biological oxidation and sundrying forms a solid waste. The characteristics of dairy industry solid waste presented in Chapter 4 provide information of its potential in improving soil conditions, as a source of available nutrients and encouragement of microbial activity.

It may be seen from the data presented in Table 6 that dsw has a near neutral pH of 6.5 indicating its suitability in ameliorating acid soils. Ameliorating property of cdsw is evident from the increase in pH observed in soil before and after application of cdsw. Sparling *et al.* (2001) have reported an increase in soil pH upto 1.8 units due to application of dairy industry waste. It contained 37.5 per cent organic carbon and 5.8 per cent N revealing that it had attained a stable C:N ratio. The low microbial count in dsw may be an attribute of its stable C:N ratio. Observational trials in coconut garden of the dairy plant at Ambalathara, Thiruvananthapuram showed that its direct application is of little use as a manure. Composting of dairy waste after mixing with kitchen waste and cowdung was resorted to in the light of this observation. Recycling of this waste in agricultural lands due to its high content of N has been proposed by Lopez- Mosquera *et al.* (2002b). Absence of heavy metals indicates that application of dairy waste in agricultural lands poses no problem of heavy metal pollution. Krishnamurthy *et al.* (1994) recommended the use of dairy effluents for growing vegetables and forage crops for the absence of heavy metals in it. The order of abundance of microorganism in dsw was bacteria > fungi > actinomycetes and it is same as that in soil.

5.2 VERMICOMPOSTING OF DAIRY INDUSTRY SOLID WASTE

Among the various methods of waste management, composting is more ecofriendly and more important method of recycling from the agricultural point of view. Composting offers several advantages as a waste disposal method including increased availability of plant nutrients, elimination of unfavourable odours and easy handling. The role of earthworms as biological agents in the degradation of organic waste is already recognized and vermicomposting is the bioconversion of organic waste material into compost through earthworm consumption.

Handling of dsw is not easy as it is very hard and dry. To make it soft and friable it is subjected to vermicomposting after mixing it with vegetable waste and cowdung. Comparison of important properties of compost (cdsw) and the biowaste mixture containing dsw given in Table 7 reveals a 3 times reduction in C:N ratio. A C:N ratio below 20 is indicative of an acceptable maturity in the finished product, ratio of 15 or even less being preferable (Inbar *et al.*, 1990). Bacteria, fungi and actinomycetes increased 5, 3 and 7 times respectively in cdsw than in biowaste mixture. Increased microbial population in cdsw is inidicative of its ability to increase soil productivity (Balasubramaniam *et al*., 1972).

5.3 INCUBATION STUDY

Any material other than known fertilizer and manures proposed to be added to soil need to address the soil deficiencies of plant nutrients or amend the soil to correct its physical, chemical or biological properties so as to sustain soil fertility on a long term basis. The results of the incubation study on the effect of dsw and cdsw on physico-chemical and microbiological properties of the soil given in Table 8 to 19 give more insight into these aspects. Salient results of incubation study revealing the influence of dsw and cdsw on available nutrients, bulkdensity, water holding capacity and microbial population in soil for a continuous period of 12 weeks are discussed here.

5.3.1 Available nutrients

5.3.1.1 N, P and K

Results in Table 8 to 10 show the significant effect of treatments on the available N, P and K status of soil. Availability of N increased with increasing periods of incubation upto 6-8 weeks (Fig.3). The available N was the highest with treatment which received cdsw at higher dose (T_5). This may be due to the beneficial microflora present in the wormcast which enhanced mineralisation of N. The high microbial count in cdsw (Table 7) support this. More availability of N in initial periods and less in later periods in cdsw applied treatment (T_5) compared to fym applied treatment (T1) indicate that mineralisation is rapid in cdsw compared to fym (Toor *et al.*, 2001). The available N content in soil incubated without any organic source remained almost constant. It may be due to the stabilized nature of organic matter with respect to its decomposition (Dinesh and Dubey, 1999).

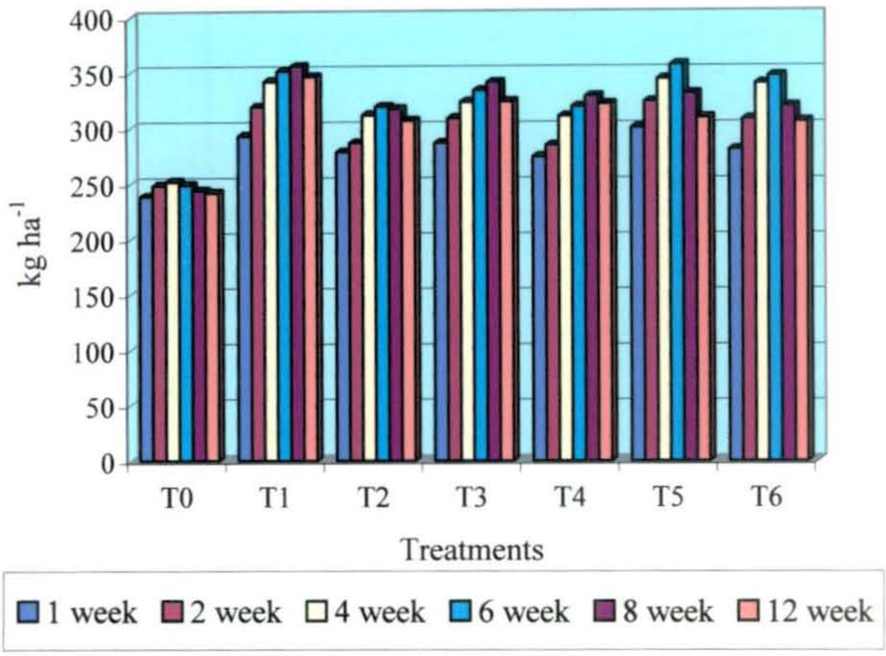

Fig. 3 Influence of dairy industry solid waste on available N (kg ha-1) in soil at different periods of incubation

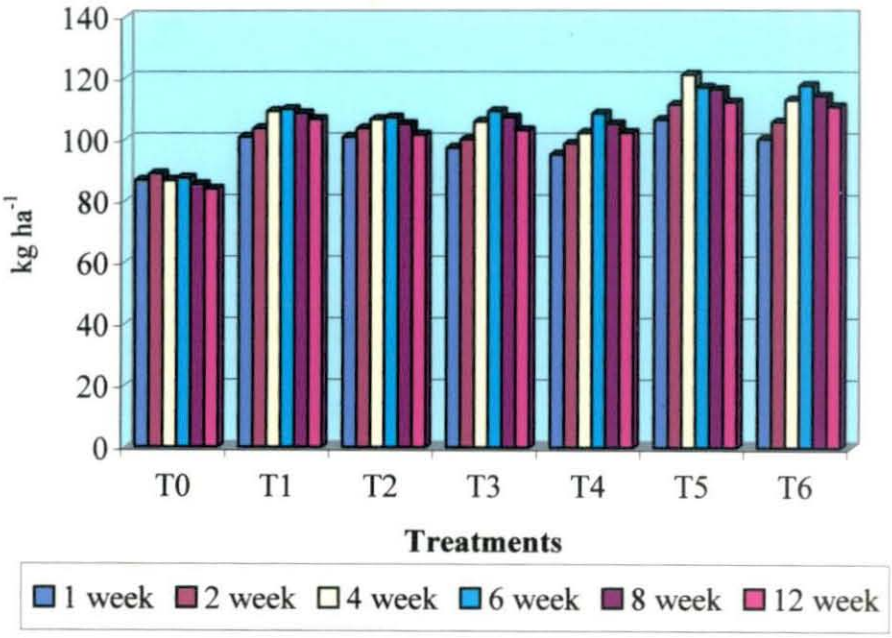

Fig. 4 Influence of dairy industry solid waste on available P ($kg\ ha^{-1}$) in soil at different periods of incubation

Available P increased upto four weeks in cdsw applied treatments and upto six weeks in fym and dsw applied treatments (Fig. 4). After that P availability decreased. Highest P availability was noticed in cdsw applied treatments throughout the incubation period. Readily available P is more with cdsw compared to fym. Highest available P (121.10 kg ha^{-1}) was recorded in T_5 at four weeks of incubation which received cdsw at higher dose. P solubilising bacteria present in the vermicompost induce mineralisation and thus increase availability of P (Indira *et al.*, 1996). Increased mineralisation of soil P due to high phosphatase and phytase activity (Alexander, 1961) might be the reason for high available P obtained with cdsw. Inspite of high content of Fe and Al in the soil (Hassan, 1977) the availability of P increased in soil due to the complexation of organic matter with iron and aluminium ions and hydrous oxides and thereby preventing these materials from reacting with phosphates (Brady, 2001).

Available K was maximum at fourth week in cdsw applied treatments (Fig.5). It might be due to faster mineralisation from cdsw during the initial periods of incubation. In other treatments which received fym and dsw, availability of K increased upto six weeks and then declined. The increase in available K is ascribed to reduction of K fixation and release of K from exchange sites due to interaction of organic matter with clay (Tan 1982). Highest K availability of 249.2 kg ha^{-1} was noticed in T_5 at four weeks of incubation in which cdsw was applied at a higher dose. It might be due to high K content (1.81%) of cdsw. As the microbial and enzyme activity is reported to be more in vermicompost, the K build up in the soil solution is also more (Basker *et al.*, 1994). K availability was more with organic matter added soil compared to control treatments. This might be due to high microbial activity in organic matter which result in better mineralisation and enhanced release of basic cations like K^+ (Ammal and Muthiah, 1994).

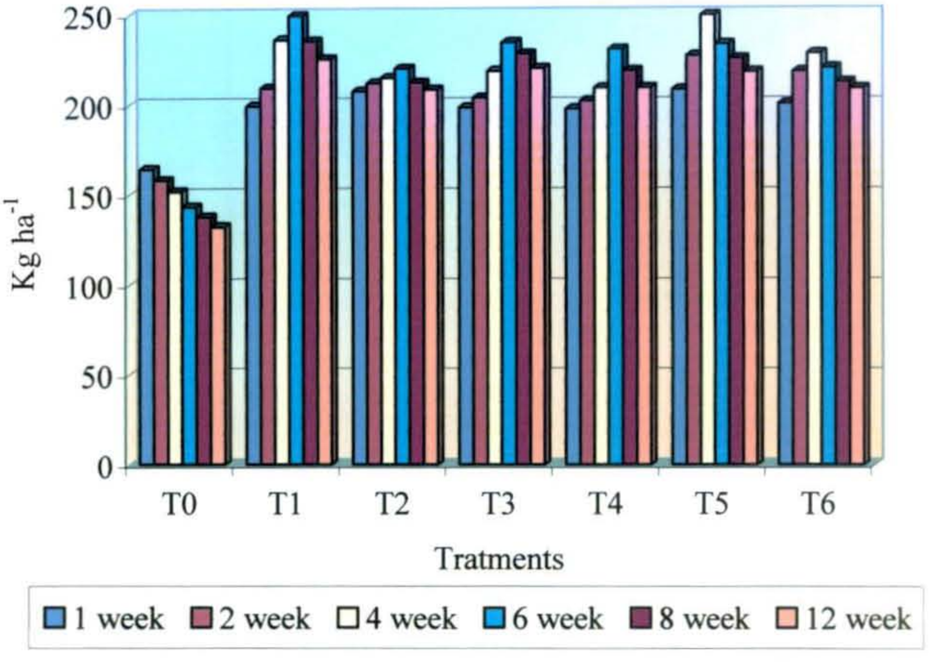

Fig. 5 Influence of dairy industry solid waste on available K (kg ha^{-1}) in soil at different periods of incubation

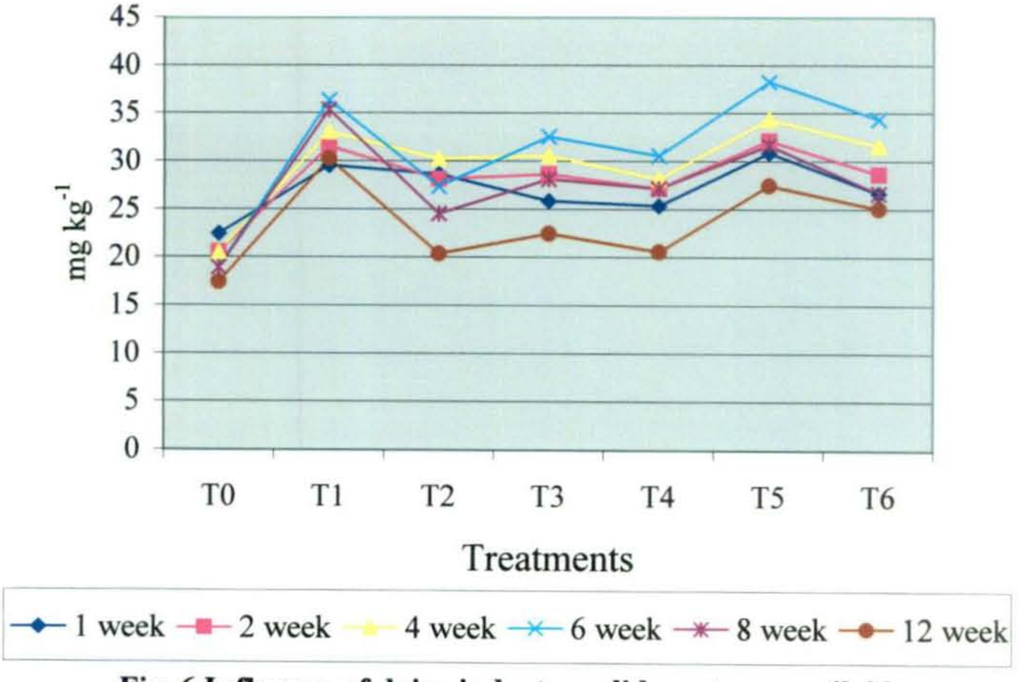

Fig. 6 Influence of dairy industry solid waste on available Fe (mg kg^{-1}) in soil at different periods of incubation

5.3.1.2 Fe, Mn, Zn and Cu

In general it is seen from the Table 11, 12, 13 and 14 that the effects of treatments of the incubation study is significant on available status of Fe, Mn, Zn and Cu content in soil (Fig.6, 7, 8 & 9). The highest value of available Fe (38.3 mg kg^{-1}), Mn (3.27 mg kg^{-1}) and Zn (8.76 mg kg^{-1}) recorded by the treatment which received cdsw at higher dose (T_5) after four to six weeks of incubation indicates that it is superior to fym in increasing the availability of micronutrients. The observed increase in the available micronutrients may be due to direct contribution of elements from incorporated organic materials (Debnath and Hajra, 1976). Moreover organic materials may supply chelating agents that aid in maintaining the solubility of micronutrients (Tisdale *et al.*, 1997). The organic complexes of micronutrients are less stable and more amenable to DTPA extraction (Das, 2000) which might have contributed to the increased availability of micronutrients. The availability of Cu was maximum in the treatments which received fym (T_1). Availability of Cu in treatments receiving dsw and cdsw is lower than that in T_1 due to the absence of Cu in dsw as seen in Table 6.

5.3.1.3 Bulk Density

The result given in Table 15 and Fig.10 indicate that all treatments except T_0 showed a decrease in bulkdensity upto six weeks and then it increased. The lowest bulkdensity is recorded by T_5 throughout the incubation period followed by T_1.

