UTILIZATION OF ELEPHANT DUNG FOR VERMICOMPOST PRODUCTION

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THESIS

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2011

DECLARATION

I hereby declare that the thesis, entitled **"Utilization of Elephant Dung for Vermicompost Production"** is a bonafide record of the research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title of any other University or society.

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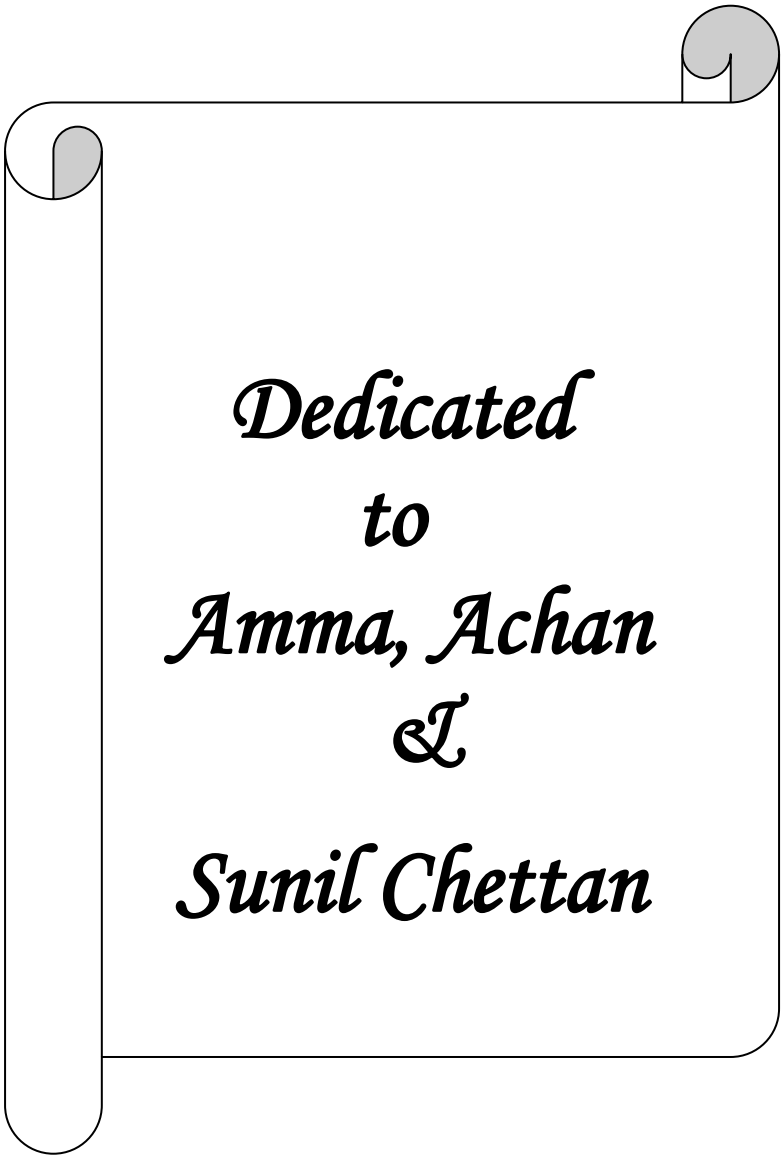
(Rekha V.R. Nair)


Dedicated
to
Amma, Achan
&
Sunil Chettan

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Introduction

1. INTRODUCTION

The elephant has been a part of the Indian culture from the time immemorial. India is home for 50% of the Asian elephant population. Kerala is abode to more than 800 captive tuskers who are admired and reversed (Ravivarma, 2009). This largest terrestrial mammal is extensively used for temple ceremonies, procession, and timber industry and also in capturing, taming and training new elephants.

Mature elephants feed continuously for a considerable length of time. In captivity, the main roughage in Kerala is palm leaves and coconut leaves. Working animals are fed with concentrate consisting of grains, millets and pulses together with common salt. Elephant's capacity to digest food is poor and only 40% is digested and 60 % passed out as faeces. The standard practice is to supply fodder at the rate of 5% of the body weight. Horse gram, rice, ragi and jaggery are the common ingredients of the concentrate fed every day (Bhaskaran & Ananthasubramaniam, 1982).

Elephant is a simple stomached animal with microbial digestion of cellulose in sacculated caeco colon. Fermentation is also evident in duodenum which is rich in protozoa and the rest of gut is mainly concerned with consolidation of faeces and reabsorption of water. Normally an elephant defecates 12 to 15 times per day at the rate of 5-8 balls at a time. Each faecal bolus weighs about1-2 kg in weight and has100 to 160 mm in diameter and 70 to 180 mm in length. So a healthy elephant produces 100 – 150 kg dung per day (Sreekumar, 2009).

Since the dung is lignocellulose complex, it takes a lot of time for natural degradation. The issue becomes a major concern especially during the festival off season, when elephants are tethered for a long period of time. Moreover, the accumulation of dung near the animal can harm its health also.

Dumping of huge quantity of dung is a common practice in elephant conservation centres. The waste accumulation creates severe socio economic problems. Even though burning is the major way adopted for dung disposal, it can create atmospheric pollution as well as health problems by causing asthma and other breathing difficulties to the people living nearby. Also burning can result in the loss of organic carbon which can otherwise nourish soil fertility especially for tropical soils. During rainy season the condition become more pathetic due to the accumulation of dung since burning cannot be practiced. Direct application of dung as a manure has little scope as it may cause wilting of plants due to excess heat generation during its decomposition. Moreover the lignocellulolytic nature of dung also demands effective decomposers for rapid decomposition of dung.

Even though exhaustive details are available on elephant care and management, the study on dung chemistry and its natural degradation is very much limited especially for Asian elephants. A study on dung chemistry of African elephants reveals that it has high nutrient composition with N (1.62%), P (0.28%), K^+ (1.66%), Ca^{2+} (1.02%), Mg^{2+} (0.23%) and Na^+ (0.03%) (Gaseitsiwes *et al*., 2006). With these factors in view the present study was taken with the following objectives.

