AEROBIC COMPOSTING AND ENRICHMENT OF AYURVEDIC WASTE

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Aerobic composting and enrichment of Ayurvedic waste"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Certified that the thesis entitled **"Aerobic composting and enrichment of Ayurvedic waste"** is a record of research work done independently by Ms. Lekshmisree C. S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Dedicated to
my intimate
friend Sidha

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Introduction

INTRODUCTION

The adoption of modern agricultural technologies has revolutionized agricultural production bringing it upto the levels to feed the quickly growing population of the world. The application of plant nutrients to different crops has contributed substantially towards this spectacular increase. In the past three decades, fertilizers have been the most commonly used sources for supplying nutrients to crop plants. In developing countries like India, fertilizer prices have been subsidized, thereby encouraging farmers to apply fertilizers in production maximizing doses. The low cost and readily available chemical fertilizers have pushed the use of organic manures into a decline the world over. But with present increase in price of fertilizers and growing concern about the limited initial resources like petroleum, it is increasingly important to pay more attention to the use of organic sources of plant nutrients. Also the complete dependence on chemical fertilizers also has led many problems in modern agriculture, the major one being soil degradation.

Limited availability of additional land for crop production along with declining yield of major food crops have raised concerns about agriculture's ability to feed a world population expected to exceed 7.5 billion by the year 2020.Decreasing soil fertility and declining nutrient use efficiency have also become international problems, which hinder the sustainability of agricultural production at current levels. Sustainable production could be achieved only when factors leading to continued maintenance of soil health are taken care of. Hence the complimentary role of organics as supplements to chemical fertilizers is important for keeping the soil health in order and sustain higher production.

The organic manures being bulky in nature are low in nutrients and thus have to be applied in large quantities to meet the nutrient demand of the crops. Moreover due to high temperature and rainfall in the tropics there is faster depletion of organic matter and this necessitates the search for good quality manures to sustain soil health. The major problems that farmers face today is the non availability of adequate quantity of organic manures due to decreasing cattle population, improper collection methods and division of agricultural wastes into different byproducts. At the same time as a result of growing urbanization and industrialization enormous quantities of solid wastes, both domestic as well as industrial, is generated each year and their accumulation is causing severe environmental problems.

Wastes are inevitably produced by the agricultural, industrial and human activities. But its safe management is really a difficult problem. Most of these waste materials contain many major and minor nutrients and can serve as a good source of organic manure and soil amendment. The probable way to tackle this problem is recycling of organic wastes as organic matter. Recycling of organic wastes not only helps to consume natural resources but also offers the potential of reutilizing secondary materials for beneficial use as well rather than their discharge into the environment, which cause detrimental effects on man. Thus land application of waste in agriculture after converting it into useful organic fertilizers by appropriate technology is one of the most economical methods for solving the problem of waste disposal.

A sustainable food production system would envisage, progressive improvement in quantitative yields in tune with increasing demands and maintaining quality of produce as well as the environment on the one side and economic viability on the other. Integrated nutrient supply through judicious combinations of organics and biological sources along with inorganic fertilizers can be a part of organic production system (Swaminathan, 1987). Combined use of organics and fertilizers is a workable way to save the cost of production. The manures like cow dung and poultry manures along with fertilizers help in maintaining the soil fertility and rhizosphere environment by improving the physico- chemical properties of soils without hindering the crop production (Tiwari and Tripathi,1998). Integrated Nutrient Management involving the intelligent use of organic, chemical and microbial sources will sustain optimum yields, improve the soil health and provide crop nutrition packages which are technically sound, economically attractive, practically feasible and environmentally safe.

There are several instances of successful utilisation of agro-industrial wastes like coirpith, pressmud, fly ash, phosphogypsum, lime sludge etc. in agriculture. One such industrial waste generated in huge quantity that requires effective disposal mechanism is Oushadhi waste produced by Pharmaceutical Corporation, Indigenous Medicines (I.M.) Kerala Limited, Thrissur, which is popularly known as Oushadhi. The Ayurvedic medicine manufacturing unit is located at Kuttanalloor, 8 km east of Thrissur town, produces more than 400 Ayurvedic formulations which generates about 1t waste per day. Due to its high alkaloids and lipid content it can't be applied as such to agricultural lands and hence its effective disposal mechanisms is in vogue.

Preliminary studies conducted have proved that the waste materials contain adequate amounts of various plant nutrients. These materials are predominantly of organic nature and may be low in inherent nutrient status. But this can serve as a good source of organic manure and soil amendment. Suitable biodegradation techniques can be applied to convert these organic waste materials to organic manure rich in nutrients. Thus the present study on "Aerobic composting and enrichment of Ayurvedic waste" was taken up with the following objectives.

(1) Study on the basic physico-chemical properties of the waste materials.
(2) Standardize the formulation of compost from Oushadhi organic wastes.
(3) Evaluation of the soil and crop response to the best formulation of compost made from Oushadhi waste.

Review of Literature

2. REVIEW OF LITERATURE

2.1. THE PROBLEM

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

Bhardwaj (1995) estimated that major crops of India annually generated a total of about 274 mt of crop residues. Nearly 100 to 114 mt of crop residues are either wasted or burnt. Kurodoa *et al.* (1996) also stated that large amount of malodorous gas emitted from waste caused complaints from nearby residents. According to him, organic products derived from industrial, agricultural and human activities are available in large quantities as waste, however their use is limited.

According to Bhinde (1999) the urban population may be double that of 1991 in 2011 but quantity of waste generated will be tripled. It will increase from 20.71 million tonnes in 1991 to 39.38 in 2001 and to 56.33 million tonnes in 2011. He also opined that 30 mt of solid waste was generated each year in urban India. India generated 345 million tonnes of solid waste annually of which approximately 25 million tonnes were Municipal solid waste and 320 million tonnes were agricultural residues (Thimmaiah and Bhatnagar, 1999). According to Gaur (1999) agricultural wastes include rice bran, rice husk and rice straw (106 MT), wheat and other cereal straw (140 MT), sugarcane trash (18.2 MT), bagasses (44 MT), molasses (3.7 MT), coir waste (33,000 t) etc.

In the wake of 21^{st} century due to technological growth, waste accumulation enhanced and disposal of these wastes has assumed serious dimensions not only in western world but also in Third World Countries. These wastes are of different kinds like crop residues, vegetable wastes, domestic wastes, city garbages, sewage effluents, industrial effluents and sludges etc which effect the environment and harmonious relationship between the biotic and abiotic components of ecosystem (Ahalwat and Sagar, 2001).

Uncontrolled discharge and open dumping of agro industrial wastes contributed to appreciable environmental deterioration which was manifested as:

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

(Hamza, 1989)

2.2 IMPORTANCE OF RECYCLING OF ORGANIC WASTE

The International Union of Pure and Applied Chemistry (IUPAC) established a committee on recycling of solid wastes in 1976. Examining the effects of recycling and heat energy transformation on agricultural as well as municipal wastes such as sewage sludge, city refuse and industrial wastes, the committee concluded that biological conversion method is as important in the utilization of urban and industrial as of agricultural wastes (IUPAC, 1977). USDA reported a growing shortage of good quality of farm organic wastes for use as soil conditions and biofertilizers because of competitive use as fuel, fodder and fibre (USDA, 1978).

Jaag (1978) opined that different waste materials could be processed to fertilizer and by this wastes were reintegrated into natural cycle. The increased practice of recycling animal waste, poultry waste and agricultural residues have been advocated for providing futuristic energy and fertilizer source (Hobson *et al.*, 1981, Vimal and Talashilkar, 1983). A sustainable agriculture would keep the environment of the region harmonious and balanced through appropriate cropping and farming systems by using resources judiciously and by minimizing the purchased inputs it would rely as much as possible on renewable resources of farm itself (Swaminathan, 1987). According to Parr and Hornick (1992) the restoration and rehabilitation of degraded and marginal soils to an acceptable level of productivity could be enhanced by using various off-farm sources of organic wastes including agricultural and industrial processing wastes, sewage sludge and Municipal solid waste.

Jain (1993) emphasized on the importance of agricultural residues and these could supplement chemical fertilizer needs of next crop. The wastes could be processed by conversion process and final product should be non pollutant and safely used in economic or agricultural activity (Gill, 1993). Organic recycling practices allowed farmers to maximise their crop production with negligible soil erosion and nutrient runoff (Parr *et al.*, 1994). According to Smith and Chambers (1995) technologies used for recycling varied greatly depending on waste material and site characteristics. An understanding of principles and problems of various technologies is essential to make a wise choice.

According to Bhardwaj (1995) the organic wastes available in India were estimated to supply 7.1, 3.0 and 7.5 mt of N, P_2O_5 and K_2O respectively. The crop residues alone supplied 1.13, 1.41 and 3.54 mt of N, P_2O_5 and K_2O respectively. Kair (1996) reported that 6 mt of plant nutrients were wasted through improper utilization of farm organic wastes. By proper recycling about 50 thousand tonnes of plant nutrients were added back to soil. Ramaswamy (1996) pointed out that the available organic waste materials and crop residues in India which supply several million tonnes of N, P_2O_5 and K_2O can be converted into value added organic manures or compost by addition of suitable biodegradation process and technology.

According to Thippaiah (1996) resource recycling reprocessing and utilization are now considered as the only sensible way to tackle the problem of waste management. The beneficial effects of organic wastes on soil physical properties are increasing water infiltration, water holding capacity, water content, aeration and permeability, soil aggregation and rooting depth and decreasing soil crusting, bulk density, runoff and erosion (Blanco and Almendros, 1997). According to Akhaury and Kapoor (1997) self sufficiency in food production can be achieved by proper management and utilization of organic matter such as agricultural residues to protect agriculture soil from wind and water erosion and also prevent nutrient losses through runoff and leaching.

Sustainable agriculture is a method of farming to produce adequate food without much adverse effect on soil productivity (Kandaswamy, 1992). Rammohan *et al.* (2001) pointed out that sustainable agriculture doesn't mean a return to the farming methods of earlier agriculture rather, it combines traditional techniques with modern technologies as well as giving emphasis for organic recycling. According to Mondini *et al.* (2002) efficient and effective use of agricultural residues as soil conditioners also provides one of the best means for maintaining soil productivity.

2.3 TYPES OF ORGANIC WASTES

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

Farm yard manure (FYM) is the traditional manure that supported our crop production system for ages. Several long term manurial studies involving FYM have been carried out throughout the country and its efficacy has been amply demonstrated (Sahu and Nayak, 1971, Varghese and Pillai, 1990, Anilakumar *et al.*, 1993, Verma and Bhagat, 1993). According to Tiwari *et al.* (1989) addition of dung as inoculum in the proportion of 10 per cent of dry weight in presence of 2 per cent rock phosphate was ideal for efficient composting of resistant materials such as wool waste. According to Gaur and Mathur (1990) dung slurry and biogas spent slurry were found to be good additives for improving the rate of decomposition of crop waste composts. Kuppuswamy (1993) noted that biogas digested slurry as basal manure enhanced the yield of cereals, pulses and oilseeds.

Organic manures including animal manures, crop residues, green manures and composts were traditionally and preferentially used in developing countries until 1960's when inorganic chemical fertilizers begin to gain popularity due to their easy availability, less of bulk and thus easiness in transport, handling and storage (Dahama, 1996). FYM of good quality is perhaps the most valuable organic matter applied to soil and is the most commonly used organic manure in most countries of the world (Dobermann and Fairhurst, 2000).

Singh and Srivastava (1971) and Singh *et al.* (1973) also attributed the higher efficiency of poultry manure to its narrow C:N ratio and comparatively higher content of readily mineralisable nitrogen. Composting of wide C:N ratio materials such as bark wastes, rich straw and saw dust with low C:N ratio material such as poultry manure resulted in a more favourable ratio for composting and compost produced had high nutrient content (Parr and Colacicco, 1987, Echeandia and Menoyo, 1991, Rynk, 1992). Poultry manure could be used as a good source of nutrient with 60 per cent nitrogen as uric acid, 30 per cent as more stable organic nitrogen and balance as mineral nitrogen (Srivastava, 1988).

Budhar *et al.* (1991) also emphasized the superiority of poultry manure as an organic source. According to Rani and Ramaswamy (1996) the volatilization loss of nitrogen in poultry droppings, which is present as uric acid due to hydrolysis to NH_3 and CO_2 can be reduced by using water hyacinth as an amendment in ratio 2:1. At the end of 60^{th} day of composting high quality friable compost was obtained with a C: N ratio of 9.79.

Utilization of crop residues to provide plant nutrients directly to the crops and to maintain soil fertility status is important. Crop residues alone can supply about 0.5, 0.6 and 1.5 million tonnes of N, P_2O_5 and K_2O respectively (Veeraraghavan *et al.*, 1983). According to Gaur (1992), the potential of cereal straw residues from rice, wheat, sorghum, pearl millet and bajra were 1.13, 1.41 and 3.54 mt of N, P_2O_5 and K_2O respectively. The vast quantities of cellulosic wastes generated during the processing of rice, sugarcane, cotton, timber and other crops could be applied safely to crop land (Silva and Breitenbeck, 1997).

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

2.4 COMPOSTING

Composting is a microbiological process accomplished by cumulative action of bacteria, fungi, actinomycetes and protozoa which are present in raw materials or introduced into the system by the use of inoculum (Gaur, 1980). According to Gaur and Sadasivam (1993), under Indian farming condition composting of manure slurries with plant residues is a more viable and profitable proposition.

Fogg (1988) summarised a negative effect of nitrogen in organic matter which higher C/N ratio and vice versa. Wilson (1989) stated that if the initial mixture of materials had a C: N ratio of 15-40, moisture content of 40-60 per cent, pH of 5-12 and greater than 30 per cent air space, it would be ideal to operate an effective composting process. Selective composting of waste materials available with other raw materials like FYM, other domestic and industrial wastes provided a readily compostable mixture and higher quality produce. Substantial quantity of nutrients were obtained from arabica coffee pulp compost, which can be advantageously recycled in coffee based cropping system to enrich the soil fertility and to substitute part of chemical fertilizers (Korikanthimath and Hosmani, 1998).

The composts contain macronutrients such as P that contributed to greater yield of different crops. The soil nutrient values were found to be high in enriched compost amended soil after the harvest of first and second crops. There was a light decrease in bulk density of soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatment (Srikanth *et al.*, 2000). Good quality composts could be produced within a period of 90 days by open heap method using materials like sludge, neem cake, mussorie rock phosphate and urea (Thomas, 2001).

2.5 COMPOST ENRICHMENT

The need for adding inorganic N to improve the manurial value of compost was realised quite early (Hutchinson and Richards, 1921). Gupta and Idani (1970) and Gaur *et al.* (1971) recommended that compost with a C: N ratio of 20:1 should be treated with ammonium sulphate or urea solution so as to bring the C:N ratio to less than 10:1 and N content to more than 2.5 per cent. Addition of mineral N increased the N content of finished compost to 1.8-2.5 per cent (Asija, 1984; Bhriguvanshi, 1988). Composting with initially high level of N induced the production of free ammonia. The loss of N was about 85 per cent where two per cent urea N was added and 75 per cent where one per cent urea N was added (Bangar, 1988).

Effect of addition of nitrogen on enrichment of phospho compost was studied by Bangar (1988, 1989) and Singh *et al.* (1992). The N content of compost was increased to 2 per cent. Organic wastes poor in nitrogen was enriched by incorporating fish meal, non edible oil cakes, poultry manure or one per cent N as urea (Jaggi, 1991). The volatilisation loss of ammoniacal nitrogen from poultry manure can be minimised by composting it with substrate having wide C: N ratio. Rice straw mixed with ten per cent poultry waste yielded a more friable and nitrogen rich compost. The output was more by 15 per cent compared to compost made from poultry manure alone (Sims and Wolf, 1994).

Application of compost produced by coinoculation of 3 mesophilic actinomycetes with and without 80 kg N effected a significant increase in grain yield in wheat over that with 120 kg N ha^{-1} (Mathur and Shukla, 2000). Fritz *et al.* (2001) pointed out that sweet corn waste was transformed into enriched compost which contains large quantities of mineralized nitrogen. Post harvest nitrate-nitrogen concentration in soil was also significantly increased by the application of sweet corn waste.

The subject of adding super phosphate, dicalcium phosphate or rock phosphate during composting engaged the attention of several workers since long (Acharya, 1954; Singh and Subbiah, 1969; Murthy, 1978). Gaur (1982) reported that rockphosphate enriched compost contained 7 per cent more P_2O_5 compared to ordinary compost. Mathur and Debnath (1983) reported that quality of compost prepared from mixture of paddy straw, grass and water hyacinth was improved when rockphosphate was applied to it with and without pyrite.

Shinde and Patel (1984) opined that higher level of rockphosphate immobilized available N temporarily and therefore lower level N and P should be used for blending. Rock phosphate was found to be a good starter material to stimulate microbial activity in the compost system (Bhardwaj and Gaur, 1985). Talashilkar and Vimal (1986) enriched 21 days old mechanical compost by mixing urea and SSP and covered it for three months. The N and P content increased from 0.76 to 1.5 and 0.23 to 0.66 per cent respectively.

Mishra (1995) observed that it is not ideal to enrich manures to N and P contents of more than 5- 6 per cent dry weight basis since the addition of at least 2.5-3 t of wet manure per hectare was needed to obtain beneficial effects on nutrient use efficiency. Verma (1995) reported that addition of rock phosphate @ 3 per cent and rice straw as substitute increased the available P level in the compost. Gowda (1996) reported that rock phosphate equivalent to 5 per cent mixed with 10 per cent cow dung and 5 per cent soil and 5 per cent well decomposed manure served as inoculum for composting any organic waste and compost obtained after 90-120 days decomposition can be used as substitute to SSP using double the quantity.

2.6 COMPOST PARAMETERS

Physical parameters such as temperature, odour and colour have been proposed to characterise compost maturity (Sugahara *et al.*, 1979; Guisquiani *et al.*, 1989). The progress of composting is normally evaluated by physico-chemical parameters such as variation in C: N ratio, loss of weight, increase in ash, formation of humic substances (Lobo *et al.*, 1987; Diaz-Burgos and Polo, 1991; Garcia *et al.*, 1992).

2.6.1 Temperature

Several workers have demonstrated that the fermentations operating at thermophilic temperatures resulted in more rapid degeneration of organic matter (Hashimoto *et al.*, 1981; Lo and Marsh, 1985; Kinochie *et al.*, 1988). Numerous studies showed that at adequate aeration the temperature in the compost pile increased to greater than 60°C. This accelerated the decomposition process and resulted in complete destruction of pathogen, parasites and weed seeds (Bishop and Godfrey, 1983; Harada and Haga, 1983; Parr *et al.*, 1994). Gaur and Geethasingh (1985) reported that due to the effect of high temperature and antibiotics produced during bioconversion, the end product is free of pathogens. Humus and CO_2 are produced and essential nutrients such as nitrate, sulphate and phosphates are released in the process of composting.

Temperature was found to rise during first two weeks of composting. CO_2 accumulation increased in the first week of composting and on maturity gets decreased. concentration of O_2 decreases in beginning due to high rate of O_2 consumption by microbial agents and on maturity consumption rate decreases. Organic matter content also shows a decrease towards maturity (Bandawi *et al.*, 1997. Eghball *et al.* (1997) reported that during composting of cattle feed lot manure, the temperature reached 65°C within 24 hours at all depths within the compost pile. After 65 days the temperature decreased to 40°C and become near ambient after 110 days. The compost attained maximum values of temperature (66.3°C) and pH (7.4) at thermophilic stage (Nair, 1997).

2.6.2 pH

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

2.6.3 C:N ratio

Clairon *et al.* (1962) , Poincelot (1975) , Golueke (1977) and Chanyasak *et al.* (1982) recommended the use of C: N ratio as index of maturity. Harada *et* *al.* (1981) and Hirai *et al.* (1983) reported that though C: N ratio was the most common parameter used to define decomposition levels it cannot be a reliable indicator of compost maturity. A C: N ratio of 10 to 12 is usually considered to be an indicator of stable and decomposed organic matter (Jimenez and Garcia, 1992). Composts with very low C: N ratio cause ammonium toxicity and interference with plant growth (Inbar *et al.*, 1993).

Shen-Qi-Rong *et al.* (1997) reported that C: N ratio decreased during composting. The satisfactory initial C: N ratio for composting is from 30 to 35. If the C: N ratio exceeds this, it takes a longer time for composting. During composting process, total carbon, total absolute N and C: N ratio decreases but N content increases (Xu *et al.*, 1997). Sameer and Sushama (2003) reported that C: N ratio of coir pith compost got reduced to 44.64 from the initial C: N ratio of 169.23 of raw coir pith. Immature composts with high C: N ratio when applied to soil results in the immobilization of mineral Nitrogen causing nitrogen deficiency to plants.

2.6.4 Cation Exchange Capacity (CEC)

Kalaiselvi and Ramasamy (1996) stated that CEC content of same type of compost might vary due to blocking of their exchange sites by certain ions such as Fe, Cu or Al. According to Saharinen (1998) CEC get increased during composting.

2.6.5 Microbial count

Kaiser (1983), Moral *et al.* (1986), Nannipieri *et al.* (1990), Benedetti *et al.* (1991) and Wittling *et al.* (1995) proposed microbial criteria as indicator of compost maturity. De Bertoldi *et al.* (1982) found that during initial stages of composting, ammonia producing and proteolytic bacteria increased considerably reaching numbers greater than 10^6 cells g^{-1} dry weight. As compost matured their population decreased while the nitrogen fixing bacterial population increased again. Faster growth of actinomycetes in the advanced stages of bark decomposition was reported by Hardy and Sivasithamparam (1989). Kostov *et al.* (1994) evaluated microbial index ratios during aerobic composting of sawdust and bark and found that ratios of number of fungi, ammonifying microorganisms and nitrogen fixing bacteria to the actinomycetes were found to decrease with age of compost. Studies conducted by Nair (1997) revealed maximum microbial population of bacteria, actinomycetes and fungi to be in the thermophilic stage. According to Zaremba *et al.* (1998) microbial content influenced the type of nutrient cycling that the compost provided for the soil and was used as one of the indicators of compost quality. Microbial biomass and respiration decreased more rapidly while turning thus leading to compost maturity (Bess, 1999).

2.6.6 Moisture content

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

2.6.7 Compost maturity

Kimber (1973) observed that aim of maturation process was to eliminate phytotoxic substances of the raw materials, which were harmful to germination and growth of plants. Biological methods including germination index of seeds in compost extracts (Zucconi *et al.*, 1981; Harada, 1995) and seedling tests (Kawada, 1981; Hoitink and Kuter, 1986) are used to characterize compost maturity. Garcia *et al.* (1988) also reported that a certain period of maturation (four months) after composting (90 days) was necessary for organic matter of compost to become stable and to avoid phytotoxicity in plants. As organic matter decomposed, the compost became a better substrate for plant growth. According to Chefetz *et al.* (1996) in immature composts low molecular weight organic acids induced phytotoxicity in addition to competition for oxygen and nutrients due to high rates of organic matter decomposition.

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

- Mature compost should have a tea brown colour, no noxious smell and good stability, which could no longer produce high temperature.
- Maximum diameter shouldn't exceed 10 mm, with 5 mm as optimum and water holding capacity below 30 per cent.
- Most common pH values ranged from 6.5 to 8.0
- Total salinity shouldn't exceed 2 g salt
- C:N ratio of mature compost should be less than 20 and CEC should be more than 70 meq/100 g of ash free material
- At least 10 per cent of the total organic carbon present in the original material should be humified at the end of composting
- Good quality compost should contain minimum levels of toxic components and non-biodegradable materials.

2.7 EFFECT OF ORGANIC MANURE AND COMPOST ON SOIL FERTILITY

The role of FYM application in increasing the organic carbon level has been reported by many workers (Biswas *et al.*, 1969; Prasad *et al.*, 1983; Bijaysingh *et al.*, 1993). A number of workers have reported the beneficial effect of organic manures viz. FYM in increasing the available P content of soil (Havangi and Mann, 1970; Azar *et al.*, 1980; Dhillon and Dev, 1986; Singh and Sarkar, 1986; Mathan and Joseph, 1998). Organic manures or composts contain a very large population of bacteria, actinomycetes and fungi and stimulate those already present in the soil. The application of organics helps microorganisms to produce polysaccharides which build up better soil structure, N fixation and P solubilisation are also increased due to improved microbiological activity in organic amended soils (Balasubramaniam *et al.*, 1972).

Application of FYM increases the availability of both native and applied micronutrient cations. These ions form stable complexes with organic ligands which decrease their susceptibility to adsorption and fixation (Swarup, 1984). Srivastava (1985) found that organic C, total N, total P and K status increased with FYM addition. Continuous application of FYM increased the organic carbon content of soil (Singh *et al.*, 1988; Sud *et al.*, 1990). Increase in soil moisture retention due to addition of FYM was observed by Sulter and Williams (1993).

Pagliai and Antisari (1993) reported that increased porosity in the top soil was accompanied by a reduction in penetration resistance by addition of organic wastes like livestock effluents and compost. Thampan (1993) recommended on farm recycling of organic wastes and application of bulky organic manures such as FYM and compost as the most popular organic measures to sustain good soil health. More (1994) reported that addition of farm wastes and organic manures increased the status of organic C, available N, P and K of the soil.

Hoffman (1983) conducted long term field experiments on acid soils and showed that by raising compost application rates, soil organic matter content increased from 2 per cent to 6.9 per cent. Similar results were reported by Guidi *et al.* (1983). Guisquiani *et al.* (1995) observed that total and humified organic carbon increased as compost ratios were increased but the rise in soil carbon wasn't proportional to the amount of organic carbon added with compost. Compost application improved soil chemistry and microbiology and could be regarded beneficial for agriculture (Beffa *et al.*, 1996). The content of soil P, K, Ca and Mg were increased in the surface by a factor of 3 or 4 times by compost application (Edward *et al.*, 1996). Adhikari *et al.* (1997) reported that compost treated soil maintained higher organic carbon and microbial biomass carbon compared to untreated soil. Repeated application of 5 Mt/ha of composted material on dry weight basis each year for 50 years accumulated about 1.5-2.7 per cent carbon in the plough layer (Shiga, 1997).