Larson and Allmaras (1971) have identified that organic matter can influence bulkdensity of soils by decreasing aggregate density, by increasing the size and narrowing the range in aggregate diameters. Evidence indicates that increasing amount of organic matter in soil will usually be accompanied by increased aggregate porosity, lowered aggregate density and a narrower range in aggregate size distribution which will result in lowered soil bulkdensity. Gupta and Larson (1979)

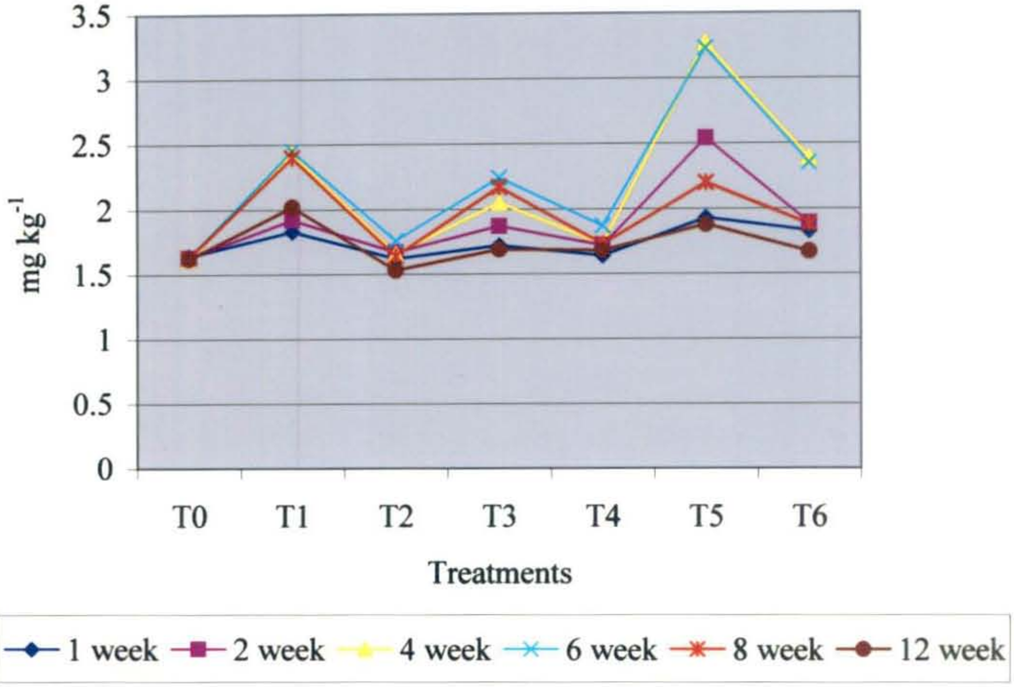

Fig. 7 Influence of dairy industry solid waste on available Mn (mg kg^{-1}) in soil at different periods of incubation

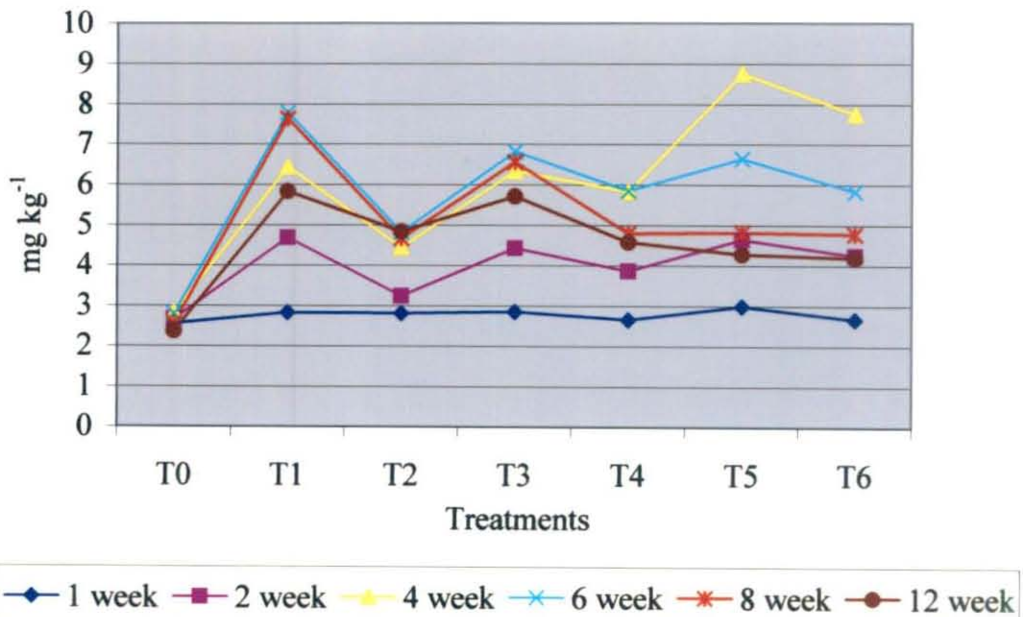

Fig. 8 Influence of dairy industry solid waste on available Zn (mg kg^{-1}) in soil at different periods of incubation

have also cited the inverse relation between organic matter content and bulkdensity of soil. A decrease in bulkdensity was reported by Gupta *et al.* (2000) in crop residue and fym incorporated treatments. Reduction in bulkdensity of soil may be due to better soil aggregation and aeration brought about by the organic amendments (Kadalli *et al.*, 2000).

5.3.14 Water Holding Capacity

It may be seen from Table 16 that water holding capacity of soil amended with organic matter is more compared to non amended soils. It is maximum in T_5 (35.6 per cent) which received cdsw at higher dose after six weeks whereas in T_2 which received dsw in higher dose it is only 31.8 per cent. This is mainly because unrotted materials holds little water and is coarse and fibrous, while the compost holds water and is friable (Larson and Clapp, 1984). Water holding capacity increased upto six weeks and then it declined (Fig.11). Gupta and Larson (1979) have reported that available water is more in soil with organic matter than without any organic matter. According to them organic matter greatly influence water retention through soil structural changes *i.e.*, through pore size and amount differences both within and between aggregates. Addition of organic matter increased the water holding capacity of soil through improved soil structure which influences the moisture energy relationships (Brady, 2000). Similar reports were given by Prasad *et al.* (1983) and Hidalgo and Harkes (2002) .

5.3.1.5 Microbial Population

In general it is evident from the Tables 17, 18 and 19 that microbial population in soil is significantly influenced by the treatments. Increase in microbial population is noted in all treatments except T_0 from second week onwards. It reached the peak in the sixth week and then declined (Fig.12,13 &14). The lag phase of microbial population that is generally observed in soil is not present in this study. This may be due to the abundance of easily decomposable organic materials in all treatments

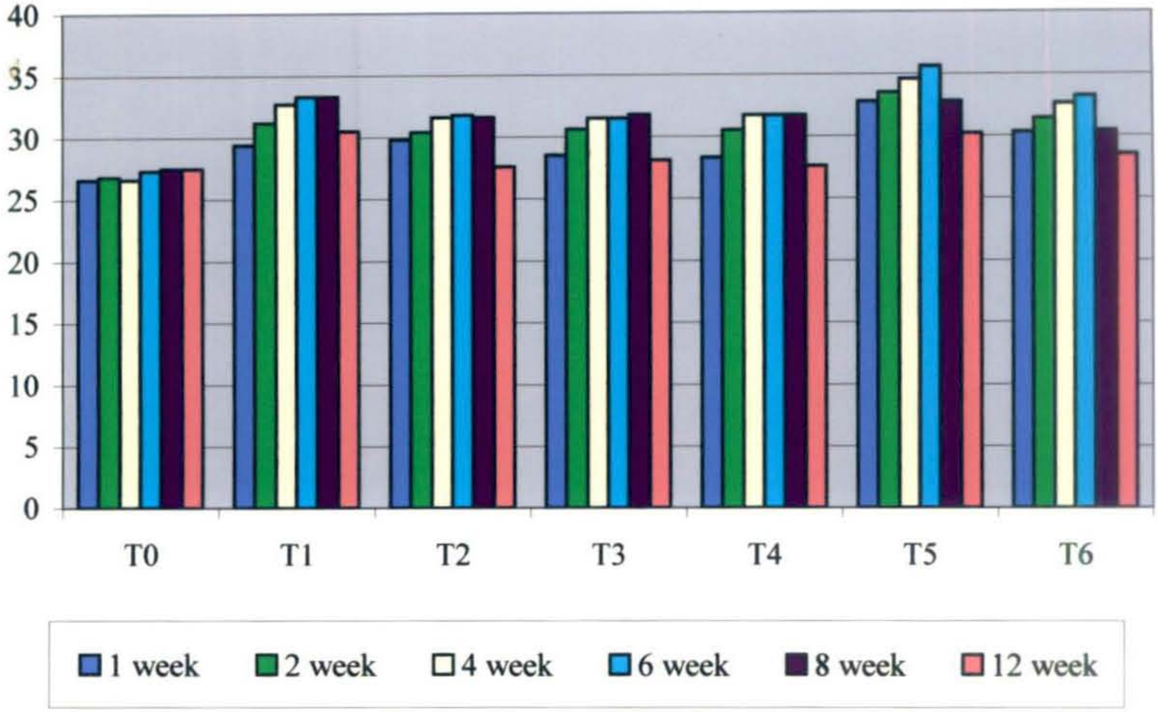

Fig.11 Influence of dairy industry solid waste on water holding capacity (%) of soil at different periods of incubation

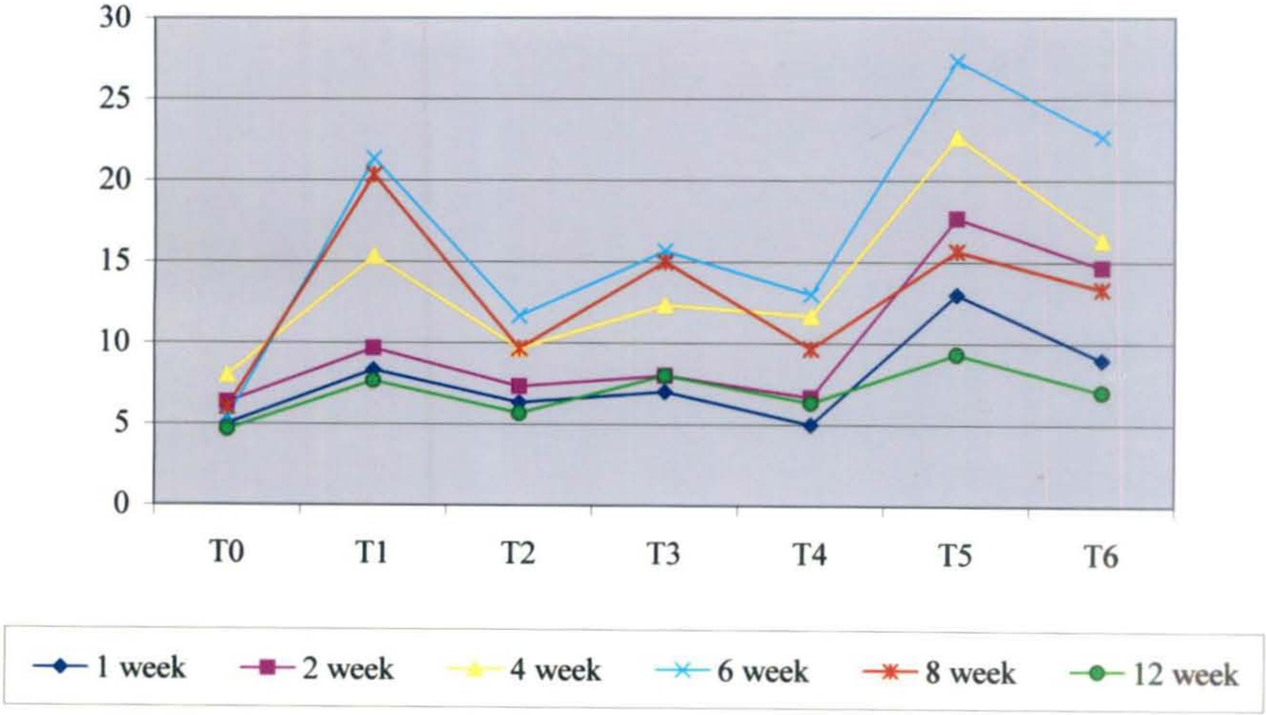

Fig.12. Influence of dairy industry solid waste on fungal population (dilution factor 10^4) in soil at different periods of incubation

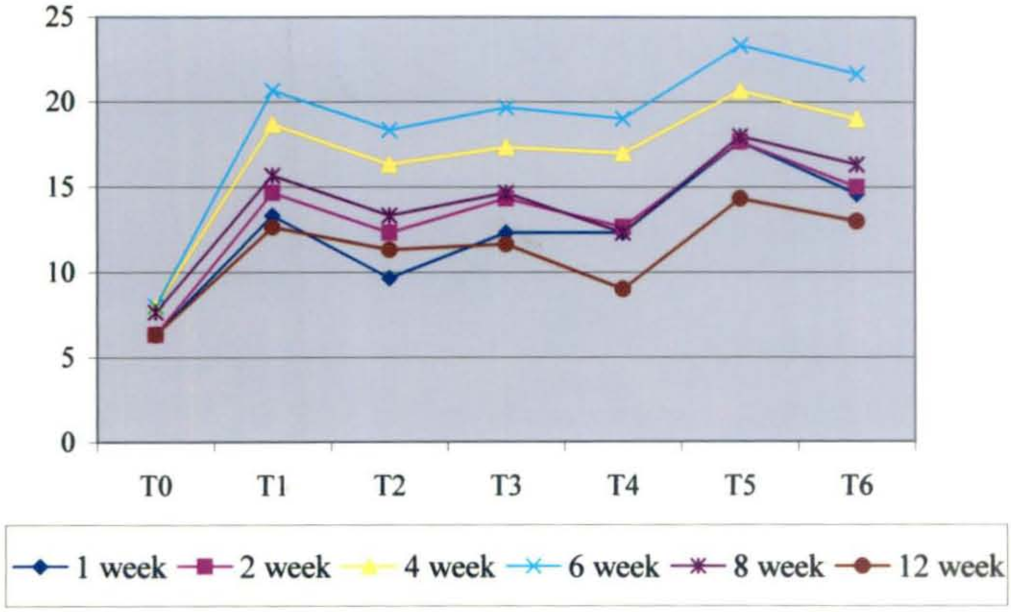

Fig.13 Influence of dairy industry solid waste on bacterial population (dilution factor 10^6) in soil at different periods of incubation

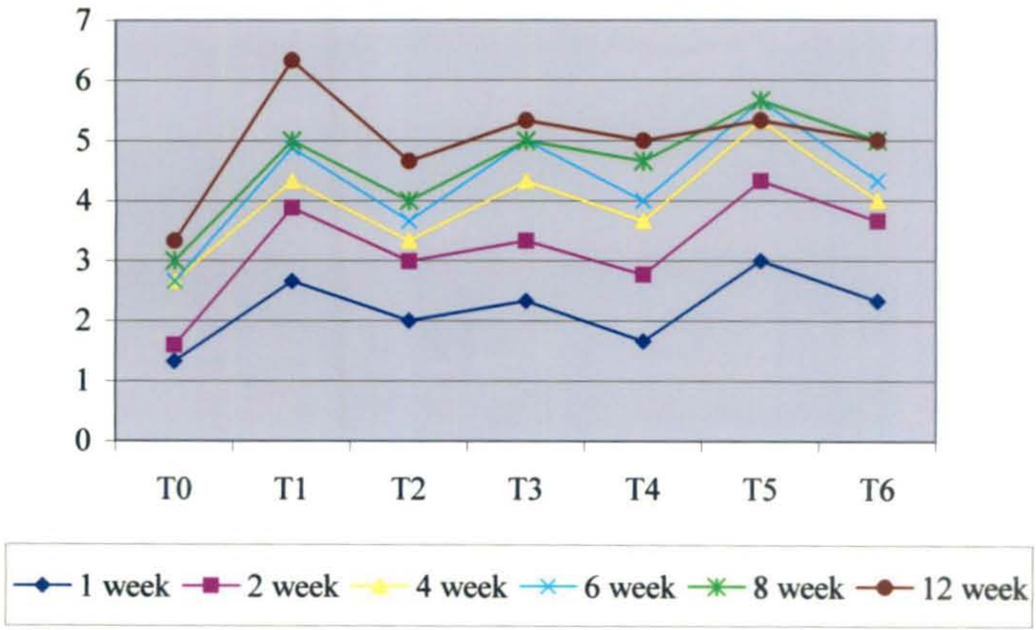

Fig. 14 Influence of dairy industry solid waste on actinomycete population (dilution factor 10^6) at different periods of incubation

except T_0. The highest bacterial (27.33 x 10^6) and fungal (23.33 x 10^4) population were recorded by the treatment which received cdsw at higher dose (T_5). It indicate that cdsw is superior to fym in increasing the microbial population in soil. This may be due to the more count of beneficial microorganisms in vermicompost (Indira *et al.*, 1996).However the effect of dsw on microbial population in soil is significantly inferior to fym. This may be due to the low microbial count in dsw than in fym and cdsw. Addition of organic materials increased population of bacteria and fungi in soil upto six weeks of incubation. Then their population decreased with advancement of time but always remained higher than those of unamended soil (Ros *et al.*, 2003). Kukraja *et al.* (1991) and Lal *et al.* (2002) also reported the beneficial effect of organic matter addition on microbial population in soil. Treatment effect was non-significant initially with respect to the population of actinomycetes in soil. This may be due to competition from bacteria and fungi for the source of food. Further actinomycetes are sensitive to acid soil conditions (Brady, 2001). The decline in microbial population with advancement of time may be due to the scarcity of food and competition for resources. Moreover microorganism will be subjected to predation taking place in the form of grazing by protozoa (Killham, 1994).