I. To study the role of macro & micro fauna on the *in situ* decomposition of elephant dung

II. To investigate the manurial value of biotically enriched elephant dung

Review of literature

2. REVIEW OF LITERATURE

2.1 LIGNOCELLULOLYTIC WASTE

It was estimated that approximately 50 billion tonnes of cellulosic & hemicellulosic waste generated worldwide (Bruce, 1985). The total annual waste generated in India was about 2500 million tonnes which includes municipal solid waste, agricultural residues, cattle manure, poultry manure and agro industrial waste (Tandon, 1995). Lignocellulolytic waste can be classified into four main categories *viz* agricultural residues, wood residues, municipal solid waste and waste from energy crops. Enzymatic degradation of lignocellulolytic waste was low due to resistant crystalline structure of cellulose & physical barrier formed by lignin that surrounds cellulose. Efficient pre treatment reduced the lignin content, cellulose crystallinity and increased surface area for enzyme reactions (Millet *et al.*, 1975). The vast quantity of cellulolytic waste could be safely applied to crop land (Silva & Britenbeck, 1997).

2.1.1 Utilization of Lignocellulolytic Waste

Lignocellulose rich sugarcane bye products *viz* bagasse, pressmud and thrash had been pre decomposed by inoculating with *Pleurotus sajor caju. Trichoderma viridae*, *Aspergillus niger* and *Pseudomonas striatum* in different combinations followed by vermicomposting with *Drawida wilsi* earth worm reduced the composting to 40 days and produced nutrient rich compost (Shweta *et al.*, 2010). Lignocellulolytic waste such as rice straw, maize cob, saw dust of *Terminalia superba* and sugarcane bagasse were treated with three white rot fungi namely *Dardelga elegans, Polyporus gigantus* and *Lezitus betulina* at three time intervals namely 30, 60 and 90 days. The highest lignin reduction was noticed in maize cob (92.9%) with *Dardelga elegans* after 90 days (Oulseyi & Fasidi, 2009). Olive cake was vermicomposted with *Eisenia andrei* alone as well as with municipal biosolids

and found that earth worm biomass had been increased 9 to 12 fold at the end of composting process and biodegradation of olive cake was also evident. But recalcitrant nature of lignocellulolytic waste prevented suitable humification process during vermicomposting (Benitez *et al.,* 2002). Oushadi waste with 35.7 and 37.9 percent of cellulose and lignin content respectively had been reduced to 28.8 and 18.8 percent respectively by composting with *Eudrillus euginae* and *Eisenia foetida*. C: N ratio was also reduced from an initial value of 33.7 to 11.1 percent at final stage of composting indicating the production of stabilized humic matter (Preetha, 2003). According to Mane *et al*., (2007) wheat straw and cotton stalks had been supplemented with groundnut cake, gram powder and rice bran and *Pleurotus sajor caju* had been grown on it to produce high value protein food. Municipal solid waste consisting of around 50 percent of lignocellulolytic component had undergone saccharification by cellulase from *Trichoderma rosei* followed by fermentation with *Sachharomyces cervisiae* led to the highest production of bioethanol after 48 hrs of fermentation (Mtui & Nakemeura, 2005).

2.1.2. Lignocellulose Degradation

Cellulose is a simple polymer of β – 1-4 linked glucose units with insoluble crystalline microfibrils (Erikkson, 1978*).* The degradation of cellulose was brought about by the enzyme complex cellulase composed of three major enzymes *viz,* endo β-1-4 glucanase (Cx), exo β-1-4 glucanase (C_1) and β- glucosidase with Cx acting randomly on native cellulose chain while C_1 attacking non- reducing ends of the polymer producing mainly cellobiose. The cellobiose generated, was acted upon by β-glucosidase converting it to glucose (Erikkson, 1978). Lignin had a very complex structure formed by oxidative polymerization of coumaryl, coniferyl and synapyl alcohol (Kirk & Farrel, 1987). Lignin degradation was important in the global recycling of carbon because of the great abundance of lignin in the biosphere and because it is an important factor delimiting the degradation of cellulose and other

polysaccharides (Kirk and Farrel, 1987*)*. Lignin degradation was reported to occur by non-specific enzymes catalyzed burning or oxidation and was induced by carbohydrates, nitrogen and sulphur limitation (Kirk and Farrel, 1987). Boominathan & Reddy (1992) reported that lignin degradation occurred during secondary metabolism when all essential nutrients exhausted. Wood (1980) reported that laccase were found to be associated with lignin degradation.

2.2. ELEPHANT DUNG AS LIGNOCELLULOLYTIC WASTE

Ananthasubrahmaniam (1979) reported that elephant dung was rich in crude fibre (25-46%), total ash (18%), acid insoluble ash (11.1-11.8%), crude protein (3-6%), and crude fat (2.1-2.7%).

2.2.1 Feeds of Elephant

The feed materials ranged from grasses, tree leaves, twigs, barks of trees, fruits and even flowers (Moss, 1988). Bhaskaran and Ananthasubramaniam (1982) reported that in Kerala the staple roughage under captivity was palm leaf (*Caryota urens*). Palm leaf fed to elephant contained dry matter-39.1%, crude protein -7.7%, crude fibre-31.0%, nitrogen free extract-48.3%, crude fat -3.4%, total ash-9.6%, acid insoluble ash-5.83%, calcium -0.44%, phosphorous-0.16% and cobalt-0.33ppm. Elephants were given concentrate part of feed once in a day in most captive establishments (Ponnappan, 1998). Sukumar (1990) observed that concentrate part of ration fed for elephants is constituted by rice, wheat, ragi, horse gram either singly or in cooked form. Holdo *et al.*, (2002) reported that elephants practiced mineral licks or geophagy to supplement sodium concentration found in plants especially during dry season to compensate sodium deficiency.

2.2.2 Digestive System of Elephants

Elephants under natural habitat were found to be continuous feeders spending on an average of 12 to 20 hrs a day for eating. The digestive system was reported to adapt continuous feeding habit. The stomach was identified as simple cylindrical sac situated on left side with spleen attached and with a number of transverse nearly circular folds projecting inward from the cardiac wall which is essentially storage organ (Ananthasubrahmaniam, 1992). Shimick (1997) reported that small intestine was 80 feet in length, appendix 5 feet, large intestine 21 feet and the rectum 13 feet in length. About 70 % of digestive tract contents were found in caecum and proximal colon. These segments harboured anaerobic micro organisms and fungi which could ferment plant cell wall, carbohydrates, simple sugars, starch and protein. Fermentation was also evident in duodenum and colon which were rich in protozoa. The digested products were absorbed through the intestinal wall.

The rest of gut was mainly concerned with consolidation of faeces (Sreekumar, 2009). According to Mercy (2009), elephants digested only 44 percent of what they consumed. Crude protein digestibility was recorded to be 89% & crude fibre digestibility to be 18.5%.