Belau and Kable (1998) reported that compost application had marked effects on yields (fresh and dry matter) as well as in environment relevant soil properties. Compost treated soil maintained higher organic C and microbial biomass C compared to untreated soil (Gagnon *et al.*, 1998). Compost controlled weeds due to physical presence of materials on soil surface or action of phytotoxic compounds generated by microbes during composting (Hampton, 1998). According to Pdilli and Mbah (1998) compost increased the total porosity, easily available water and buffering capacity of soil.

2.8 CROP RESPONSE TO ORGANIC MANURES

Nilson (1979) reported that organic fertilizers provided the highest dry matter content in carrots, but the lowest dry matter content in cabbage and leek. Composts contained macro nutrients such as P that contributed to greater yield of different crops (Hornick and Parr, 1987; Sikora and Yakovchenko, 1996). The use of different organic amendments in crop production like farmyard manure, biogas slurry, poultry and coir pith produced higher yields as well as nutrient build up (Anon, 1991). Lazic *et al.* (1992) obtained better yield and fruits with excellent quality in capsicums with the use of organic fertilizers alone.

Annanurova *et al.* (1992) reported that addition of FYM to basic NPK fertilizer increased the number and mean weight of tomato fruits. Anilakumar *et al.* (1993) reported that continuous application of cattle manure produced 24 per cent more yield than complete fertilizer source. In okra, application of poultry manure resulted in an increase in growth and yield and reduction in nematode populations in soil as observed by Khan (1994).

Gagnon and Berrouald (1994) found that organic fertilisers produced best growth and significantly increased dry weight by 57-83 per cent compared to non-fertilized control. Thamburaj (1994) found that organically grown tomato plants were taller with more number of branches. They yielded 28.18 t ha^{-1} which was on par with recommended dose of FYM and NPK (20:100:100). Sorghum grain yield was highest with 120 kg N + 60 kg P as phosphocompost than with 60 kg P as SSP (Jadhav *et al.*, 1996).

The residual effect of plant nutrients supplied to wheat on rice yields resulted in higher yields of rice from treatments including compost. N and K uptake of rice was highest when wheat crops had given combination of compost and inorganic fertilizer (Fawaz *et al.*, 1997). Organic manures like FYM, compost, oil cakes etc. improved yield as well as quality of vegetable crops like tomato, onion, gourds, chillies etc. (Rani *et al.*, 1997). Roe *et al.* (1997) reported that the plant height and stem diameter in bell pepper was better when compost was applied along with fertilizers. They also found that composts increased plant height and root weight of tomato and cucumbers. Application of compost showed a marked increase on average head weight/plant for lettuce compared with non composted controls (Devliegher and Rooster, 1997).

Sukumar (1997) obtained significantly increased nitrate content in amaranthus with an increase in the level of nitrogen. Parmar *et al.* (1998) reported that the palnt height and root nodulation in vegetable pea (*Pisum sativum* var. arvense) was improved with the application of FYM alone and in presence of NPK. Warman and Haward (1998) revealed 10 per cent increase in cauliflower than with non composted controls. According to Maheswarappa *et al.* (1999) organic manures like FYM and compost were able to improve pH, organic carbon and soil microbial population when arrowroot is grown as an inter crop in coconut garden.

Materials and Methods

3. MATERIALS AND METHODS

The investigations on aerobic composting and enrichment of ayurvedic wastes of Oushadhi Pharmaceutical Corporation was conducted at College of Horticulture, Vellanikkara, during July 2002 to May 2003. The study was carried out in three parts as given below:

1. Studies on the characterization of basic physico-chemical properties of ayurvedic wastes obtained from Oushadhi
2. Standardization of the formulation of compost from ayurvedic wastes
3. Evaluation of soil and crop response to the best formulation of compost from Oushadhi wastes.

3.1. Basic properties of the ayurvedic waste

The study material consists of ayurvedic wastes generated by Oushadhi Pharmaceutical Corporation, Indigenous Medicines (IM) Kerala Limited situated at Kuttanallor, 8 km east of Thrissur town. These wastes are produced during the process of manufacturing of different ayurvedic formulations like Asavarishtam, Thailam, Gurutham, Lehyam, Gulika, Kalkkam, Himam, Choornam, Kashayam, Lepanam etc. Through the different processes, about 1 tone waste was being generated per day which are not properly processed off, creating severe environmental as well as disposal problems.

3.1.1. Physico-chemical properties

A preparatory study was conducted to confirm the basic physico-chemical properties of the waste material. For this composite samples of the ayurvedic waste from various outlet points were drawn three times every month at 10 days interval for a period of six months from July 2002 - December 2002. These samples were subjected to the analysis of different physico – chemical properties as detailed in Table 3.1.

Table 3.1. Physico – chemical properties of the ayurvedic waste

Property	Method	Reference
Colour, odour	Physical appearance	Jackson, 1958
Consistency	Using sieves of size 0.5mm, 1mm, 2mm and 4.75mm	
pH	1:2.5 suspension	Jackson, 1958
Temperature		
Microbial count	Dehydrogenase activity	Domsch *etal.*, 1979
Moisture content	Gravimetric	Jackson, 1973
N	Microkjeldahl digestion and distillation	Jackson, 1958
P	Diacid extract - Spectrophotometry	,,
K	Diacid extract - Flame photometry	,,
C: N ratio	Gravimetric	Jackson, 1973

3.2. Preparation of substrate

3.2.1. Substrate controlled microenvironment

The collected ayurvedic wastes were divided into three major types of substrates, viz.

1) Unsieved composite samples as obtained from factory (O_1)
2) Composite samples sieved through 4 mm sieve (O_2)
3) Composite samples sieved through 2 mm sieve (O_3)

(Plate 1, 2 and 3)

3.2.2. Substrate enrichment

The different substrates were enriched using organic enrichers like cow dung (C), poultry manure (P), neem cake (N) of inorganic materials like urea (U), rock phosphate (RP) in different proportions as per the treatment combinations for improving the appearance, acceptability and manurial value. Urea and RP were basically used as common inorganic enricher of nitrogen and phosphorus. The other materials like cow dung, poultry manure and neemcake were used as organic nitrogen enricher. The components and ratio of enriching materials are given in Table 3.2.

Table 3.2. Components and ratio of enriching materials in ayurvedic waste substrates

Treatment No.	Components	Level of additives
1	$O_1 + C_1$	C 5%
2	$O_1 + C_2$	C 10%
3	$O_1 + C_3$	C 15%
4	$O_1 + P_1$	P 5%
5	$O_1 + P_2$	P 10%
6	$O_1 + P_3$	P 15%
7	$O_1 + N_1$	N 5%
8	$O_1 + N_2$	N 10%
9	$O_1 + N_3$	N 15%
10	$O_1 + C_1 + P_1 + N_1$	C 5%, P 5%, N 5%
11	$O_1 + C_2 + P_2 + N_2$	C 10%, P 10%, N 10%
12	$O_1 + C_3 + P_3 + N_3$	C 15%, P 15%, N 15%
13	$O_2 + C_1$	C 5%
14	$O_2 + C_2$	C 10%
15	$O_2 + C_3$	C 15%

16	$O_2 + P_1$	P 5%
17	$O_2 + P_2$	P 10%
18	$O_2 + P_3$	P 15%
19	$O_2 + N_1$	N 5%
20	$O_2 + N_2$	N 10%
21	$O_2 + N_3$	N 15%
22	$O_2 + C_1 + P_1 + N_1$	C 5% + P 5% + N 5%
23	$O_2 + C_2 + P_2 + N_2$	C 10% + P 10% + N 10%
24	$O_2 + C_3 + P_3 + N_3$	C 15% + P 15% + N 15%
25	$O_3 + C_1$	C 5%
26	$O_3 + C_2$	C 10%
27	$O_3 + C_3$	C 15%
28	$O_3 + P_1$	P 5%
29	$O_3 + P_2$	P 10%
30	$O_3 + P_3$	P 15%
31	$O_3 + N_1$	N 5%
32	$O_3 + N_2$	N 10%
33	$O_3 + N_3$	N 15%
34	$O_3 + C_1 + P_1 + N_1$	C 5% + P 5% + N 5%
35	$O_3 + C_2 + P_2 + N_2$	C 10% + P 10% + N 10%
36	$O_3 + C_3 + P_3 + N_3$	C 15% + P 15% + N 15%
37	$O_1 + U_1$	U 2.5%
38	$O_1 + U_2$	U 5%
39	$O_1 + RP_1$	RP 2.5%
40	$O_1 + RP_2$	RP 5%
41	$O_1 + U_1 + RP_1$	U 2.5% + RP 2.5%
42	$O_1 + U_2 + RP_2$	U 5% + RP 5%
43	$O_2 + U_1$	U 2.5%
44	$O_2 + U_2$	U 5%
45	$O_2 + RP_1$	RP 2.5%

46	$O_2 + RP_2$	RP 5%
47	$O_2 + U_1 + RP_1$	U 2.5% + RP 2.5%
48	$O_2 + U_2 + RP_2$	U 5% + RP 5%
49	$O_3 + U_1$	U 2.5%
50	$O_3 + U_2$	U 5%
51	$O_3 + RP_1$	RP 2.5%
52	$O_3 + RP_2$	RP 5%
53	$O_3 + U_1 + RP_1$	U 2.5% + RP 2.5%
54	$O_3 + U_2 + RP_2$	U 5% + RP 5%

Note: O_1 - Oushadhi waste unsieved
O_2 - 4 mm sieved
O_3 - 2 mm sieved

C - cow dung
P - poultry manure
N - neemcake
U - urea
RP - rock phosphate

3.2.3. Chemical composition and source of enrichers

The required cow dung for the enrichment studies was procured from the University Livestock Farm, Mannuthy, where the animals were fed with feeds of uniform composition. The enrichment material the poultry manure, was collected from the University Poultry Unit located at Mannuthy. Neemcake, urea and rock phosphate were taken from a recognized fertilizer shop in Thrissur.The nutrient content of the enrichers were presented below (Table 3.3.).

Table 3.3. Chemical composition of enriching materials

Nutrient sources	Nutrient content (%)		
	N	P	K
Cow dung	0.8	0.5	0.6
Poultry manure	1.2	1.4	0.8
Neem cake	4.3	0.7	0.9
Urea	46.0	_	_
Rock phosphate	_	18 - 20	_

3.2.4. Method of composting

The Oushadhi ayurvedic waste materials collected from the factory served as substrate materials. Both unsieved and sieved substrates were used as described in section 3.2.1. The size of sieved materials were 2 mm and 4 mm. The different treatments for compost preparation were tried in pots of size 30 x 32 cm^2 in CRD, with 3 replications. The substrates as well as different enrichers were mixed thoroughly as per the treatments before filling the pots. Pots were filled with five kg of wastes along with organic and inorganic enrichers in prescribed proportions. Before filling the pots, the bottom, portion of the pot was covered with sack pieces. Moisture content of the pots was maintained at 60-70 per cent throughout the active phase of decomposition. After filling, pots were covered with moist gunnysack pieces. The required moisture and aeration was provided by sprinkling water and mixing thoroughly whenever necessary. The contents of the pot were protected from direct sunlight by keeping them in a shady area, and pots were maintained properly till decomposition was completed to get quality compost (Plate 5).

3.3. Observations

Daily measurement of temperature was taken during the entire composting phase. Other parameters like pH, microbial count and C: N ratios of the materials were measured periodically at fortnightly intervals to judge the progress towards maturity of the composting process. Microbial population changes were studied at mesophilic, thermophilic and maturity stages of compost by analyzing the dehydrogenase enzyme activity at different stages. Qualitative observations on colour, odour, consistency and appearance of the compost were made at fortnightly intervals to judge the effectiveness of each treatment in converting the waste materials into good quality compost. The period required for the completion of composting process was also recorded.

Microbial count of compost formulations at 10 days interval was indirectly assessed by determining the dehydrogenase enzyme activity (Domsch *etal.*,1979).For the determination of dehydrogenase activity, the samples were mixed with phosphate buffer containing 1 per cent Triphenyl Tetrazolium Chloride (TTC) and incubated for 15 hours at room temperature. Then it was mixed with 90 per cent Carbon tetrachloride and centrifuged at 3000rpm for 10 minutes. The concentration of Tri Phenyl Formazon (TPF) produced by the reduction of TTC was estimated by measuring the intensity of the reddish colour at 530 nm in a spectrophotometer. With reference to the calibration graph prepared from TPF standards, the activity of dehydrogenase was expressed as μg of TPF formed g^{-1} soil h^{-1}.

3.3.1. Physico-chemical properties of formulations

The composts produced from various treatments were studied in detail for determining their physico-chemical properties. The methodologies followed were listed in Tables 3.1 and 3.2.

3.3.2. Nutrient content of matured compost

The contents of major nutrients of matured compost viz. N, P, K and carbon were estimated for all the treatments during the initial and final stages of composting. The methodologies followed were listed in Table 3.2.

3.4. Soil crop response studies with selected enriched compost

From the CRD experiment the most effective treatment possessing desirable physico-chemical properties was selected. It was then prepared in large scale by open heap method. The treatment selected was a combination of the unsieved waste materials enriched with cow dung, poultry manure and neem cake @ 10 per cent each (O_1 + 10% C + 10% P + 10% N).

Ayurvedic waste of about 184 kg was mixed with organic enrichners C, P and N @ 10 per cent of the substrate i.e., 18.4 kg each. These were mixed properly and was heaped into large open heaps of about 50 cm diameter and 75 cm height. It was then covered with moist gunny sacks. The heaps were periodically mixed with regular sprinkling of water to maintain the optimum moisture and aeration. All these operations were done in a clean shady area. Observations on physico chemical properties were taken at an interval of 10 days. Amaranthus (*Amaranthus tricolor. L*) crop was used as test crop for field verification of efficiency of selected compost.

3.4.1. Site, soil and climate

The field experiment was laid out near the vegetable seed farm of the Department of Olericulture, College of Horticulture, Vellanikkara during March 2003 to May 2003. The soil used for the study was of laterite type belonging to Vellanikkara series. During the period of study, the temperature varied from a maximum of 39°C to a minimum of 29°C.

Variety

The high yielding red coloured variety, Arun, which can be grown throughout the year, was selected for the field study.

Field study

The main field was laid out near the vegetable seed farm of Department of Olericulture. The land was thoroughly ploughed using tractor, followed by leveling. Then plots of size 3 x 2 m^2 were laid out at the experimental site. Shallow trenches of width 40 cm were taken 30-40 cm apart. Incorporation of the compost and inorganic fertilizers as per the treatments were done in the trenches, followed by transplanting 20 days old seedlings, with a spacing of 30 cm. The design of field experiment is RBD with 3 replications. Gross area of the site was 216 m^2. The lay out of field is shown in Fig. 1. The over all view of the experimental plot is shown in Plate 6.

Treatments

Field experiment was conducted with 12 treatments as given below.

Treatments	Treatment expansion
T_1	Absolute control
T_2	5 t ha^{-1} Farm Yard Manure (FYM)
T_3	5 t ha^{-1} FYM + 50:50:50 kg NPK ha^{-1}
T_4	5 t ha^{-1} selected enriched compost (SEC)
T_5	5 t ha^{-1} SEC + 50:50:50 kg NPK ha^{-1}
T_6	5 t ha^{-1} SEC+ 25:25:25 kg NPK ha^{-1}
T_7	2.5 t ha^{-1} SEC
T_8	2.5 t ha^{-1} SEC+ 50:50:50 kg NPK ha^{-1}
T_9	2.5 t ha^{-1} SEC+ 25:25:25 kg NPK ha^{-1}
T_{10}	1 t ha^{-1} SEC
T_{11}	1 t ha^{-1} SEC+ 50:50:50 kg NPK ha^{-1}

T_{12} 1 t ha^{-1} SEC +25:25:25 kg NPK ha^{-1}

Design: RBD **Replication**: 3

Nutrient sources and agronomic practices

In the experiment, N, P and K were supplied as urea (46% N), Rock phosphate (28.4% P) and Muriate of Potash (60% K) respectively. The entire quantity of selected compost as per the treatments were given as basal. The full dose of P was also given as basal. N and K fertilizers were given in 2 split doses one as basal and the other 20 days after transplanting. Weeding was done once in every 10 days and irrigation was done once in 2 days.

Observations

Biometric observations were noted at two stages of growth ie 15 days after planting and 30 days after planting. List of observations taken were detailed in Table 3.4.

Table 3.4. Biometric observations and yield parameters of Amaranthus

Biometric observations	Yield parameters
Height of plants (cm)	Fresh weight $plant^{-1}$
	Dry weight $plant^{-1}$
No. of leaves $plant^{-1}$	Yield per treatment for the first and second harvest

Chemical analysis

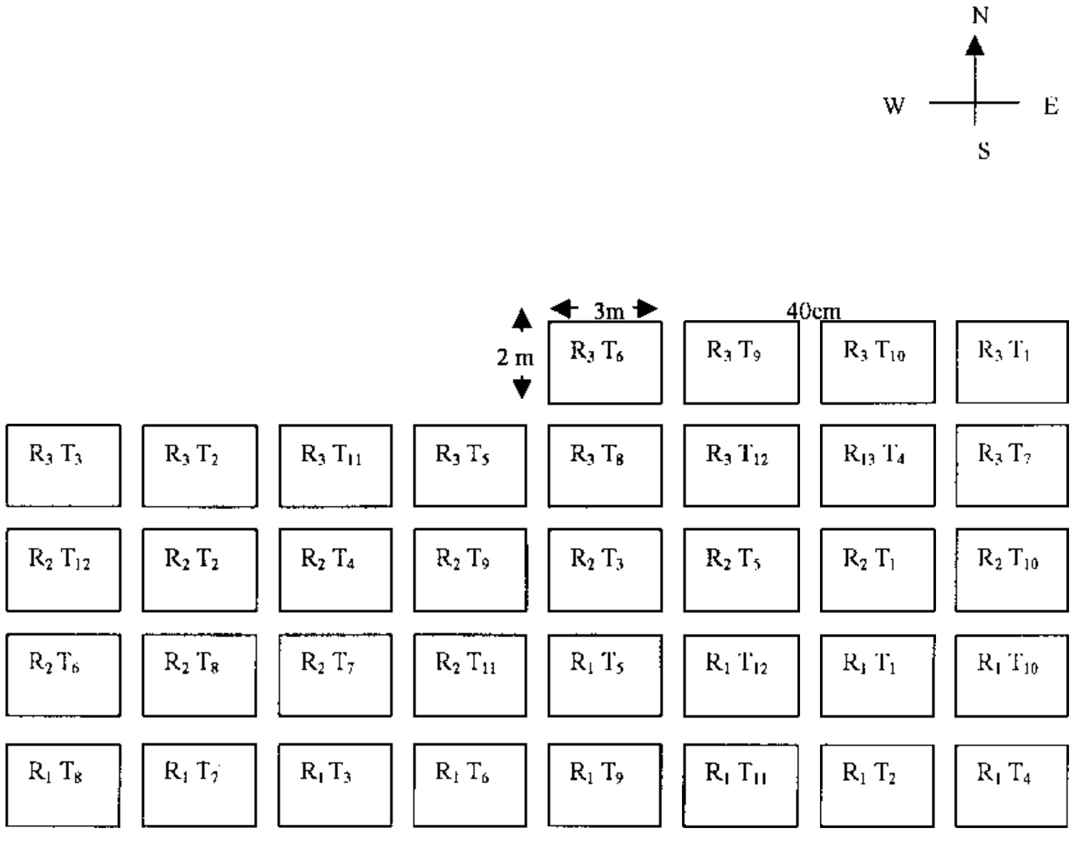
Plant and soil samples were analyzed for nutrient contents following standard procedures (Table 3.5.).

Table 3.5.Methods for analysis

Characters	Method	Reference
SOIL ANALYSIS		
pH	1:2.5 soil water suspension	Jackson, 1958
Organic carbon	Walkley and Black titration	Walkley and Black, 1934
Available N	Alkaline permanganate distillation	Subbiah and Asija, 1956
Available P	Bray-1 extractant ascorbic reductant - spectrophotometry	Bray and Kurtz, 1945
Available K	Neutral Normal ammonium acetate - Flame photometry	Jackson, 1958
PLANT ANALYSIS		
N	Microkjeldahl digestion and distillation	Jackson, 1958
P	Vanadomolybdo phosphoric yellow colour spectrophotometry	Jackson, 1958
K	Flame photometry	Jackson, 1958

Statistical analysis

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



R_1 – Replication 1 R_2– Replication 2 R_3 – Replication 3

Fig. 1. Layout of the field

Results

4. RESULTS

Studies on the aerobic composting and enrichment of Ayurvedic waste was carried out as described under chapter 3 and the results of various experiments are presented in this chapter.

4.1 Basic properties of Oushadhi Ayurvedic Waste

Being a new material, the physico chemical properties of Ayurvedic waste was studied in detail using the composite samples drawn for the purpose. The details were provided in Tables 4.1. and 4.2.

4.1.1 Physico-chemical properties of the waste

The Ayurvedic waste is light to deep brown in colour with a pleasant pungent smell due to the presence of alkaloids and lipids. It is mixture of various sized materials and is fibrous in nature and was oily too. The consistency of material remained solid and is non plastic.

The details regarding the physical properties of material is given in Table 4.1. While considering the consistency, particles with size ranging from 2- 4.75 mm was dominating with a value of around 35.62 per cent. It was then followed by particles with size more than 4.75mm constituting about 26.94 per cent. About 22.46 per cent of the particles have a size between1mm-2mm and 10.47 per cent of particles were having a size of 0.5mm-1mm. About 4.5 per cent of the particles were below 0.5mm. The data is depicted in fig.2.The mean moisture content of the samples drawn for the six months period ranged from 52.02 to 57.07 per cent with an average value of around 53.56 per cent. There was no significant difference in moisture content within the different dates of sampling.

Table 4.1. Consistency of Ayurvedic waste

Particle size	July	August	September	October	November	December	Mean
> 4.75 mm (%)	27.04	27.12	26.59	27.54	27.92	25.44	26.94
2 - 4.75 mm (%)	34.68	35.25	35.97	35.82	36.01	35.99	35.62
1 mm - 2 mm (%)	22.56	22.49	22.38	21.64	22.99	22.72	22.46
0.5 mm - 1 mm (%)	10.60	10.10	11.01	10.99	9.50	10.60	10.47
< 0.5 mm (%)	5.15	5.04	4.05	4.01	3.58	5.25	4.51
Moisture content (%)	52.02	57.07	53.06	51.9	54.52	52.79	53.56

The other parameters of samples from the Oushadhi waste materials collected for a period of 6 months were studied month wise. The observations are tabulated in Table 4.2.

Various parameters like temperature, pH, microbial count, C: N ratio and also the major nutrient content of ayurvedic waste were studied. By looking into the table we can see that there was not much significant difference for each property during the study period. The temperature has a mean value of 108.98 with a maximum temperature of 110.60 which was recorded at July. The pH of the study material was around 6.17 and thus it seems to be a near neutral substrate. The dehydrogenase activity and C: N ratio were 556.22 μg g^{-1} soil $h^{-1}$and 35.72 respectively.

The nutrient content of the waste material given in table 4.2. should that material has comparatively higher content of Nitrogen than Phosphorous and potassium. The Nitrogen content was around 1.99 per cent followed by Potassium with 0.27 per cent and Phosphorous with 0.02 per cent. The nutrient content also does not exhibit significant difference within different dates of sampling.

4.2 Standardisation of formulation techniques of Ayurvedic waste

Different enrichment techniques were employed to prepare enriched compost from the Oushadhi waste as described under section 3.2. The three types of substrates were enriched with organic and inorganic materials and parameters like Temperature, pH, Microbial count and C: N ratio were recorded at an interval of 10 days. The content of the nutrients were analysed during the initial and final stages only.

Table 4.2. Physico-chemical and biological properties of Ayurvedic waste

Properties	July	August	September	October	November	December	Mean
Temperature (°C)	110.6	108.3	105.9	110.1	108.6	110.4	108.98
pH	6.2	6.0	5.9	6.4	6.0	6.5	6.17
Dehydrogenase activity (µg g^{-1} soil h^{-1})	560.7	555.7	551.4	553.2	556.9	559.4	556.22
C:N ratio	35.2	36.1	35.6	35.9	36.1	35.4	35.72
Nitrogen (%)	2.07	1.92	2.05	2.00	1.96	1.98	1.99
Phosphorus (%)	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Potassium (%)	0.22	0.29	0.31	0.26	0.25	0.28	0.27

4.2.1 Physico-chemical properties

The physico-chemical properties of the various substrates, unsieved waste material, 4 mm sieved waste material and 2 mm sieved waste material were given in Table 4.3. From the table it was seen that the Oushadhi waste was neutral in reaction. The moisture content was around 50 per cent with the unsieved samples registering the highest value of 52 per cent. Consistency of the three substrates also varies in proposition. Incase of unsieved substrate (O_1) particles of size ranging between 2 mm- 4.75 mm is dominating with a value of 34.88 per cent and in 4 mm sieved and 2 mm sieved substrates the dominating forms are having a particle size of <0.5 mm with values of 32 and 38.2 respectively.

The physical properties of various treatment combinations were observed. The variation in physical properties was almost same irrespective of treatments. The time period taken for this variation is also same in all treatments. The colour of the initial substrate was deep brown which begin to change after first fortnight onwards. Towards maturity phase the colour become black. The intensity of ayurvedic smell of the substrate began to reduce from third day onwards and finally at the final stage of composting the material left behind was odourless. The particle size of various treatment combination during the initial stage was same as that of the type of substrate used (Table 4.3.).Towards maturity stage the dominating particle size was 0.5-1.0mm in most of treatment combinations. The end product obtained in all treatments was crumby, fine textured finished products with black colour.But it was seen that the time taken for attaining this favourable consistency and there by maturity was less in case of organic enrichers than inorganic enrichers.