5.4 INFLUENCE OF DAIRY INDUSTRY SOLID WASTE ON AMARANTHUS

Dairy industry solid waste is an organic waste rich in N. Despite the high N content, it is unsuitable for direct use as it is hard dry and inactive.. Hence its compost is tested in amaranthus which is a leafy vegetable having high requirement of N. Pot culture study has clearly revealed the effect of cdsw on growth, yield and quality of amaranthus and physico-chemical properties of the soil. The important results obtained from the study are discussed here.

5.4.1 Effect on Growth

The results presented in the preceding chapter (Tables 20, 21 and 22) show that the effect of treatment is significant on height of plant, number of branches, leaf stem ratio and internodal length at three stages.

Height of the plant was maximum in T_2 which received NPK @ POP and cdsw 50 t ha^{-1} (Fig.15). T_3 and T_5 were statistically on par to T_2. Same trend was observed in internodal length also (Fig17). Maximum number of branches and minimum leaf-stem ratio were recorded by T_2 in the first two stages and by T_3 in the third stage (Fig. 16&18). The increased vegetative growth is due to the higher utilization of plant nutrients, that are more available from cdsw. Plant growth promoting hormones present in compost can also enhance the vegetative growth of plant (Nielson, 1965). Increased vegetative growth of crops due to plant growth promoting substances in vermicompost has been reported earlier by Pushpa (1996) and Sailajakumari (1999). Data given in Table 8 reveals that available N status was maximum in soil when cdsw was used at higher dose upto 4-6 weeks after its application. Amaranthus being a C_4 plant CO_2 fixation is high, N demand is also considerable during the vegetative growth and formation of new leaves, stem and root (Devlin and Witham 1986). As cited by Mengal and Kirkby (1987) meristematic tissues have a very active protein metabolism and photosynthates transported to these sites are used predominantly in the synthesis of nucleic acids and proteins. For this reason, during vegetative stage, N nutrition controls the growth rate of crops. These explains the reasons for the enhanced effect of cdsw on growth characters. Similar increase in growth character due to increase in N fertilization have been reported by Singh *et al.* (1986) and Ramachandra and Thimmaraju (1983) in amaranthus.

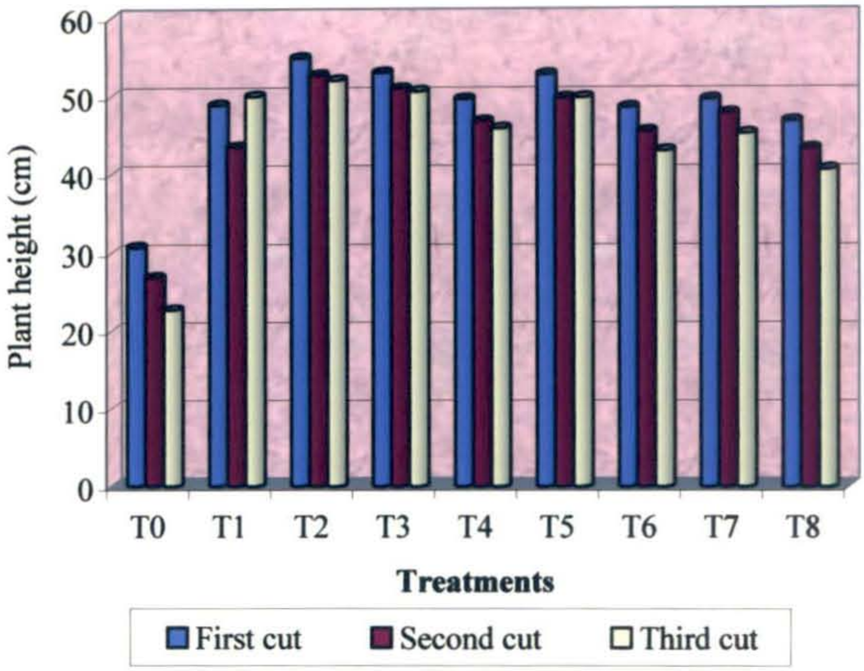

Fig.15 Influence of composted dairy solid waste on height of amaranthus

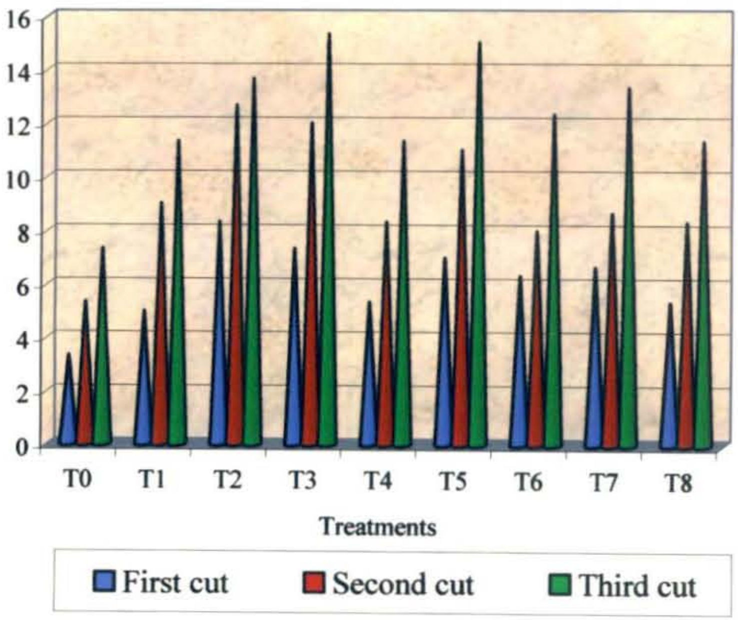

Fig. 16 Influence of composted dairy solid waste on number of branchesof amaranthus

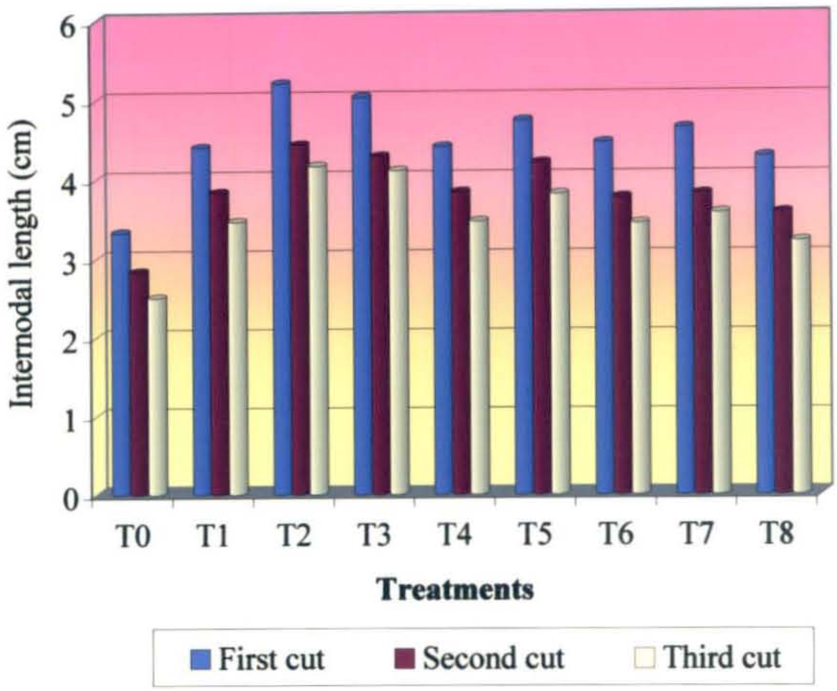

Fig.17. Influence of composted dairy solid waste on internodal length of amaranthus

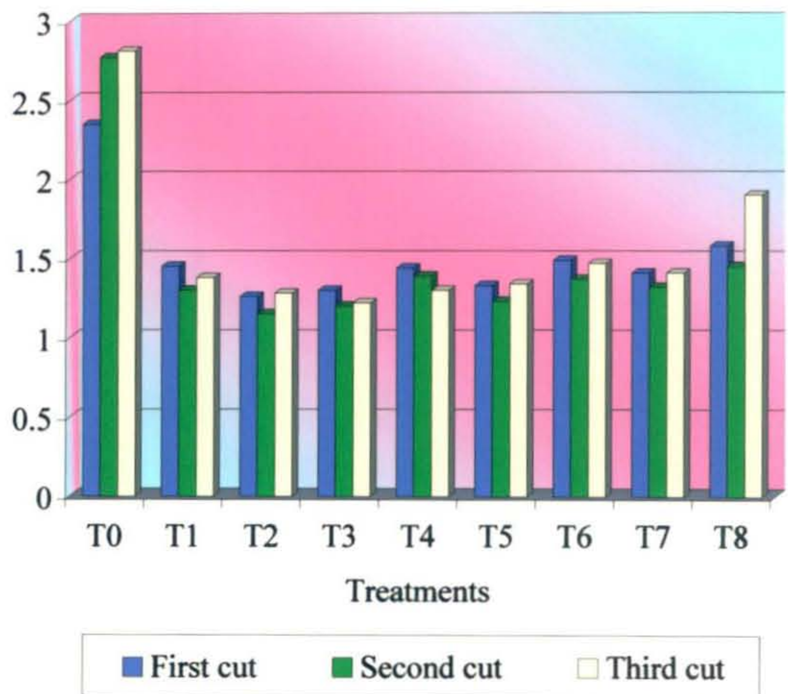

Fig.18 Influence of composted dairy solid waste on leaf stem ratio of amaranthus

5.4.2 Effect on Yield

The results presented in Tables 20, 21 and 22 indicate that the yield was maximum in T_2 (NPK @ POP and cdsw 50 t ha^{-1}) in the first and second cut and in T_3 (NPK @ POP and cdsw and fym @ 25 t ha^{-1} each) in the third cut. The higher availability of N towards later periods of incubation from fym as evidenced from the incubation study (Table 8) might have contributed to the higher yield in T_3 in the third cut. The enhanced microbial activity in cdsw resulted in an increase in concentration of nutrients. The higher availability of nutrients especially N (Table 8) improved soil physical conditions and increased soil microbial population as indicated in the incubation experiment of the present study might have contributed to high yield (More, 1994). Debale (1998) and Vasanthi and Kumaraswamy (1999) have reported significant improvement in growth components and yield with increase in nutrient supply. Data given in Table 30 indicates that total yield was the highest (378.8 g pot^{-1}) in T_3 which received NPK @ POP and fym and cdsw @ 25 t ha^{-1} each. T_2 and T_5 were on par to T_3 (Fig. 10) indicating that use of cdsw can reduce use of fym and fertilizer N to the extent of ½ and $^{1}/_{3}$ respectively of POP recommendation.

B:C ratio ranged from 0.60 to 1.85 (Table 30). The highest B:C ratio was noticed in T_3 (Fig.22) in which 50 per cent of the recommended dose of fym was substituted by cdsw. T_3 was followed by T_2 (NPK @ POP and cdsw 50 t ha^{-1}) and T_5 ($^{2}/_{3}$ N and PK @ POP and fym + cdsw @ 25 t ha^{-1} each) and they were statistically on par. The highest B:C ratio in T_3 is consequent to the significant increase in yield due to the use of cdsw. The results also revealed that use of cdsw can reduce the use of fym and fertilizer N to the extent of ½ and $^{1}/_{3}$ respectively of POP recommendation.

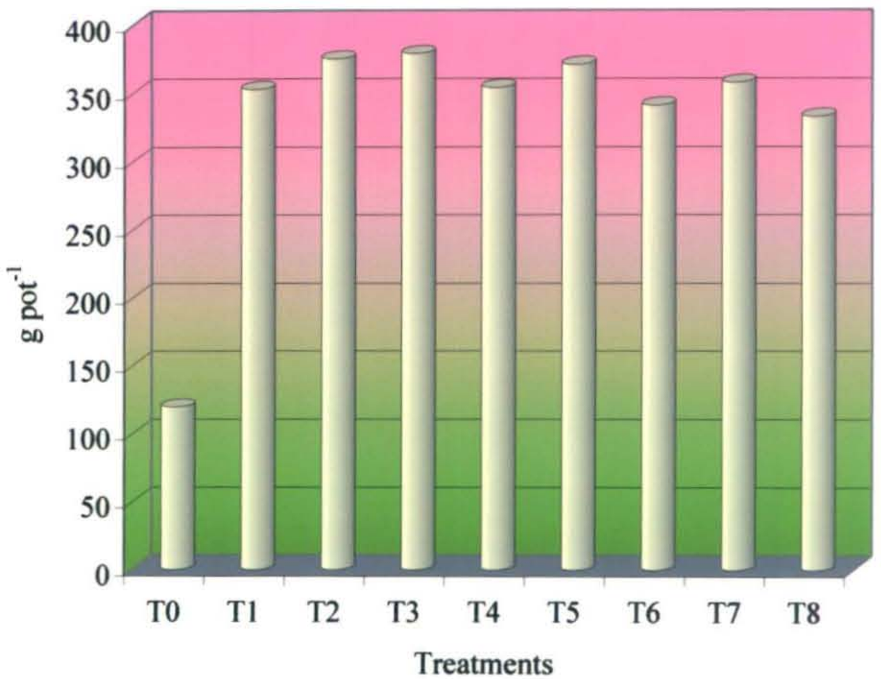

Fig.21 Influence of composted dairy waste on total yield of amaranthus

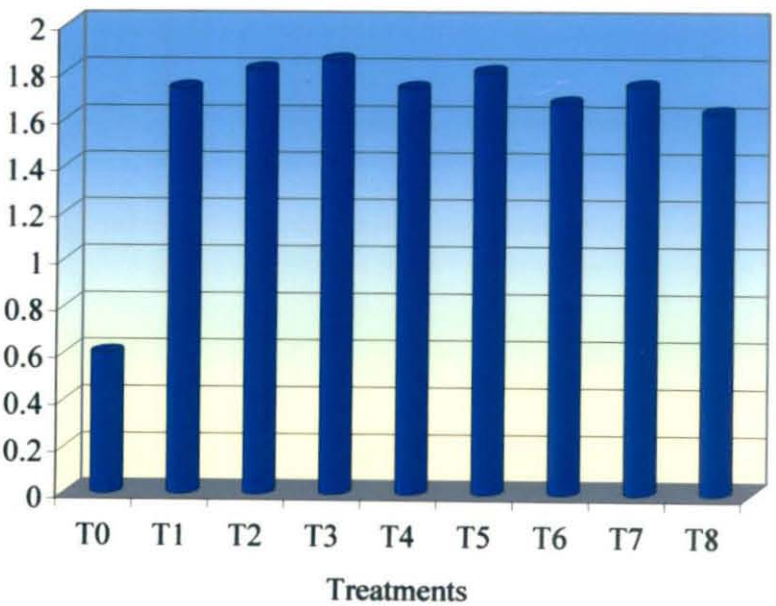

Fig.22 Influence of composted dairy waste on B:C ratio of amaranthus

Plate 1. Effect of treatments T_0, T_1, T_2 and T_3 on growth and yield of amaranthus

Plate 2. Effect of treatments T4, T5, T6, T7 and T8 on growth and yield of amaranthus

5.4.3 Crop Quality

The quality parameters studied were the content of nitrate (antinutrient factor) and beta carotene (nutrient factor). Results presented in Table 23 revealed that content of nitrate and beta carotene were the highest in T_2 which received NPK @ POP and cdsw 50 t ha^{-1}. The critical content of nitrate in leafy vegetables is 0.3 per cent (Mengel and Kirkby 1987). Nitrate content ranged from 0.04 to 0.35 per cent in various treatments in the present study indicating that in some treatments it is above the critical level. Treatments which exceeded the critical limit of nitrate are T_1, T_2, T_3 and T_5 in the first cut, T_1, T_2 and T_3 in the second and T_2 in the third cut. Nitrate content was higher in first and second cut compared to third cut (Fig. 19). This coincides with more availability of N at 6-8 weeks as indicated in the incubation study (Table 8). Nitrate content in plants depends largely on the level of nitrogen nutrition. Studies conducted by Sukumar and Rajan (2001) revealed that nitrate content in amaranthus increased with increase in level of N.