2.2.3. Dung Decomposition

Role of macro fauna

Moist dung was attractive to a wide diversity of decomposers especially to dung beetles and coprophagous fungi which were considered as agents of decomposition (Krug *et al.,* 2004). It was noted that the activity of coprophagous beetle on elephant dung decreased as that of termite increased (Malcom, 1977). During the dry season dung beetle *Kheper* n*igianeus,* was found to be the dung decomposer (Gavinn, n.d.). Dung decomposition rates were studied with and without the presence of arthropods using pairs of exposed dung enclosed in nylon mesh bag

respectively in semi arid Botswana. Dung decomposition rates were lower in the absence of arthropods (Gaseitsiwes *et al*., 2006). Termite could quickly remove large amount of mammalian dung especially in dry season and about 1/3rd of dung deposited in given habitat was removed by them within one month (Freymann *et al*., 2008). Weir (1971) reported that dung beetles were responsible for the removal of almost all the dung during the wet season. Xinewei and Shucun (2010) reported that the rate of dung removal was less for flies compared to beetles because the consumption rate was lower and resident time was shorter for flies.

Role of micro fauna

Lignocellulose degrading bacteria could be found in fresh elephant dung, buffallo's caecum and colon, horse's caecum. The highest colony number was observed in buffallo's colon (376) and the least in elephant dung (46). The highest lignocellulolitic efficiency was observed in buffallo's caecum and superior isolate were identified as *Entrococcus casseliflavum* (Wahyudi *et al*., 2010). With regard to fungal succession, *Cladosporium cladosporoides* and *Eurotium brefeldianum* occurred in later stages of dung decomposition where as *Talaromyces helicus* and *Sporomiella minima* occurred at all stages (Gaseitsiwes *et al*., 2006).

2.3 VERMICOMPOSTING

Vermicomposting is a non-thermophilic biodegradation of organic material through interaction between the earth worms and microorganisms resulting in the production of vermicompost (Edward and Burrows, 1988). Earth worm species was able to consume wide range of organic waste such as sewage sludge, animal dung, crop residue and industrial refuse (Chan and Griffth, 1988). Cow dung was the most suitable of the all animal waste for earth worm (Datar *et al.*, 1997).

Vermicomposting of organic waste accelerated organic matter stabilization and gave chelating and phytohormonal elements (Tomati *et al*., 1995). It could be

viable cost effective and rapid technique for the efficient management of organic solid waste (Logsdon, 1994). Suthar (2007) stated that factors relating to growth of earth worm might be considered in terms of physico-chemical and nutrient characteristics of waste feed socks. Regular inputs of feed materials for the earth worm could be in the form of agro waste, kitchen waste, cow dung, goat manure and pig manure (Aalok *et al*., 2008). After passing through the earth worm gut the ingested material was expelled as globular aggregates called vermicasts (Meena, 2003)

2.3.1 Factors Responsible for Production and Maturity of Vermicompost

The important factors that influenced the production as well as maturity were C: N ratio, pH, temperature, moisture, aeration, particle size and microbial presence.

Carbon Nitrogen ratio

Reduced concentration of carbon and enhanced nitrogen level as a consequence of microbial activity during humification process resulted in reduction of C: N ratio at the end of composting process (Hamoda *et al*., 1998). A C: N ratio ranging from 10-12 was usually considered to be an indicator of stable and decomposed organic matter (Jimenez and Garzia, 1992). Garg *et al*., (2005) reported a 58.4 % reduction in the organic carbon in cow dung and 55.4 % reduction in horse dung after 90 days of composting. Kaviraj and Sharma (2003) reported a 25 – 45 % loss of organic carbon during vermicomposting of industrial waste.

pH

According to Wilson (1989), most well stabilized compost had a pH between 6.5 and 7.5. Zacchariah (1994) reported that vermicompost always showed a pH ranging from neutral to alkaline. Studies conducted by Thomas (2001) revealed that

maximum pH during composting was observed at the thermophilic stage. The substrate was unsuitable for worms if it was too acidic or too alkaline.

Temperature

According to Nair, (1997) peak value of temperature, (66.3^0C) was attained during thermophilic stage of composting. Eghball *et al.,* (1997) reported that during composting of cattle manure the temperature reached 65^{o}C within 24 hours at all depths within the compost pile. After thermophilic stage the microbial activity was decreased. This leads to maturation phase of the compost and it started to fall within the ambient temperature (Zibilske, 1999). The heat was released by the oxidative action of microbes during the conversion of organic matter (Peigne and Girardin, 2004).

Moisture

Hand (1988) reported that moisture of 50-60 % was ideal for vermicomposting process. High initial moisture content in compost hindered aeration and induced undesirable anaerobic condition during composting resulted in occurrence of foul odours (Haug, 1980).

Aeration

Parr *et al*., (1994) reported that by adequate aeration, temperature in compost pile increased to greater than 60^0C. It resulted in complete destruction of pathogens, parasites and weed seeds.

Particle size

Mature compost had a tea brown colour, no noxious smell and good stability (Kalaiselvy and Ramaswamy, 1996). They also found that maximum diameter of compost should not exceed 10 mm, with 5mm as optimum.

Microbial presence in worm cast

The presence of large number of micro organisms as surface and gut micro flora of earth worm was reported by Galli *et al*., (1990). Edward and Burrows (1988) reported that vermicompost was rich in fungi, bacteria, and actinomycetes compared to soil. According to Ismail (1993), the enzymes and gut micro organisms took active part in earth worm digestion and after absorption of nutrients for its own metabolism, the cast ejected through anus. Earth worm casts had higher microbial biomass which had implications on soil fertility and wider ecosystem functions (Scullion, 2002). Worm cast increased soil fertility through the addition of plant growth hormones and increased level of soil enzymes (Chaoui *et al.,* 2003). Studies on quantitative estimation of micro flora conducted by Nisha (2007) revealed that bacterial population was predominant in vermicompost followed by actinomycetes and fungi. Population of anaerobic heterotrophic bacteria, filamentous actimycetes and spore producing bacteria was higher in vermicomposted cow manure where as fungal population was abundant in vermicomposted coconut leaf. Cellulose degradation was also observed in both types of substrate (Gopal *et al.,* 2009).