Table 4.3. Physical properties of the various substrates

Properties	Values		
	Unsieved (O_1)	4mm sieved (O_2)	2mm sieved (O_3)
Particle size (mm)			
> 4.75 mm (%)	27.04	_	_
2 mm – 4.75 mm (%)	34.68	15.7	_
1 mm – 2 mm (%)	22.56	24.3	29.0
0.5 mm – 1 mm (%)	10.60	28.0	33.0
< 0.5 mm (%)	5.15	32.0	38.2
Moisture content (%)	52.0	50.3	49.7
Colour	Light to deep brown	Light to deep brown	Light to deep brown
Odour	Pleasant aromatic	Pleasant aromatic	Pleasant aromatic
pH	6.72	6.68	6.62

Plate 1 Unsieved Oushadhi waste

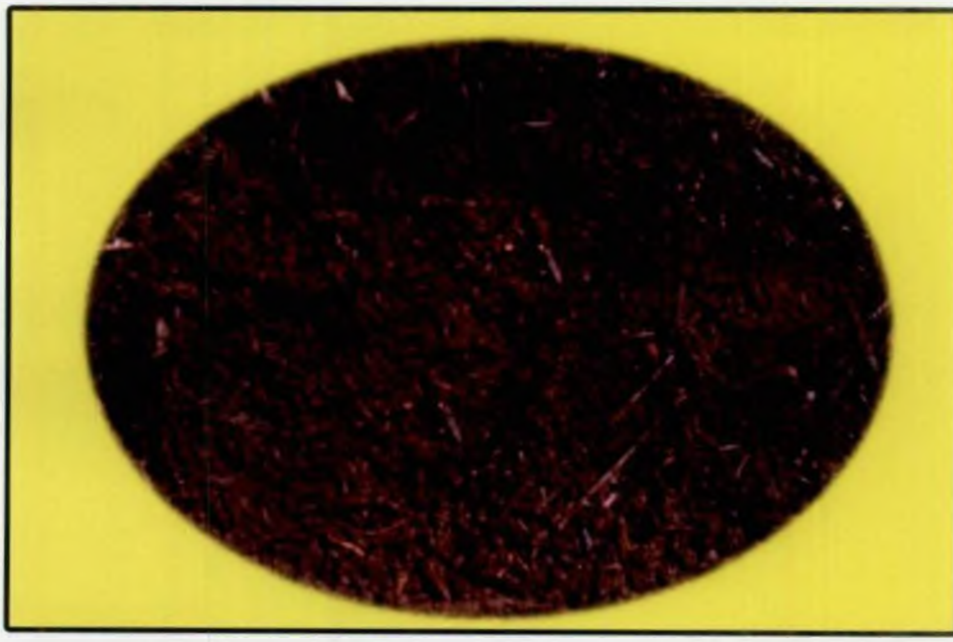
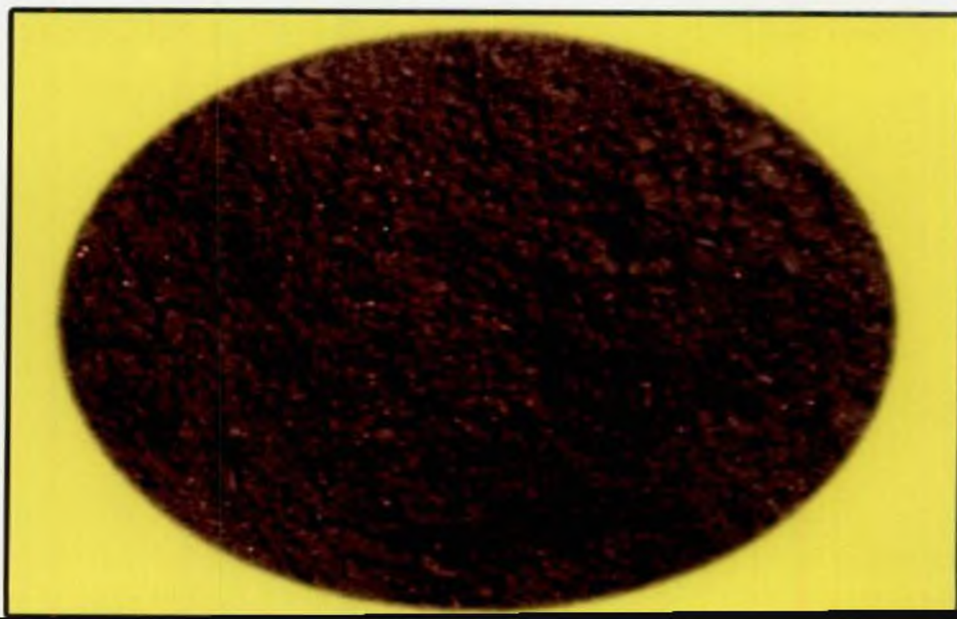


Plate 2 4mm sieved Oushadhi waste



4.2.1.1. Temperature

The variations in temperature due to different levels and types of enrichment during composting were noted. The data on temperature variations due to the influence of organic enrichers were pooled at an interval of 10 days for a period of 60 days and is given in Table 4.4. The temperature variation in the substrates (Oushadhi waste material) showed a steady increase in the initial period of 10 days and there afterwards decreased. The 2mm sieved substrate (O_3) recorded a maximum temperature of 39.59°C and then subsequently decreased to 26.99°C towards the end of composting. The same pattern was observed in 4mm sieved substrate (O_2) and unsieved substrate (O_1) with maximum values of 36.53°C and 35.14°C respectively. It was then decreased to 26.33°C and 26.27°C respectively for the same treatments. All the substrate recorded the maximum temperature at the tenth day after composting. Irrespective of nature of substrates, the organic enrichment combination $C_3P_3N_3$ had a maximum temperature throughout the intervals of study. In general a slow decrease in temperature from 41.86°C to 27.24°C could be noticed (Table 4.4.). The temperature variation for the three substrates with organic enrichment was given in fig.3.

The temperature variation in substrate- organic enricher interactions also followed the same trends of observation. It was evident from the Table 4.5. Here the maximum temperature of 43.07°C was attained by the treatment $O_3C_3P_3N_3$ at the tenth day. It then decreased to 28°C towards the end of composting. The temperature decreased and get stabilized around 26.6°C in most of the treatments.

In the case of the inorganic treatments also, the temperature follows the same trend as in case of organics which is evident from Table 4.6. but the peak value is slightly lower than that of organics. The substrates also showed the same trend in temperature variation as that of organic enrichers. Here also the 2 mm

Table 4.4. Influence of substrate and organic enrichers on temperature (°C) during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	30.14^{b}	35.14^{c}	30.35^{c}	28.31^{c}	27.08^{c}	26.38^{c}	26.27^{c}
O_2	30.21^{ab}	36.50^{b}	31.34^{b}	28.91^{b}	27.27^{b}	26.43^{b}	26.33^{b}
O_3	30.25^{a}	39.59^{a}	33.65^{a}	29.80^{a}	28.02^{a}	27.01^{a}	26.99^{a}
Organic enrichers							
C_1	29.76^{i}	32.76^{k}	28.00^{j}	26.87^{g}	26.28^{g}	25.93^{h}	25.93^{f}
C_2	29.83^{h}	33.38^{j}	28.69^{i}	27.34^{f}	26.77^{f}	26.18^{gh}	26.23^{e}
C_3	29.92^{ef}	35.67^{h}	30.68^{g}	28.88^{d}	27.43^{bcd}	26.44^{efg}	26.43^{de}
P_1	29.93^{e}	36.61^{f}	31.70^{f}	28.97^{d}	27.33^{cde}	26.62^{def}	26.53^{cd}
P_2	30.00^{d}	37.70^{e}	32.97^{b}	28.93^{c}	27.66^{b}	26.80^{cd}	26.67^{c}
P_3	30.01^{cd}	38.24^{c}	33.73^{c}	30.30^{b}	28.17^{a}	26.90^{bc}	26.90^{b}
N_1	29.90^{b}	35.23^{i}	29.87^{h}	28.37^{e}	27.10^{b}	26.37^{fg}	26.24^{e}
N_2	29.92^{e}	36.16^{g}	30.00^{g}	28.50^{e}	27.20^{d}	26.40^{ef}	26.33^{de}
N_3	29.99^{a}	37.82^{e}	32.40^{e}	28.47^{e}	27.53^{bc}	26.40^{efg}	26.37^{de}
$C_1P_1N_1$	30.11^{b}	38.82^{d}	32.90^{f}	29.03^{d}	27.29^{cde}	26.60^{cde}	26.52^{cd}
$C_2P_2N_2$	30.12^{a}	40.27^{b}	34.13^{b}	30.30^{b}	28.40^{a}	27.07^{b}	26.96^{b}
$C_3P_3N_3$	30.12^{a}	41.86^{a}	35.41^{a}	31.11^{a}	28.37^{a}	27.42^{a}	27.24^{a}

Table 4.5. Effect of substrate organic enricher interactions on temperature (°C) during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1C_1	29.2	28.5	27.6	26.3	25.9	25.4	25.4
O_1C_2	29.1	29.1	28.2	27.4	26.5	26.1	26.1
O_1C_3	29.6	32.1	30.9	28.9	27.6	26.4	26.2
O_1P_1	29.5	33.1	31.0	28.8	27.5	26.5	26.5
O_1P_2	29.4	33.5	31.2	28.9	27.6	26.5	26.5
O_1P_3	30.1	34.1	32.9	29.6	27.3	26.7	26.6
O_1N_1	28.8	29.9	27.5	27.3	26.9	26.3	26.0
O_1N_2	29.0	30.2	28.1	27.2	26.9	26.3	26.1
O_1N_3	29.1	31.3	29.4	27.1	26.9	26.5	26.5
$O_1C_1P_1N_1$	29.3	32.5	30.3	28.6	27.2	26.4	26.2
$O_1C_2P_2N_2$	29.8	34.7	32.8	29.4	27.6	26.5	26.5
$O_1C_3P_3N_3$	30.2	36.6	34.3	30.2	27.1	26.9	26.7
O_2C_1	29.4	30.1	28.3	27.1	26.0	25.9	25.9
O_2C_2	29.6	30.8	28.5	27.6	26.9	25.8	26.0
O_2C_3	29.7	32.8	30.1	28.9	27.2	26.4	26.2
O_2P_1	29.8	33.7	31.2	28.5	27.2	26.7	26.2
O_2P_2	29.6	34.1	32.9	29.6	27.3	26.7	26.5
O_2P_3	31.1	34.6	32.8	29.6	27.3	26.5	26.6
O_2N_1	30.5	32.9	30.6	28.9	27.1	26.1	26.0
O_2N_2	30.6	33.6	31.2	28.7	27.4	26.2	26.0
O_2N_3	29.1	33.7	31.3	28.6	27.9	26.2	26.1
$O_2C_1P_1N_1$	29.7	33.9	31.5	28.9	27.3	26.6	26.5
$O_2C_2P_2N_2$	29.4	35.2	33.1	29.4	27.6	27.1	26.9
$O_2C_3P_3N_3$	29.8	36.9	34.5	31.2	28.1	27.2	27.0
O_3C_1	30.8	30.6	28.1	27.2	26.9	26.5	26.5
O_3C_2	31.5	31.2	29.4	27.1	26.9	26.6	26.6
O_3C_3	31.6	33.1	31.0	28.8	27.5	26.5	26.9
O_3P_1	32.3	34.1	32.9	29.6	27.3	26.9	26.9
O_3P_2	32.4	36.5	34.8	31.3	28.1	27.2	27.0
O_3P_3	32.5	40.0	35.5	31.7	29.9	27.5	27.5
O_3N_1	31.5	33.9	31.5	28.9	27.3	26.7	26.7
O_3N_2	31.4	35.7	33.4	29.6	27.3	26.9	26.9
O_3N_3	31.2	39.5	36.5	29.7	27.8	26.5	26.5
$O_3C_1P_1N_1$	31.6	39.6	36.9	29.5	27.4	27.0	26.9
$O_3C_2P_2N_2$	32.3	41.9	36.5	32.1	30.0	27.6	27.5
$O_3C_3P_3N_3$	32.4	43.1	37.4	32.0	29.9	28.2	28.0
CD	NS	0.33	0.48	0.33	0.49	0.43	0.35

Table 4.6. Influence of substrate and inorganic enrichers on temperature (°C) during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	29.40[b]	30.18[b]	28.22[b]	27.09[b]	26.71[ab]	26.27[b]	26.25[b]
O_2	29.50[ab]	30.62[a]	28.96[ab]	27.62[a]	26.87[ab]	26.37[b]	26.35[b]
O_3	29.60[a]	31.75[a]	29.71[a]	27.52[a]	26.99[a]	26.69[a]	26.68[a]
Inorganic enrichers							
U_1	29.70[c]	30.56[d]	28.32[d]	27.00[d]	26.50[c]	26.07[c]	26.07[d]
U_2	29.50[d]	32.33[c]	28.63[c]	27.20[c]	26.62[c]	26.33[c]	26.33[c]
RP_1	29.62[d]	32.73[c]	28.68[c]	27.37[b]	26.90[b]	26.30[c]	26.27[c]
RP_2	30.00[a]	34.13[b]	29.03[b]	27.37[b]	26.93[b]	26.64[a]	26.63[b]
U_1RP_1	29.92[b]	34.90[a]	28.67[c]	27.26[c]	26.83[b]	26.50[b]	26.50[b]
U_2RP_2	29.93[b]	35.30[a]	30.43[a]	28.27[a]	27.33[a]	26.80[a]	26.77[a]

Table 4.7. Effect of substrate- inorganic enrichers interaction on temperature (°C) during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1U_1	30.1	28.8	27.4	26.5	26.1	25.6	25.6
O_1U_2	30.2	29.1	28.2	27.4	26.53	26.1	26.1
O_1RP_1	30.2	30.2	28.1	27.2	26.9	26.3	26.2
O_1RP_2	30.4	30.7	28.1	27.2	26.9	26.5	26.5
$O_1U_1RP_1$	30.4	30.5	28.1	27.2	26.9	26.5	26.5
$O_1U_2RP_2$	30.4	31.8	29.4	27.1	26.9	26.6	26.6
O_2U_1	30.2	29.1	28.2	27.4	26.5	26.1	26.1
O_2U_2	30.1	30.0	28.3	27.1	26.4	26.1	26.1
O_2RP_1	30.1	30.7	28.5	27.6	26.9	26.2	26.2
O_2RP_2	30.1	31.0	29.4	27.1	26.9	26.5	26.5
$O_2U_1RP_1$	29.8	30.8	28.5	27.6	26.9	26.5	26.5
$O_2U_2RP_2$	29.6	32.1	30.9	28.9	27.6	26.8	26.7
O_3U_1	31.1	31.2	29.4	27.1	26.9	26.5	26.5
O_3U_2	30.9	31.9	29.4	27.1	26.9	26.8	26.8
O_3RP_1	30.9	31.3	29.4	27.3	26.9	26.4	26.4
O_3RP_2	31.2	31.7	29.6	27.8	27.0	26.9	26.9
$O_3U_1RP_1$	30.6	31.4	29.4	27.0	26.7	26.5	26.5
$O_3U_2RP_2$	31.2	33.0	31.0	28.8	27.5	27.0	27.0
CD	NS	0.47	0.38	0.53	0.22	0.25	0.33

sieved substrate (O_3) ranked first with a maximum temperature of 31.75°C which decreased to26.68°C at maturity (fig.4.). At all the intervals the maximum temperature was recorded in 2mm sieved substrate (O_3) followed by 4mm sieved substrate (O_2) and unsieved substrate (O_1). Within the inorganic treatments, the combination U_2RP_2 had a maximum temperature throughout the intervals of study which showed a decrease in temperature from 35.30°C to 26.77°C.

The temperature variation of substrate- inorganic enrichers interactions was shown in Table 4.7. It was seen that the maximum temperature was recorded by the combination of $O_3U_2RP_2$ with a value of 33°C which decreased to 27°C. This treatment combination registered the highest temperature at all the intervals of composting. Significant differences were noted among the treatments through out the intervals of study except the 0^{th} day.

4.2.1.2. pH

The pH of the compost heaps observed for two months periods at 10 days interval for organic enrichers is shown in Table 4.8. All the enrichers recorded a pH of 6.42 at the initial stage of composting. The pH shows a gradual increase from 0^{th} day up to 30^{th} day. Then it began to decline and became stabilised around 6.32 at maturity. Considering the variation in pH for the three types of substrates a high pH was recorded by O_3 which is 8.00on the 30^{th} day. Then the pH came around 6.25 at maturity, while O_1 and O_2 were showing par values of 6.36 at maturity. Among the treatments with organic additives the treatment N_2 ,P_3 and P_1 showed a maximum pH of 8.00 on the 30^{th} day while C_3 attained the same value on 20^{th} day itself. Latter on the pH stabilize around 6.31, 6.34, 6.32 and 6.34 for the respective treatments.

The data on the effect of substrate- organic enricher interaction on pH was given in Table 4.9. From the table it was seen that the pH of the treatment

Table 4.8. Influence of substrate and organic enrichers on pH during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	6.43^{b}	6.84^{b}	7.88^{b}	7.96^{b}	7.14^{a}	7.14^{a}	6.37^{a}
O_2	6.45^{ab}	6.86^{ab}	7.96^{a}	7.97^{b}	7.09^{b}	7.09^{b}	6.36^{a}
O_3	6.48^{a}	6.88^{a}	7.95^{a}	8.00^{a}	7.06^{b}	7.06^{b}	6.25^{b}
Organic enrichers							
C_1	6.41^{e}	6.81^{efg}	7.93^{abcd}	7.93^{ab}	7.08^{cd}	7.08^{cd}	6.32^{bc}
C_2	6.41^{c}	6.88^{bcde}	7.93^{bcd}	7.99^{a}	7.09^{cd}	7.09^{cd}	6.35^{bc}
C_3	6.42^{d}	6.83^{def}	8.00^{a}	7.98^{ab}	7.10^{bcd}	7.10^{bcd}	6.34^{bc}
P_1	6.43^{c}	6.93^{ab}	7.92^{bcd}	8.00^{a}	7.05^{d}	7.05^{d}	6.32^{bc}
P_2	6.41^{c}	6.91^{abc}	7.99^{ab}	7.97^{ab}	7.12^{abc}	7.12^{abc}	6.25^{d}
P_3	6.40^{f}	6.80^{fg}	7.97^{abc}	8.00^{a}	7.17^{a}	7.17^{a}	6.34^{bc}
N_1	6.42^{d}	6.85^{cdef}	7.83^{e}	7.99^{ab}	7.10^{bcd}	7.10^{bcd}	6.37^{b}
N_2	6.43^{c}	6.85^{cdef}	7.92^{bcd}	8.00^{a}	7.16^{ab}	7.16^{a}	6.31^{c}
N_3	6.44^{b}	6.85^{cdef}	7.90^{cde}	7.91^{b}	7.06^{cd}	7.06^{cd}	6.31^{c}
$C_1P_1N_1$	6.43^{c}	6.95^{a}	7.99^{ab}	7.96^{ab}	7.04^{d}	7.04^{d}	6.42^{a}
$C_2P_2N_2$	6.45^{a}	6.89^{abcd}	7.88^{de}	7.99^{a}	7.08^{cd}	7.08^{cd}	6.34^{bc}
$C_3P_3N_3$	6.45^{a}	6.75^{g}	7.90^{cde}	7.96^{ab}	7.09^{cd}	7.09^{cd}	6.24^{d}

Table 4.9. Effect of substrate- organic enricher interaction on pH during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1C_1	6.00	6.87	7.89	7.81	7.14	7.14	6.37
O_1C_2	6.40	6.97	7.80	7.96	7.18	7.18	6.30
O_1C_3	6.40	6.87	7.97	7.98	7.17	7.17	6.42
O_1P_1	6.40	6.93	8.02	7.99	7.18	7.18	6.39
O_1P_2	6.10	6.97	8.01	8.03	7.22	7.22	6.29
O_1P_3	6.20	6.65	7.95	7.98	7.25	7.25	6.38
O_1N_1	6.30	6.81	7.87	8.01	7.05	7.05	6.44
O_1N_2	6.40	6.73	7.82	7.92	7.23	7.23	6.34
O_1N_3	6.60	6.90	7.93	8.01	7.10	7.09	6.37
$O_1C_1P_1N_1$	6.40	7.04	8.01	7.94	7.07	7.07	6.47
$O_1C_2P_2N_2$	6.30	6.77	7.52	7.88	7.07	7.07	6.37
$O_1C_3P_3N_3$	6.20	6.51	7.78	7.97	7.01	7.01	6.26
O_2C_1	6.10	6.60	7.87	7.92	7.02	7.01	6.26
O_2C_2	6.00	6.77	8.01	8.02	7.08	7.08	6.49
O_2C_3	6.70	6.79	8.01	7.94	7.11	7.11	6.37
O_2P_1	6.00	6.94	7.91	7.96	6.99	6.99	6.31
O_2P_2	6.70	6.91	7.99	7.95	7.08	7.08	6.32
O_2P_3	6.10	6.79	7.91	7.96	7.11	7.11	6.39
O_2N_1	6.20	6.92	7.80	8.02	7.17	7.17	6.42
O_2N_2	6.60	7.02	8.01	7.97	7.12	7.12	6.36
O_2N_3	6.80	6.81	7.89	7.90	7.08	7.08	6.34
$O_2C_1P_1N_1$	6.90	6.89	7.97	7.99	7.01	7.01	6.37
$O_2C_2P_2N_2$	6.70	6.94	8.02	8.02	7.06	7.06	6.36
$O_2C_3P_3N_3$	6.00	6.92	7.99	7.97	7.19	7.19	6.33
O_3C_1	6.10	6.97	8.08	8.06	7.07	7.07	6.33
O_3C_2	6.20	6.88	7.98	8.01	7.01	7.01	6.26
O_3C_3	6.20	6.82	8.03	8.04	7.02	7.02	6.23
O_3P_1	6.40	6.92	7.83	8.05	6.96	6.96	6.26
O_3P_2	6.30	6.83	7.97	7.94	7.07	7.07	6.16
O_3P_3	6.50	6.97	8.05	8.06	7.14	7.15	6.23
O_3N_1	6.40	6.82	7.61	7.93	7.07	7.07	6.24
O_3N_2	6.30	6.80	7.92	8.12	7.12	7.12	6.22
O_3N_3	6.10	6.83	7.86	7.83	6.99	6.99	6.22
$O_3C_1P_1N_1$	6.40	6.92	7.98	7.94	7.05	7.05	6.42
$O_3C_2P_2N_2$	6.50	6.96	8.11	8.09	7.11	7.11	6.31
$O_3C_3P_3N_3$	6.20	6.82	7.91	7.95	7.08	7.08	6.13
CD	NS	0.10	0.11	0.11	0.10	0.10	0.01

Table 4.10. Influence of substrate and inorganic enrichers on pH during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	6.45[c]	6.92[a]	8.00[a]	7.97[a]	7.09[a]	7.09[a]	6.17[b]
O_2	6.48[b]	6.85[b]	7.95[a]	7.98[a]	7.05[a]	6.66[a]	6.30[a]
O_3	6.49[a]	6.85[b]	7.94[a]	7.94[a]	7.09[a]	7.09[a]	6.28[a]
Inorganic enrichers							
U_1	6.42[c]	6.88[ab]	8.01[a]	7.98[a]	7.11[a]	7.11[a]	6.25[ab]
U_2	6.41[d]	6.89[ab]	7.95[a]	7.94[a]	7.08[a]	7.08[a]	6.11[b]
RP_1	6.45[b]	6.87[ab]	7.98[a]	7.99[a]	7.06[a]	7.06[a]	6.26[ab]
RP_2	6.49[a]	8.84[b]	7.92[a]	7.94[a]	7.05[a]	7.05[a]	6.33[a]
U_1RP_1	6.41[d]	6.86[ab]	7.92[a]	7.93[a]	7.08[a]	6.31[a]	6.29[a]
U_2RP_2	6.42[c]	6.90[a]	8.01[a]	7.99[a]	7.08[a]	7.08[a]	6.25[ab]

Table 4.11. Effect of substrate - inorganic enricher interaction on pH during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1U_1	6.60	6.97	8.04	7.98	7.13	7.13	6.25
O_1U_2	6.10	6.83	7.97	7.93	7.04	7.04	5.78
O_1RP_1	6.20	6.96	8.06	8.02	7.06	7.06	6.29
O_1RP_2	6.00	6.96	8.03	7.95	7.07	7.07	6.31
$O_1U_1RP_1$	6.10	6.91	7.91	7.90	7.16	7.16	6.22
$O_1U_2RP_2$	6.20	6.87	8.02	8.03	7.05	7.05	6.20
O_2U_1	6.90	6.75	8.02	8.02	7.06	7.06	6.13
O_2U_2	6.60	6.87	7.89	7.97	7.03	7.03	6.31
O_2RP_1	6.80	6.93	8.07	8.04	7.04	7.04	6.33
O_2RP_2	6.70	6.79	7.86	7.88	7.06	7.06	6.38
$O_2U_1RP_1$	6.30	6.79	7.90	8.01	7.06	7.73	6.36
$O_2U_2RP_2$	6.20	6.96	7.99	7.99	7.06	7.06	6.28
O_3U_1	6.50	6.93	7.97	7.95	7.16	7.16	6.39
O_3U_2	6.40	6.93	7.99	7.93	7.16	7.16	6.24
O_3RP_1	6.10	6.73	7.82	7.92	7.07	7.07	6.17
O_3RP_2	6.00	6.76	7.87	7.99	7.01	7.01	6.32
$O_3U_1RP_1$	6.10	6.87	7.97	7.87	7.02	7.02	6.28
$O_3U_2RP_2$	6.10	6.88	8.03	7.96	7.12	7.12	6.28
CD	NS	0.091	0.17	0.12	0.12	1.57	0.24

combinations also showed an increase up to 30 th day and there after it decreased. The pH then stabilized around 6.3 in most of the treatment combinations towards the end of composting. Among the treatment combination maximum pH of 8.12 was attained by O_3N_2 (2mm sieved substrate enriched with neem cake 10 per cent) which then decreased to 6.22 at maturity stage (60th day).