Beta carotene content in the present study ranged from 2192 to 7027 μg 100 g^{-1} in different treatments. Prakash and Pal (1991) noticed the range of carotene content in different accessions of vegetable amaranth as 90-200 mg kg^{-1}. The highest beta carotene content was noticed in second cut and the lowest in third cut (Fig.20). This may be due to increased N supply at six to eight weeks as evidenced from the incubation study (Table 8). This is in conformity with the findings of Scharrer and Burke (1953) who reported that increasing levels of N supply raised carotene content in plants.

5.4.5 Effect on Nutrient Content of Plant

Data presented in Table 24 to 29 clearly indicate that the nutrient content in plants was significantly influenced by different treatments.

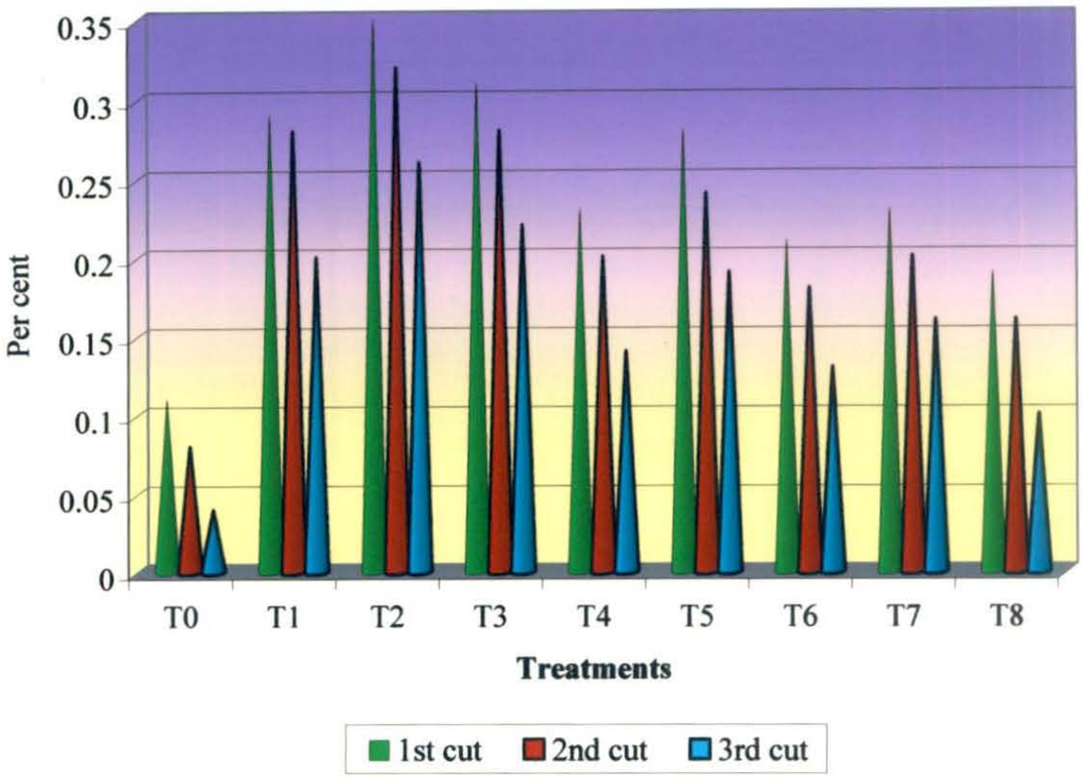

Fig.19, Influence of composted dairy solid was on nitrate content of amaranthus

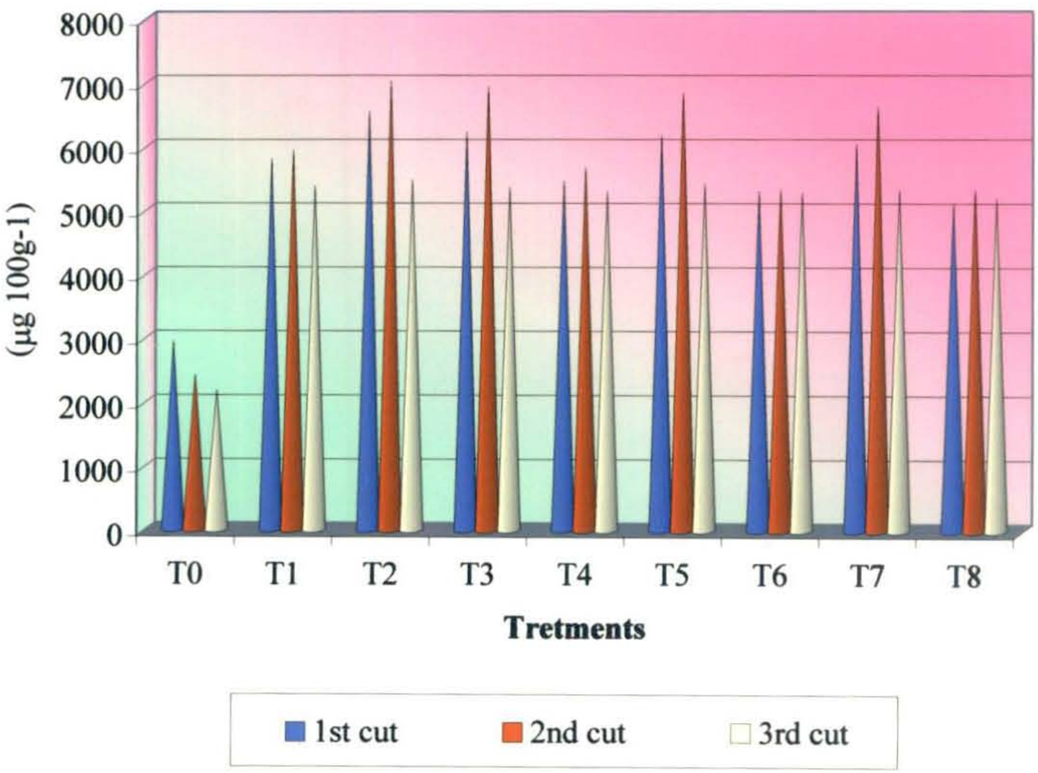

Fig. 20. Influence of composted dairy solid was on beta carotene content of amaranthus

N content in plant was higher in the second cut in all treatments than in the first and third cuts. In the first cut, highest N content was noticed in T_2 which received NPK @ POP and cdsw 50 t ha^{-1}. The highest N content was recorded by T_3 (NPK @ POP and fym + cdsw 25 t ha^{-1} each) and T_1 (NPK @ POP and fym + 50 t ha^{-1}) in the second cut and third cut respectively. The initial increase in N content with cdsw applied treatment may be attributed to the enhanced availability through faster mineralisation (Stephens *et al.*, 1994). The high availability of N from fym at later periods as evidenced from the incubation study (Table 8) might have contributed to the high N content in T_3 and T_1 in second and third cut respectively.

P content was maximum in T_2 which received NPK @ POP and cdsw 50 t ha^{-1}. Readily available P is more with cdsw compared to fym. This may be due to the higher P content in cdsw (1.97 %) than in fym which contains only 0.2 per cent P. Mineralisation induced by P solubilising bacteria present in cdsw increased the availability of P in soil (Indira *et al.*, 1996) and thus increased P content in plant.

The highest content of K in first, second and third cut was noticed in T_2, T_3 and T_1 respectively. Treatment which received cdsw at higher level (T_2) showed the highest K content initially. This may be due to the high microbial and enzyme activity in cdsw (Basker *et al.*, 1994). K availability was more from fym in the later periods as evidenced from the incubation study (Table 10). This might have contributed the higher K content in T_3 and T_1 in second and third cut respectively.

The highest Ca content was noticed in T_2. The highest Mg content was noticed in T_2 in the first cut, T_3 in the second cut and T_1 in the third cut. Higher amount of Ca present in cdsw than in fym enhanced their availability in soil and thus in plants.

Fe, Mn and Zn content were maximum in T_2 (NPK @ POP and cdsw 50 t ha^{-1}) in the first cut while in the second and third cut T_1 (NPK

@ POP and fym 50 t ha^{-1}) showed the highest value. Cu content was maximum in T_1 in all the cuts. The higher micronutrient content in plant is mainly due to their higher availability. Fe, Mn and Zn availability was more from cdsw applied treatments in the initial periods and it was more from fym applied treatments in the later periods as evidenced from the incubation study (Tables 11 and 13). Micronutrient content in plants in the pot culture, coincides with the micronutrient release pattern in the incubation experiment of the present study. Cu content was more in treatment with fym (T_1) than in those with cdsw (T_2). This may be due to the absence of Cu in cdsw as indicated in Table 7. In general, organic materials supply chelating agents and increase the solubility of micronutrients in soil and thus increase their content in plant (Tisdale *et al.*, 1997).

5.4.6 Effect on Physico-chemical Properties of Soil

Analysis of soil was done after the experiment to study the effect of cdsw on physico-chemical properties of soil. The parameters studied were pH, EC, organic carbon and available nutrient status (Table 31). The salient results of the study are discussed here.

pH increased in all treatments except T_0 after the experiment. Before starting the experiment pH was 5.2 which ranged from 5.0 to 6.2 after the experiment. Highest pH was noticed on T_2 (Fig.23) which received NPK @ POP and cdsw 50 t ha^{-1}. Table 7 reveals that cdsw is near neutral in pH. So the incorporation of this might have increased the pH of soil. Findings by Lee (1985) supports the present result.

Organic carbon content in soil increased significantly after the experiment in all treatments except T_0. The organic carbon content ranged from 0.85 to 0.97 per cent. This result is in agreement with the view of Khaleel *et al.* (1981) who reported that as a result of organic manure application, soil organic carbon content increased. The treatment which received highest level of cdsw (T_2) has shown the highest level of residual

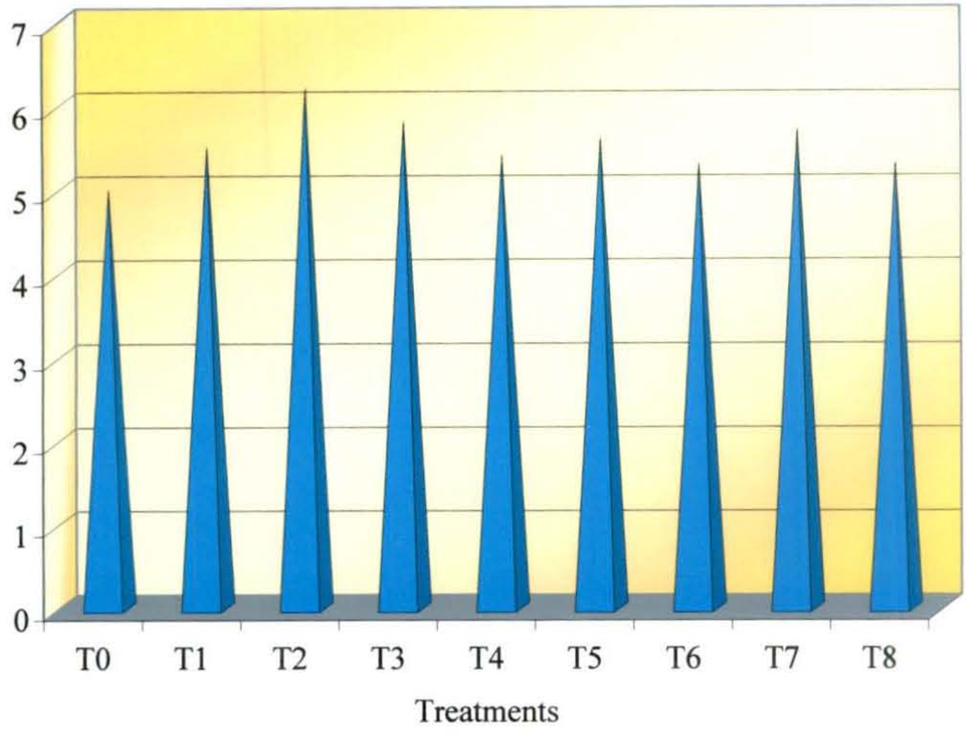

Fig. 23.Effect of composted dairy waste on pH of soil after harvest

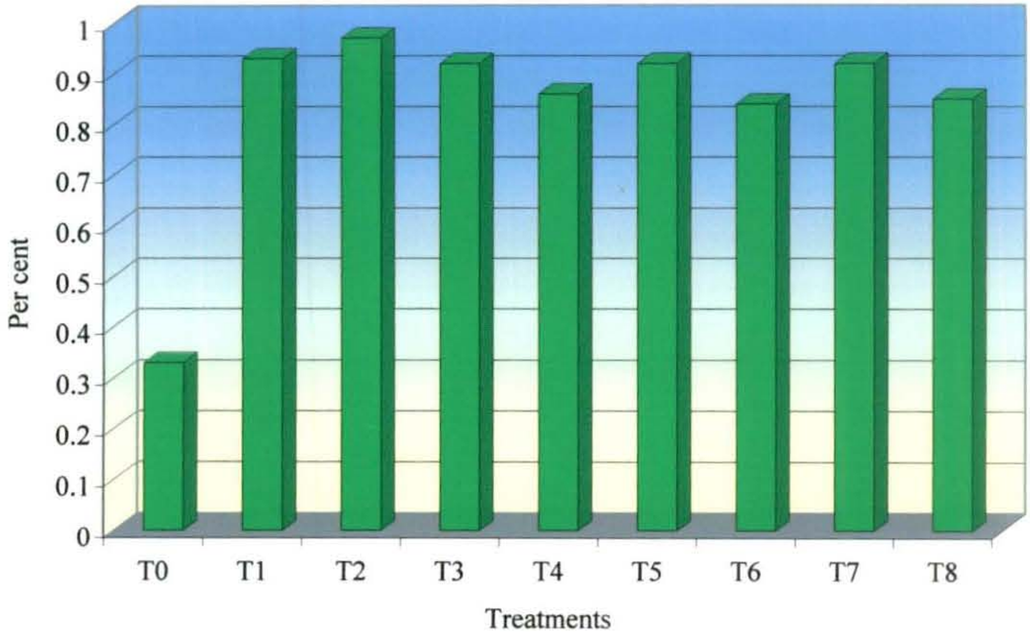

Fig. 24.Effect of composted dairy waste on organic carbon content of soil after harvest