2.3.2 Manurial Value of Vermicompost

Vermicompost contains large amount of humic substance (Masciandro *et al*., 1997). Earth worm modified soil physical, chemical and biological properties and enhanced nutrient cycling by ingestion through soil humus and production of vermicompost (Rao, 1986). Application of organic manures in the form of vermicompost in soil recorded the highest value for all the available nutrients (Rajalekshmi, 1996). Availability of N, P, Ca^{2+}, and Mg^{2+} was highest when 25 tones of vermicompost with full dose of inorganic fertilizers were used for tomato production (Pushpa, 1996). Vermicompost was found to be rich in macro and micronutrients, vitamins, growth hormones and immobilized micro flora (Tiwari,

2002). The worm castings were rich in nutrients and readily available to plants (Hansen, 2007).

2.3.2.1 Total contents of primary nutrients

Nitrogen

According to Crawford (1983), nitrogen content in vermicompost was the resultant of initial nitrogen content of substrate and degree of decomposition. Addition of nitrogen in the form of nitrogenous excretory substances, growth stimulating hormone, enzymes from earthworm had been reported by Tripathi and Bharadwag (2004). Elvira *et al*., (1998) reported 55- 100 % increase in total nitrogen due to mineralization of organic matter, where as Warma and Anglopez (2002) observed 42-85% increase in total nitrogen due to vermicomposting.

Phosphorous

Increase in phosphorous content was due to direct action of worm gut enzyme and directly by stimulation of micro flora (Garg *et al.*, 2006). Satchel & Martin (1984) found out a 25% increase in P content from paper waste sludge after worm activity. Bijulal (1997) reported that the release of different forms of P *viz* Bray extractable P, Fe-P and Al-P from rock phosphate registered the highest contents in vermicompost compared to other organic manures.

Potassium

Delgado *et al*., (1995) reported the highest total K content in vermicomposted sewage sludge. Orazco *et al.*, (1996) reported lower total potassium content in coffee pulp waste after vermicompsoting. Elvira *et al.*, (1998) also reported significant reduction in total K content by the end of vermicompsoting.

Calcium, Magnesium and Sodium

Orazco *et al.,* (1996) reported an increase in total calcium content after ingestion of coffee pulp waste by earthworm. Ca^{2+} and Mg^{2+} contents had also been reported to be increased by vermicomposting of decayed sludge (Gratelly *et al.*, 1996). Total calcium content had increased from 1.68 to 3.08 fold where as Mg^{2+} content increased from 1.29 to 2.67 times by vermicompsoting of spent mushroom waste by *Eisenia foetida & E.andrei* (Tajbakhsh *et al.,* 2008). A simple and potentially inexpensive Hydro Based Operating Bioreactor (HBOB) was developed for aeration and turning of plant biomass for efficient aerobic composting process. The vermicompost developed in the HBOB was found to have comparatively high value of nutrients such as calcium (13.5%), sodium (354.68 mg/100 g), magnesium (832.48 mg /100 g) **(**Jadia and Fulekar, 2008**).** In three consecutive years (1996-98) on the sludge originating from a biological and chemical tannery sewage treatment plant was used for vermicompost production by adding fruit tree leaves and wheat straw. Higher abundance of organic matter, nitrogen, calcium and sodium was found for both untreated tannery sludge and sludge composted by *Eisenia fetida* in comparison to the farmyard manure (Gondek and Mazur, 2001). While vermicomposting of biosolids with cow manure and oat straw the sodium concentration was found to be 152 mg kg^{-1} dry compost (Ramos *et al*., 2005).

Materials and Methods

3. MATERIALS & METHODS

The investigation on 'Utilization of elephant dung for vermicomposting' was conducted at College of Horticulture, Vellanikkara during January 2009 to May 2010. The entire study consisted of three parts.

1. Identifying the role of macro and micro fauna on the *in-situ* decomposition of elephant dung.
2. Biochemical analysis of elephant dung.
3. Vermicomposting of elephant dung.

MATERIALS USED FOR THE STUDY

The elephant dung was procured from Padukkad, the elephant conservation centre of Paramekkavu Devaswam Board, Thrissur, Kerala. Samples were collected from this site for further chemical & biochemical analysis and for vermicomposting. Weather data are recorded and provided in Appendix 1.

3.1. IDENTIFYING THE ROLE OF MACRO AND MICRO FAUNA ON THE *IN-SITU* DECOMPOSITION OF ELEPHANT DUNG

The two phases of the experiment are indicated as follows:

Role of macro and micro fauna on the *in-situ* decomposition of elephant dung.

Isolation of native microbes from dung.

3.1.1. Role of Macro and Micro Fauna on the *in-situ* Decomposition of Elephant Dung.

Elephant dung at various stages of degradation was carefully monitored at monthly intervals for six months. The different degradation sites identified in the field located at Padukkad were maintained without any disturbance throughout the period of study (Plate 1). The details of sampling collection are indicated as follows

Table 3.1 Elephant dung at different stages of degradation- sampling details

Sl No	Stage of dung degradation	Notation
1	More than 12 months old	E_1
2	12 months old	E_2
3	Eight months old	E_3
4	Four months old	E_4
5 a	Body washings (Fresh sample)	E_5
5 b	Faecal bolus (Fresh sample)	E_6
6	Composite sample	E_7

First sampling was done in January 2010 and continued up to June 2010.

Observations

The variations in temperature and moisture were recorded at monthly intervals for six months using multichannel temperature recorder and soil moisture metre (plate 2 and 3). The C: N ratio of dung at different stages of degradation was also observed. Common invertebrates (macro organisms) present in the field were

a) More than 12 months old

b) 12 months old

c) Eight months old

d) Four months old

e) Body washings (Fresh sample

f) Faecal bolus (Fresh sample)

Plate1 Different stages of degradation of dung

Plate 2. Temperature measurement with multi channel temperature recorder

Plate 3. Moisture measurement with moisture metre

investigated. Sampling was done by using plastic spoons and painting brushes. The enumeration of microorganisms were estimated by serial dilution using different media as given in table 3.2. The media composition is provided in Appendix 2.

Table 3.2 Media used for enumeration of different micro organisms

Sl No	Microbe	Medium	Reference
1	Fungi	Martin Rose Bengal Agar	Martin, 1950
2	Bacteria	Nutrient agar	Rao, 1986
3	Actinomycetes	Kenknight	Rao,1986

3.1.2 Isolation of Native Microbes from Dung and Calculation of Solubulization Efficiency

Serial dilution of elephant dung sample collected in the last period of sampling was subjected to study. All the six stages of degradation were examined for native microbe isolation (Sharma, 2007). Ten gram sample was added to 90 ml sterile water blank and mixed well to get 10^{-1} dilution. From this tenfold dilution up to 10^{-6} were prepared. One ml aliquot from 10^{-6} and 10^{-5} were used for pour plating for bacteria, fungi and actinomycetes respectively. From 10^{-5} dilution, one millilitre quantity of diluted aliquot was poured on Martin rose bengal agar medium for fungal isolation. Similarly one ml from 10^{-6} was poured on nutrient agar for bacterial isolation and from 10^{-5} was poured on Kenknight medium for actinomycetes isolation. After five days of incubation fungal hyphae were placed on Martin rose bengal medium for purification. Streaking of bacterial colony was done on nutrient

agar for bacterial purification and the same was done for actinomycetes purification, on Kenknights medium. Incubation was given for five days.