The effect of inorganic enrichers on pH during composting was shown in Table 4.10. The trend in pH fluctuation was the same as that of organics .The initial pH of 6.47 tend to show an increase upto 30th day and thereafter decreased and stabilized around 6.25 at final stage of composting. Among the inorganic enrichers the highest pH of 8 was noted in O_1 at 30th day which declined to 6.17 at 60th day. The O_2 and O_3 showed par values of 6.30 and 6.28 at maturity. Among inorganic additive maximum pH is attained by treatments U_2 and U_2RP_2 with values 8.01 on 20th day of composting. The pH lowered to 6.25 at maturity.

Regarding the effect of substrate- inorganic enrichers interaction on pH as shown in Table 4.11. it was found that the fluctuation in pH followed the same trend as in case of organic treatments. Here the maximum pH of 8.07 was recorded by the treatment combination O_2RP_1.This was attained at the 20th day of composting. Then it decreased and stabilized around 6.33.

4.2.1.3 C: N ratio

The variation in C: N ratio of compost formulation enriched with organic substrates were recorded at 10 days intervals and were given in Table 4.12. There was a gradual decrease in C: N ratio towards maturity phase (60th day). Initially all the treatment combinations had a C: N ratio of around 35.20irrespective of enrichment. The substrates differ significantly in the C: N ratio during different periods of composting. While looking into the table it was found that initially all the three substrates had a C: N ratio of 32.1, which were on par. Then it graduallydecreased to 11.00, 11.85 and 13.23 for O_3, O_2 and O_1 respectively.

Table 4.12. Influence of substrate and organic enrichers on C: N ratio during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	32.10^{a}	30.01^{a}	21.68^{a}	17.02^{a}	14.39^{a}	13.43^{a}	13.23^{a}
O_2	32.12^{a}	27.32^{b}	19.63^{b}	15.07^{b}	12.82^{b}	11.91^{b}	11.85^{b}
O_3	32.11^{a}	25.04^{c}	17.98^{c}	13.55^{c}	11.71^{c}	11.06^{c}	11.00^{c}
Organic enrichers							
C_1	35.21^{d}	35.01^{a}	24.90^{a}	18.57^{a}	14.70^{a}	13.30^{a}	13.13^{ab}
C_2	35.25^{b}	32.86^{b}	23.17^{b}	18.40^{a}	13.77^{b}	12.37^{c}	11.98^{cde}
C_3	35.20^{d}	30.91^{c}	20.47^{c}	16.92^{b}	13.23^{cd}	11.77^{d}	11.60^{def}
P_1	35.32^{b}	23.81^{i}	15.60^{g}	13.42^{f}	11.77^{ef}	11.30^{e}	11.23^{ef}
P_2	35.22^{c}	22.10^{j}	14.87^{h}	12.10^{g}	11.43^{f}	10.97^{f}	10.87^{f}
P_3	35.40^{a}	20.87^{k}	19.33^{d}	11.63^{h}	10.87^{g}	10.60^{g}	10.83^{f}
N_1	35.22^{c}	30.47^{d}	20.87^{c}	16.89^{b}	14.43^{a}	13.53^{a}	13.47^{a}
N_2	35.19^{c}	28.33^{e}	18.47^{f}	15.90^{c}	13.50^{bc}	12.90^{b}	12.73^{bc}
N_3	35.30^{b}	26.03^{g}	19.10^{de}	14.10^{c}	12.93^{d}	12.33^{c}	12.30^{cd}
$C_1P_1N_1$	35.25^{a}	28.24^{e}	19.07^{de}	15.77^{c}	13.80^{b}	12.77^{b}	12.59^{bc}
$C_2P_2N_2$	35.20^{bc}	26.67^{f}	18.63^{ef}	14.83^{d}	13.13^{cd}	12.10^{c}	12.03^{cd}
$C_3P_3N_3$	35.30^{b}	24.51^{h}	22.70^{b}	14.00^{c}	12.10^{c}	11.67^{d}	11.57^{def}

Table 4.13. Effect of substrate- organic enricher interaction on C: N ratio during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1C_1	38.24	38.24	28.60	20.20	16.30	15.50	15.40
O_1C_2	38.12	35.74	26.80	21.70	15.20	13.90	13.20
O_1C_3	38.56	34.24	24.90	20.27	15.80	13.33	12.90
O_1P_1	37.89	25.63	17.20	14.57	12.50	12.10	12.10
O_1P_2	37.63	24.20	16.90	13.10	12.00	11.90	11.90
O_1P_3	37.66	23.10	16.90	12.57	11.90	11.60	11.50
O_1N_1	36.66	32.26	24.20	18.70	16.10	15.80	15.80
O_1N_2	36.12	30.90	22.10	17.40	15.20	14.60	14.30
O_1N_3	36.50	29.30	20.60	16.50	14.90	13.90	13.70
$O_1C_1P_1N_1$	37.16	30.70	22.00	17.10	15.00	13.30	13.00
$O_1C_2P_2N_2$	37.20	29.71	20.80	16.20	14.60	13.00	12.90
$O_1C_3P_3N_3$	37.30	27.14	19.20	15.90	13.20	12.20	12.10
O_2C_1	36.21	34.90	25.70	20.10	14.90	13.10	12.90
O_2C_2	36.39	33.25	23.80	17.60	14.20	12.20	12.10
O_2C_3	36.42	31.20	21.10	16.90	12.80	11.90	11.90
O_2P_1	35.92	23.90	15.40	12.80	11.70	11.10	11.10
O_2P_2	36.12	22.05	14.20	12.10	11.60	10.80	10.70
O_2P_3	36.13	20.80	21.70	11.43	10.60	10.30	10.30
O_2N_1	37.66	30.24	19.20	16.77	13.80	12.50	12.50
O_2N_2	37.66	27.90	16.90	15.90	13.20	12.20	12.10
O_2N_3	37.59	24.10	19.50	13.10	12.00	11.80	11.90
$O_2C_1P_1N_1$	35.12	28.32	19.20	15.30	13.90	12.90	12.70
$O_2C_2P_2N_2$	35.30	26.90	16.70	15.90	13.20	12.20	12.10
$O_2C_3P_3N_3$	35.50	24.30	22.10	12.90	12.00	11.90	11.90
O_3C_1	35.60	31.90	20.40	15.40	12.90	11.31	11.10
O_3C_2	35.70	29.60	18.90	15.90	11.90	11.00	10.63
O_3C_3	35.80	27.30	15.40	13.60	11.10	10.07	10.01
O_3P_1	35.90	21.90	14.20	12.90	11.10	10.70	10.50
O_3P_2	35.20	20.06	13.50	11.10	10.70	10.20	10.00
O_3P_3	35.10	18.72	19.40	10.90	10.10	9.90	10.70
O_3N_1	36.10	28.90	19.20	15.20	13.50	12.30	12.10
O_3N_2	36.20	26.20	16.40	14.40	12.10	11.90	11.80
O_3N_3	35.90	24.70	17.20	12.70	11.90	11.30	11.30
$O_3C_1P_1N_1$	35.40	25.70	16.00	14.90	12.50	12.10	12.06
$O_3C_2P_2N_2$	35.30	23.40	18.40	12.40	11.60	11.10	11.10
$O_3C_3P_3N_3$	36.30	22.10	26.80	13.20	11.10	10.90	10.70
CD	NS	0.71	0.93	0.58	0.75	0.55	1.20

Table 4.14. Influence of substrate and inorganic enrichers on C: N ratio during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	32.10^{b}	33.05^{a}	23.02^{a}	18.28^{a}	14.23^{a}	12.63^{a}	12.70^{a}
O_2	32.20^{a}	30.41^{b}	21.30^{b}	16.00^{b}	12.38^{b}	11.13^{b}	11.03^{b}
O_3	32.20^{a}	29.17^{c}	19.94^{c}	15.40^{c}	11.63^{c}	10.75^{c}	10.60^{c}
Inorganic enrichers							
U_1	35.21^{c}	33.97^{a}	22.40^{a}	19.33^{a}	14.87^{a}	13.10^{a}	13.13^{a}
U_2	35.20^{d}	32.23^{b}	22.37^{a}	18.10^{b}	13.67^{b}	12.17^{b}	12.07^{b}
RP_1	35.32^{a}	31.32^{c}	20.20^{c}	16.37^{c}	13.00^{c}	11.60^{c}	11.47^{bc}
RP_2	35.21^{c}	29.07^{e}	20.73^{b}	15.30^{e}	11.73^{e}	10.73^{c}	10.6^{cd}
U_1RP_1	35.25^{b}	30.40^{d}	20.17^{c}	15.63^{d}	12.17^{d}	11.17^{d}	11.27^{bc}
U_2RP_2	35.25^{b}	28.27^{f}	22.61^{a}	14.63^{f}	11.07^{f}	10.27^{f}	10.13^{d}

Table 4.15. Effect of substrate- inorganic enricher interaction on C: N ratio during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1U_1	38.90	35.62	24.90	21.70	15.20	13.90	14.20
O_1U_2	38.70	34.90	23.80	20.60	15.80	12.90	12.70
O_1RP_1	38.60	32.90	21.10	17.60	14.20	12.20	12.10
O_1RP_2	38.20	30.40	22.00	16.90	12.80	11.80	11.60
$O_1U_1RP_1$	37.90	33.90	21.50	17.10	15.00	13.30	14.00
$O_1U_2RP_2$	37.20	30.60	24.80	15.80	12.40	11.70	11.60
O_2U_1	37.90	33.60	21.10	18.70	15.20	13.20	12.10
O_2U_2	37.50	31.10	22.10	16.90	12.80	11.90	11.90
O_2RP_1	37.20	31.06	20.60	15.40	12.90	11.30	11.10
O_2RP_2	37.00	29.20	20.60	15.40	11.30	10.30	10.20
$O_2U_1RP_1$	36.90	29.40	19.60	15.40	11.30	10.30	10.20
$O_2U_2RP_2$	36.40	28.10	23.80	14.20	10.80	9.80	9.70
O_3U_1	36.40	32.70	21.20	17.60	14.20	12.20	12.10
O_3U_2	36.50	30.70	21.20	16.80	12.40	11.70	11.60
O_3RP_1	36.60	30.01	18.90	16.10	11.90	11.30	11.20
O_3RP_2	36.40	27.60	19.60	13.60	11.10	10.10	10.01
$O_3U_1RP_1$	36.20	27.90	19.40	14.40	10.20	9.90	9.60
$O_3U_2RP_2$	36.30	26.10	19.33	13.90	10.00	9.30	9.10
CD	NS	0.90	0.66	0.07	0.63	0.56	1.52

During all intervals of measurement treatments ($C_3P_3N_3$) recorded the lowest C: N ratio ranging from 24.51 from 10th day onwards to 11.57 at maturity stage in case of organic treatments. The variation in C: N ratio during different periods of composting of the substrates with organic enrichment was given in fig. 3.

From the Table 4.13. it was found that the treatment combinations with organic enrichers also differ significantly with respect to C: N ratio. The C: N ratio tends to decrease from initial value during all stages of composting thus attaining a suitable ratio of around 10 to12 at maturity. The lowest C: N ratio of 10.00 was recorded by the combination O_3P_2.

In case of treatments with inorganic enrichers the variation in C: N ratio was shown in Table 4.14.Initially all the substrate showed a par value of 32.20. O_1 differed significantly from the other two substrate with a high value of 12.70,while O_3 registered the lowest value of 10.60 followed by O_2 with a value of 11.02 (fig.4.). While considering the inorganic enrichers the treatment U_2RP_2 showed the lowest C: N ratio of 10.13 at 60th day. This treatment differed significantly with other treatments at all intervals of composting.

The effect of substrate- inorganic enrichers on C: N ratio at 10 days interval was given in Table 4.15. From the table it was seen that the C: N ratio in general showed a decrease from its initial high value. From the table it was seen that the treatment $O_3U_2RP_2$ showed lowest C: N ratio at all intervals of measurement finally reaching a value of 9.10 at the end of composting. The treatment combinations with unsieved enriched with urea alone showed high C: N ratio at 60th day than other treatment combinations.

4.2.1.4 Dehydrogenase activity

The microbial count expressed as dehydrogenase activity was also recordedintervals. The variations in the dehydrogenase activity for organic

Table 4.16. Influence of substrate and organic enrichers on dehydrogenase activity ($\mu g\ g^{-1}$ soil h^{-1}) during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	655.70^{c}	1175.30^{c}	1266.29^{c}	1232.09^{c}	1172.86^{c}	858.51^{c}	778.10^{c}
O_2	657.30^{b}	1290.03^{b}	1397.81^{b}	1375.13^{b}	1251.55^{b}	925.69^{b}	844.08^{b}
O_3	658.20^{a}	1378.67^{a}	1497.18^{a}	1488.03^{a}	1334.79^{a}	1022.13^{a}	914.98^{a}
Organic enrichers							
C_1	560.70^{d}	937.86^{e}	1026.46^{l}	996.23^{l}	981.43^{l}	752.91^{l}	655.41^{l}
C_2	560.90^{c}	1014.39^{k}	1120.62^{k}	1091.48^{k}	1038.51^{k}	772.36^{k}	694.21^{k}
C_3	560.10^{h}	1072.29^{j}	1179.92^{j}	1160.83^{j}	1106.67^{j}	812.89^{j}	705.81^{j}
P_1	561.20^{b}	1160.00^{i}	1256.04^{i}	1239.93^{i}	1148.36^{i}	839.68^{i}	725.06^{i}
P_2	561.90^{a}	1213.38^{h}	1324.92^{h}	1309.75^{h}	1229.52^{h}	883.21^{h}	790.68^{h}
P_3	561.20^{b}	1294.28^{g}	1382.05^{g}	1372.71^{g}	1246.78^{g}	898.94^{g}	798.25^{g}
N_1	560.60^{e}	1338.71^{f}	1453.32^{f}	1439.45^{f}	1325.82^{f}	996.22^{f}	885.27^{f}
N_2	560.90^{c}	1394.31^{e}	1493.14^{e}	1472.96^{e}	1328.04^{e}	1010.02^{e}	891.33^{e}
N_3	560.10^{h}	1427.01^{d}	1547.77^{d}	1520.03^{d}	1375.15^{d}	1038.46^{d}	962.75^{d}
$C_1P_1N_1$	560.20^{g}	1447.62^{c}	1574.88^{c}	1543.36^{c}	1384.13^{c}	1043.59^{c}	985.38^{c}
$C_2P_2N_2$	560.50^{f}	1494.25^{b}	1610.21^{b}	1595.47^{b}	1402.23^{b}	1063.78^{b}	1001.57^{b}
$C_3P_3N_3$	560.70^{d}	1581.91^{a}	1675.78^{a}	1638.85^{a}	1470.16^{a}	1113.27^{a}	1052.92^{a}

Table 4.17. Effect of substrate- organic enricher interaction on dehydrogenase activity (μg g $^{-1}$ soil h $^{-1}$) during different periods of composting

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1C_1	559.20	814.30^{G}	905.71^{G}	900.00^{H}	885.00^{z}	701.28^{A}	611.71^{x}
O_1C_2	559.80	840.60^{F}	948.57^{F}	940.63^{G}	940.50^{y}	720.14^{z}	655.29^{w}
O_1C_3	559.40	908.70^{E}	1005.71^{E}	1000.92^{F}	954.30^{w}	725.70^{y}	655.32^{w}
O_1P_1	560.10	1074.30^{A}	1100.00^{D}	1100.00^{D}	1064.22^{u}	799.15^{w}	702.78^{t}
O_1P_2	559.20	1100.00^{z}	1191.43^{A}	1151.40^{A}	1105.71^{b}	820.16^{v}	720.16^{s}
O_1P_3	560.20	1191.43^{w}	1268.57^{y}	1254.28^{y}	1142.86^{q}	848.92^{t}	732.32^{q}
O_1N_1	560.90	1237.14^{b}	1337.28^{v}	1300.00^{v}	1251.02^{o}	888.80^{r}	740.95^{o}
O_1N_2	560.80	1291.43^{r}	1354.28^{u}	1321.15^{u}	1275.00^{n}	899.72^{p}	741.12^{o}
O_1N_3	561.20	1345.71^{o}	1474.29^{p}	1402.86^{q}	1326.73^{k}	950.75^{n}	926.52^{j}
$O_1C_1P_1N_1$	560.90	1362.86^{n}	1495.34^{o}	1412.29^{p}	1330.12^{j}	955.62^{m}	926.83^{j}
$O_1C_2P_2N_2$	560.80	1402.86^{k}	1522.85^{l}	1495.87^{l}	1348.31^{i}	965.99^{l}	929.22^{i}
$O_1C_3P_3N_3$	559.70	1534.29^{d}	1591.43^{I}	1505.71^{J}	1450.52^{b}	1025.91^{i}	995.00^{g}
O_2C_1	559.60	948.57^{D}	1025.57^{E}	948.57^{G}	948.57^{x}	725.29^{y}	659.12^{v}
O_2C_2	560.20	1065.43^{B}	1142.86^{c}	1074.29^{E}	1032.16^{v}	748.02^{x}	695.01^{u}
O_2C_3	560.40	1105.30^{y}	1224.29^{f}	1191.43^{c}	1122.13^{r}	832.16^{u}	725.87^{r}
O_2P_1	560.70	1137.14^{x}	1268.57^{y}	1297.14^{z}	1105.07^{t}	820.18^{v}	720.16^{s}
O_2P_2	561.80	1220.04^{u}	1337.14^{v}	1337.14^{t}	1252.12^{o}	888.80^{r}	740.95^{o}
O_2P_3	561.90	1300.12^{q}	1372.57^{t}	1369.97^{s}	1291.19^{m}	895.60^{q}	750.06^{n}
O_2N_1	560.70	1320.14^{p}	1450.14^{q}	1435.55^{o}	1326.73^{k}	991.10^{k}	915.19^{k}
O_2N_2	559.40	1397.22^{l}	1516.62^{m}	1498.26^{k}	1306.32^{l}	1004.44^{w}	929.11^{i}
O_2N_3	558.20	1412.18^{j}	1536.91^{r}	1530.62^{i}	1376.16^{h}	1025.60^{l}	932.07^{h}
$O_2C_1P_1N_1$	558.60	1474.29^{h}	1594.29^{h}	1588.13^{g}	1399.72^{g}	1036.12^{h}	999.66^{f}
$O_2C_2P_2N_2$	559.40	1505.61^{f}	1615.01^{I}	1609.77^{e}	1410.61^{e}	1052.63^{g}	1005.40^{e}
$O_2C_3P_3N_3$	558.60	1594.29^{b}	1689.79^{c}	1680.71^{B}	1447.78^{c}	1088.31^{f}	1056.33^{c}
O_3C_1	558.70	1050.71^{C}	1148.11^{B}	1140.11^{b}	1110.71^{s}	832.16^{u}	695.39^{u}
O_3C_2	559.70	1137.14^{x}	1270.44^{x}	1259.51^{x}	1142.86^{q}	848.92^{t}	732.32^{q}
O_3C_3	560.10	1202.86^{v}	1309.76^{w}	1290.12^{w}	1243.59^{p}	880.80^{s}	736.25^{p}
O_3P_1	567.20	1268.57^{s}	1399.54^{s}	1382.65^{r}	1275.77^{n}	899.72^{p}	752.25^{m}
O_3P_2	562.10	1320.10^{p}	1446.19^{r}	1440.72^{n}	1330.72^{j}	940.67^{o}	910.92^{l}
O_3P_3	561.10	1391.29^{m}	1505.01^{n}	1493.87^{m}	1306.29^{l}	952.29^{n}	912.37^{l}
O_3N_1	558.50	1458.86^{i}	1572.54^{j}	1582.80^{h}	1399.72^{g}	1108.75^{e}	999.66^{f}
O_3N_2	558.90	1494.28^{g}	1608.51^{g}	1599.46^{f}	1402.80^{f}	1125.91^{d}	1003.76^{e}
O_3N_3	560.00	1523.14^{e}	1632.12^{e}	1626.61^{d}	1422.55^{d}	1139.02^{c}	1029.65^{d}
$O_3C_1P_1N_1$	561.10	1505.17^{f}	1635.01^{d}	1629.65^{c}	14222.55^{d}	1139.02^{c}	1029.65^{d}
$O_3C_2P_2N_2$	562.20	1574.29^{c}	1692.76^{b}	1680.77^{b}	1447.78^{c}	1172.73^{b}	1070.10^{b}
$O_3C_3P_3N_3$	563.30	1617.14^{a}	1746.13^{a}	1730.13^{a}	1512.19^{a}	1225.59^{a}	1107.43^{a}

Table 4.18. Influence of substrate and inorganic enrichers on dehydrogenase activity (µg g $^{-1}$ soil h $^{-1}$) during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
Substrates							
O_1	655.70^{c}	1279.05^{c}	1387.10^{c}	1381.83^{c}	1253.65^{c}	1000.05^{c}	866.98^{c}
O_2	657.60^{b}	1436.62^{b}	1551.08^{b}	1544.25^{b}	1388.07^{b}	1106.45^{b}	993.83^{b}
O_3	658.60^{a}	1587.08^{a}	1708.91^{a}	1702.13^{a}	1507.20^{a}	1199.67^{a}	1078.28^{a}
Inorganic enrichers							
U_1	560.70^{d}	1053.14^{f}	1165.32^{f}	1191.12^{f}	1131.72^{f}	838.51^{f}	698.65^{f}
U_2	560.80^{c}	1170.57^{e}	1251.22^{e}	1270.60^{e}	1175.72^{e}	842.27^{e}	727.45^{e}
RP_1	560.90^{b}	1328.57^{d}	1436.35^{d}	1431.04^{d}	1294.44^{c}	945.24^{b}	884.27^{d}
RP_2	560.50^{e}	1411.57^{c}	1528.94^{c}	1461.91^{c}	1285.82^{d}	1036.50^{c}	922.44^{c}
U_1RP_1	561.10^{a}	1759.74^{b}	1902.42^{b}	1894.34^{b}	1680.04^{b}	1438.10^{d}	1278.57^{b}
U_2RP_2	561.10^{a}	1881.90^{a}	2009.94^{a}	2005.40^{a}	1750.12^{a}	1511.74^{a}	1366.79^{a}

Table 4.19. Effect of substrate- inorganic enricher interaction on dehydrogenase activity (μg g $^{-1}$ soil h $^{-1}$) during different periods of composting.

Treatments	Period (days)						
	0	10	20	30	40	50	60
O_1U_1	560.20	911.43^{r}	1010.71^{q}	1108.10^{r}	1032.30^{p}	794.56^{r}	662.32^{r}
O_1U_2	560.10	1014.29^{q}	1092.51^{p}	1167.56^{o}	1099.10^{o}	802.29^{q}	699.98^{p}
O_1RP_1	559.90	1191.43^{o}	1268.57^{n}	1264.28^{m}	1152.86^{l}	858.92^{n}	742.32^{m}
O_1RP_2	559.80	1237.14^{l}	1348.14^{l}	1164.35^{p}	1022.70^{q}	106.16^{k}	762.15^{k}
$O_1U_1RP_1$	559.70	1617.14^{f}	1746.13^{f}	1730.13^{f}	1512.19^{e}	1225.59^{f}	1122.43^{f}
$O_1U_2RP_2$	558.70	1702.96^{e}	1856.54^{e}	1856.54^{e}	1702.78^{c}	1412.75^{e}	1212.66^{e}
O_2U_1	560.10	1042.27^{p}	1148.11^{o}	1140.11^{q}	1110.71^{n}	832.16^{p}	695.39^{q}
O_2U_2	561.10	1197.43^{n}	1268.57^{n}	1254.28^{n}	1142.86^{m}	848.92^{o}	732.32^{o}
O_2RP_1	558.70	1320.00^{j}	1446.19^{j}	1440.72^{j}	1330.72^{i}	940.61^{j}	910.92^{j}
O_2RP_2	560.20	1422.86^{i}	1545.91^{i}	1540.62^{i}	1386.99^{h}	1030.60^{i}	935.07^{i}
$O_2U_1RP_1$	561.10	1751.43^{d}	1892.56^{d}	1890.32^{d}	1702.79^{c}	1486.53^{d}	1290.15^{d}
$O_2U_2RP_2$	562.20	1885.71^{c}	2005.13^{c}	1999.43^{c}	1654.33^{d}	1499.90^{c}	1399.13^{c}
O_3U_1	559.70	1205.71^{m}	1337.14^{m}	1325.14^{l}	1252.14^{k}	888.80^{l}	738.25^{n}
O_3U_2	560.10	1300.00^{k}	1392.57^{k}	1389.97^{k}	1285.19^{j}	875.60^{m}	750.06^{l}
O_3RP_1	560.20	1474.29^{h}	1594.29^{h}	1588.13^{h}	1399.73^{g}	1036.19^{h}	999.56^{h}
O_3RP_2	559.80	1574.71^{g}	1692.76^{g}	1680.77^{g}	1447.78^{f}	1172.73^{g}	1070.10^{g}
$O_3U_1RP_1$	558.80	1910.65^{b}	2068.57^{b}	2068.56^{b}	1825.13^{b}	1602.17^{b}	1423.13^{b}
$O_3U_2RP_2$	560.90	2057.14^{a}	2168.14^{a}	2160.23^{a}	1833.25^{a}	1622.59^{a}	1488.57^{a}

enrichers during the different periods of study were recorded and were given in Table 4.16. The dehydrogenase activity was found to increase in all treatments upto 20[th] day and thereafter it showed a decline up to maturity. The initial value did not show any significant difference among treatments.