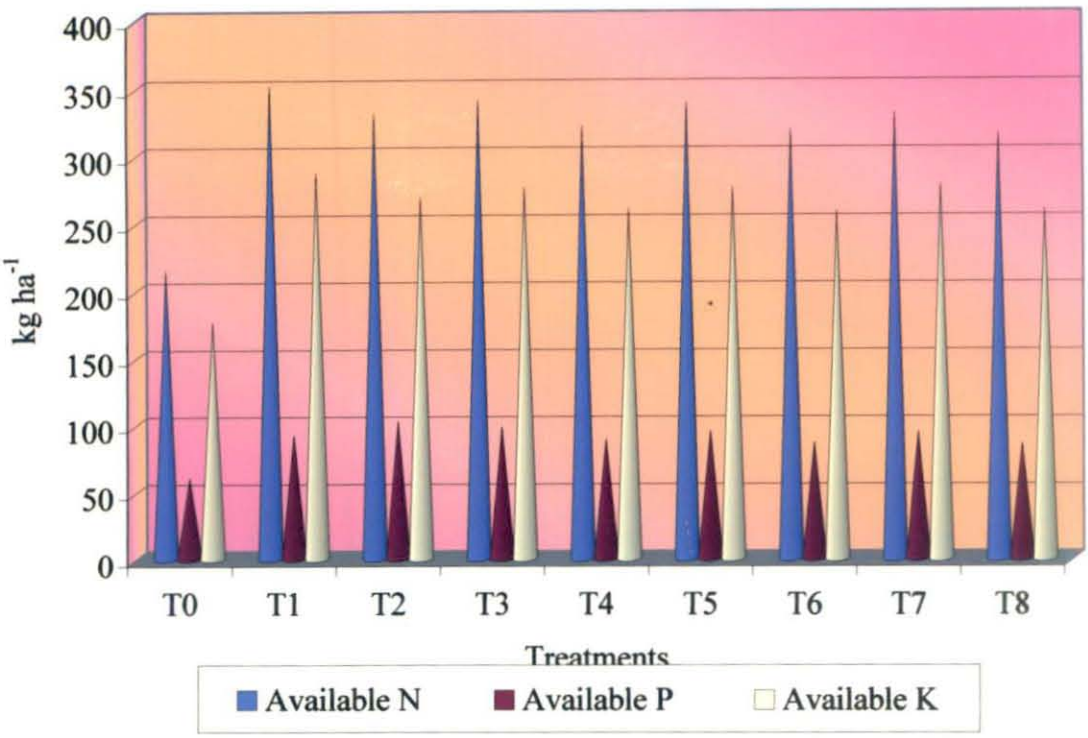

Fig.25 Effect of composted dairy waste on N, P and K (kg ha^{-1}) content of soil after harvest

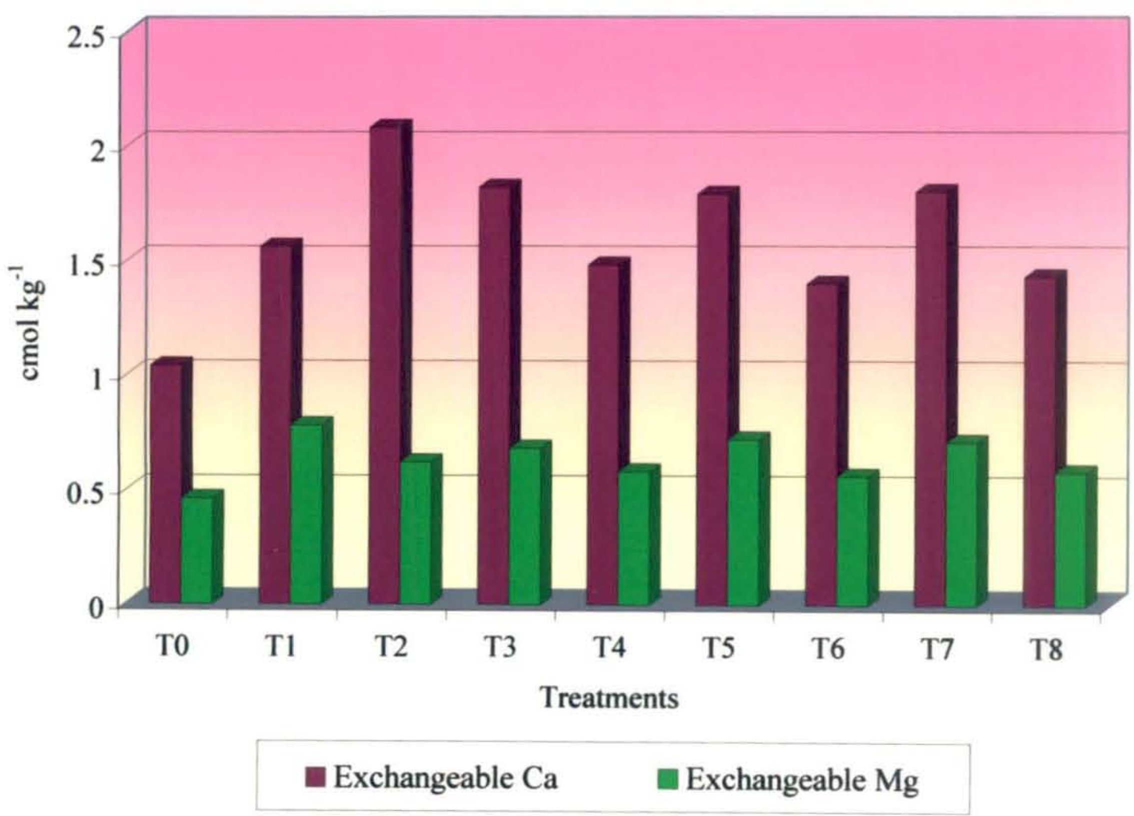

Fig. 26 Effect of composted dairy waste on exchangeable Ca and Mg (cmol kg^{-1}) of soil after harvest

organic carbon (Fig.24). This is attributed to the high content of organic carbon in cdsw. Reduction in mineralisation of N in cdsw applied treatments observed in the later periods of incubation might have contributed to increase in organic carbon content in soil.

Available N, P and K content in soil was significantly influenced by different treatment (Fig.25). Availability of N, P and K increased in all treatments except T_0. The highest available N and K was noticed in T_1 which received NPK @ POP and fym 50 t ha^{-1}. Incubation study (Table 8) revealed that N availability was more from cdsw applied treatments during the initial periods and it was more from fym applied treatments in the later periods. Increase in mineralisation of N from fym during the later periods may be the reason for high residual N content in fym applied treatment in soil.

Phosphorus availability was the highest in T_2 which received NPK @ POP and cdsw 50 t ha^{-1}. Increase in available P with organic manure application might be due to the solublisation of the native P in the soil through release of various organic acids (Vyas and Mothiramani, 1971). P solubilising bacteria present in organic materials might have induced mineralisation and increased availability of P (Indira *et al.*, 1996).

Increase in available K is ascribed to reduction of K fixation and release of K from exchange sites due to interaction of organic matter with clay (Tan 1982). Faster decomposition of organic matter release bases including K thus results in an increase in K^+ concentration in soil solution (Basker *et al.*, 1994).

The treatment effect was significant with exchangeable Ca and Mg in the soil. All treatments except T_0 showed increase in exchangeable Ca and Mg in soil after the experiment (Fig.26). The highest exchangeable calcium (2.08 cmol kg^{-1}) was noticed in T_2 which received NPK @ POP and cdsw 50 t ha^{-1} while the exchangeable Mg content was more in T_1 which received NPK @ POP and fym 50 t ha^{-1}. The increase in

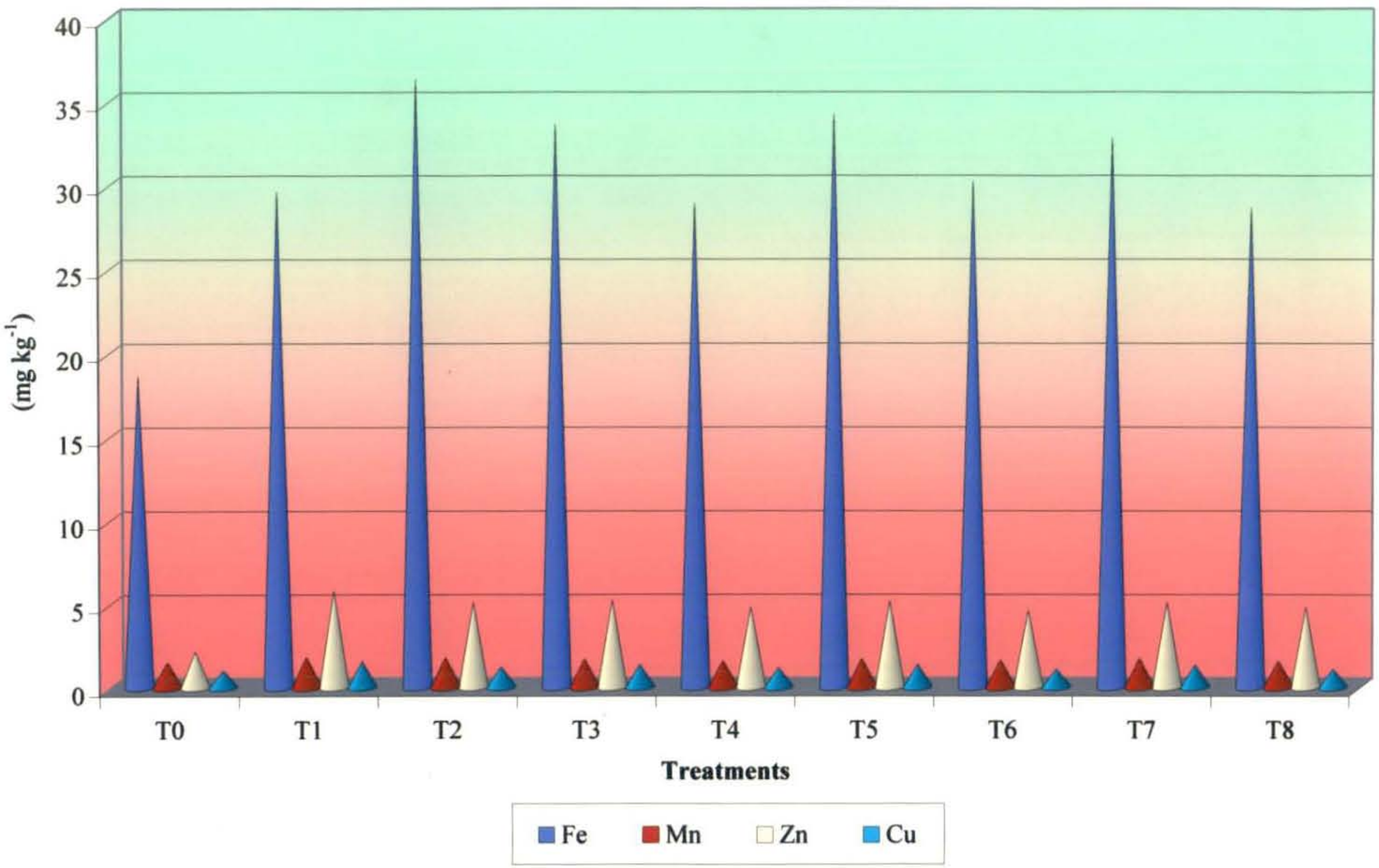

Fig. 27.Effect of composted dairy waste on Fe, Mn, Zn and Cu (mg kg^{-1}) content of soil after harvest

concentration of Ca and Mg may be due to the faster release of these basic cations during mineralisation of organic materials (Ammal and Muthiah, 1994).

Available Fe, Mn, Zn and Cu content in soil showed increase in all treatments except T_0 (Fig.27). T_2 which received NPK @ POP and cdsw 50 t ha^{-1} showed the highest available Fe content in soil. While T_1 which received NPK @ POP and fym 50 t ha^{-1} showed the highest available Mn, Zn and Cu content in soil after the experiment. The observed increase in micronutrients is due to the formation of organic complexes of micronutrients which are less stable and more amenable to DTPA extraction. Organic materials supply chelating agents that aid in maintaining the solubility of micronutrients (Das, 2000). In general, soil analysis after pot culture indicated that availability of major nutrients except N and Mg was more in treatments with cdsw than fym. While it was reverse in the case of micronutrients except Fe.

SUMMARY

6. SUMMARY

The effluents of many industries contain essential nutrients which can be used to increase the productivity of soils if proper treatments to these wastes are provided and proper ecofriendly technology is adopted for their management in agricultural land. Dairy industry is one of the major industries which generates large volume of liquid waste rich in organic load. Biological oxidation of liquid waste discharges a sludge which is hard when dry. An investigation was carried out at College of Agriculture, Vellayani to study the feasibility of using dairy industry solid waste as an organic source in improving soil productivity. The salient results emerged from the studies are summarized here.

Analysis of physico-chemical and microbiological properties of dsw from TRCMPU Ltd. at Ambalathara, Thiruvananthapuram revealed that it had a near neutral pH (6.5) and EC of 2.75 mSm^{-1}. It contained 37.5 per cent organic carbon, 5.80 per cent N, 2.04 per cent P, 0.71 per cent K, 1.69 per cent Ca, 1.58 per cent Mg, 1.71 per cent Fe, 159 mg kg^{-1} Mn and 1084 mg kg^{-1} Zn. Population of bacteria, fungi and actinomycetes in dsw were 13.3×10^6, 11.6×10^4 and 1.3×10^4 respectively.

Vermicomposting of biowaste mixture (dsw, vegetable waste and cowdung in 3:5:1 ratio) had brought down the C:N ratio to 11.17 from 33.20. pH increased to 6.9 from 5.8. The vermicompost contained 3.12 per cent N, 1.97 per cent P, 1.81 per cent K, 2.05 per cent Ca, 3.55 per cent Mg, 0.80 per cent Fe, 230 mg kg^{-1} Mn, 408 mg kg^{-1} Zn and 44 mg kg^{-1} Cu. Number of bacteria, fungi and actinomycetes in the compost at maturity stage were 42.6×10^6, 38.6×10^4 and 21.3×10^4 respectively. Number of earthworms at 45 days of composting was 420 which increased to 510 at 60 days of composting.

Incubation study revealed that the availability of N was maximum in T_5 (356.40 kg ha^{-1}) which received cdsw at higher dose in the initial six weeks. After that it was maximum in fym applied treatments (T_1). Throughout the period of incubation, T_5 recorded the maximum value for available P. The highest available P (121.1 kg ha^{-1}) was recorded by T_5 at four weeks of incubation. In cdsw applied treatments availability increased upto four weeks and in fym applied treatments it increased upto six weeks and then declined. The same trend was seen in available K also. The highest value of available K was 249.2 kg ha^{-1}. It was recorded in T_5 and T_1 at four and six weeks respectively.

Availability of Fe increased in all treatments except T_0 and T_2 upto six weeks and then it declined. It was the highest in T_5 which received cdsw at higher dose upto six weeks. From eighth week onwards, maximum content of available Fe was showed by T_1 and this trend continued till the end of incubation period. Available Mn, Zn and Cu content in soil increased upto four weeks in cdsw applied treatments and upto six to eight weeks in fym applied treatments and then they showed a decreasing trend.

Effect of treatments on bulk density and water holding capacity was significant throughout the incubation period. Bulk density decreased in all treatments except T_0. It was minimum (1.22 Mg m^{-3}) in T_5 which at six weeks of incubation. Increase in bulk density was noticed after 6weeks. Water holding capacity of soil was increased by the treatments. Treatment that received cdsw at higher dose (T_5) showed the highest water holding capacity (35.6 per cent) upto six weeks. At eight and twelve weeks, water holding capacity was the highest in T_1 which received fym.

Increase in microbial population in soil was noted in all treatments except T_0 from second week onwards. It reached the peak in sixth week and then declined. The lag phase of microbial population that is generally observed in soil receiving materials of wide C:N ratio is not present in this study due to narrow C:N ratio of dsw (6.4) and cdsw (11.17). Treatments that received cdsw at higher dose (T_5) showed more fungal and bacterial population compared to other treatments. The effect of treatments was non-significant with respect to actinomycete population upto eight weeks. The highest actinomycete population was recorded by T_5 throughout the incubation period.