The pure culture thus obtained for each type of micro fauna was plated on Carboxy Methyl Cellulose (CMC) and lignosulphonate media for the detection of their cellulose and lignin degradation efficiency respectively. A clear zone/ halo were produced by effective lignocellulose degraders on these media. Colony diameter and size of halo were measured (plate 4). Based on these parameters solubulization efficiency was worked out as follows (Sharma, 2007).

$$\text{Solubulization Efficiency (S.E)} = \frac{\text{Size of halo}}{\text{Colony diameter}} \times 100$$

Observations

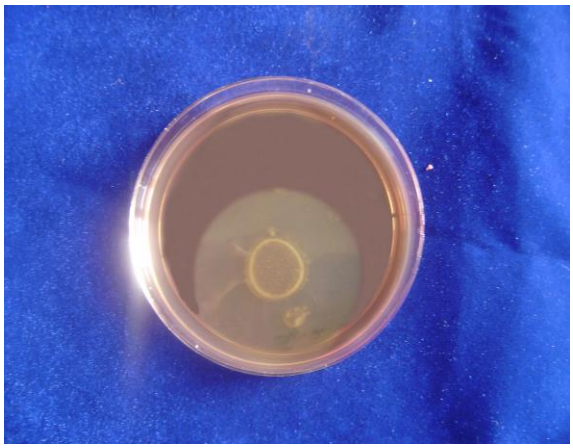
Total number of morphotypes of bacteria, fungi and actinomycetes and their total population in cfu/10 g sample were recorded during the study. The number of cellulose & lignin degrading microbes (on specific media) were also observed as a part of the experiment.

3.2 BIOCHEMICAL ANALYSIS OF ELEPHANT DUNG

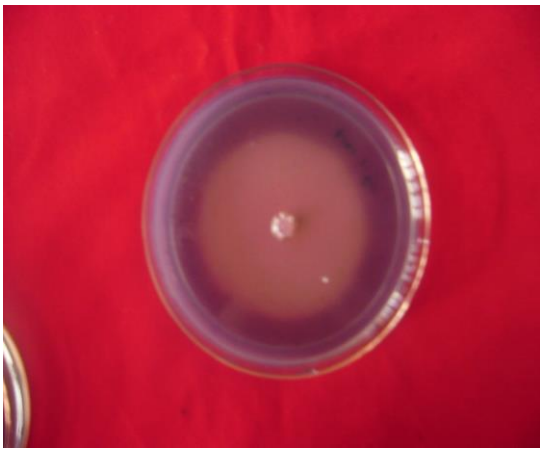
Composite sample (E_7) was prepared by quartering of samples collected during each month of field study. A pooled sample was prepared from the composite sample obtained during each month of field study and was used for the estimation of physico chemical and biochemical properties as per the standard procedure indicated in table 3.3 and table 3.4.

a) Zone production by bacteria on CMC

b) Zone production by fungus on CMC



c) Zone production on lignosulphonate by bacteria



d) Zone production on lignosulphonate by fungus

Plate 4. Isolation of effective lignocellulose degraders from dung

Observations

Carbon, nitrogen, phosphorous, potassium, calcium, magnesium, sodium, crude protein, crude fat, crude fibre, cellulose, hemicelluose and lignin were analyzed for the pooled sample. pH variations of composite samples (E_7) were also recorded at monthly intervals.

Table 3.3. Physico chemical properties of elephant dung- procedures

Property	Method	Reference
pH	1:2.5 suspension	Jackson, 1958
Carbon	Ashing	
Nitrogen	Microkjeldahl digestion and distillation	
Phosphorous	Diacid extract-spectrophotometry	
Potassium	Diacid extract - flame photometry	
Sodium	Diacid extract - flame photometry	
Calcium	Diacid extract - Atomic Absorption Spectrometer	Perkin-Elmer, 1982
Magnesium	Diacid extract - Atomic Absorption Spectrometer	

Table 3.4 Biochemical properties of elephant dung- procedures

Property	Method	Reference
Crude protein	Microkjeldahl digestion and distillation for N and multiplication by the factor 6.5	Thimmaiah. 1989
Crude fat	Extraction with ether using soxhlet apparatus and estimation by gravimetry	Thimmaiah. 1989
Crude fibre	Acid alkali treatment for extraction and estimation by gravimetry	Thimmaiah. 1989
Cellulose	Extraction using acetic nitric acid mixture and estimation by spectrophotometry	Updegroff,1969
Hemicellulose	Estimation by neutral detergent solution	Thimmaiah. 1989
Lignin	Extraction by 64 percent H_2SO_4 and estimation by gravimetry	Thimmaiah. 1989

3.3 VERMICOMPOSTING OF ELEPHANT DUNG

The study mainly focussed on identification of suitable microbial degraders for pre composting (factor M) and selection of the best substrate for vermicomposting (factor S). The design followed was factorial CRD with the two factors, factor S and factor M. Factor M was at four levels and factor S was at six levels with two replications. Accordingly, 48 treatment combinations, 4x6x2 were tested. The compost worms used were *Eudrillus euginae.* The details of factors are mentioned in section 3.3.1 and 3.3.2.