While considering the effect of substrate on dehydrogenase activity it was found that the three substrates O_1, O_2 and O_3 differ significantly with respect to dehydrogenase activity. The maximum value of 1497.18 µg g $^{-1}$ soil h $^{-1}$ was attained by 2mm sieved substrate (O_3) which decreased to 914.98 µg g $^{-1}$ soil h $^{-1}$ towards maturity. It was then followed by 4mm sieved substrate (O_2) and unsieved substrate (O_1) respectively. The change in activity for the substrates was shown in fig.5.

The maximum amount of dehydrogenase content was seen in $C_3P_3N_3$ which is 1675.78 µg g $^{-1}$ soil h $^{-1}$ during 20[th] day and it decrease attaining a value of 1052.92 µg g $^{-1}$ soil h $^{-1}$ at maturity.

The Table 4.17. provides data on effect of substrate- organic enrichment on dehydrogenase activity. From the table it was evident that maximum dehydrogenase activity was exhibited by the combination of $O_3C_3P_3N_3$ with a value of 1746.13 µg g $^{-1}$ soil h $^{-1}$ and then decreased to 1107.43 µg g $^{-1}$ soil h $^{-1}$ towards maturity. All the treatments differ significantly with respect to dehydrogenase activity during all periods of composting.

The data on the effect of inorganic enrichers on the dehydrogenase activity was provided in Table 4.18. From the table it was evident that among the inorganic enrichers the treatments with Rock phosphate as enricher recorded a high microbial load. The effect of substrates on dehydrogenase activity reavled from table showed that O_3 with fine particle size recorded the maximum value at all stages of composting. The maximum value attained by the same was 1708.91 µg g $^{-1}$ soil h $^{-1}$ on the 20[th] day. Then it decreased to 1072.28 µg g $^{-1}$ soil h $^{-1}$

towards the end. It was then followed by O_2 and O_1 with values of 993.83 μg g $^{-1}$ soil h $^{-1}$ and 866.98 μg g $^{-1}$ soil h $^{-1}$ respectively (fig.6.).

Maximum dehydrogenase activity in case of inorganic enrichers (Table 4.18.) is reached by U_2RP_2 which is 2009.94 μg g $^{-1}$ soil h $^{-1}$ during 20th day and it decreases to 1366.79 μg g $^{-1}$ soil h $^{-1}$ at maturity.

The effect of substrate-inorganic enricher interaction on dehydrogenase activity was given in Table 4.19. From the table it was found that $O_3U_2RP_2$ recorded maximum value of 2168.14 μg g $^{-1}$ soil h $^{-1}$ during the 20th day and decreased to 1488.5 μg g $^{-1}$ soil h $^{-1}$ at maturity. The treatment combination with rock phosphate registered high values than treatments without it.

4.2.1.5 Maturity period

The periods taken by the various organic enrichers to attain maturity was given in Table 4.20. The effect of substrates on maturity period in case of organic enrichers revealed that O_3 took the lowest time to attain maturity, which is around 49.21 days. O_2 and O_1 follows O_3 with maturity period of 50.33 and51.33 days respectively. In case of organic enrichers the minimum maturity period of around 49.33 days was attained by treatment mixtures containing Cow dung, Poultry manure and Neem cake each at 10 per cent ($C_2P_2N_2$) and 15 per cent ($C_3P_3N_3$). The treatment with cow dung alone as enricher showed maximum time taken to attain maturity. Generally the poultry manure as enricher at various level showed comparatively lesser time to attain maturity.

Table 4.20. Effect of various substrates and organic enrichers on maturity period of composting

Treatments	Maturity period (days)
Substrates	
O_1	51.33[a]
O_2	50.33[b]
O_3	49.21[c]
Organic enrichers	
C_1	58.22[a]
C_2	57.00[b]
C_3	55.56[c]
P_1	54.67[de]
P_2	54.33[e]
P_3	52.33[f]
N_1	55.33[cd]
N_2	54.33[e]
N_3	54.44[e]
$C_1P_1N_1$	52.67[f]
$C_2P_2N_2$	49.33[g]
$C_3P_3N_3$	49.33[g]

Table 4.21. Effect of substrate organic enricher interactions on compost maturity period.

Treatments	Maturity Period (days)
O_1C_1	60^{a}
O_1C_2	58^{b}
O_1C_3	57^{bc}
O_1P_1	56^{cd}
O_1P_2	56^{cd}
O_1P_3	54^{ef}
O_1N_1	58^{b}
O_1N_2	57^{bc}
O_1N_3	57^{bc}
$O_1C_1P_1N_1$	55^{de}
$O_1C_2P_2N_2$	50^{ij}
$O_1C_3P_3N_3$	50^{ij}
O_2C_1	58^{b}
O_2C_2	57^{bc}
O_2C_3	55^{de}
O_2P_1	54^{ef}
O_2P_2	54^{ef}
O_2P_3	53^{fg}
O_2N_1	56^{cd}
O_2N_2	55^{de}
O_2N_3	55^{de}
$O_2C_1P_1N_1$	53^{fg}
$O_2C_2P_2N_2$	49^{j}
$O_2C_3P_3N_3$	49^{j}
O_3C_1	57^{bc}
O_3C_2	56^{cd}
O_3C_3	55^{de}
O_3P_1	54^{ef}
O_3P_2	53^{fg}
O_3P_3	50^{ij}
O_3N_1	52^{gh}
O_3N_2	51^{hi}
O_3N_3	51^{hi}
$O_3C_1P_1N_1$	50^{ij}
$O_3C_2P_2N_2$	49^{j}
$O_3C_3P_3N_3$	49^{j}

Table 4.22. Effect of various substrates and inorganic enrichers on maturity period of composting

Treatments	Maturity period (days)
Substrates	
O_1	56.78[a]
O_2	55.22[b]
O_3	53.44[c]
Inorganic enrichers	
U_1	57.33[a]
U_2	57.33[a]
RP_1	55.67[b]
RP_2	55.00[bc]
U_1RP_1	54.33[c]
U_2RP_2	52.67[d]

Table 4.23. Effect of substrate-inorganic enrichers interactions on compost maturity period

Treatments	Maturity period (days)
O_1U_1	60 [a]
O_1U_2	59 [ab]
O_1RP_1	58 [bc]
O_1RP_2	57 [cd]
$O_1U_1RP_1$	58 [bc]
$O_1U_2RP_2$	56 [de]
O_2U_1	59 [ab]
O_2U_2	57 [cd]
O_2RP_1	55 [ef]
O_2RP_2	54 [fg]
$O_2U_1RP_1$	52 [ghi]
$O_2U_2RP_2$	51 [i]
O_3U_1	53 [gh]
O_3U_2	56 [de]
O_3RP_1	54 [fg]
O_3RP_2	54 [fg]
$O_3U_1RP_1$	53 [gh]
$O_3U_2RP_2$	51 [i]

The maturity period taken by various substrate-organic enricher combination is given in Table 4.21. From the table it was seen that the minimum maturity period of 49 days was shown by four treatments namely $O_2C_2P_2N_2$, $O_2C_3P_3N_3$, $O_3C_2P_2N_2$ and $O_3C_3P_3N_3$.In the interaction combination also the treatment containing cow dung registered a higher maturity period where as the treatment with poultry manure recorded the lowest maturity period.

The effect of various substrate and inorganic enrichers on maturity period was given in Table 4.22. It was found that the 2mm sieved substrate witnessed a lower maturity period of 53 days followed by O_2 and O_1 with values 55 and 57 days respectively. It was seen that the maturity period taken in case of inorganic enrichment treatment was higher than organic enrichment combinations. Among the inorganic enrichers the treatment U_2RP_2 shows a minimum maturity period of 53 days. The maximum time to attain maturity was shown by U_1 and RP_1, which was 57 days.

Considering the effect of substrate-inorganic enricher interaction on maturity period, which was shown in Table 4.23, it was seen that the lowest maturity period of 51 days was attained by $O_2U_2RP_2$ and $O_3U_3RP_2$. The highest value of 60 days was shown by the treatment O_1U_1. In general the treatment combinations with urea alone registered a higher value for maturity period.

4.2.2. Nutrient content

The nutrient contents of the various compost formulations at initial phase of composting are given in Table 4.24. Perusal of data with respect to organic treatments revealed that among the substrates O_3 registered a highest nutrient content than the other two substrates with values of 2.82, 0.21and 0.80 per cent for N, P and K respectively. In case of enrichers $C_3P_3N_3$ witnessed a higher content of N, P and K than all other treatments. In case of Nitrogen content

Table 4.24. Influence of substrate and organic enrichers on contents of N, P and K at initial stages of composting

Treatments	N (%)	P (%)	K (%)
Substrates			
O_1	2.32[c]	0.11[c]	0.58[c]
O_2	2.49[b]	0.16[b]	0.64[b]
O_3	2.82[a]	0.21[a]	0.80[a]
Organic enrichers			
C_1	2.21[k]	0.07[j]	0.37[h]
C_2	2.25[j]	0.10[i]	0.47[g]
C_3	2.42[i]	0.12[g]	0.56[ef]
P_1	2.51[h]	0.16[f]	0.51[fg]
P_2	2.54[g]	0.20[d]	0.61[e]
P_3	2.56[f]	0.24[c]	0.69[d]
N_1	2.56[f]	0.11[h]	0.56[ef]
N_2	2.58[e]	0.16[f]	0.70[d]
N_3	2.63[d]	0.18[e]	0.77[cd]
$C_1P_1N_1$	2.66[c]	0.24[c]	0.81[c]
$C_2P_2N_2$	2.70[b]	0.28[b]	0.92[b]
$C_3P_3N_3$	2.75[a]	0.31[a]	1.08[a]

Table 4.25. Effect of substrate- organic enricher interaction on initial content of N, P and K during composting.

Treatments	N (%)	P (%)	K (%)
O_1C_1	2.03	0.02	0.28
O_1C_2	2.04	0.04	0.36
O_1C_3	2.07	0.06	0.42
O_1P_1	2.54	0.09	0.46
O_1P_2	2.84	0.10	0.56
O_1P_3	2.96	0.14	0.64
O_1N_1	2.42	0.06	0.48
O_1N_2	2.57	0.07	0.58
O_1N_3	2.66	0.10	0.66
$O_1C_1P_1N_1$	2.35	0.18	0.74
$O_1C_2P_2N_2$	2.42	0.24	0.80
$O_1C_3P_3N_3$	2.95	0.29	0.96
O_2C_1	2.24	0.09	0.34
O_2C_2	2.29	0.12	0.42
O_2C_3	2.95	0.14	0.54
O_2P_1	3.04	0.14	0.48
O_2P_2	3.09	0.19	0.58
O_2P_3	3.11	0.24	0.66
O_2N_1	2.54	0.13	0.56
O_2N_2	2.84	0.17	0.66
O_2N_3	2.96	0.14	0.74
$O_2C_1P_1N_1$	3.20	0.21	0.76
$O_2C_2P_2N_2$	3.25	0.29	0.88
$O_2C_3P_3N_3$	3.30	0.31	1.04
O_3C_1	2.36	0.11	0.50
O_3C_2	2.42	0.14	0.62
O_3C_3	2.71	0.17	0.72
O_3P_1	3.12	0.25	0.58
O_3P_2	3.19	0.31	0.69
O_3P_3	3.20	0.34	0.78
O_3N_1	2.71	0.16	0.64
O_3N_2	2.84	0.23	0.86
O_3N_3	2.94	0.29	0.91
$O_3C_1P_1N_1$	3.29	0.26	0.94
$O_3C_2P_2N_2$	3.35	0.31	1.09
$O_3C_3P_3N_3$	3.40	0.36	1.25
CD	0.14	0.05	0.14

Table 4.26. Influence of substrate and inorganic enrichers on contents of N, P and K at initial stages of composting

Treatments	N (%)	P (%)	K (%)
Substrates			
O_1	2.98[c]	1.05[c]	0.32[c]
O_2	3.19[b]	1.15[b]	0.39[b]
O_3	3.25[a]	1.35[a]	0.44[a]
Inorganic enrichers			
U_1	3.17[c]	0.23[f]	0.33[b]
U_2	3.29[b]	0.29[e]	0.34[b]
RP_1	2.62[e]	1.31[d]	0.33[b]
RP_2	2.70[d]	1.92[c]	0.38[b]
U_1RP_1	3.35[a]	2.14[b]	0.39[b]
U_2RP_2	3.43[a]	2.29[a]	0.41[a]

Table 4.27. Effect of substrate - inorganic enricher interaction on initial content of N, P and K during composting.

Treatments	N (%)	P (%)	K (%)
O_1U_1	3.13	0.13	0.26
O_1U_2	3.21	0.15	0.28
O_1RP_1	2.71	1.02	0.26
O_1RP_2	2.94	1.75	0.30
$O_1U_1RP_1$	3.12	1.82	0.52
$O_1U_2RP_2$	3.23	2.06	0.60
O_2U_1	3.27	0.26	0.32
O_2U_2	3.36	0.34	0.40
O_2RP_1	2.84	1.32	0.32
O_2RP_2	3.05	1.92	0.36
$O_2U_1RP_1$	3.29	2.10	0.58
$O_2U_2RP_2$	3.34	2.19	0.64
O_3U_1	3.47	0.32	0.40
O_3U_2	2.94	0.39	0.46
O_3RP_1	4.46	1.74	0.42
O_3RP_2	3.12	2.09	0.48
$O_3U_1RP_1$	3.89	2.49	0.66
$O_3U_2RP_2$	3.94	2.61	0.78
CD	0.17	0.02	0.13

treatment $C_2P_2N_2$ follows $C_3P_3N_3$ with a value of 2.70 which was immediately followed by $C_1P_1N_1$ with a value of 2.66. In case of Phosphorus content treatment $C_2P_2N_2$ comes 2^{nd} with a value of 0.28. The K content also shows significant difference between treatments and $C_2P_2N_2$ follows $C_3P_3N_3$ with a value of 0.92.

The effect of substrate-organic enricher interaction on initial nutrient content was given in Table 4.25.The analysis of data showed that the treatment $O_3C_3P_3N_3$ has highest values with respect to nutrient content. It recorded a value of 3.40 per cent on case of N content, 0.36 per cent in case of P content and 1.25 per cent in case of K content. The treatment $O_3C_2P_2N_2$ showed par values with respect to N and P content which was 3.35 per cent and 0.31per cent respectively. But the K content of the treatment was about 1.09 per cent.

While analyzing the nutrient content of inorganic treatments given in Table 4.27. it was found that the initial nutrient status varies significantly within the treatments. Here also the 2mm sieved substrate (O_3) registered a higher content of nutrients than O_2 and O_1.The N, P and K content of O_3 were 3.25 per cent, 1.35 per cent and 0.44 per cent respectively. In case of the nutrient content of inorganic enrichers the Nitrogen content of treatments U_2RP_2 and U_1RP_1 were almost on par with values 3.43 and 3.35 respectively. But in case of P and K content, treatment U_2RP_2 ranks first with values 2.29 and 0.41 respectively followed by U_1RP_1 in both cases. The K content of rest of the treatments were on par. The initial nutrient content of substrate-inorganic enricher treatment combination was given in Table 4.27. From the table it was seen that the treatment $O_3U_2RP_2$ ranks first with respect to P and K content with values of 2.61 per cent and 0.78 per cent respectively. The highest N content was recorded in treatment combination O_3RP_1

While considering the final nutrient status of the substrates with organic enrichers, the highest value was registered by O3 with 3.56 per cent, 0.37 per cent and 0.62 per cent N, P and K respectively. It was then followed by O2 with values of 3.24 per cent, 0.32 per cent and 0.48 per cent for N, P and K. The nutrient

Table 4.28. Influence of substrate and organic enrichers on contents of N, P and K at maturity

Treatments	N (%)	P (%)	K (%)
Substrates			
O_1	2.89^{c}	0.24^{c}	0.41^{c}
O_2	3.24^{b}	0.32^{b}	0.48^{b}
O_3	3.56^{a}	0.37^{a}	0.62^{a}
Organic enrichers			
C_1	2.69^{g}	0.20^{j}	0.25^{h}
C_2	2.82^{f}	0.25^{i}	0.32^{gh}
C_3	3.13^{e}	0.27^{h}	0.42^{ef}
P_1	3.39^{d}	0.29^{g}	0.36^{fg}
P_2	3.42^{d}	0.33e	0.40^{fg}
P_3	3.59^{bc}	0.37^{c}	0.52^{d}
N_1	3.43^{d}	0.25^{i}	0.42^{ef}
N_2	3.50^{c}	0.29^{g}	0.50^{de}
N_3	3.56^{bc}	0.31^{f}	0.58^{cd}
$C_1P_1N_1$	3.63^{b}	0.34^{d}	0.64^{c}
$C_2P_2N_2$	3.65^{a}	0.40^{b}	0.76^{b}
$C_3P_3N_3$	3.66^{a}	0.44^{a}	0.87^{a}

Table 4.29. Effect of substrate- organic enricher interaction on content of N, P and K at maturity.

Treatments	N (%)	P (%)	K (%)
O_1C_1	2.13	0.16	0.16
O_1C_2	2.24	0.18	0.23
O_1C_3	2.31	0.19	0.32
O_1P_1	2.94	0.20	0.34
O_1P_2	3.05	0.24	0.36
O_1P_3	3.33	0.29	0.46
O_1N_1	2.89	0.16	0.34
O_1N_2	3.06	0.20	0.38
O_1N_3	3.08	0.21	0.40
$O_1C_1P_1N_1$	2.99	0.32	0.50
$O_1C_2P_2N_2$	3.25	0.36	0.68
$O_1C_3P_3N_3$	3.25	0.40	0.72
O_2C_1	2.99	0.21	0.26
O_2C_2	2.99	0.26	0.32
O_2C_3	3.45	0.29	0.38
O_2P_1	3.59	0.29	0.34
O_2P_2	3.68	0.32	0.40
O_2P_3	3.75	0.36	0.46
O_2N_1	2.96	0.27	0.42
O_2N_2	3.27	0.30	0.46
O_2N_3	3.59	0.33	0.56
$O_2C_1P_1N_1$	3.89	0.34	0.61
$O_2C_2P_2N_2$	3.85	0.42	0.68
$O_2C_3P_3N_3$	3.99	0.44	0.88
O_3C_1	2.96	0.23	0.34
O_3C_2	3.22	0.30	0.42
O_3C_3	3.62	0.32	0.55
O_3P_1	3.82	0.39	0.39
O_3P_2	3.79	0.44	0.44
O_3P_3	3.89	0.46	0.65
O_3N_1	3.59	0.32	0.49
O_3N_2	3.71	0.37	0.65
O_3N_3	3.94	0.38	0.78
$O_3C_1P_1N_1$	4.01	0.38	0.80
$O_3C_2P_2N_2$	4.08	0.44	0.91
$O_3C_3P_3N_3$	4.10	0.49	1.01
CD	0.16	0.02	0.15

Table 4.30. Influence of substrate and inorganic enrichers on contents of N, P and K at maturity

Treatments	N (%)	P (%)	K (%)
Substrates			
O_1	3.89[b]	1.61[c]	0.20[c]
O_2	3.93[b]	2.12[b]	0.26[b]
O_3	4.43[a]	2.38[a]	0.31[a]
Inorganic enrichers			
U_1	4.00[b]	0.44[f]	0.17[b]
U_2	4.06[b]	0.53[e]	0.20[b]
RP_1	3.52[b]	1.90[d]	0.18[b]
RP_2	3.73[c]	2.74[c]	0.20[b]
U_1RP_1	4.21[a]	3.08[b]	0.38[a]
U_2RP_2	4.30[a]	3.53[a]	0.44[a]

Table 4.31. Effect of substrate- inorganic enricher interactions on content of N, P and K at maturity

Treatments	N (%)	P (%)	K (%)
O_1U_1	3.89	0.27	0.13
O_1U_2	2.93	0.19	0.13
O_1RP_1	3.33	1.33	0.14
O_1RP_2	3.71	2.04	0.16
$O_1U_1RP_1$	4.17	2.49	0.32
$O_1U_2RP_2$	4.30	3.26	0.34
O_2U_1	4.08	0.38	0.18
O_2U_2	4.11	0.60	0.20
O_2RP_1	3.59	1.95	0.18
O_2RP_2	3.71	3.04	0.18
$O_2U_1RP_1$	3.99	3.26	0.39
$O_2U_2RP_2$	4.08	3.50	0.44
O_3U_1	4.21	0.69	0.19
O_3U_2	3.96	0.72	0.26
O_3RP_1	3.23	0.41	0.22
O_3RP_2	4.17	3.15	0.26
$O_3U_1RP_1$	4.46	3.49	0.42
$O_3U_2RP_2$	4.52	3.85	0.53
CD value	0.17	0.02	0.11

content of the various formulations containing organic enrichers at maturity phase is also recorded at Table 4.28. The nutrient content increased at the maturity phase in all treatments. The treatment $C_3P_3N_3$ is considered to be the best with respect to P and K content which were 0.44 and 0.87 respectively. It was then followed by $C_2P_2N_2$.The Nitrogen content of the two treatments $C_3P_3N_3$ and $C_2P_2N_2$ showed par values of 3.66 and 3.65 respectively.

While considering the final nutrient status of the substrate-organic enricher interaction as given in Table 4.29 It was found that there was an increase in nutrient content with respect to N and P in all treatments. But the K content tends to show a decrease. From the table it was seen that the maximum content of N, P and K was in $O_3C_3P_3N_3$ with values of 4.10, 0.49 and 1.01 per cent respectively. The initial and final nutrient content of organic enrichers were given in fig.7 and 8 respectively.

The final nutrient content of substrates and inorganic enrichers was given in Table 4.31. Here also the 2mm sieved substrate ranks first with respect to nutrient content with a value of 4.43 per cent for N, 2.06 per cent for P and 0.20 per cent for K.Among the treatments U_1RP_1 and U_2RP_2 ranks first in case of N and K content and were on par. But the P content of U_2RP_2 was high with a value of 3.53.The initial and final nutrient content of various inorganic enrichers were given in fig.9 and 10 respectively.

The effect of substrate-inorganic enricher combination on final nutrient content of the compost was given in Table 4.31. The nutrient content of the combinations showed the same trend as in case of organics with an increase in N and P content and decrease in K content. The highest nutrient content was in treatment combination O_3 $U_2RP_2$with values of 4.52,3.85 and 0.53 per cent for N, P and K respectively.

Plate 4 Selected Enriched Compost

Table 4.32. Physico-chemical properties of the selected enriched compost

Properties	Values
% distribution of particle size (mm)	
> 4.75 mm	3.52
2 mm – 4.75 mm	6.45
1 mm – 2 mm	23.90
0.5 mm – 1 mm	29.04
< 0.5 mm	37.20
Moisture content (%)	59.80
Colour	Deep black
Odour	Odourless
pH	6.37

Table 4.33. Chemical properties of the selected enriched compost

Characters	Values
Carbon (%)	41.83
Nitrogen (%)	3.25
Phosphorous (%)	0.36
Potassium (%)	0.68
C: N ratio	12.90

4.3. Selected enriched compost

Physico-chemical properties of selected enriched compost was provided in Tables 4.32. and 4.33.

4.3.1. Physico-chemical properties of selected enriched compost

As revealed from the Table 4.32 the moisture content of the compost was around 59.8 and compost obtained was finally pulvarised, crumby and fine textured material compared to original unsieved waste material. The particle size distribution was such that the fine particles of size less than 0.5 mm constitute about 37.2 per cent followed by particles of size ranging from 0.5 mm – 1.0 mm with a value of 29.04 per cent. The bigger sized particles of size more than 4.75 mm were only 3.52 per cent of total weight, showing the extend of degradation that has occurred in original substrate material. The pH of selected enriched compost was around 6.37. The selected compost was shown in plate 4.

4.3.2 Chemical composition of selected enriched compost

The carbon content was around 41.83 per cent, the N, P and K of selected enriched compost was appreciably high with values of 3.25,0.36, and 0.68 per cent respectively. The C: N ratio decreased to 12.90 which is an index of maturity of compost (Table 4.33.).

4.4. Soil- Crop response studies

Field experiments were conducted as detailed under item 3, to study the direct influence of enriched compost and its efficacy on the major growth and

Table 4.34. Effect of treatments on height and number of leaves at 15 DAP and 30 DAP

Treatments	15 DAP		30 DAP	
	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves
T_1	19.57 ^{h}	10.33 ^{g}	33.27 ^{hi}	14.02 ^{f}
T_2	23.20 ^{g}	14.00 ^{e}	38.00 ^{g}	18.67 ^{de}
T_3	33.10 ^{b}	16.30 ^{cd}	47.27 ^{b}	23.33 ^{c}
T_4	31.27 ^{c}	18.33 ^{c}	43.23 ^{d}	23.00 ^{c}
T_5	39.10 ^{a}	25.67 ^{a}	52.07 ^{a}	31.00 ^{a}
T_6	34.00 ^{b}	23.67 ^{ab}	46.17 ^{bc}	28.67 ^{bc}
T_7	27.17 ^{e}	15.00 ^{d}	38.93 ^{fg}	19.67 ^{d}
T_8	33.20 ^{b}	23.00 ^{b}	45.04 ^{c}	26.67 ^{b}
T_9	29.13 ^{d}	18.33 ^{c}	41.33 ^{e}	22.33 ^{cd}
T_{10}	23.20 ^{g}	12.12 ^{f}	32.60 ^{i}	15.32 ^{e}
T_{11}	28.50 ^{d}	16.67 ^{cd}	39.70 ^{f}	22.54 ^{c}
T_{12}	25.60 ^{f}	14.12 ^{e}	34.10 ^{j}	20.11 ^{d}

yield parameters on test crop, amaranthus. Results on crop growth parameters and yield attributes are presented below.