Pot culture experiment was conducted to study the influence of cdsw on growth, yield and quality of amaranthus. Height of plant and internodal length were maximum in T_2 which received NPK @POP and cdsw @ 50 t ha^{-1}. Maximum number of branches and minimum leaf stem ratio were also noted in T_2 in first and second cut. While number of branches was maximum in T_3 and T_5 and the leaf stem ratio was the lowest in T_3 in the third cut.

Nitrate (antinutrient factor) and beta carotene (nutrient factor) were the highest in T_2. Nitrate content was within critical limit (0.3 per cent) in all treatments except T_1, T_2, T_3 and T_5. Beta carotene content ranged from 2192 to 7027 μg 100^{-1}g in different treatments. It was the highest in T_2 which received cdsw at higher dose.

At first cut, all the nutrients except Cu were more in T_2 which received cdsw at higher dose. Cu content was more in T_1 which received fym. During second cut, the highest N, K and Mg content were noticed in T_3 while Ca and P content were more in T_2. Content of Fe, Mn, Cu and Zn were the highest in T_1. During third cut, N, K, Mg, Fe, Mn, Cu and Zn were more in T_1 while P and Ca were more in T_2.

Total yield was the highest (378.8 g pot^{-1}) in T_3 which received NPK @ POP and fym and cdsw @ 25 t ha^{-1} each. T_2 and T_5 were on par to T_3 indicating that use of cdsw can replace fym partially or fully and reduce fertilizers N to the extent of 1/3 of POP recommendation.

B:C ratio ranged from 0.60 to 1.85. The highest B:C ratio was noticed in T_3 in which 50 per cent recommended dose of fym was substituted by cdsw. T_3 was followed by T_2 (NPK @ POP and cdsw 50 t ha^{-1}) and T_5 (2/3 N and PK @ POP and fym and cdsw @ 25 t ha^{-1} each) and they were statistically on par.

physico-chemical properties of soil after the pot culture experiment revealed that pH, EC, organic carbon and available nutrients increased in all treatments except in T_0 compared to the initial soil. pH, EC, organic carbon, available P, Ca and Fe were the highest in T_2 which received cdsw at higher dose. The highest available N, K, Mg, Mn, Zn and Cu were noticed in T_1 which received fym.

From the above results it can be concluded that effective biomanagement of dsw can be carried out using *Eudrillus eugeniae*. Compost of dairy industry solid waste is as good as fym as organic manure in leafy vegetables like amaranthus. Better availability of nutrients especially nitrogen from cdsw than from fym immediately after application as evidenced by incubation study is advantageous for short duration leafy vegetables. cdsw can reduce the use of fym partially or it can replace fym fully in amaranthus. Fertilizer N can also be reduced to the extent of 1/3 of POP recommendations.

The results of the present study may be verified and confirmed by conducting field experiments with vegetables and if the results are found encouraging use of fertilizer N can be reduced and fym can be replaced partially or fully without affecting the net returns.

REFERENCES

7. REFERENCES

Ahmad, A., Inam, A., Ahmad, I., Hayat, S., Azam, Z.M. and Samiullah,A. 2003. Response of sugarcane to treated waste water of oil refinery. *J. Environ. Biol.* 24 (2): 141-146

Alexander, M. 1961. *Introduction to Soil Microbiology* John Wiley and sons,Inc. Newyork. 467.p

Ammal, B.U. and Muthiah, D.N. 1994. Potassium release characters in soil as influenced by inorganic and organic manuring. *J. Potass. Res.* 10 (2): 223-228

Anand, H.S., Devi, L.S., Srinivasamurthy, C.A. and Tharamani, G.H. 1998. Chemical and biochemical properties of coir dust compost as influenced by pre-treatment and enrichment. *Mysore J. agric. Sci.* 32: 286-293

Arunkumar, K.R. 2000. Organic nutrition in amaranthus (*Amaranthus tricolor* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 105 p.

Augusthy, N. and Mani, A.S. 2001. Effect of rubber factory effluent on seed germination and seedling growth of *Vigna radiata* L. *J. Environ. Biol.* 22 (2): 137-139

*Badanur, V.P., Poleshi, C.M. and Balachandra, N.K. 1990. Effect of organic matter on crop yield, physical and chemical properties of a vertisol. *J. Indian Soc. Soil Sci.* 38: 426-429

*Balasubramaniam, A., Shankaram, M.V. and Siddaramappa, R. 1972. Effect of organic manuring on the activities of the enzyme hydrolyzing sucrose and area on soil aggregation. *Pl. Soil* 37: 319-328

Bano, K. 1997. Vermicomposting in changing agricultural scenario. *Food Security in Harmony with Nature* (ed. Shivshankar, K). Proceedings of third IFOAM – Asia Scientific Conference and General Assembly, 1-4 December, 1997, Bangalore, pp. 144-147

Bano, K., Kale, R.D. and Gajanan, G.N. 1987. Culturing of earthworm *Eudrillus eugeniae* for cast production and assessment of wormcast as biofertilizers. *J. Soil Biol. Ecol.* 7: 98-104

Banu, J.R., Logakanthi, S. and Vijayalakshmi, G.S. 2001. Biomanagement of paper mill sludge using an indigenous (*Lamito mauritii*) and two exotic (*Eudrillus eugeniae* and *Esenic foetide*) earthworms. *J. Environmental Biol.* 22 (3): 181-185

Basker,A., Kirkman, J.H. and Macgreger, A.N. 1994. Changes in potassium availability and other soil properties due to soil ingestion by earthworms. *Biol. Fertil. Soil* 10: 178-183

Bhagat, R.M. and Verma, T.S. 1991. Impact of rice straw management on soil physical properties and wheat yield. *Soil Sci.* 152 (2): 108-115

Bhagat, R.M., Bhardwaj, A.K. and Sharma, K.P. 2003. Long term effect of residue management on soil physical properties, water use and yield of rice in North Western India. *J. Indian Soc. Soil Sci.* 51 (2): 111-117

Bhat, R. 2003. Vermicompost and its production technology for areca and cocoa wastes. *Short course on recent advances in organic farming technologies in plantation crops.* November 18-27, 2003. Central Plantation Crops Research Institute, Kasargode, pp. 62-65

Bhatacharyya, P., Chakrabarthi, K., Chakraborthy, B. and Bhattacharya, B. 2001. Microbial biomass and activities of soils amended with municipal solid waste compost. *J. Indian Soc. Soil Sci.* 49: 98-103

Bhatia,A., Pathak, H. and Joshi, H.C. 2001. Use of sewage as a source of plant nutrient - potentials and problems. *Fertil. News* 46 (3): 55-64

Bijulal, B.L. 1997. Effect of vermicompost on the electrochemical properties and nutritional characteristics. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 74 p

*Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L. and Clark, F.E. 1965. *Methods of Soil Analysis*. Part I. American Society of Agronomy Inc., Madison, USA, 1569 p.

Bopaiah, B.M., Khan, H.H., Thomas, G.V. and Chowdappa, P. 1996. *Studies on Vermicomposting for recycling of palms and cocoa wastes.* Annual Report 1995-96. Central Plantation Crops Research Institute, Kasargode, 220 p.

Borde, B.K., Kadam, J.R. and Patil, N.D. 1984. Effect of press mud cake and phosphate fertilizer on yield and uptake of nutrients of greengram. *J. Indian Soc. Soil Sci.* 32: 516-518

Brady, N.C. 2001. *The Nature and Properties of Soils*. Tenth edition. Prentice Hall of India Pvt. Ltd., New Delhi, 621 p.

*Caravaca, F., Lax, A. and Albaladejo, J. 2001. Soil aggregate stability and organic matter in clay and fine silt fraction in urban refuse amended semi arid soils. *Soil Sci. Soc. Am. J.* 65 (4): 1235-1238

Chatterjee, A., Joshi, H.C. and Pathak, H. 2003. Impact of distillery and paper mill effluent irrigation on yield of rice and soil fertility. *J. Indian Soc. Soil Sci.* 51 (4): 564-566

Chitdeshwari, T., Savithri, P. and Mahimairaja, S. 2002. Effect of sewage biosolids compost on biomass yield of amaranthus and heavy metal availability. *J. Indian Soc. Soil Sci.* 50 (4): 480-484

Cochran, W.G. and Cox, G.M. 1965. *Experimental Designs.* John Willey and Sons Inc. New York, 182 p.

*Connel, D.B., Sheralipour, A. and Smith, W.H. 1993. Compost application improves soil properties. *Biocycle* 34 (4): 61-63

*Darwin, C.R. 1881. *The formation of vegetable mould through the action of worms with observations on their habits.* Murray, London, 298 p.

Das, A. 1988. City garbage compost as source of humus. *Biol. Wastes* 26 (1): 65-69

Das, D.K. 2000. *Micronutrients : their Behaviour in Soils and Plants.* Kalyani Publishers, New Delhi, 307 p.

Das, P.K., Bhogesh, K., Sundareswaran, P. and Chaudhary, P.C. 1996. Application of vermiculture technology in sericulture and its scope. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture, 9-11 October 1996 (ed. Veeresh, C.K.), Association for Promotion of Organic Farming, Bangalore, pp. 42

*Debele, T.C. 1998. Effect of enriched farmyard manure and nitrogen fertilizer levels on growth and yield of maize . M.Sc. (Ag.) thesis, University of Agricultural Sciences, Bangalore, 95p

Debnath, N.C. and Hajra, J.N. 1972. Transformation of organic matter in soil in relation to mineralisation of carbon and nutrient availability. *J. Indian Soc. Soil Sci.* 20: 95-102

Devarajan, L., Rajannan, G., Ramanathan, G. and Oblisami, G. 1994. Performance of field crops under distillery effluent irrigation. *Kisan Wld* 21 (6): 48-49

Devlin, M.R. and Witham, F.H. 1986. *Plant Physiol.* Fourth edition. CBS Publishers, New Delhi, 577 p.

Dhillon, K.S. and Dhillon, S.K. 1991. Effect of crop residues and phosphorus levels on yield of groundnut and wheat grown in a rotation. *J. Indian Soc. Soil Sci.* 39: 104-108

Dinesh, R. and Dubey, R.P. 1999. Nitrogen mineralisation rates and kinetics in soils amended with organic manures. *J. Indian Soc. Soil Sci.* 47 (3): 421-425

FAI. 1986. *The Fertilizers(Control) Order 1985 and the Essential Commodities Act, 1955.* The Fertilizer Association of India, New Delhi, 194 p.

Gajalakshmi, S., Ramaswamy, E.V. and Abbasi, S.A. 2001. Vermicomposting of different forms of water hyacinth by the earthworm *Eudrillus eugeniae. Bioresource Technol.* 82 (2): 165-169

*Gallardo-Lara, F. and Nogales, R. 1987. Effect of the application of town refuse compost on the soil plant system : A review. *Biol. Wastes* 19: 35-62

Gaur, A.C. and Mukherjee, D. 1979. Note on the effect of straw on the yield of groundnut and the following wheat. *Indian J. agric. Sci.* 49:984-987

Gaur, A.C. and Prasad, S.K. 1970. Effect of organic matter and inorganic fertilizers on plant parasitic nematodes. *Indian J. Ent.* 32: 186-188

Gowda, T.K.S., Radhakrishna, D., Balakrishna, A.N., Sreenivas, K.N. 1992. Studies on the manurial value and nutrient – enrichment of municipal waste compost produced from Bangalore city garbage. Proceedings of National Seminar on Organic Farming. Pune, pp. 39-41

Goyal, S., Mishra, M.M., Shankar, S.S. and Chander, K. 1994. Relationship of soil microbial biomass and mineralisation of nitrogen following incorporation of organic materials to soil. *J. Indian Soc. Soil Sci.* 42: 474-476

Gunathilagaraj, K. and Ravignanam, T. 1996. Vermicomposting of sericultural wastes. *Madras agric. J.* 83: 455-457

Gupta, R.K., Arora, B.R., Sharma, K.N. and Ahluwalia, S.C. 2000. Influence of biogas slurry and fym application on changes in soil fertility under rice – wheat cropping sequence. *J. Indian Soc. Soil Sci.* 48 (3): 500-505

Gupta, S.C. and Larson, W.E. 1979. Estimating soil water retention characteristics from particle size distribution, organic matter per cent and bulk density. *Water Resour. Res.* 15: 1633-1635

Haridas, P. 1996. Organic farming in tea through waste recycling. *National Workshop on Tropical Organic Farming* (ed. Jacobmani Mannothra). The UPASI R & D Centre, Kottayam, pp. 17-21

*Harinikumar, K.M., Bagyaraj, D.J. and Kale, R.D. 1991. Vesicular-Arbuscular mycorrhizal propagules in earthworm cast. Proceedings of Tenth International Soil Zool Coloq, Bangalore, pp. 605-610

Hassan, M.A. 1977. Fertility investigations on the laterite soils of Kerala state. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 100 p

*Hernado, S., Labo, M.C. and Polo, A. 1989. Effect of the application of a municipal refuse compost on the physical and chemical properties of soil. *Sci. Tot. Environ.* 81 & 82: 589-596

Hesse, P.R. 1971. *A Textbook of Soil Chemical Analysis*. William Clowes and Sons, London, 513 p.

Hidalgo, P.R. and Harkess, R.L. 2002. Earth worm castings as substrate amendment for chrysanthemum production. *Hort. Sci.* 37 (7): 1035-1039

Humphries, E.C. 1956. *Modern Methods of Plant Analysis*. Volume 1. (eds. Peach, K. and Tracey, M.V.). Narosa Publishing House, New Delhi, p.

Indira, B.N., Rao, J.C.B., Senappa, C. and Kale, R.D. 1996. Microflora of vermicompost. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture, 9-11 October 1996 (ed. Veeresh, C.K.), Association for Promotion of Organic Farming, Bangalore, pp. 51-52

*Inbar, Y., Chen, Y., Hadar, Y. and Hoitink, H.A.J. 1990. New approaches to compost maturity. *Biocycle* 31: 64-69

Ismail, S.A., Seshadri, C.V., Jeejabai, N. and Suryakumar, C.R. 1991. Yield of watermelon (*Citrullus crelgaris*) with vermicompost as compared to conventional method. Monograph Series on Engineering of Photosynthetic System 35: 8-10

Ismail, S.A., Seshadri, C.V., Jeejabai, N. and Suryakumar, C.R. 1993. Composting through earthworms. Monograph Series on the Engineering of Photosynthetic System 35: 30-35

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, 498 p.

Jambhakar, H. 1996. Effect of vermicompost on short duration crops. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp. 41

Jiji, T., Dale, D. and Padmaja, P. 1996. Vermicompost reduces the requirement for chemical fertilizer in cowpea and bittergourd. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming,Bangalore, pp.87-88

Joseph, P. 1998. Evaluation of organic and inorganic sources of nutrients on yield and quality of snakegourd (*Thrichosanthes anguina* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 95 p

Jothimani, P., Prabhakaran, J. and Bhaskaran, A. 2002. Characterization and impact of dyeing factory effluent on germination and growth of Maize (Co1) and cowpea (Co 4). *Madras agric. J.* 89 (10-12): 568-571

Kadalli, G.G., Devi, L.S., Siddaramappa, R. and Patil, C.R. 2000. Quality and efficiency of value added coir dust based compost. *J. Indian Soc. Soil Sci.* 48 (4): 141-144

Kale, R.D. 1998. *Earthworm: Cindrella of Organic Farming*. Prism Books Pvt. Ltd., Bangalore, 70 p.

Kale, R.D., Bano, K. and Krishnamoorhty, R.V. 1982. Potential of *Perionyx excavatus* for utilising organic wastes. *Pedobiologica* 23: 419-425

KAU. 2002. *Package of Practices Recommendations*. Twelfth edition. Directorate of Extension Education, Kerala Agricultural University, Thrissur, 278 p.