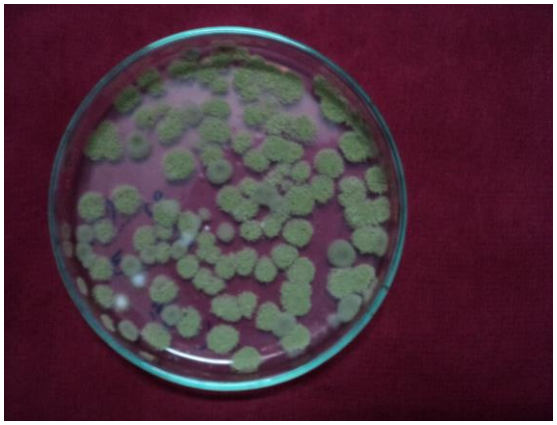
3.3.1 Microbes for Pre-composting

Pleurotus platypus (M_1) is the coir pith fungus was obtained from the sales division of ATIC at Mannuthy. Combination of lignocellulose degraders *Aspergillus flavus* and *Bacillus subtilis* indicated as M_2 were obtained from Department of Agricultural microbiology, College of Horticulture, Vellanikkara, Thrissur. Native degraders, consortium of bacteria and fungus (M_3) were isolated as per the procedure listed in 3.1.2. The treatments without microbes (M_0) were also included in the study for effective comparison of lignocellulose degraders. The details are being given in table 3.5. The microbial agents used for pre composting are depicted in plate 5.

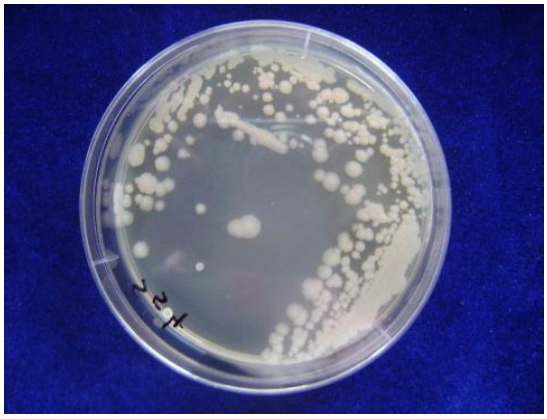
3.3.2 Substrate for Vermicomposting

The main substrate was elephant dung. Banana pseudostem and FYM were obtained from ATIC-ABARD unit attached to College of Horticulture, Vellanikkara. The different substrates were tried both at 1:1 and 1:8 levels. The details are indicated in table 3.5.

a) Pleurotus platypus

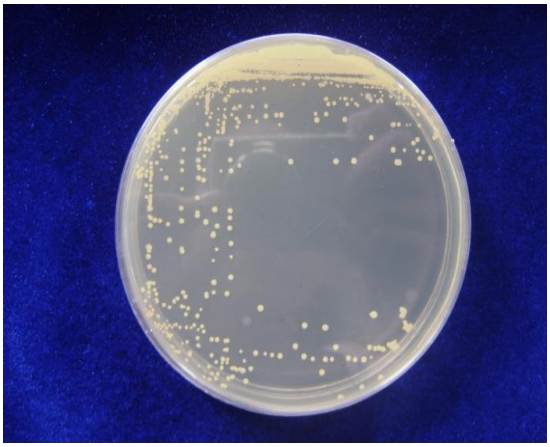


b) *Aspergillus flavus*



c) *Bacillus subtilis*

d) Native fungus



e) Native bacteria

Plate 5. Microbial agents for pre-composting

Table 3.5 Different treatment combinations with notations

Treatment Combination	Notation
S_1M_0	FYM : BPS* in ratio 1:1, pre composted without microbes
S_2M_0	FYM :ED* in ratio 1:1, pre composted without microbes
S_3M_0	ED: BPS in ratio 1:1, pre composted without microbes
S_4M_0	FYM : BPS in ratio 1:8, pre composted without microbes
S_5M_0	FYM :ED in ratio 1:8, pre composted without microbes
S_6M_0	ED: BPS in ratio 1:8, pre composted without microbes
S_1M_1	FYM:BPS in ratio 1:1, pre composted with *Pleurotus platypus*
S_2M_1	FYM :ED in ratio 1:1, pre composted with *Pleurotus platypus*
S_3M_1	ED: BPS in ratio 1:1, pre composted with *Pleurotus platypus*
S_4M_1	FYM:BPS in ratio 1:8, pre composted with *Pleurotus platypus*
S_5M_1	FYM: ED in ratio 1:8. pre composted with *Pleurotus platypus*
S_6M_1	ED: BPS in ratio 1:8 pre composted with *Pleurotus platypus*
S_1M_2	FYM : BPS in ratio 1:1, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_2M_2	FYM :ED in ratio 1:1, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_3M_2	ED: BPS in ratio 1:1, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_4M_2	FYM : BPS in ratio 1:8, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_5M_2	FYM :ED in ratio 1:8, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_6M_2	ED: BPS in ratio 1:8, pre composted with *Aspergillus flavus* & *Bacillus subtilis*
S_1M_3	FYM : BPS in ratio 1:1, pre composted with native microbes
S_2M_3	FYM :ED in ratio 1:1, pre composted with native microbes
S_3M_3	ED: BPS in ratio 1:1, pre composted with native microbes
S_4M_3	FYM : BPS in ratio 1:8, pre composted with native microbes
S_5M_3	FYM: ED in ratio 1:8. pre composted with native microbes
S_6M_3	ED: BPS in ratio 1:8, pre composted with native microbes

*ED: elephant dung

*BPS: banana pseudostem

3.3.3. **Preparation of Microbial Consortium for Vermicomposting**

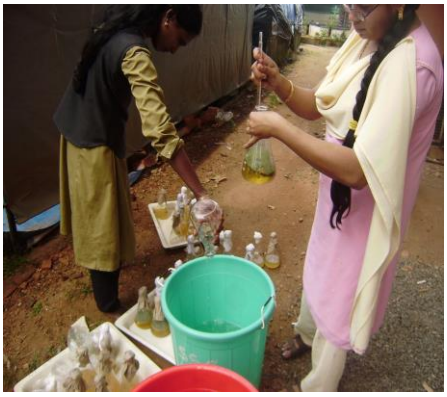
Combination of lignocellulose degraders (M_2) and native degraders (M_3) were mass multiplied in suitable medium for pre composting process. Potato dextrose broth for fungus and nutrient broth for bacteria were used as medium for mass multiplication. The various steps in the procedure were as follows (plate 6).

Procedure

1. One millilitre of pure bacterial culture and two to three fungal hyphae were inoculated on 300 ml of nutrient broth and potato dextrose broth respectively.
2. Bacterial culture incubated for five days and fungal culture for fifteen days for effective multiplication.
3. For each bacteria and fungus, three litres of nutrient broth and potato dextrose broth was used for mass multiplication.
4. 10 litres of boiled cooled water was used for consortium preparation for fungus and bacteria.
5. The pure culture of bacteria and fungus was added to clean bucket and 20 litres of boiled cooled water has been added to it and stirred well using a stick.