4.4.1 Plant height

The data on plant height (cm) at 15 days after planting (DAP) and 30 days after planting (DAP) are shown in Table 4.34. Analysis of variance showed that there was significant difference between treatments in both the stages. Plant height increased progressively with advancing age of crop, irrespective of treatments. At 15 DAP treatment T_5 recorded maximum height with a value of 39.10 cm. This was followed by treatment T_6 (34.00 cm), which was on par with treatment T_8 (33.20 cm) and T_3 (33.10 cm). At 30 DAP also the treatments T_5 recorded the maximum height of 52.07 cm followed by T_3 and T_6 which recorded a height of 47.27 and 46.17 cm. The treatment T_8 (45.04 cm) was also found to be on par with T_6 and T_3.

4.4.2 N umber of leaves

Observations on number of leaves was taken during 15 DAP and 30 DAP and the data were given in Table 4.34.Based on the results of analysis of variance it was found that there was a progressive increase in number of leaves from 15 DAP to 30 DAP irrespective of treatments. At both intervals T_5 recorded a value of 25.67 at 15 DAP and 31 at 30 DAP. It was then followed by T6 with values 23.67 and 28.67 at 15 DAP and 30 DAP respectively. T1, the control plot showed the lowest value of 10.33 and 14.02 at respective intervals.

4.4.3 Fresh weight

The fresh weight (g) was also recorded during 15 DAP and 30 DAP. The results are presented in Table 4.35. Fresh weight was also found to increase from

Table 4.35. Effect of treatments on fresh weight and dry weight plant^{-1} during first harvest and second harvest

Treatments	1st harvest		2nd harvest	
	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)
T_1	8.29^{l}	0.97^{h}	9.05^{j}	1.05^{g}
T_2	15.20^{k}	1.75^{g}	17.23^{i}	2.00^{fg}
T_3	33.08^{g}	3.84^{e}	34.67^{f}	4.06^{de}
T_4	29.80^{h}	2.67^{f}	27.99^{g}	3.59^{ef}
T_5	88.00^{a}	11.02^{a}	93.00^{a}	11.63^{a}
T_6	65.74^{c}	8.93^{b}	72.75^{c}	9.09^{bc}
T_7	22.58^{i}	2.82^{f}	20.86^{h}	2.61^{efg}
T_8	70.79^{b}	8.52^{b}	78.03^{b}	9.75^{b}
T_9	44.31^{e}	5.24^{d}	45.00^{e}	5.63^{d}
T_{10}	19.58^{j}	2.32^{fg}	18.63^{hi}	3.15^{ef}
T_{11}	53.12^{d}	6.71^{c}	60.17^{d}	7.52^{c}
T_{12}	38.56^{f}	4.82^{d}	43.72^{e}	5.47^{d}

Plate 5 Aerobic composting in pots

Plate 6 Field experiment with selected compost on Amaranthus

first harvest to second harvest. In the first harvest, the fresh weight was found to be maximum in T_5 which was 88.00 g followed by T_8 which was 70.79 g. During second harvest, the highest value was given by T_5 which was 93.00 g followed by T_8 which was 78.03 g.

4.4.4. Dry matter production

Dry matter accumulation was seen to increase during the second harvest compared to that of 1st harvest as shown in Table 4.35. There was significant difference in dry matter production between treatments, in both 1st and 2nd harvests. Treatment T_5 recorded the maximum dry matter production of 11.02 g during the 1st harvest followed by T_6 and T_8 which recorded 8.93 g and 8.52 g respectively. The treatment T_1, the control recorded the least dry matter accumulation of 0.97 g. During the second harvest, the dry matter production ranged between 1.05 g (T_1) to 11.63 g (T_5). Immediately following the treatment T_5 there were treatments T_6 and T_8 with dry matter accumulation values of 9.09 and 9.75 respectively.

4.4.5. Yield

Data on the yield of amaranthus during the first and second harvests are being presented in Table 4.36. In the first harvest, the lowest yield was recorded in T_1, the control, receiving no organic or inorganic fertilizers. The value was 190.8 g plot^{-1}.

The maximum yield of 1880.63 g plot^{-1} was recorded in treatments T_5 receiving 5 t ha^{-1} of enriched compost and full dose of NPK as per POP. The second largest yield was recorded in treatment T_8 receiving 2.5 t ha^{-1} of compost and full dose of NPK as per POP followed by treatment T_6, receiving 5 t ha^{-1} compost and ½ dose of NPK as per POP recommendation. Treatment T_4 receiving

Table 4.36. Effect of treatments on yield $plot^{-1}$ during first harvest and second harvest

Treatments	1st harvest	2nd harvest
	Yield $plot^{-1}$ (g)	Yield $plot^{-1}$ (g)
T_1	190.83^{l}	210.15^{j}
T_2	350.67^{k}	400.27^{i}
T_3	762.46^{g}	798.06^{g}
T_4	525.07^{h}	542.19^{h}
T_5	1880.63^{a}	1920.70^{a}
T_6	1350.13^{c}	1590.30^{c}
T_7	450.27^{i}	400.33^{i}
T_8	1790.83^{b}	1795.33^{b}
T_9	1020.47^{e}	1035.46^{e}
T_{10}	400.00^{j}	400.60^{i}
T_{11}	1025.50^{d}	1057.48^{d}
T_{12}	976.80^{f}	1000.23^{f}

5 t ha^{-1} of compost alone was significantly superior than treatment T_2 receiving 5 t ha^{-1} FYM alone.

In the second harvest, the yield of amaranthus ranged from 210.15 g $plot^{-1}$ in treatment T_1 to 1920.70 g $plot^{-1}$ in treatment T_5. The treatment T_4 receiving 5t ha^{-1} compost gave significantly superior yield of 542.19 g $plot^{-1}$ than treatment T_2 receiving 5 t ha^{-1} as FYM, which recorded a yield of 400.27 g $plot^{-1}$. However the yields of treatment T_2, T_7 and T_{10} were on par with values of 400.33 g $plot^{-1}$ and 400.60 g $plot^{-1}$ respectively. In both harvest, the treatment T_5 receiving 5 t ha^{-1} of compost and full dose of NPK as per POP, recorded the highest yield, followed by T_8 receiving 2.5 t ha^{-1} of compost and full dose of NPK as per POP. Increasing the levels of enriched compost, brought about significant yield increase in both the harvests. The effect of three treatments namely T_1, T_3 and T_5 on yield at two harvest was given in fig.11.

4.4.6 Nutrient uptake

The uptake of major nutrients N, P and K were studied during the two harvest intervals and is presented in Table 4.37. In the case of Nitrogen uptake during 1st harvest maximum uptake was recorded in treatment T_5 i.e., 5236.00 mg $plot^{-1}$. It was followed by T_8 and T_6 with values of 4260.00 mg $plot^{-1}$ and 3685.00 mg $plot^{-1}$ respectively.

The N uptake was seen to increase in the 2nd harvest in almost all treatments except T_4, T_7 and T_{10}. In the 2nd harvest also T_5 recorded the highest nitrogen content of 8432.00 mg $plot^{-1}$. There was significant difference between treatments ranging from 389.58 mg $plot^{-1}$ in T_1 to 8432.00 mg $plot^{-1}$ in T_5. Immediately following T_5 there was T_6 and T_8 with N uptake 5831.00 mg $plot^{-1}$ and 4855.00 mg $plot^{-1}$ respectively.

Table 4.37. Effect of treatments on major nutrient uptake (mg plot^{-1}) during first harvest and second harvest

Treatments	1st harvest			2nd harvest		
	N (mg plot^{-1})	P (mg plot^{-1})	K (mg plot^{-1})	N (mg plot^{-1})	P (mg plot^{1})	K (mg plot^{-1})
T_1	343.50^{c}	35.81^{l}	471.92^{l}	389.58^{l}	40.23^{l}	510.50^{l}
T_2	798.27^{c}	84.82^{k}	895.36^{k}	927.62^{k}	88.91^{k}	1058.23^{j}
T_3	2151.90^{de}	234.50^{g}	2230.12^{g}	2344.63^{h}	228.35^{f}	2420.60^{g}
T_4	1755.60^{bcde}	156.81^{h}	1475.12^{h}	1682.23^{i}	152.81^{h}	1450.90^{h}
T_5	5236.00^{cde}	740.50^{a}	6912.28^{a}	8432.00^{a}	705.19^{a}	6940.70^{a}
T_6	3685.00^{bc}	466.00^{d}	4698.70^{c}	5831.00^{b}	432.80^{d}	5657.10^{b}
T_7	2910.00^{bcd}	122.53^{i}	1250.10^{i}	1237.00^{j}	102.25^{i}	1100.40^{i}
T_8	4260.00^{ab}	610.23^{b}	5221.10^{b}	4855.00^{c}	592.03^{b}	5470.50^{c}
T_9	2900.00^{bcd}	310.90^{e}	2824.00^{e}	3570.00^{e}	300.90^{e}	2922.90^{e}
T_{10}	2651.00^{bcd}	109.11^{j}	1032.40^{j}	2535.89^{g}	96.97^{j}	1008.10^{k}
T_{11}	3125.60^{bc}	499.42^{c}	3476.80^{d}	4057.90^{d}	488.20^{c}	3656.30^{d}
T_{12}	2624.38^{bcd}	201.50^{g}	2412.00^{f}	3026.25^{f}	189.70^{g}	2682.70^{f}

There was significant difference in the P uptake between various treatments. In the first harvest treatment T_5 recorded the maximum uptake of P i.e., 740.50 mg plot $^{-1}$ followed by T_8 with a value of 610.23 mg plot $^{-1}$. The lowest P uptake was recorded in T_1 i.e., 35.81 mg plot $^{-1}$.

In the 2nd harvest, the P uptake/plot was seen to decrease in almost all the treatments (Table 4.37.). The maximum P uptake of 705.19 mg plot $^{-1}$ was recorded POP. There was significant difference between the treatment T_4 receiving 5 t ha $^{-1}$ compost and treatment T_2 receiving 5 t ha^{-1} FYM thus revealing the efficacy of compost. T_1 the control treatment recorded the least P uptake of 40.23 mg plot $^{-1}$.

K uptake seemed to differ significantly within treatments both during 1st and 2nd harvests. In the first harvest, the K uptake ranged between 471.92 mg plot $^{-1}$ in the control plot (T_1) to 6912.28 mg plot $^{-1}$ (T_5). The treatment T_8 recorded the second highest K uptake of 5221.10 mg plot $^{-1}$.

In the 2nd harvest K uptake plot^{-1} was seen to increase in almost all the treatments except in T_4, T_7 and T_{10}. K uptake ranged between 510.50 mg plot $^{-1}$. in control plot T_1 to 6940.70 mg plot $^{-1}$, the highest K uptake recorded with treatment T_5. The effect of three treatments namely T_1, T_3 and T_5 on nutrient uptake was given in fig.12.

4.4.7 Nutrient status of soil

The soil samples from all the plots were analysed for pH, organic carbon, major nutrients like N, P and K and CEC at the beginning and end of the crop. The initial status of the soil before receiving the treatments were given in Table 4.38. and data indicated that the fertility status of the selected plots are of uniform

Table 4.38. Status of various parameters like pH, CEC, organic carbon and available major nutrient contents of pre treated soil

Treatments	pH	CEC (C mol (+) kg^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	6.01	3.08	1.15	263.84	14.62	82.20
T_2	6.03	3.05	1.13	260.93	14.62	82.36
T_3	6.01	3.06	1.11	265.66	14.59	81.99
T_4	5.99	3.08	1.15	263.16	14.60	82.52
T_5	6.01	3.08	1.13	260.99	14.61	80.98
T_6	6.03	3.06	1.15	262.18	14.56	81.67
T_7	6.03	3.04	1.17	263.84	14.62	82.42
T_8	6.01	3.06	1.15	261.11	14.61	83.10
T_9	6.02	3.05	1.11	265.67	14.60	82.00
T_{10}	6.05	3.08	1.10	262.93	14.63	82.20
T_{11}	6.01	3.05	1.15	262.18	14.62	82.21
T_{12}	6.05	3.06	1.11	265.38	14.69	81.98

fertility. The effect of treatments on pH, CEC,Organic Carbon and available major nutrient contents of soil was given in Table 4.39.

The pH of the soil after harvest ranged from 6.29 in treatment T_6 to 5.72 in treatment T_8. pH of soil seemed to increase in almost all treatments at the end of harvest except in treatments T_8 and T_9, T_{11} and T_{12}. Treatment T_5 with 5 t ha^{-1} of compost and full dose of NPK, T_7 with 2.5 t ha^{-1} of compost and T_{10} with 1 t ha^{-1} of compost recorded a pH of 6.18, 6.19 and 6.18 respectively which were on par.

The CEC of soil recorded after the harvest showed significant variation between treatments ranging from 6.73 C mol (+) $kg^{-1}$of soil to 2.42 C mol (+) kg^{-1} of soil. The highest CEC of 6.73 was recorded for treatment T_4 receiving 5 t ha^{-1} of enriched compost followed by T_5 and T_7 with values of 4.85 and 5.2 respectively and were on par. The lowest value was recorded by T_{12} receiving 1 t ha^{-1} of compost along with ½ dose of NPK as per POP.

After the harvest of the crop, organic carbon status of the soil ranged from 1.15 in T_1 to 1.75 in T_5. There was significant difference in the percentage of organic carbon between the treatments except in case of T_5 and T_6 which were on par. The organic carbon content of T_4, the treatment receiving 5 t ha^{-1} of compost was for superior than treatment T_2 receiving 5 t ha^{-1} of FYM as well as treatment T_3 receiving 5 t ha^{-1} FYM and full dose of NPK.

The available N status showed a considerable increase after the harvest of the crop is almost all the treatments except in T_1, the control. The available N status ranged from 263.84 to 390.34 kg ha^{-1}. The highest available N status of 390.34 kg ha^{-1} was recorded in treatment T_5 followed by treatment T_3 and T_8 which recorded value of 361.74 kg ha^{-1} and 348.63 kg ha^{-1} respectively. Treatments T_9 receiving 2.5 t ha^{-1} of enriched compost along with ½ dose of NPK

Table 4.39. Effect of treatments on pH, CEC, organic carbon and available major nutrient contents of soil

Treatments	pH	CEC (C mol (+) kg^{-1})	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1	6.08^{e}	3.08^{d}	1.15^{g}	263.84^{j}	14.60^{h}	82.20^{i}
T_2	6.10^{d}	3.27^{d}	1.20^{fg}	300.5i	16.20^{gh}	89.30^{fg}
T_3	6.05^{f}	4.23^{c}	1.50^{bc}	361.74^{b}	18.70^{defg}	96.70^{bc}
T_4	6.30^{a}	6.73^{a}	1.62^{ab}	326.43^{f}	23.50^{bcd}	92.40^{c}
T_5	6.18^{c}	4.85^{b}	1.75^{a}	390.34^{a}	27.60^{a}	109.00^{a}
T_6	6.29^{b}	4.05^{c}	1.69^{a}	340.76^{d}	25.40^{ab}	98.00^{b}
T_7	6.19^{c}	5.20^{b}	1.32^{def}	318.92^{g}	18.60^{efg}	88.10^{g}
T_8	5.72^{j}	3.04^{d}	1.45^{cd}	348.63^{c}	24.20^{abc}	97.60^{bc}
T_9	5.80^{i}	3.19^{d}	1.38^{cde}	336.13^{e}	21.70^{bcde}	90.30^{f}
T_{10}	6.18^{c}	3.25^{d}	1.21^{fg}	369.54^{h}	16.50^{gh}	95.30^{h}
T_{11}	5.90^{h}	2.99^{d}	1.28^{efg}	338.72^{de}	20.80^{cdef}	95.60^{cd}
T_{12}	6.01^{g}	2.42^{e}	1.25^{efg}	328.32^{f}	17.20^{fgh}	93.70^{de}

as per POP and treatment T_{11} receiving 1 t ha^{-1} of enriched compost along with full dose of NPK as per POP were seen to be on par.

After the harvest of crop the soil available P status significantly differed between treatments, with the highest value of 27.60 kg ha^{-1} recorded for treatment T_5 immediately followed by treatment T_6 with a value of 25.40 kg ha^{-1}. The lowest soil available P was 14.60 kg ha^{-1} , recorded for treatment T1. However for all the treatments there was considerable increase in the available P status of soil after harvest of the crop, when compared to the initial status.

After the harvest of the crop, the available K status of the soil showed significant variation between treatments ranging from 82.20 kg ha^{-1} for T_1 to 109.00 kg ha^{-1} for T_5. It was followed by T_6 which recorded a value of 98.00 kg ha^{-1}. T_3 and T_8 followed next with par values of 96.70 kg ha^{-1} and 97.60 kg ha^{-1} respectively.

Discussion

5. DISCUSSION

The results of the various experiments on the basic properties of the waste material and the influence of both organic and inorganic enrichers while composting were detailed under section 4. The response of a sensitive crop to the addition of the best enriched compost material was also described under the same section. They were discussed below:

5.1. *Basic properties of Oushadi ayurvedic waste*

Studies on the basic properties of the material revealed that physico-chemical properties did not vary much at monthly intervals of sampling. Moreover observations on consistency, moisture content and temperature tend to fall within a specified range as the loading of waste material was almost at the same rate, type and amount. The pH values indicate that the material is neutral. Due to microbial population the dehydrogenase activity is also high. The material also registered a wide C: N ratio (35.72) necessitating proper composting. The low values of nutrient contents of P and K as provided in Table. 4.2. showed that the enrichment is necessary. The fairly high values of nitrogen (1.99 %) as compared to P and K signals the possibility of aerobic composting with native micro and macro organism.

The studies on the physico-chemical properties of the various substrates (Table. 4.3.) revealed that most of the fractions are lesser than 4.75mm in case of unsieved substrate and so sieving which is a cumbersome process is not much necessary. Moreover the same materials possess a moisture content of 52 per cent which will be a contributory factor in the easiness of composting. Though the reduced particle size is a good parameter for composting the moisture level of other two substrates of 4mm and 2mm size are comparatively low. The decrease in moisture content with increase in fineness of the substrate can be attributed to the reduced fibre content and high phenolic and lipid constituents, which were

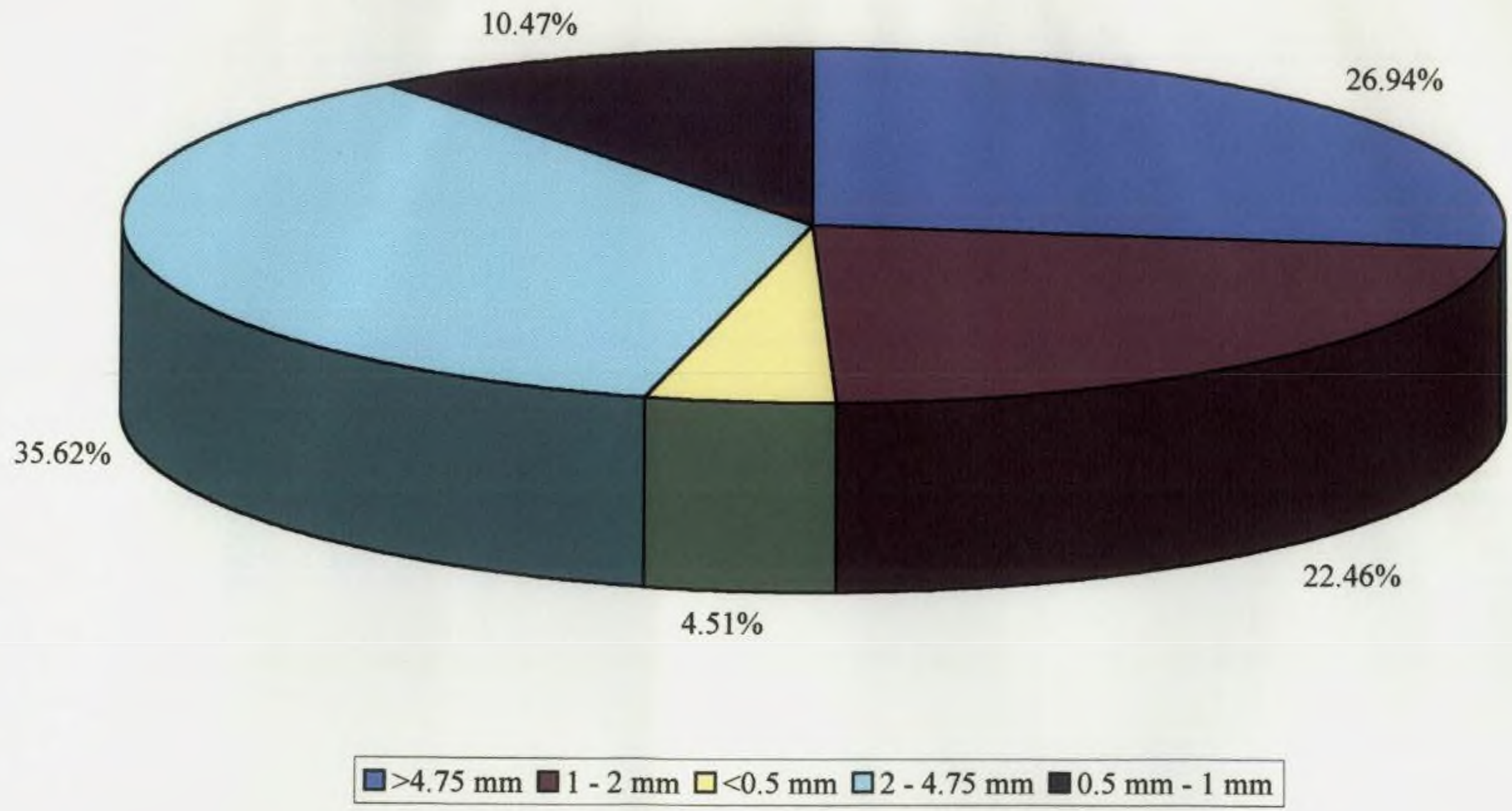


Fig. 2.Consistency of Ayurvedic waste

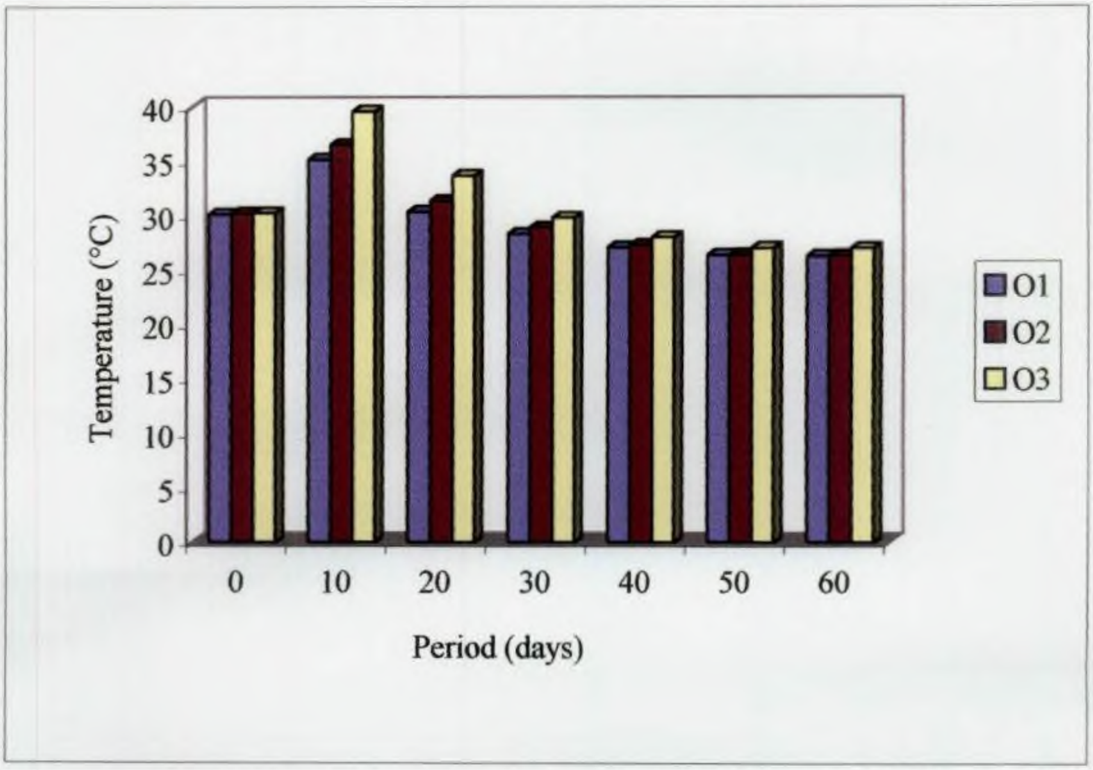
repulsive to moisture fractions. As reported by earlier workers (Gaur and Sadasivam, 1993) a substrate with 50 per cent inherent moisture and with dominance of finer fractions can assume congenial substrate controlled environment for rapid composting. The Oushadi waste which is available in ideal consistency and 52 per cent moisture content (Table 4.1.) can there fore be considered as a good substance without added efforts for sieving and separation.