Kaurav, D.L. and Verma, G.P. 1982. Improvement of soil structure of a degraded soil with organic amendments. *J. Indian Soc. Soil Sci.* 30: 528-530

Kavian, M.F., Ghatnekar, S.D. and Kulkarni, P.R. 1991. Biomanagement of dairy effluent using culture of red earthworms *Lumbricus rubellus*. *Indian J. Environmental Protection* 11 (9): 680-682

Kavian, M.F., Ghatnekar, S.D. and Kulkarni, P.R. 1996. Biomanagement of paper mill sludge using culture of red American earthworm *Lumbricus rubellus*. *Indian J. Environmental Protection* 15 (5): 330-333

Kavian, M.T., Ghatnekar, S.D. and Kulkarni, P.R. 1998. Conversion of coir pith into value added biofertilizer using *Lumbricus rubellus*. *Indian J. Environmental Protection* 18 (5): 330-333

Khaleel, R., Reddy, K.R. and Overcash, M.R. 1981. Changes in soil physical properties due to organic waste application – a review. *J. Envtl. Qlty.* 10 (2): 133-141

Khan, G., Gupta, S.K. and Banerjee, S.K. 1981. Studies on the solubilisation of phosphorus in presence of different city wastes. *J. Indian Soc. Soil Sci.* 29: 120

Khosla, B.K. 1976. Infiltration and water distribution in sodic soil as influenced by application of amendments to soil. *Madras agric. J.* 66: 278-280

Killham, K. 1994. *Soil Ecology*. Cambridge University Press, New York, 220 p.

Krishnamurthi, V.V., Mathan, K.K. and Subbian, P. 1994. Chemical composition of dairy effluent. *Madras agric. J.* 81 (11): 642

Krishnamurty, K. 2002. Recycling and enriching sugar factory wastes for sugarcane crop. *Kisan Wld* 29 (3): 69-70

Kukraja, K., Mishra, M.M., Dhankar, S.S., Kapoor, K.K. and Gupta, A.K. 1991. Effect of long term manurial application on microbial biomass. *J. Indian Soc. Soil Sci.* 39: 685-688

Kumaresan, K.R., Dhakshinamoorthy, M., Subramaniam, V. and Manickam, T.S. 1984. Effect of agricultural and industrial wastes on the availability of nutrients and yield of groundnut. *Madras agric. J.* 71 (2): 783-787

Lal, R. and Akinene, O.O. 1983. Physical properties of earthworm casts and surface soil as influenced by management. *Soil Sci.* 135: 114-122

Lal, J.K., Mishra, B. and Sarkar, A.K. 2000. Effect of plant residue incorporation on specific microbial groups and availability of some plant nutrients in soil. *J. Indian Soc. Soil Sci.* 48: 67-71

*Lal, J.K., Mishra, B. and Sarkar, A.K. 2002. Organic waste and their effect on soil biological environment. *J.Res. Birsa agric. Univ.* 14(1):25-28

*Larson, W.E. and Allmaras, R.R. 1971. Management factors and natural forces and related in compaction of agricultural soils. *Am. Soc. agric. Engg.* St. Joseph, Missouri, pp. 367-427

Larson, W.E. and Clapp, C.E. 1984. Effects of organic matter on soil physical properties. *Organic matter and rice*. International Rice Research institute. Phillippines, PP. 363-386

Larson, W.E., Gilley, J. and Linden, D.R. 1975. Consequence of waste disposal on land. *J. Soil Water Conserv.* 30: 68-71

Lee, K. E. 1985. Some trends and opportunities in earthworm research or Darwin's children – The future of four descipline. *Soil. Biol. Biochem.* 24 (12) :1765-1771

Lei Wang, S.H. I., Virginia,S., Lohr and David,L .C. 1984. Spent mushroom compost as a soil amendment for vegetables. *J. Am. Soc. Hort. Sci.* 95 (5): 698-702

Lindsay, W.L. and Norvell, W.A. 1978. Development of a DTPA soil test for Zn, Fe, Mn and Cu. *J. Soil Sci. Soc. Am.* 42: 421-428

Logamadevi, A. 1997. Influence of coir waste on soil health and crop productivity. *Food Security in Harmony with Nature* (ed. Shivshankar, K). Proceedings of third IFOAM – Asia Scientific Conference and General Assembly, 1-4 December, 1997, Bangalore, pp.129-131

Loganathan, S. 1990. Effect of certain tillage practices and amendments on physico-chemical properties of problem soils. *Madras agric. J.* 77: 204-208

Marchesini, A., Allievi, L., Comotti, E. and Ferrai, A. 1988. Long term effects of quality compost treatment on soil. *Pl. Soil* 106: 253-261

Martin, J.P. 1950. Use of acid, rose bengal and streptomycin plate method for estimating soil fungi. *Soil Sci.* 69: 215-233

Mba, C.C. 1997. Rockphosphate solublilising *Streptosporangium* isolates from casts of tropical earthworm. *Soil Biol. Biochem.* 29: 381-385

Meera, A.V. 1998. Nutrient economy through seed coating with vermicompost in cowpea (*Vigna unguiculata* L. Walp.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 137 p.

Mengel, K. and Kirkby, E.A. 1987. *Principles of Plant Nutrition.* International Potash Institute, Switzerland, 698 p.

Mirza, W.A., Rao, Y.Y, Reddy, C.S. and Naidu, N.G. 1982. Foliar application of *Eichornia* inoculum spray and leaf incorporation of *Eichornia* as supplemented source of nitrogen to rice. *Indian J. Agron.* 27: 177-178

Mishra, M.M., Kapoor, K.K. and Yadav, K.S. 1982. Effect of compost enriched with mussorie rock phosphate on crop yield. *Indian J. agric. Sci.* 52: 674

Mohanty, S.K. and Sharma, A.R. 2000. Nutrient management in rice-rice cropping system. *Fertil. News* 45 (3): 45-48

More, S.D. 1994. Effect of farm wastes and organic manures on soil properties, nutrient availability and yield of rice – wheat grown on sodic vertisol. *J. Indian Soc. Soil Sci.* 42 (2): 253-256

*Myhre, D.L., Marton, H.W. and Nemec, S. 1990. Yield and juice quality of oranges in groves treated with phosphogypsum and mixed gypsum. Proceedings of Third International Symposium on Phosphogypsum (ed. Chang, W.F.). Floria Institute of Phosphate Research, Florida, pp. 11-40

Nair, G.K. 1987. Continuous use of municipal sewage effluents on soil physical and chemical properties. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 156 p.

Nair, S.K. 1999. *Microflora associated with earthworm and use of vermicompost.* Science,technology and environment department project report, Kerala Agricultural University, Thrissur, 19 p.

Nair, S.K., Naseema, A., Meenakumari, K.S. Prabhakumari, P. and Peethambaran, C.K.1997. Microflora associated with earthworms and vermicompost. *J. trop. Agric.* 35: 68-70

*Nielson, R.L. 1965. Presence of plant growth substances in earthworms demonstrated by paper chromatography and went pea test. *Nature* 208: 113-114

*Omae, K., Fukudome, K., Onjo, M. and Hayashi, M. 2003. Effects of application of cattle compost on the yield, quality and the soil property in melon (*Cucumis melo* L.) cultivation. *Bull. Faculty Agric.* 53: 1-4

Pagliai, M. and Antisari, L.V. 1993. Influence of waste organic matter on soil micro and macro structure. *Bioresource Technol.* 43 (3): 205-213

Pain, A.K. 1961. Effect of compost mulberry manure on the nutrition of mulberry. *J. Indian Soc. Soil Sci.* 9: 29-33

Palaniappan, S.P. and Annadurai, K. 1999. *Organic Farming, Theory and Practice.* Scientific Publishers, Jodhpur, 257 p.

Patil, G.D. and Chaudhari, R.D. 2002. Effect of levels of spent wash on CO_2 evolution, yield and uptake of nutrients by maize (*Zea mays* L.). *Madras agric. J.* 89 (10-12): 726-729

*Piccolo, A. and Mbagwa, J.S.C. 1990. Effect of different organic waste amendments on soil micro aggregate stability and molecular sizes of humic substances. *Pl Soil* 123: 27-37

Piper, C.S. 1944. *Soil and Plant Analysis*. Interscience Publishers, Inc., New York, 368 p.

*Ponomareva, S.L. 1953. Influence of the activity of earthworms on the creation of a stable structure in a sod podsolized soil. *Trud. Pochu. Inst. Dokuchaeva* 41: 304-378

Prabhu, S.R. and Thomas, G.V. 2002. Biological conversion of coirpith into a value added organic resource and its application in agri-horticulture : current status, prospects and perspectives. *J. Plantation Crops* 30 (1): 1-17

*Prakash, D. and Pal, M. 1991. Nutritional and antinutritional composition of vegetable and grain leaves. *J. Sci. Fd Agric.* 57: 573-583

Prasad, B., Singh, R.P., Roy, H.K. and Sinha, H. 1983. Effect of fertilizer, lime and manure on some physical and chemical properties of a red loam soil under multiple cropping. *J. Indian Soc. Soil Sci.* 31: 601-603

Prasad, R.A. and Singhania, R.A. 1989. Effect of different types of enriched manures and time of incubation on soil properties. *J. Indian Soc. Soil Sci.* 37 (2): 319-322

Pushpa, S. 1996. Effect of vermicompost on the yield and quality of tomato (*Lycopersicon esculentus*). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 90 p

Rajalekshmi, K. 1996. Effect of vermicompost / vermiculture on physico-chemical properties of soil and yield of chilli (*Capsicum annuum* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 121 p.

Rajkhowa, D.J., Gogoi, A.K., Kandali, R. and Rajkhowa, K.M. 2000. Effect of vermicompost on greengram nutrition. *J. Indian Soc. Soil Sci.* 48 (1): 207-208

Ramachandra, H.A. and Thimmaraju, K.R. 1983. Effect of different levels of nitrogen and phosphorus on growth components and yield of amaranthus (*Amaranthus gangeticus* L.) cv. A.25. *Mysore J. agric. Sci.* 17 (2): 158-164

Ramaswamy, P.P. 1999. Recycling of agricultural and agro industry wastes for sustainable agricultural production. *J. Indian Soc. Soil Sci.* 47: 661-666

Rani, P.J., Khannan, M. and Thamburaj, S. 1997. Nutritive value of vegetables. *Kisan Wld* 24 (1): 53-54

Rathinasamy, A. and Lakshminarasimhan, C.R. 1998. Effect of sugar factory effluent on growth, yield and quality of bhindi var. PKM-1. *Madras agric. J.* 85 (7-9): 403-a105

Ravikumar, V. and Krishnamoorthy, K.K. 1980. Effect of soil amendment on the chemical properties of vertisol and yield of fingermillet (*Eleusine coracana*). *Madras agric. J.* 67 (6): 369-374

Reddy, B.G. and Reddy, M.S. 1997. Soil health under organic farming in maize, soybean cropping system. *Food Security in Harmony with Nature* (ed. Shivshankar, K). Proceedings of third IFOAM – Asia Scientific Conference and General Assembly, 1-4 December, 1997, Bangalore, pp. 221-224

Ros, M., Hernandez, M.T. and Garcia, C. 2003. Soil microbiological activity after restoration of a semi arid soil by organic amendments. *Soil Biol. Biochem.* 35 (3): 463-469

*Sabrah, R.E.A., Magid, H.M.A., Abdel-Aal-Si and Rabie, R.K. 1995. Optimising physical properties of a sandy soil for higher productivity using town refuse compost. *J. Arid Envt.* 29 (2): 253-262

Sadasivam, S. and Manickam, A. 1992. *Biochemical Methods for Agricultural Sciences*. Wiley Eastern Ltd., New Delhi, 246 p.

Saha, H. and Hajra, J.N. 2001. Preparation of phospho-compost from rice straw and response of groundnut. *J. Indian Soc. Soil Sci.* 49: 144-149

Sailajakumari, M.S. 1999. Effect of vermicompost enriched with rock phosphate on cowpea (*Vigna unguiculata* L. Walp). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 104 p.

Sailajakumari, M.S. and Ushakuamri, K. 2001. Evaluation of vermicompost and farmyard manure for growth, yield and quality of cowpea (*Vigna unguiculata* (L.) Walp.). Proceedings of Thirteenth Kerala Science Congress,(ed.Das .C.R.)27-29 January *2001*, Thrissur, pp. 29-31

Sailajakumari, M.S. and Ushakumari, K. 2002. Effect of vermicompost enriched with rock phosphate of growth and yield of cowpea (*Vigna unguiculata* L. Walp). *J. Indian Soc. Soil Sci.* 50 (2): 223-224

Sarawad, I.M., Radder, B.M. and Badanur, V.P. 1996. Effect of vermicompost in conjunction with fertilizers on soil properties and sorghum yield. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp.87

*Sayed, M.S. 1997. Pollution control in dairy plants. *Dairy India*. National Dairy Development Board, Gujarat, pp. 351-354

Scharrer, K. and Burke, R.G. 1953. The influence of nutrition on vitamin A (carotene) synthesis in crops. *Z. Pflanzenernhr Dung. Bodenk.* 62: 244-262

Sedha, R.K., Chahal, D.S. and Pandher, M.S. 1991. Microbial degradation of wheat straw in field. Changes in microflora during decomposition. *Indian J. Microbiol.* 31: 301-307

Sharma, S.N. 2001. Effect of residue management practices and nitrogen rates on chemical properties of soil in a rice (*Oryza sativa*) – wheat (*Testicum aestivum*) cropping system. *Indian J. agric. Sci.* 71 (4): 293-295

Shuxin, L., Xiong, D. and Debing, W. 1991. Studies on soil. *Advances in Management and Conservation of Soil Fauna* (eds. Veersh, G.K., Rajagopal, D. and Virakamath, C.A.). Oxford and IBH Publishing, New Delhi, pp. 543-545

Sidhu, B.S. and Beri, V. 1989. Effect of crop residue management on the yields of different crops and soil properties. *Biol. Wastes* 27: 15-27

Singh, A., Agrawal, S.B., Rai, J.P.N. and Singh, P. 2001. Assessment of pulp and paper mill effluent on growth, yield and nutrient quality of wheat (*Triticum aestivum*). *J. Environ. Biol.* 23 (3): 283-288

*Singh, A.B., Biswas, A.K. and Ramana, S. 2003. Effect of distillery effluent on plant and soil enzymatic activities and ground water quality. *J. Pl. Nutr. Soil Sci.* 166 (3): 345-347

Singh, J. and Rai, S.N. 1996. Sustainable soil management through earthworm research. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp. 49-50

Singh, M. 1991. Effect of trash mulching on population and activity of soil microorganism. *J. Indian Soc. Soil Sci.* 39: 580-582

Singh, P., Sharma, P.P. and Arya, P.S. 1986. Studies on the effect of nitrogen and potassium on growth, fruit yield and quality of chilli. *Indian Cocoa Arecanut Spices J.* 9 (3): 67-69

Sivaramakrishnan, L.A., Shanmugavelu, K.G. and Rajasekaran, L.R. 1983. Studies on the effect of sugar factory effluent on growth, yield and quality of onion *Allium cepa*. Proceedings of National Seminar on Utilization of Organic Wastes. Tamil Nadu Agricultural University, Coimbatore, pp. 199

*Sparling, G.P., Schipper, L.A. and Russell, J.M. 2001. Changes in soil properties after application of dairy industry effluent to New Zealand volcanic ash and pumice soils. *Aust. J. Soil Res.* 39 (3): 505-518

Stanford, S. and English, L. 1949. Use of flame photometer in rapid soil tests of K and Ca. *Agron. J.* 41:446-447

*Stephens, P.M., Davoren, C.N. Doube, B.M. and Ryder, M.H. 1994. Ability of earthworms *Aporrectodea rosea* and *Aporrectodea trapezoids* to increase plant growth and foliar concentration of elements in wheat (*Triticum aesticum* cv. Speas) in a sandy loam soil. *Biol. Fertil. Soils* 18: 150-154

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available nitrogen in soils. *Curr. Sci.* 25:259-260

Suharban, M., Geetha, D. and Nair, M.C. 1997. Degradation of coirpith by oyster mushroom (*Pleurotus* spp.) and its effects on yield of bhindi. *Mushroom Res.* 6 (2): 101-102

Sukanya, T.S., Meli, S.S. and Patil, R.H. 2002. Effect of spent wash as irrigation water on performance of maize (*Zea mays*) and soil fertility. *Indian J. agric. Sci.* 72 (12): 736-138

Sukumar, D. and Rajan, S. 2001. Impact of NPK nutrition and frequency of cuttings on nitrate content in *Amaranthus tricolor* L. Proceedings of the Thirteenth Kerala Science Congress, 29-31 January 2001 (ed. Das, M.R.). Kerala Institute of Local Administration, Thrissur, pp. 323-324

Sunitha, S. and Varghese, P.T. 1996. *Utilization of oil palm wastes for nutrient management.* Annual Report 1995-96. Central Plantation Crops Research Institute, Kasargode, 220 p.