3.3.4 Preparation of Substrate for Vermicomposting

The filling of earthen pot with substrate was done on volume basis. The microbial inoculam *Pleurotus platypus* was given @ 2.30g/kg of substrate; M_2 and M_3 were given @ 250ml/kg of substrate. The biotic agent *Eudrillus euginae* was applied @ 60/kg of substrate after cessation of thermophilic stage (plate 7). The



a) Mixing effective lignocellulose degraders from dung

b) Prepared consortium for application

c) Treating the substrate with consortium

Plate 6. Application of microbial consortium

Plate 7. Introduction of earthworms for composting

moisture content was maintained at 70 percent throughout the experimental period by sprinkling required quantity of water after measuring the daily variations in moisture by moisture metre. The mud pots were protected from sunlight and contents were throughtly mixed at alternate days till the decomposition was completed. The earthen pots used for the experiment are depicted in plate 8.

Observations

The variations in temperature were noted using multichannel temperature recorder at 8.00 am daily during the entire period of composting. Moisture was recorded daily using moisture metre.

Microbial count at three different stages of composting namely thermophilic, mesophilic and maturity stage of composting was analyzed by serial dilution technique using the medium as indicated in table 3.2. Earthworm counts were taken at compost harvest stage.

pH, major nutrients such as carbon, N, P, K and other nutrients like Ca. Mg and Na of the compost at maturity stage of composting were analyzed as per the procedure given in table 3.3.

3.4 STATISTICAL ANALYSIS

The data obtained was stastistically analysed by the method of analysis of variance (ANOVA) (Panse and Sukhatme, 1985) and using DMRT by M STATC programme. Correlations were worked out using the method of Snedcor and Cochran (1967).

Plate 8. Vermicomposting of elephant dung in earthen pots

Results

4. RESULTS

4.1. IDENTIFYING THE ROLE OF MACRO AND MICRO FAUNA ON THE *IN-SITU* DECOMPOSITION OF ELEPHANT DUNG

In order to attain the objective of the study, three consecutive experiments were conducted and results are presented in this section.

4.1.1. *In-situ* Decomposition of Elephant Dung.

Influence of macro and micro fauna on different stages of dung degradation was observed continuously for six months as detailed in section 3.1.1.

4.1.1.1 Influence of temperature, moisture and C: N ratio on degradation stages of dung during different months of sampling

The weather parameters are represented in Appendix1. The study area is under tropical climate condition with dry periods from January to May which coincides with sampling period. Data pertaining to temperature, moisture and C: N ratio during the period of sampling is furnished in table 4.1. Considering the influence of temperature for different period of sampling on different stages of dung degradation the highest temperature was recorded in February (37.32 ^{0}C) which was found to be significantly superior to that recorded during March, April and January, which were on par. The least temperature of 28.50^{0}C was recorded in June, which was found to be significantly inferior to that recorded during all other months of sampling.

Moisture status of dung at different stage of degradation was ranged from 8.40 percent to 14.70 percent at monthly intervals. The lowest moisture was recorded

in February (8.40%), which was on par with that recorded during March, April and January. The highest moisture status was recorded in June (14.70%), which was on par with May (11.37%).

There was no significant difference on C: N ratio during different periods of sampling. However, the highest C: N ratio of 49.11 was recorded on January and lowest value of 48.31 on May.

Table 4.1. Variations of temperature, moisture & C: N ratio of the dung at different months of sampling.

Period of sampling	Temperature (^{0}C)	Moisture (%)	C: N Ratio
January	31.63^{ab}	10.45^{b}	49.11^{NS}
February	37.32^{a}	8.40^{b}	48.69^{NS}
March	33.88^{ab}	8.98^{b}	48.74^{NS}
April	33.68^{ab}	9.68^{b}	48.97^{NS}
May	31.35^{ab}	11.37^{ab}	48.31^{NS}
June	28.50^{b}	14.70^{a}	48.46^{NS}

The treatment values in a column followed by same superscript do not differ significantly

4.1.1.2 Effect of C: N ratio & microbial population at different degradation stages of dung

The influence of C: N ratio & microbial population at different degradation stages of dung are furnished in table 4.2

There was significant difference of C: N ratio at different stages of degradation of dung. The highest C: N ratio of 52.91, which was significantly

superior to all, was recorded on E_4 followed by E_3. E_6 and E_2 were on par. E_5 (46.16) was also found to be on par with E_1 recording the lowest value of 45.14.

There was no significant difference in bacterial population at different stages of degradation of dung. The highest population of 91.68x 10^6 cfu $10g^{-1}$was recorded on E_3 and lowest population of 20.51 x10^6 cfu $10g^{-1}$was recorded on E_1. There was significant difference in fungal population at different stages of dung degradation. The highest population of 16.34 x10^5 cfu $10g^{-1}$ was observed in E_4 stage, which was on par with E_3. The lowest population was recorded in E_1 (8 .00 x 10^5cfu 10 g^{-1}), which was on par with E_6 and E_2.With respect to actinomycetes, also there was no significant difference at different stages of dung degradation. However the highest population was recorded at E_4 (4.19 x 10^5 cfu $10g^{-1}$) and the lowest population in E_5 (2.85x 10^5 cfu $10g^{-1}$).

Table 4.2 Variations of C: N ratio and microbial population at different degradation stages of dung

Treatment	C:N Ratio	Microbial population(cfu $10g^{-1}$)		
		Bacteria(10^6)	Fungus(10^5)	Actinomycetes(10^5)
E_1	45.14^{d}	20.51^{NS}	8.00^{c}	2.92^{NS}
E_2	47.95^{c}	24.81^{NS}	9.33^{bc}	3.60^{NS}
E_3	51.71^{b}	91.68^{NS}	16.33^{ab}	3.94^{NS}
E_4	52.91^{a}	45.342^{NS}	16.34^{ab}	4.19^{NS}
E_5	46.16^{d}	37.17^{NS}	15.67^{abc}	2.85^{NS}
E_6	48.42^{c}	51.75^{NS}	8.58^{bc}	3.10^{NS}

The treatment values in a column followed by same superscript do not differ significantly

4.1.1.3 Macro fauna at the degradation stages of dung

Observations on macro fauna at different stages of degradation of dung are given in table 4.3. At E_1 and E_2 site, silver fish & earwig were dominant where as at E_3 and E_4, termites, millipeds and centipeds were dominant. On the fresh sample, flies were the dominant macro organisms.