5.2 Compost enrichment techniques

The results of the various enrichment techniques using organic and inorganic substrates on temperature, pH, microbial count and C: N ratio at different stages of composting is provided in Table. 4.3. to 4.18. They are discussed below:

5.2.1 Temperature

From the Table 4.3 to 4.6. the temperature showed an increase during the 1st fortnight of composting reaching a peak value of 41.86°C in case of organic enrichers and then decreased and stabilized towards the final stage of composting to around 27.24°C. In the case of inorganic enrichers also the same trend was noted but with lower peaks as well as stabilized values. Here the temperature reached a peak of 35.3°C which stabilized around 26.77°C towards the end of composting. Irrespective of treatments, the whole fluctuations in temperature tended to specify 3 stages in composting - mesophilic with a mean value around 27.3°C, thermophilic, a mean value around 38.86°C and maturity stage around 27.24°C. Supportive findings were reported by Gaur and Sadasivam (1993); Eghball *et al.* (1997); Klamer and Baath (1998) and Thomas (2001). Several workers have demonstrated that there is rapid degeneration of organic matter at thermophilic stage (Hashimoto *et al.*, 1981; Lo and Marsh, 1985; Kinochie *et al.*, 1988). In all composting processes, thermophilic stage is of great importance. The elevated temperatures of 40-50°C, found during the thermophilic stage are



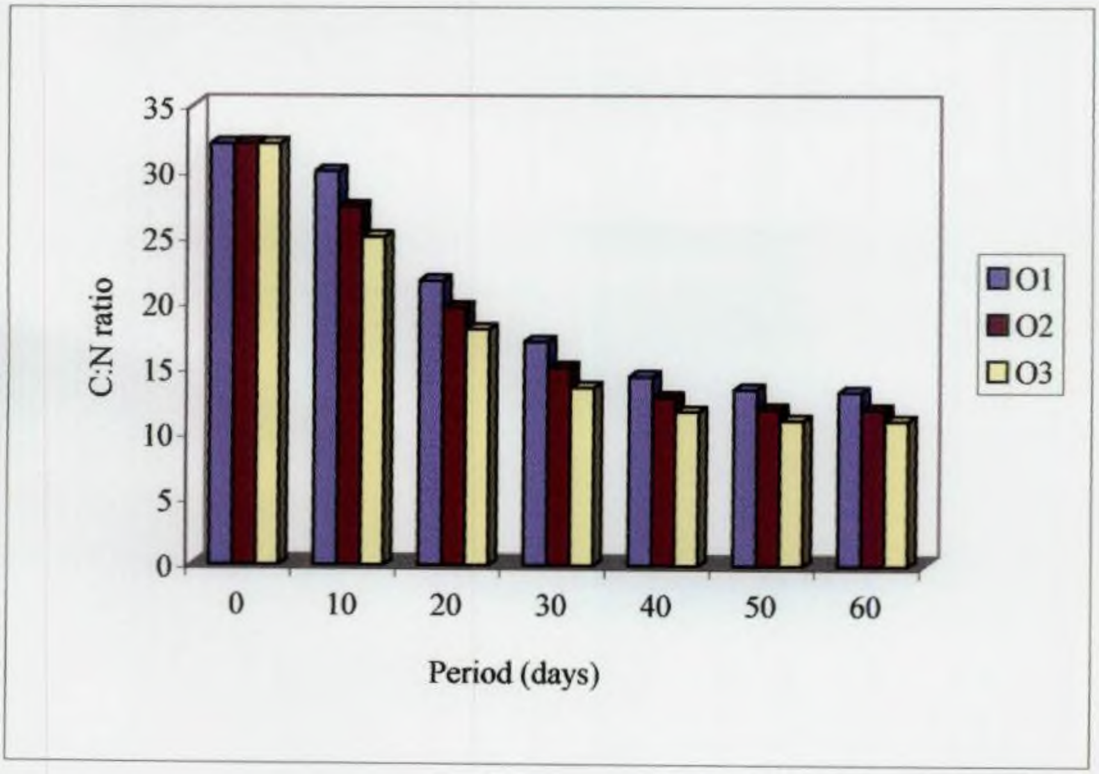


Fig. 3. Effect of substrates with organic enrichment on temperature (°C) and C:N ratio at different periods of composting

essential for rapid degeneration of lignocellulose, as the thermophilic micro fungi and actinomycetes involved in rapid degeneration of complex organic compounds, thrive at that temperature (Tuomela *et al.*, 2000). So there exists an intrinsic relationship between temperature and the time of composting. Maturity of compost always coincides with the temperature stabilization period.

Particle size also plays a major role in rate of decomposition and thereby determining the time taken to attain maturity. From the Table 4.4. and 4.6. it was clear that the highest temperature and hence quicker decomposition was observed with 2 mm sieved substrates at different stages of composting compared to 4 mm sieved and unsieved substrates. On consideration of the different particle size of the substrates, the maximum and minimum temperatures at all stages of composting were recorded in 2 mm sieved substrates and unsieved substrates respectively, irrespective of type of enrichers used, whether organic or inorganic. In case of unsieved substrate the water retention is more and hence temperature never rises to very high values though it also got composted satisfactory without much variation in the period of maturity. The hike in temperature for the finer substrate is understandable in the backdrop of microbial proliferation enhanced by the greater surface area of the substrate (Gaur and Sadasivam, 1993; Gaur, 1980). However, the particle constitution as discussed under section 5.1. provides satisfactory explanation for the comparable compostability and period of maturity of the unsieved substrate.

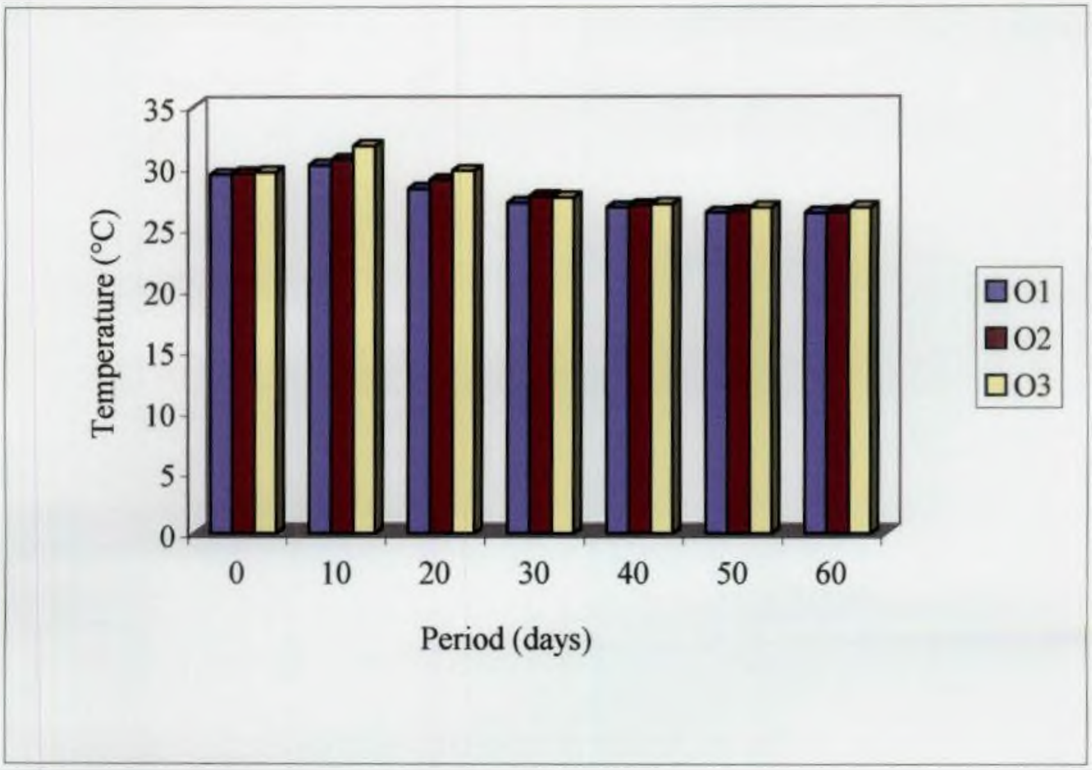
During the different stages of composting, the treatments with mixtures of cow dung, poultry manure and neemcake at higher concentration (15%) showed higher temperature. On perusal of the data given in Table 4.4 and 4.6. it was revealed that the values of maximum temperature recorded at thermophilic stage was high for organic enrichers than on inorganic ones. The same trend in temperature was observed in substrate enrichment interactions also.

5.2.2 pH

The trend in pH fluctuation was different from that of temperature. pH raised from a near neutral value of 6.8 during first 10 days to about 8.00 during the period of 20-30 days after composting. Then it decreased afterwards and reached a stable value of around 6.3 at the end of composting. This was supported by the findings of Wilson (1989). The decrease in pH during the first 10 days was due to the building up of organic acids, an intermediary product of biological degradation of starch, proteins and fats (Biddlestone and Grey, 1985) and then a corresponding increase in pH consequent to assimilation of these products and their further conversion to simplified units. Most materials decomposing aerobically will come within a pH range that is conducive for microbiological growth thus eliminating the need for pH control (Gaur and Sadasivam, 1993). Unlike in the case of temperature, the variations in pH within the treatments was not clearly noticed. The particle size of the substrates (Oushadhi waste) also had negligible effect on pH variation irrespective of organic and inorganic enrichers.

5.2.3. C: N ratio and compost maturity period

C: N ratio is another maturity parameter that determines the worth of compost as manure (Golueke, 1977 and Chanyasak *et al.*, 1982). C: N ratio is the most conventional index, which reflects organic matter decomposition and stabilization during composting. As composting proceeds, the microflora use the substrate carbon as energy source and carbonaceous materials are converted into microbial biomass, CO_2, water and humus. N is used for cell building. It is the major nutrient required by microorganisms in the assimilation of carbon compounds in the organic wastes. Decomposition involves the reduction of relative proportion of elements to a point where available carbon has been totally consumed and bacterial activity ceases.



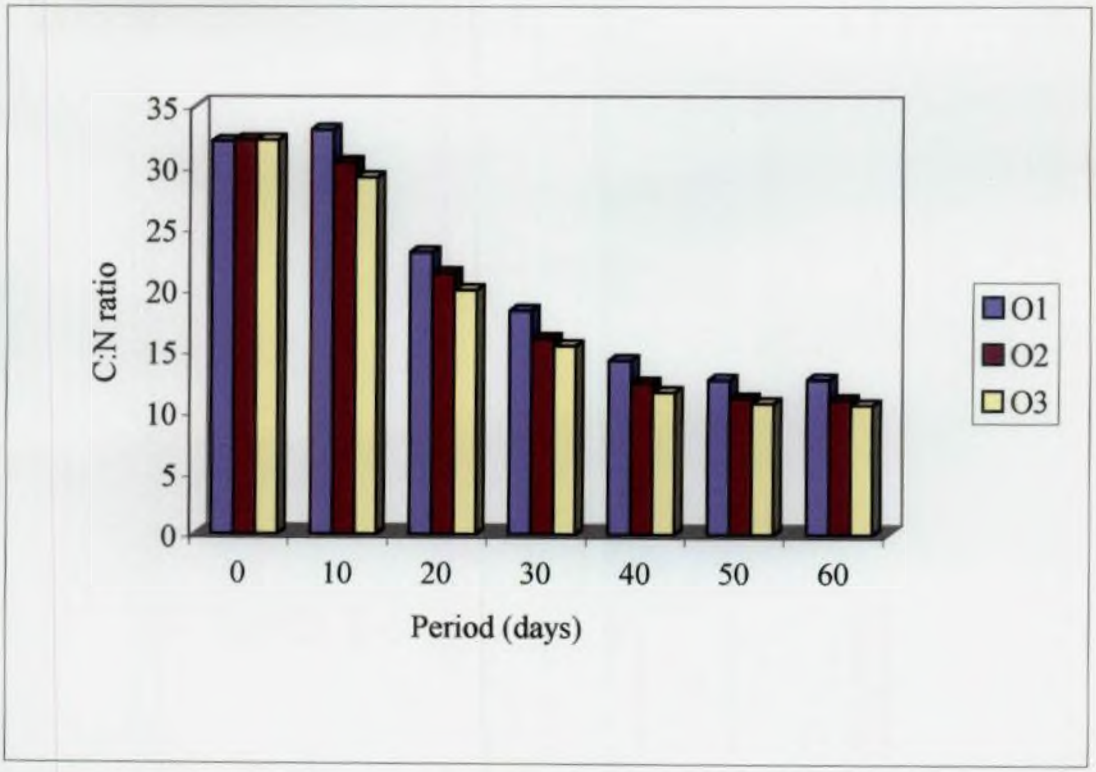


Fig. 4. Effect of substrates with inorganic enrichment on temperature (°C) and C:N ratio at different periods of composting

In the present study there was a pronounced decrease of the C: N ratio in all treatments. This was in accordance with findings of Shen-Qi-Rong *et al.* (1997) and Xu *et al.* (1997). During initial stages the C: N ratio was around 35 in all treatments. The value then decreased to a range of 10 to 12. According to Jimenez and Garcia (1992) C: N ratios ranging from 10 to 12 can be considered as an indicator of stable and decomposed organic matter.

The influence of substrates over C: N ratio was also studied. It was seen that the 4 mm sieved, 2 mm sieved and unsieved substrates were having a C: N ratio of about 32 in case of organic and inorganic enrichers. These values decreased to a range of 11-13 in case of organic enrichers and 10-12 in case of inorganic enrichers. The lowest C: N ratio of 11.00 in case of organic enrichers and 10.6 in case of inorganic enrichers was recorded for the 4 mm sieved samples with comparable values for other substrates as well, indicating the overall acceptability of the Oushadi waste as a good material for composting.

With regard to the influence of substrate enricher on C: N ratio, it was seen that the lowest value of C: N ratio was observed in treatment combination of cowdung, poultry manure and neemcake each at 15 per cent of substrate. The highest C: N ratio was observed for the combination of Neemcake and waste material as well as cowdung and waste material. In the case of inorganic enrichers, the lowest C: N ratio was observed for the treatment receiving both urea and rockphosphate at higher levels (5%). This can be due to the fact that in both type of enrichers the treatment with low value of C: N ratio records high temperature and microbial activity at all stages of composting. This might have lead to the rapid destruction of organic carbon and increase in nitrogen content. This was in accordance with findings of Bandawi *et al.* (1997)

The compost maturity period was lowest in case of organic treatments. The treatments combination of Oushadhi waste along with cowdung, poultry manure and neemcake each at 10 per cent and 15 per cent recorded lowest values. The maturity period of poultry manure enriched treatments were lower due to high temperature and microbial biomass resulting in rapid degradation. Moreover Press *et al.* (1996) had found that organic enrichers like poultry manure had brought shift in bacterial populations and changes in species richners (number of species detected) and evenness (relative abundance of each species). There shifts appear to be the result of increased substrate for carbon mineralisation, rather than any properties of biological control. When inorganic treatments and organic treatments are compared the maturity period required for organic treatments is slightly less than inorganic treatments. The lowest maturity period was detected by the treatment receiving a combination of urea and rock phosphate at higher levels.

5.2.4 Dehydrogenase activity

The results of the microbial count determined as dehydrogenase activity of the various treatments at different stages as influenced by various substrates, substrate enrichers and their interactive combinations are provided in Table. 4.16 to 4.19. The relevant points are discussed below.

The microbial activity as indicated by the dehydrogenase activity is lower during the initial mesophilic stages and then it increased to a maximum value at thermophilic stage, and then again decreased towards maturity. When considering the activity in mesophilic and maturity stages it was found that the activity was more in maturity stages than in mesophilic stage. The dehydrogenase activity at mesophilic, thermophilic and maturity stages of the superior treatment is 560.7, 1675.78 and 1052.92 respectively. The same trend was noticed in case of inorganic enrichers also.

The highest microbial population and the consequent increase in temperature was observed within the first fortnight of composting. This was due to the capacity of microbes to synthesize enzyme involved in breaking down

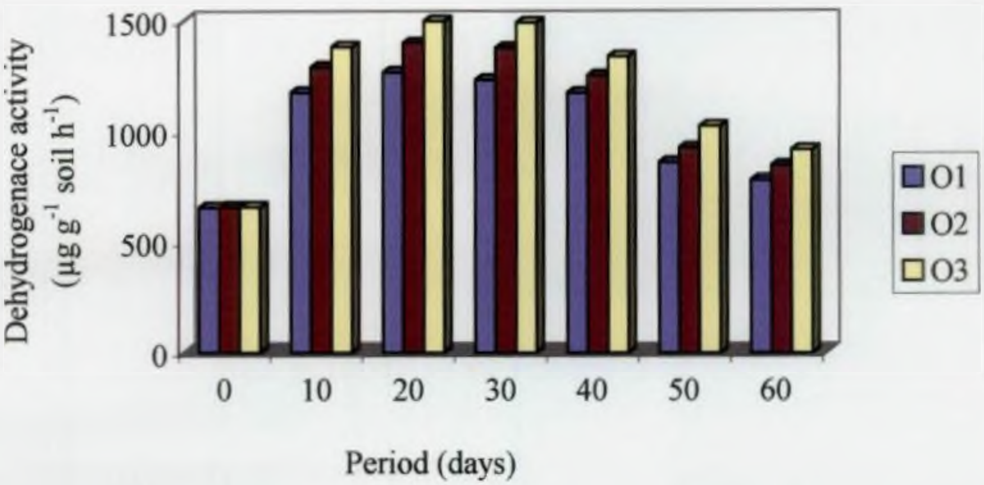


Fig. 5. Effect of substrates with organic enrichers on dehydrogenase activity (µg g^{-1} soil h^{-1}) at various periods of composting

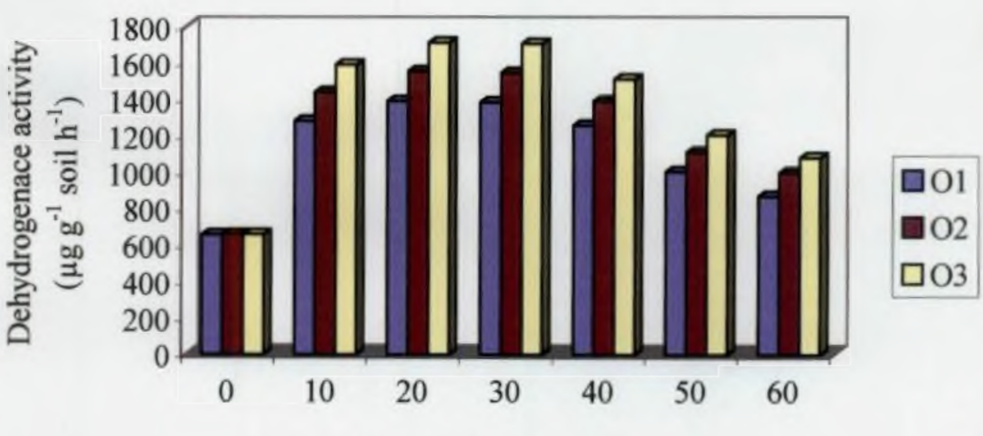


Fig. 6. Effect of substrates with inorganic enrichers on dehydrogenase activity (µg g^{-1} soil h^{-1}) at various periods of composting

complex compounds into intermediate simpler metabolites (Gaur and Sadasivam, 1993; Gaur 1999). Hence there is an intrinsic relationship between temperature and bacterial build up during biodegradation of complex molecules to simpler ones.

With respect to the substrates, the 2 mm sieved substrates recorded the maximum dehydrogenase activity at all stages of composting both in organic and inorganic enrichers compared to unsieved substrates. This was due to the much cohesive nature of the substrate, which encourages more microbial activity. Moreover due to fine particle size the surface area available for the microbes to act upon was greater in 2mm sieved substrates, which in turn was responsible for greater microbial activity.

In the case of organic enrichers, maximum dehydrogenase activity was recorded by the treatment containing mixture of cowdung, poultry manure and Neemcake each 15 per cent of Oushadhi substrate. This high activity may be due to the proliferation of thermophilic microorganisms due to the high temperature maintained by this treatment in all stages of composting. The direct relationship between temperature and microbial count was evident from this aspect.

While considering the inorganic enrichers, the treatment with combination of urea and rock phosphate at higher levels recorded the maximum activity. When the different treatments were compared it was seen that the treatments receiving rock phosphate alone has higher activity than those really urea alone. Thus rock phosphate was found to be a good starter material to stimulate microbial activity in the compost system (Bhardwaj and Gaur, 1985; Hajra *et al.*, 1992 and Manna *et al.*, 1997). Inorganic enrichers also showed the same trend as in case of organic enrichers irrespective of the treatments.

5.2.5 Major nutrient contents of the Oushadhi waste and the resultant compost material

The initial and final nutrient contents of compost material as influenced by substrates, substrate enrichers and their interactions are provided in Tables. 4.24 to 4.31. and the relevant points are discussed below.

Regarding the variations in the initial nutrient concentration of the different materials, there is only a vague indication, as the sampling was done immediately after the substrate enrichment. But the data provided at the final stage showed a clear indication that at the final stage of composting there was drastic increase in the nutrient contents of N and P irrespective of treatments while the content of K showed a decrease towards maturity in all treatments.

With regard to substrates, in general the initial N content ranged from 2.49 per cent to 2.96 per cent in the unsieved and 2 mm sieved substrates respectively. Coming to inorganic enrichers the N content was 3.06, 3.19 and 3.64 per cent for unsieved, 2 mm and 4 mm sieved substrates respectively. This increased in N content of the substrate can be attributed to the addition of inorganic enrichers like urea at different levels which is more concentrated with regard to N.

The range of initial P content of organic treatments varied from 0.19 per cent to 0.27 per cent in case of unsieved and 2 mm sieved substrates respectively whereas the P content of inorganic treatments of the same substrates recorded a value of 1.15 per cent and 1.61 per cent respectively. In case of initial K content, the organic treatment recorded values of 0.58, 0.64 and 0.8 per cent for unsieved, 4 mm sieved and 2 mm sieved substrates respectively. The values were 0.37 per cent, 0.44 per cent and 0.53 per cent for the three substrates in case of inorganics. The higher initial nutrient content of the substrate with inorganic enrichers can be attributed to the addition of inorganic enrichers like urea and rock phosphate.

The initial K content was found to be more in treatments with organic enrichers. This can be attributed to the fact that the enrichers namely cowdung, poultry manure and neemcake contributed to the higher content of K. Since the K content in the inorganic enrichers used was negligible when compared to organic enrichers, the final K content in the compost was attributed only to the inherent content of the substrates.

With respect to the final nutrient content also the 4 mm sieved substrate showed a higher content of nutrients irrespective of enrichers. But the total content of nutrients was higher in inorganic enrichers. Generally the N and P content shows an increase in the content while the K content showed a decrease as the final stage of composting.

While considering the effect of enrichers on the nutrient content, in case of organic enrichers maximum nutrient content with reference to N, P and K was shown by the treatment receiving combination of cow dung, poultry manure and neemcake at higher levels. Poultry manure could be used as a good source of nutrient with 60 per cent nitrogen as uric acid, 30 per cent as more stable organic nitrogen and balance as mineral nitrogen (Srivastava, 1988). It was immediately followed by the treatment combination with cow dung, poultry manure and neemcake at 10 per cent of the substrate. When coming to inorganic enrichers the highest quantity of P was shown by the treatment receiving high quantity of rockphosphate and urea (Gaur, 1982). The N content of the treatments containing urea and rockphosphate both at 2.5 per cent and 5 per cent were found to be on par. This is supported by the findings of Bhriguvanshi (1988). The initial and final nutrient content of organic and inorganic enrichers were given in fig. 7,8,9 and 10 respectively.

Even though the potassium content showed a decrease towards the final stage of composting it was on par with the treatments with urea and rockphosphate both at 2.5 per cent and 5 per cent each. The reduction in K content

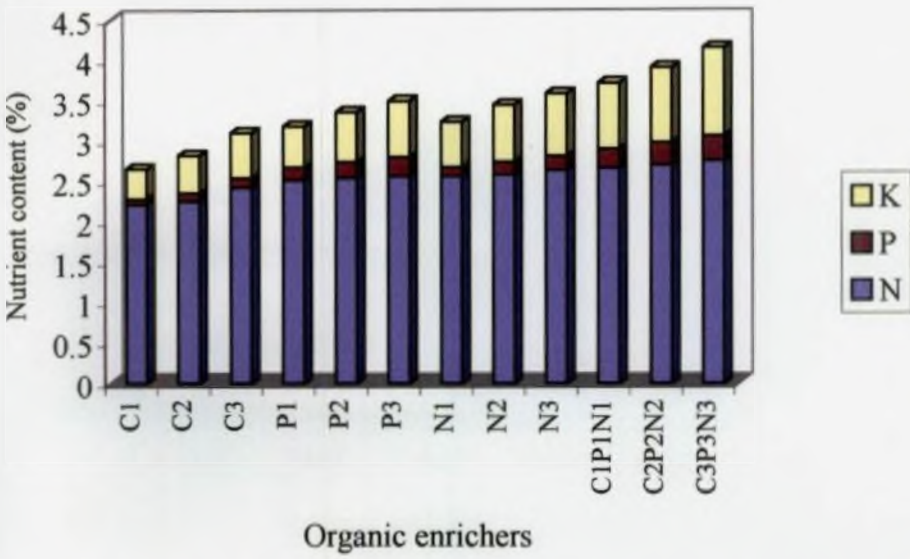


Fig. 7. Effect of organic enrichers on contents of N, P and K at initial stages of composting

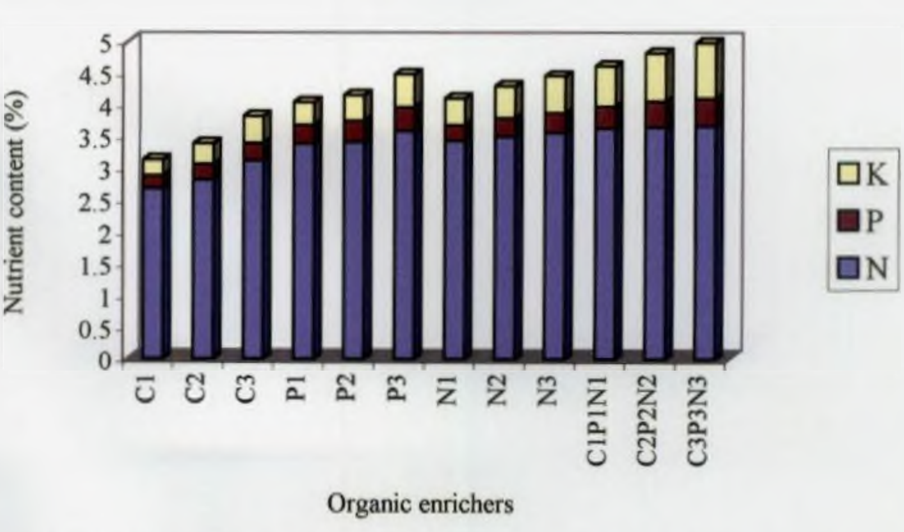


Fig. 8. Effect of organic enrichers on contents of N, P and K at maturity

may be attributed to reasons like low mineralisation function of K while composting, low content of K in the enrichers like cow dung. Gaur *et al.* (1971) reported that chemical composition of compost varies depending on the sources from which it is prepared. The low potassium content of the original Oushadi substrate is one of the reasons for the reduction in K content due to composting. Moreover the K is not bound to any organic compound in the plant. Hence organic matter decomposition is not an index of potassium availability (Mengel and Kirkby, 1987)

Moreover nitrogen mineralizing as well as phosphorus solubilising organisms present during composting may increase the availability of those elements, but due to the peculiar nature of the element potassium, different microorganisms have no role in increasing its availability. Availability of K mainly decided by weathering of minerals. Organic matter decomposition is not an index of potassium availability. Also substrates itself have certain inhibitory factors, which will retard the K availability during composting. However further clarification in this regard is needed.