Sureshkumar, S.N. 1998. Vermicompost as a potential organic source and partial substitute for inorganic fertilizers in sweet potato (*Ipomoea batatas* L.). M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 117 p.

Talashilkar, S.C., Dosani, A.A.K. and Chatterjee, A. 2002. Soil fertility and organic recycling. *Indian J. agric. Chem.* 35 (1): 1-31

Tan, K.H. 1982. *Principles of Soil Chemistry.* Marcel Dekker, Inc., New York, 267 p.

Tandon, H.L.S. 1993. *Methods of Analysis of Soils, Plants, Water and Fertilizers.* Fertilizer Development and Consultation Organisation, New Delhi, 144 p.

Terman, G.L., Soilean, J.M. and Allen, S.C. 1973. Municipal waste compost : Effect on crop yields and nutrient content in greenhouse pot experiments. *J. Environ. Qual.* 2: 84-89

Thangavel, P., Balagurunathan, R., Divakaran, J. and Prabakaran, J. 2003. Effect of vermiwash and vermicast extract on soil nutrient status, growth and yield of paddy. *Adv. Pl. Sci.* 16 (1): 187-190

Thanunathan, K. and Arulmurugan, K. 1997. Effect of enriched bioconverted agricultural wastes on soyabean yield and soil fertility management. *Food Security in Harmony with Nature* (ed. Shivshankar, K). Proceedings of third IFOAM – Asia Scientific Conference and General Assembly, 1-4 December, 1997, Bangalore, pp. 154-155

Thilagavathi, T. and Mathan, K.K. 1995. Influence of partially composted coirpith on the yield attributes and yield of rice (var. ADT 36). *Madras agric. J*: 82 (9 &10): 528-530

Thomas, G.V., Prabhu, S.R. and Gopal, M. 2003. Production of vermicompost from coconut plantation wastes as a quality organic input for coconut farming.Proceedings of National Seminar on OrganicFarming with Special Reference to Organic Inputs, 21-24 October, IAT, Bangalore, pp. 7

Thomas, L. and Gopinathan, R. 2002. Organic meals from KCPL slurry – A break through in industrial waste utilization for sustainable agriculture. Proceedings of the Fourteenth Kerala Science Congress 29-31 January 2002 (ed. Das, M.R.). Kochi, PP. 253-257

*Timonin, M.J. 1940 . The interaction of higher plants and soil microorganisms – Microbial population of rhizosphere of seedlings of certain cultivated plants. *Can. J. Res.* 181: 307-317

Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Haulin, J.L. 1997. *Soil Fertility and Fertilization*. Fifth edition. Prentice Hall of India Pvt. Ltd., New Delhi, 634 p.

Tiwari, R.C., Saraswat, P.K. and Agrawal, H.P. 2003. Changes in macronutrient status of soils irrigated with treated sewage water and tubewell water. *J. Indian Soc. Soil Sci.* 51 (2): 150-155

Tiwari, V.N., Tiwari, K.N. and Upadhyay, R.M. 2000. Effect of crop residues and biogas slurry incorporation in wheat on yield and soil fertility. *J. Indian Soc. Soil Sci.* 48 (3): 515-520

Tomati, U., Galli, E., Grappelli, A. and DiLena, G. 1990. Effect of earthworm cast on protein synthesis in radish and lettuce seedlings. *Biol. Fertil. Soil* 9: 288-289

Tomati, U., Grappelli, A., Galli, E. and Rossi, W. 1985. Fertilizers from vermiculture as an option for organic waste recovery. *Agrochemica* 27: 244-251

Toor, A.S., Bishnoi, S.R. and Kumar, R. 2001. Available N release pattern from farmyard manure, cage system and deep litter system of poultry manure with time. *J. Indian Soc. Soil Sci.* 49 (2): 358-360

Toppo, S., Srivastava, H.P., Narayan, R. and Majumdar, S.,2003. Composting of poultry droppings with plant materials and its effect on crop production. *Indian Fmg* 52 (12): 20-22

Udayasoorian, C. and Prabhu, P.C. 2003. Impact of treated paper mill effluent irrigation on quality of soil and ground water. *Madras agric. J.* 90 (7-9): 540-541

Ushakumari, K., Prabhakumari, P. and Padmaja, P. 1996. Seasonal response of bhindi (*Abelmoschus esculentus*) to vermicompost/vermiculture. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp. 42

Ushakumari, K., Prabhakumari, P. and Padmaja, P. 1997. Efficiency of vermicompost on yield and quality of banana (AB) cv. Njalipoovan. *S. Indian Hort.* 45 (3 & 4): 158-160

Vadiraj, B.A., Siddagangaiah and Sudharsan. 1996. Effect of vermicompost on growth and yield of turmeric. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp.47

Vasanthi, D. and Kumaraswamy, K. 1996. Efficacy of vermicompost on the yield of rice and on soil fertility. Proceedings of National Seminar on Organic Farming and Sustainable Agriculture 9-11 October, 1996 (ed. Veeresh, C.K.). Association for Promotion of Organic Farming, Bangalore, pp. 40

Vasanthi, D. and Kumaraswamy, K. 1999. Efficacy of vermicompost to improve soil fertility and rice yield. *J. Indian Soc. Soil Sci.* 47 (2): 268-272

*Vijayalakshmi, G.S. 1993. Role of worm cast in ameliorating soil characteristics. National Symposium on soil biology and ecology, 17-19 February 1993. Indian Society of Soil Science and Ecology, Bangalore. *Abstract* : 56

Vyas, M.K. and Mothiramani, D.P. 1971. Effect of organic matter, silicates and moisture levels on availability of phosphate. *J. Indian Soc. Soil Sci.* 19 (1): 39-43

Walkley, A. and Black, C.A. 1934. An examination of the Degjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci* 37:29-34

Yaduvanshi, N.P.S. and Yadav, D.V. 1990. Effects of sulphitation press mud and nitrogen fertilizers on biomass, nitrogen economy, plant composition in sugarcane and on soil chemical properties. *J. agric. Sci.* 114: 259-263

Zachariah, A.S. 1995. Vermicomposting of vegetable garbage. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 156 p.

*Zibilske, L.M., Clapham, W.M. and Rourke, R.V. 2000. Multiple application of paper mill sludge in agricultural system : soil effects. *J. Environ. Quality* 29 (6): 1975-1981

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* Orginal not seen

UTILISATION OF DAIRY INDUSTRY SOLID WASTE AS AN ORGANIC SOURCE IN SOIL PRODUCTIVITY

INDU, B.

Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2004

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ABSTRACT

An investigation entitled 'Utilization of dairy industry solid waste as an organic waste in soil productivity' was carried out at College of Agriculture, Vellayani to study the feasibility of using dairy industry solid waste (dsw) as an organic source for improving soil productivity. The experiment consisted of four parts *viz.*, characterization of dsw, vermicomposting of dsw, incubation study to monitor the changes in physical property, nutrient availability and microbial population in soil and pot culture experiment to study the influence of cdsw on amaranthus. The dairy waste collected from TRCMPU Ltd. at Ambalathara, Thiruvananthapuram was used in the present study. The physico-chemical and microbial analysis of dsw were done using suitable analytical procedures.

Vermicomposting was carried out in pits of size 1 m x 0.5 m x 0.5 m using vegetable wastes, ground dsw and cowdung in the ratio 5:3:1 by the activity of earthworm *Eudrillus eugeniae.* Vermicompost was prepared according to package of practices recommendations of Kerala Agricultural University.

Incubation study was conducted at the laboratory to monitor the nutrient release pattern and changes in physical properties and microbial population in soil. Two kg of soil was taken in plastic containers of uniform size and incubated at 60 per cent field capacity for three months after application of treatments. The experiment was laid out in CRD with seven treatments *viz.*, T_0 - absolute control, T_1 – soil + 25 g fym, T_2 – soil + 25 g dsw, T_3 – soil + 12 ½ g fym + 12 ½ g dsw, T_4 – soil 12 ½ g fym + 6 ¼ g dsw, T_5 – soil + 12 ½ g cdsw, T_6 –soil+ 6 ¼ g cdsw. Physico-chemical and microbilogical properties of soil were analysed at an interval of 1, 2, 4, 6, 8 and 12 weeks.

The pot culture experiment was conducted to study the influence of dsw on growth, yield and quality of amaranthus. It was laid out in CRD with a treatments *viz.*, T_0 – absolute control, T_1 – fertilizers and fym as per POP, T_2 – POP fertilizers and 50 t ha^{-1} cdsw, T_3 – POP fertilizers + fym 25 t ha^{-1} and cdsw 25 t ha^{-1}, T_4 – POP fertilizers and fym 25 t ha^{-1} and cdsw 12 ½ t ha^{-1}, T_5 – 2/3 N + full NPK of POP + fym 25 t ha^{-1} and cdsw 25 t ha^{-1}, T_6 – 2/3 N + full PK of POP and fym 25 t ha^{-1} + cdsw 12 ½ t ha^{-1}, T_7 – ½ N + full PK of POP + fym 25 t ha^{-1} + cdsw 25 t ha^{-1}, T_8 – ½ N + full PK of POP and fym 25 t ha^{-1} and cdsw 12 ½ t ha^{-1}. Observations on various biometric and yield parameters have been recorded and analysis of plant sample were done at three stages of growth of plant *viz.*, 30, 45 and 60 days after transplanting. The nutrient status of soil after the experiment was also analysed.

Analysis of physico-chemical and microbial properties of dsw revealed that it had a near neutral pH (6.5) and it contained 37.5 per cent organic carbon, 5.80 per cent N, 2.04 per cent P, 0.71 per cent K, 1.69 per cent Ca, 1.58 per cent Mg, 1.71 per cent Fe, 159 mg kg^{-1} Mn and 1084 mg kg^{-1} Zn. Population of bacteria, fungi and actinomycetes in dsw were 13.3 x 10^6, 11.6 x 10^4 and 1.3 x 10^4 respectively.

The results of the study revealed that vermicomposting can be successfully done in dsw using *Eudrillus eugeniae*. Vermicompost with a C : N ratio of 11.12 was obtained after 60 days of composting. The final compost contained 3.12 per cent N, 1.97 per cent P, 1.81 per cent K, 2.05 per cent Ca, 3.55 per cent Mg, 0.80 per cent Fe, 230 mg kg^{-1} Mn, 408 mg kg^{-1} Zn and 44 mg kg^{-1} Cu. Number of bacteria, fungi and actinomycetes in the compost at maturity stage were 42.6 x 10^6, 38.6 x 10^4 and 21.3 x 10^4 respectively.

From the incubation study, it can be seen that nutrient content of soil increased upto 6-8 weeks in all treatments except T_0 followed by a gradual decline. All nutrients except Cu were more on cdsw applied treatment in the initial period. Cu content was more in fym applied treatment. Nutrient availability was more from fym applied treatments during later periods of incubation. Bulk density of soil decreased in all treatments except T_0 upto six weeks of incubation followed by a gradual increase in 8 and 12 weeks. Treatment in which cdsw was applied at higher dose showed the lowest bulk density. Upto six weeks the highest water holding capacity was noticed in cdsw applied treatments, after that fym applied treatments showed highest water holding capacity. Bacterial and fungal population reached the peak in sixth week and then declined. Upto eight weeks the effect of treatments was non significant with respect to actinomycete population.

The pot culture experiment indicated the influence of cdsw on growth, yield and quality of amaranthus. Biometric and yield observation have proved the superiority of cdsw over fym. Beta-carotene content was more in cdsw applied treatments. Total yield and B:C ratio were the highest when cdsw was used as a partial substitute for fym.

Physico-chemical properties of soil after the pot culture experiment revealed that pH, EC, organic carbon and available nutrients increased in all treatment except in T_0 compared to the initial soil. pH, EC, organic carbon, available P, Ca and Fe were the highest in T_2 which received cdsw at higher dose while the available N, K, Mg, Mn, Zn and Cu were the highest in T_1 which received fym.

From the results it can be concluded that effective biomanagement of dsw can be carried out using *Eudrillus eugeniae.* Better availability of nutrients especially nitrogen from cdsw compared to fym immediately after application as evidenced by incubation study is advantageous for short duration leafy vegetables. Use of cdsw can reduce the use of fym partially or fully in amaranthus. Fertilizer N can also be reduced to the extent of 1/3 of POP recommendation.

APPENDICES

APPENDIX - I

Composition of different medium used for isolation of different groups of microorganisms in dairy waste, vermicompost and soil

1. Potato Dextrose Agar

Potato	–	200 g
D Glucose	–	20 g
Agar	–	15 g
Distilled water	–	1 litre

2. Nutrient agar

Beef extract	–	3 g
Peptone	–	5 g
Agar	–	15 g
Distilled water	–	1000 ml

3. Kauster's Agar

Glycerol	–	10 g
Casein	–	0.3 g
$MgSO_4.7H_2O$	–	0.5 g
$FeSO_4$	–	0.1 g
KNO_3	–	2 g
NaCl	–	2 g
$K_2H\ PO_4$	–	0.5 g
$CaCO_3$	–	0.2 g
Agar	–	15 g
Distilled water	–	1000 ml
pH	–	7

4. Vermicompost Extract Agar

Glucose	–	1.0g
$K_2H\ PO_4$	–	0.5g
Agar	–	15g
Vermicompost extract	–	1000 ml
pH	–	6.8

The vermicompost extract was prepared by steaming one kg of vermicompost in 2 litres of water for 30 minutes. The supernatant was filtered and previously weighed nutrient components were added to 1000 ml of this extract.

5. Martin's rose Bengal Agar

Dextrose	–	10 g
Peptone	–	5g
KH_2PO_4	–	1 g
$MgSO_4.\ 7H_2O$	–	0.5 g
Rose Bengal	–	33 mg
Agar	–	15 g
Distilled water	–	1000 ml
Streptomycin	–	30 mg

6. Soil Extract Agar

Soil extract	–	100 ml
Glucose	–	1 g
K_2HPO_4	–	0.5 g
Agar	–	15 g
Tap water	–	900 ml
pH	–	6.8

One kg of sieved garden soil is mixed with 1000 ml of tap water and steamed in autoclave for 30 minutes. A small amount of $CaCO_3$ is added and the whole filtered through double filter paper. Dissolve agar in 900 ml of water. Add 100 ml of stock soil extract solution. Add glucose before dispensing in flasks.

7. Kenknight's Medium

Dextrose	–	1
$K_2H\ PO_4$	–	0 g
$NaNO_3$	–	0.[illegible]
KCl	–	0.1
MgSO4. 7H2O	–	0.1
Agar	–	15g
Distilled water	–	1 lit

APPENDIX - II

Weather parameters during the cropping period

(December 2003 –March 2004)

Fortnight	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Rain fall (mm)	Evaporation (mm)
December I	31.00	22.10	74.43	0.00	2.60
December II	31.40	20.90	77.68	0.00	3.33
January I	31.50	22.30	76.43	0.00	3.45
January II	31.80	22.90	77.37	6.80	3.65
February I	32.00	21.30	77.35	0.40	4.05
February II	32.10	24.50	74.35	0.00	4.30
March I	33.10	24.70	75.95	0.00	4.60
March II	32.70	24.50	77.15	1.20	4.56