5.3 Selected enriched compost

The physico-chemical properties of the selected enriched compost were given in Table. 4.33. and 4.34. The selected compost(unsieved substrate enriched with cow dung,poultry manure and neem cake each at 10 % level) maintained a stable C:N ratio of 12 which gives an indication of maturity attained by it. Moreover the compost was odourless. This is because, most well stabilized compost had a pH range near neutral, which reduced the volatilization of ammonia and other compounds (Wilson, 1989). Regarding the nutrient content the N, P, and K content of the compost where 3.25 per cent, 0.36 per cent and 0.68 per cent respectively. This was appreciably higher than the nutrient content of the original material. This gives the importance of enriched composting.

5.4 Field studies

From the results of the present investigation as indicated in section 4.3 it can be seen that the application of manures and fertilizers together imparted a significant effect on the vegetative growth of amaranthus. The influence of enriched compost was highly perceptible in all the growth characters studied. Plant height and fresh weight were found to be maximum with the treatment that received the highest dose of compost and full dose of NPK fertilizers (T_5). The same treatment exhibits much superiority over the treatment which received almost the same doze of FYM and fertilizers (T_3). This clearly indicates the influence of compost on improved plant metabolism leading to higher utilization of plant nutrients. Compost has beneficial effects on soil microorganisms and thus improves its physical (Gaur *et al.*, 1971 (b)) and chemical characteristics (Gaur *et al.*, 1972). The direct effects relate to the uptake of humic substances favourably affecting plant growth and metabolism. In contrast to FYM, the presence of Nitrogen fixing bacteria (De Bertoldi *et al.*, 1982) in the compost may lead to an increased Nitrogen content of the soil by biological nitrogen fixation together with the increase in plant growth. The microbial content also influences the type of nutrient cycling that compost may provides (Zaremba *et al.*, 1998).

5.4.1 Yield and Yield attributes

The yield of a crop may be considered in biological as well as agricultural terms. Biological yield has been defined as the total production of plant material by a crop whereas the economic yield takes into account only those parts for which particular crops are cultivated and harvested. As the harvestable produce is the end result of effective sinking of photosynthetic assimilates (Bidwell, 1974 and Devlin and Witham, 1986) yield is influenced by vegetative as yield attributing characters.

For crop plants like Amaranthus, the amount of plant material produced above ground is equivalent to economic yield. The dependence on the vegetative growth stage lies in the fact that during this period grown plant tissues are formed, which provide photosynthates for entire plant growth. As meristematic tissues have a very active protein metabolism, photosynthates transported to these sites are used predominantly in the synthesis of nucleic acids and proteins. So nutrition plays a major role in this aspect.

The yield obtained during the 1st and 2nd harvest was high in T_5 (selected compost 5 t ha $^{-1}$ + full dose of inorganic fertilizers) than in T_3 which receives a combination of equal quantity of FYM and full dose of inorganic fertilizers. Moreover there was significant difference between yields in the control plot and the superior treatment. As yield is the manifestation of the complementary functions of innate genetic constitution (Russell, 1963;) and desirable environmental characters, the differences observed in the study can definitely be attributed to the nutritional physiology dependant to the nutritional source, the compost material. The effect of compost on better yield and quality of different crops was reported by Hornick *et al.* (1984); Lazic *et al.* (1992) in capsicum and also by Sikora and Yakovchenko (1996) in different crops.

The study also indicates that importance of balanced fertilization as the highest yield of 1880.63 g/plot and 1920.7 g/plant during 1st and 2nd harvest was obtained for treatment which combines the highest quantity of compost and full doze of inorganic fertilizers. The same result was reported in case of rice and wheat (Fawaz *et al.*, 1997) and also in bell pepper (Roe *et al.*, 1997). The effect of compost in general in yield and growth parameters were noted by Roe *et al.* (1997), Devliegher and Rooster (1997) ,Warman and Haward (1998) and Patra *et al.*,(2000)

It can be inferred from the experiment that the complete substitution by the organic fertilizers was not possible. It was evident from the Table. 4.36. which

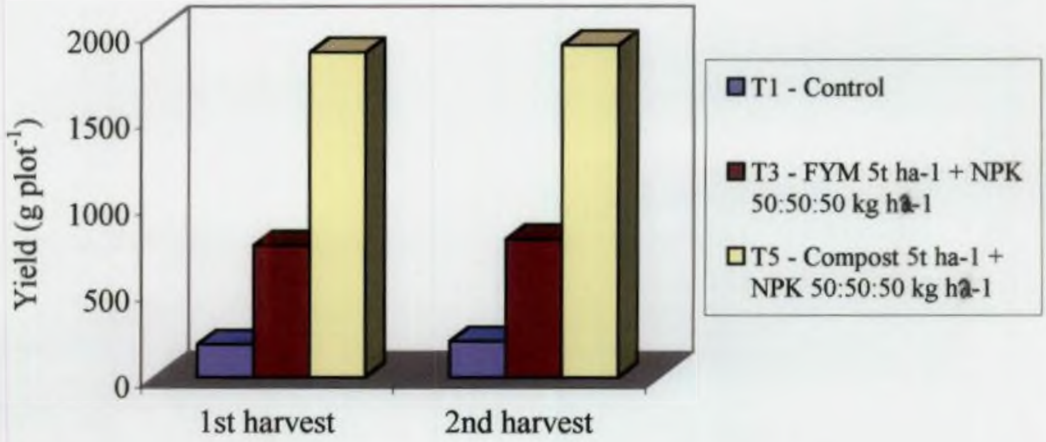


Fig. 11. Effect of various treatments on yield (g plot^{-1}) during first and second harvest

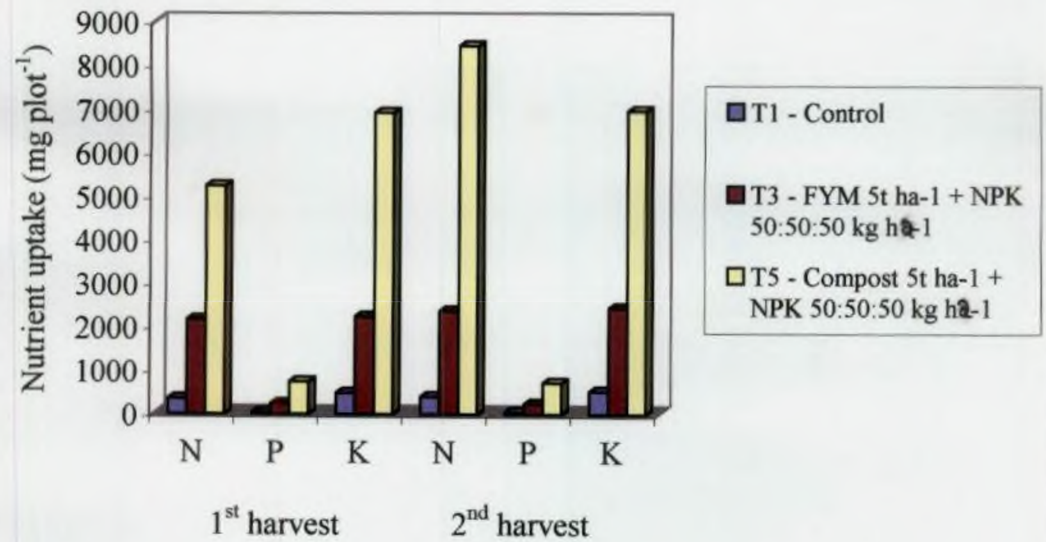


Fig. 12. Effect of various treatments on nutrient uptake (mg plot^{-1}) during first and second harvest

shows that the treatment receiving the highest quantity of organic matter only shows a lower yield than all the treatments which receives combination of organic fertilizer and inorganic fertilizer. Inorganic and organic fertilizers however differ in the availability of the nutrients they contain. Nutrients in inorganic fertilizers are directly available to plants whereas the nutrients of organic materials especially organic nitrogen are of low availability (Kumaraswamy, 2002). Only about one third nitrogen of FYM applied to the soil is available to a crop in the first year. Thus relatively slow release of N by organic fertilizers in comparison with inorganic N fertilizers have some effect on environmental factors for the release of N. A comparison of yields obtained by the three treatments namely T1, T3, and T5 during the two harvests were given in fig.11.

The conversion of the amino nitrogen and the heterocyclic nitrogen of organic substances via reduction to ammoniacal nitrogen and then the subsequent oxidation to nitrate nitrogen is accomplished by a number of soil microbes (Brady, 1996). The metabolic activities of these organisms are highly dependent on soil conditions. The observations on yield and dry matter accumulation of the present study tends to conclude the fact that the complete substitution of inorganic fertilizers by organic manures such as FYM or compost is not a feasible proposition due to scarcity of manures. However sustained productivity and profitability of short duration crop under organic farming needs to be explored in expanded investigation.

5.4.2 Nutrient uptake

Nutrient content of a plant at any point of time is a function of its availability and is a factor for growth where as nutrient uptake is a function of growth, absorption and accumulation. Nutrient concentration in plant is influenced by variety of crop, soil climate and management factors which ultimately results in nutrient removal by crop, which is also directly related to yield . Nutrient uptake by different crops is a fairly good guide for the response of the crops to fertilizers. The response of crops to fertilizer application directly depends on the chemical composition of the soil in respect of the available plant nutrients. Vegetables are generally heavily manured with organic manures. A balanced use of NPK is necessary to obtain good yields of these crops. In the case of vegetable crops, response to nitrogen is most conspicuous. Haris (1989) previously reported a higher plant content of nitrogen due to higher levels of nitrogen nutrition. Similar results was obtained by Parmar *et al.* (1988) in vegetable pea. The experiments conducted by Lavanya and Manickam (1993) accorded an increased nutrient content in ragi crop by adding compost with 75 per cent recommended dose of NPK. Sukumar (1997) obtained significantly increased nitrate content in amaranthus with an increase in level of soil nitrogen.

The increase in phosphorous uptake in the initial stages can be attributed to the increased P availability due to organic matter application. The availability and uptake of P increases as a result of formation of organophosphate complexes that are more easily assimilated by plants, anion replacement of $H_2PO_4^-$ on adsorption sites and reduction of P adsorption due to the coating of Fe and Al by humus particles. Moreover the need for P by plants is most critical at early growth stages. Hence P absorption is more in early growth stage. The application of compost increases the P uptake since the microbial biomass and enzyme phosphatase activity get increased by the application of compost (Gagnon *et al.*, 1998). Phosphorous availability is increased by increase in solubility of P by higher phosphatase activity .

5.4.3 Nutrient status of soil

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

In this suitable pH range the population of Nitrogen fixing bacteria and actinomycetes will flourish resulting in increased N content of the soil (Brady, 1996). At low pH inhibition of N fixation by higher concentration of H^+ ion and presence of Fe or Al ions was reported by Mohan *et al.* (1987). Application of organics helps microorganisms to produce polysaccharides resulting in better soil structure, N fixation and P solubilization (Balasubramaniam *et al.*, 1972; Swarup, 1984). More (1994) also reported the increased status of organic carbon, available N, P and K of soil by applying organics. Edward *et al.* (1996) reported an increase in soil P, K, Ca and Mg in surface by a factor of 3 or 4 times by compost application. From the Table we can see that the soil nutrient status with refer to N, P and K showed considerable increase when compared to initial soil status. Within the treatments also the treatment which is found to be superior excelled all other treatments with refer to nutrient content.

The selected compost having a comfortable C: N ratio of around 10-12 can release inorganic phosphates from insoluble rock phosphate with the help of microbial activity and phosphatase activity (Alexander, 1978 and Gagnon *et al.*, 1998). The process of solubilisation of added rock phosphate by the organic acids and other ligands present in organics must have played a vital role in releasing insoluble soil P (Gaur, 1992). Faster degradation of organic matter leading to a better mineralisation pattern consequent to high microbial activity results in enhanced released of basic cations like K^+ (Ammal and Muthiah, 1994).

The organic carbon content of the soil both initial and final were depicted in Tables. 4.38. and 4.39. Initially the soil OC was around 1.2 which increased to a value of 1.75 in T_5. All the treatments which receive highest doze of compost showed high reading. It is then followed by treatment T_3 which receives almost same quantity of FYM as of compost and full dose of inorganic fertilizers. Earlier

Hoffman (1983) reported that application of compost will increase the organic matter content from 2 per cent to 6.9 per cent. Similar results were also reported by Guidi *et al.* (1983) and Guisquini *et al.* (1995). Work by Shanmukham and Ravikumar (1980) proved an increase in organic carbon content of soil by application of organic matter in alkali soils. Adhikari *et al.* (1997) and Gagnon *et al.* (1998) reported that compost treated soil maintained higher organic carbon and microbial biomass carbon compared to untreated soil.

Application of organic manure has beneficial effects on soil microorganisms and thus improve its physical (Gaur *et al.*, 1971, 1973) and chemical characteristics (Gaur *et al.*, 1972). This is evident from the Table. 4.38 and 4.39. From this tables we can have a comparison of initial and final CEC of compost treated soil. Before receiving organic manures the soil is having an initial CEC of around 3.11. By the application of organic manures the CEC attains a value of 6.73 in soil which receives full dose of compost alone. The CEC of all plots widnessed a significant increase than control plot thus emphasizing the role of organic matter in improving the soil physical properties. Enhancement of CEC by compost application was reported by Reddy (1973) Raja and Raj (1979) and Balasubramaniyam (1981). Ravikumar and Krishnamurthy (1980) gave a positive relationship between organic carbon and CEC of soil. Venkataraman (1984) also proved the generation of higher concentration of cation by organic material than control. Increased CEC of soil by compost application was reported by Venugopal (1995) and Cresswell (1997). The beneficial effects of organic wastes on soil physical properties are increasing water infiltration, water holding capacity, water content, aeration and permeability, soil aggregation and rooting depth and decreasing soil crusting, bulk density, runoff and erosion (Blanco and Almendros, 1997). There were also works to show that application of compost increased the total porosity, availability of water and buffering capacity of soil and thus in turn resulted in improved physical condition of soil (Thampan, 1993 and Pdilli and Mbah, 1998).

Summary and Conclusion

SUMMARY AND CONCLUSION

Study on the "Aerobic composting and enrichment of Ayurvedic waste" was conducted at College of Horticulture, Vellanikkara during the period 2001-2003. The experiment included:

i) a preparatory study to confirm the basic physico-chemical properties of the waste material.

ii) an enrichment study to standardize the best substrate controlled micro environment in the composting of ayurvedic waste.

iii) a field study with the crop amaranthus, near vegetable seed farm, Department of Olericulture, to evaluate the effectiveness of the selected enriched compost on crop and soil.

In order to conduct the preliminary study on the basic physico-chemical properties of the waste material, composite samples were taken from the Oushadhi Pharmaceutical Corporation at Kuttanelloor at 10 days intervals for 6 months. Observations on consistency, colour, odour, temperature, pH, microbial count, C: N ratio and also the chemical composition of the waste material were taken during the specified intervals.

For standardization of formulation of compost, the waste material was categorized into three substrates i.e. unsieved Oushadhi Waste material, 4 mm sieved material and 2 mm sieved material. Then each substrate was enriched with different types of organic enrichers and inorganic enrichers at different levels. The organic enrichers used were cowdung, poultry manure and neemcake each at 5, 10 and 15 per cent of the substrate and their combinations at above levels. Urea and rockphosphate were the inorganic enrichers used each at 2.5 and 5 per cent levels and also their combinations. Then observations on temperature, pH, microbial count (dehydrogenase activity) and C: N ratio were taken at 10 days interval upto 2 months.

Besides this, the nutrient contents i.e., N, P and K and compost maturity of all the formulations were assessed. Based on these an enriched compost was selected and test verified in field studies with Amaranthus. Field study was conducted in micro plots of size 3 x 2 m^2 near the vegetable seed farm of Department of Olericulture. Observations on growth, yield attributes, nutrient uptake and soil nutrient status are taken during the study. The salient results are summarized below:

1. **Preliminary study**

- The Oushadhi waste is a light brown coloured, near neutral substance with a pleasant ayurvedic smell due to the presence of alkaloids and lipids.
- About 35.62 per cent of the particles has a size ranging between 2 - 4.75 mm and the waste in general had a moisture content of 53.56 per cent.
- The temperature of the waste was found to be 108.98°C with a high value recorded at July. The dehydrogenase activity of around 556.22 µg g^{-1} soil h^{-1} for the waste material indicates the survival of native micro-organisms in the substrate.
- The nutrient content of the waste was low with N, P and K contents of 1.99, 0.02 and 0.27 per cent respectively. This indicates the need for enrichment before composting.

2. **Standardization of formulations of enriched compost**

- During the composting process, the 2 mm sieved substrate registered the highest values of temperature, while the unsieved substrates registered the lowest values at all stages of composting.
- The temperature showed a hike in the value from 30.25°C to 39.59°C (O_3) after 10 days, then decreased and finally stabilized, thus pointing out the three distinct stages of composting - mesophilic, thermophilic and maturity.

- The temperature also showed highest values in organic enrichers compared to inorganic enrichers. This can be the reason for the rapid decomposition and hence lowest maturity period for organic enriched treatments.
- With respect to organic enrichers, the maximum temperature hikes were observed in mixture of cowdung, poultry manure and neemcake at 15 per cent of the substrate. In case of inorganic enrichers, the maximum temperature during all stages of composting was seen in mixture of urea and rockphosphate at 5 per cent level of substrate (U_2RP_2).
- The pH value of the substrates as well as the enriched treatment combinations showed a definite trend with a rise in value upto second fortnight and then a decrease and subsequent stabilisation at the end of composting.
- With regard to organic enrichment combinations, the maximum value of pH 8.00 was registered by treatments enriched with poultry manure at 15 per cent (P_3) and neemcake 10 per cent (N_2) which finally came down to about 6.34 towards maturity. Regarding the inorganic enrichment combinations, the maximum value of 8.01 was shown by treatments enriched with urea 2.5 per cent (U_1) and urea and rock phosphate 5 per cent level (U_2RP_2) which then came down to 6.25.
- The initial value of 32.1 for the C: N ratio of Oushadhi waste material showed a reduction to values ranging between 11 to 13 at final stages of composting. In case of organic enrichment, the lowest C: N ratio of 11.6 was shown by the combination of cowdung, poultry manure and neem cake at 15 per cent level ($C_3P_3N_3$).
- Regarding the compost maturity period the lowest value of 50 days was observed in two treatment combinations cowdung, poultry manure and neemcake each at 10 per cent and 15 per cent of the substrate. Compared to other enrichment combinations, both organic and inorganic.
- The variation in dehydrogenase activity followed an increase from a low initial value to very high values at thermophilic stage and then a subsequent decrease by the end of composting. However the dehydrogenase activity noted at compost maturity period was always higher than that at initial mesophilic stage, showing the proliferation of microorganisms in matured compost.

- Compared to various enrichment combinations, both organic and inorganic, the inorganic enrichment with rock phosphate at various levels registered a high dehydrogenase value.
- The final compost material was black, crumbly odourless material with the major fraction of particles falling in the category 0.5 mm - 1 mm.
- The nutrient content of organic enricher combinations, the maximum values of P and K content was shown by the combination of cowdung, poultry manure and neem cake as 15 per cent. The values were 0.44 per cent and 0.87 per cent respectively. The highest N content of 3.66 per cent was registered for the two treatments viz., cowdung, poultry manure and neem cake at 10 per cent as well as 15 per cent levels of the substrate.
- The nutrient content of inorganic enrichment treatments was high for the combination of urea and RP with (U_2 RP_2). The contents were 4.30, 3.53 and 0.44 per cent for N, P and K respectively.
- The reduction in K content in all formulations after composting was a significant observation.

3. Soil-crop response studies

- The maximum yield of 1880.63 g $plot^{-1}$ for the first harvest and 1920.70 g $plot^{-1}$ for the second harvest were noted in treatment T_5, where full dose of NPK along with 5 t ha^{-1} of selected enriched compost were applied.
- The dry matter production was higher in treatment T_5 (11.02 g $plant^{-1}$) during first harvest as well as second harvest (11.63 g $plant^{-1}$). However in all the treatments, there was always an increased dry matter production during the second harvest, compared to the first harvest.
- During first harvest, N uptake was maximum in T_5 (5236.00 mg $plot^{-1}$) and minimum in T_1 (343.50 mg $plot^{-1}$). During second harvest also, the same trend was seen with T_5 recording a value of 8432.00 mg $plot^{-1}$ and T_1 recorded a value of 389.58 mg $plot^{-1}$.

- P uptake during first and second harvests were maximum in treatment T_5, with values 740.50 and 705.19 mg $plot^{-1}$ respectively. However a decrease in P uptake was noticed during the second harvest.
- Treatment T_5 recorded the maximum uptake of K during the first harvest (6912.28 mg $plot^{-1}$) and the second harvest (6940.70 mg $plot^{-1}$).
- The pH, CEC and organic carbon content of the post harvest soil showed a hike from the initial values, irrespective of the treatments. The treatment T_4 receiving 5 t ha^{-1} of selected enriched compost, recorded the maximum CEC value of 6.73 C mol (+) kg^{-1}. *The maximum content of organic carbon was 1.75 per cent noted* for the treatment T_5.
- Available N, P and K in the post harvest soil showed much higher values compared to the initial status indicating increased build up of nutrients in the soil. Treatment T_5 showed maximum values for available N (390.34 kg ha^{-1}), available P (27.60 kg ha^{-1}) and available K (109.00 kg ha^{-1}).

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* Originals not seen

AEROBIC COMPOSTING AND ENRICHMENT OF AYURVEDIC WASTE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The study on "Aerobic Composting of Ayurvedic Waste" was conducted at College of Horticulture, Vellanikkara during the period 2001-2003, to investigate the basic physico-chemical properties of Oushadhi waste material, standardize formulations of enriched compost from the waste material and also to determine the effect of compost on plant and soil.

The waste material for the study was collected from the manufacturing unit of Oushadhi pharmaceuticals located at Kuttanelloor, 8 km east of Thrissur. The factory produced nearly 1 tonne of waste per day during the manufacture of various products like Lehyam, Arishtam, Choornam, Kalkam etc. Hence the safe disposal of these wastes was a serious problem.

A preliminary study was conducted to confirm the basic physico-chemical properties of the waste material for a period of 6 months by taking composite samples from the factory at an interval of 10 days. Temperature, pH, microbial count, colour, odour and consistency as well as the major nutrient contents of the waste material were analysed during the time period.

Then the waste material were categorised into three substrates namely unsieved (O_1), 4 mm sieved (O_2) and 2 mm sieved (O_3) fractions. Then each substrate was enriched with organic and inorganic enrichers at different levels. The organic enrichers used were cowdung, poultry manure and neemcake each at 5, 10 and 15 per cent of substrate and also their mixtures. The study involved aerobic composting of enriched treatment combinations in pots of size 30 x 32 cm^2.

Temperature was measured daily and other parameters like pH, dehydrogenase activity and C: N ratio were monitored at 10 days interval throughout the composting process. The end phase of the bioprocessing was arrived at through indications on stabilisation of temperature, pH and the quality of material. Nutrient quality of the composted waste material was arrived at by analysing the content of N, P and K at initial and final stages of composting.

The best selected enriched compost was used to study the effect on plant and soil. It was field tested using amaranthus (var. Arun) near the vegetable farm of Department of Olericulture. The selected enriched compost was tried at three levels - 5, 2.5 and 1 t ha^{-1}. A combination of the selected enriched compost at these three levels along with full doze and half doze of recommended NPK was also tried. For comparing the efficiency of the compost over FYM, FYM @ 5 t ha^{-1} and FYM 5 t ha^{-1} along with full dose of recommended NPK was also tried. An absolute control was also tried in field.

The pot experiments on composting revealed that the selected enriched compost was superior in nutrient contents compared to ordinary composts. This enriched compost contained 3.25, 0.36 and 0.68 per cent N, P and K respectively. Apart from its nutrient value compost observed was odourless and fine textured near neutral pH of 6.37. The compost matured within 50 days resulting in a favourable C:N ratio of 12 at maturity. With respect to organic and inorganic enrichers, eventhough the nutrient content was high in inorganic enrichment the time taken for attaining maturity was low in organic enricher treatment combinations due to the high temperature registered by these treatment combinations during all periods of composting.

From the field study, it was inferred that with higher doses of selected compost, there was corresponding increase in growth and yield in test crop. However the selected compost at the highest level i.e. 5 t ha^{-1} with full dose of recommended NPK emerged as the best treatment for economic yield return. This treatment also witnessed the increased build of available nutrient status of soil. This treatment could bring down expenditure for raising the crop without affecting the yield. The SEC application also resulted in increased nutrient availability by increasing the CEC and water holding capacity of soil.