Table 4.3. Observations on macro fauna at different stages of degradation of dung

Stage of degradation	**Macro fauna observed**
More than 12 months old	Silver fish, earwig
Twelve months old	Silver fish, earwig, Field roaches
Eight months old	Termites, millipedes, centipedes
Four months old	Termites, millipedes, centipedes
Body washings	Centipedes
Faecal bolus	Flies

4.1.2. Isolation of Native Microbes from Dung

The experiment was done to find out the lignocellulolytic solubulization efficiency of native microbes from the dung.

4.1.2.1 Number of morphotypes of native microbes & their population

Details of number of morphotypes of native microbes are furnished in table 4.4 to 4.6. Based on size and color, bacteria were classified into six different morphotypes. Based on color, fungi were classified into five different morphotypes and actinomycetes into three. The population of native microbes during the last period of sampling is also detailed in the above tables. The population was maximum for bacteria ($40.50x10^6$ cfu $10g^{-1}$) followed by fungi ($19.67x10^5$ cfu $10g^{-1}$) and actinomycetes ($3.58x10^5$ cfu $10g^{-1}$)

Table 4.4. Morphotypes of bacteria isolated from dung

Size/Sample	Yellow			White			Total (10^6 cfu $10g^{-1}$)	Mean
	Small	Medium	Large	Small	Medium	Large		
E_1	11	3	3	9	5	3	34.5	40.50
E_2	17	4	4	12	3	-	40.5	
E_3	14	5	4	9	11	5	48.0	
E_4	13	3	2	9	5	4	36.5	
E_5	12	6	5	11	7	4	45.0	
E_6	12	5	2	14	4	1	38.5	

Table 4.5 Morphotypes of fungi isolated from dung

Color/Sample	Green	White	Purple	Yellow	Cream	Total (10^5 cfu $10g^{-1}$)	Mean
E_1	4	3	1	-	-	18.0	19.67
E_2	8	5	-	2	-	15.0	
E_3	6	5	-	2	-	24.0	
E_4	3	2	-	-	-	16.0	
E_5	4	3	-	-	1	26.0	
E_6	3	1	1	-	-	19.0	

Table 4.6 Morphotypes of actinomycetes isolated from dung

Color/Sample	Grey	White	Cream	Total (10^5 cfu $10g^{-1}$)	Mean
E_1	3	2	2	7.5	3.58
E_2	2	3	-	5.0	
E_3	3	-	2	4.5	
E_4	-	1	-	1.0	
E_5	-	-	1	2.0	
E_6	-	1	-	1.5	

4.1.2.2. Lignocellulolytic solubulization efficiency of bacteria from dung

Data pertaining to lignocellulolytic solubulization efficiency of native bacteria isolated from dung are presented in table 4.7. Among 30 isolates of native bacteria

from the dung sample, ten are found to be efficient in cellulose solubulization where as, two are found to be efficient in lignin solubulization and five are found to be efficient in lignocelluloses solubulizaion. Two isolates from $E_{1,}$ three from E_2, three from E_3, four from E_4, three from E_5 and two from E_6 were found to be efficient in either lignin or cellulose or lignocellulolytic solubulization. Maximum cellulose solubulization of 264.3 % was observed on E_5 4and that of lignin solubulization on E_4 3 (263.7 %). E_3 2 was found to be efficient in lignocellulose solubulization with cellulose and lignin solubulization percentage of 270.0% and 283.3% respectively.

4.1.2.3 Lignocellulolytic solubulization *efficiency of fungus from dung*

Lignocellulolytic solubulization efficiency of native fungus isolated from the dung are given in table 4.8. Among 15 isolates of native fungus two were efficient in cellulose solubulization and three in lignocelluloses solubulization. Highest cellulolytic efficiency was recorded by E_5 2 (153.9%) and lignocellulolytic efficiency by E_5 1 with lignin and cellulose solubulization efficiency of 281.8% and 306.7% respectively.

4.2. BIOCHEMICAL ANALYSIS OF DUNG

The physiochemical and biochemical properties of the pooled dung were analyzed as detailed in section 3.2.

4.2.1 Biochemical Analysis of Dung

Data pertaining to the biochemical analysis of the pooled dung are represented in table 4.9.The dung was low in crude fat with 2.8 percent and highest in crude fibre content with 21.4 percent. Cellulose, hemicellulose and lignin fractions were accounted to be 35.8, 30.1 and 17.5 percent respectively.

Table 4.7 Solubulization efficiency on CMC and lignosulphonate medium by native bacteria

Bacterial culture	Solubulization efficiency	
	CMC	Lignosulphonate
E_1 3	150.0	0
E_1 4	175.0	225.0
E_2 1	161.5	0
E_2 2	175.0	164.3
$E_2$4	200.0	0
E_3 2	276.9	283.3
E_3 4	214.3	0
E_3 5	228.6	0
E_4 2	241.7	261.6
E_4 3	0	263.8
E_4 5	0	208.3
E_4 6	241.7	0
E_5 2	200.0	0
E_5 3	173.3	242.9
E_5 4	264.3	0
E_6 1	188.9	0
E_6 4	158.3	0

Table 4.8. Solubulization efficiency on CMC and lignosulphonate medium by native fungi

Fungal isolate	Solubulization efficiency	
	CMC	Lignosulphonate
$E_3$1	126.7	0
E_4 1	125.0	186.3
E_5 1	306.7	281.8
E_5 2	153.9	0
E_6 2	330.8	142.9

Table 4.9. Biochemical composition of pooled dung

Property	Crude fat	Crude protein	Crude fibre	Others	Cellulose	Hemicellulose	Lignin	Others
Content (%)	2.8	6.5	21.4	30.7	35.8	30.1	17.5	16.6

Table 4.10. Nutrient composition of pooled dung

Property	C	N	P	K	Ca^{2+}	Mg^{2+}	Na
Content (%)	48.18	0.864	0.342	0.373	0.192	0.045	0.251

4.2.2 Nutrient Composition of Dung

The details of chemical analysis of pooled dung are given in table 4.10. The dung possessed carbon content of 48.18 percent, nitrogen 0.864 percent, phosphorous 0.342 percent, potassium 0.373 percent, calcium 0.192 percent, magnesium 0.045 percent and sodium 0.251 percent respectively. The highest nutrient status was for carbon and the lowest nutrient status was recorded for magnesium.

4.2.3 Variations of pH at Monthly Intervals

Variations of pH of pooled dung at monthly intervals are furnished in table 4.11. The pH of dung was from neutral to alkaline range. The highest pH was recorded on March (7.3), which was on par with that of February (7.2). It was followed by January (7.1), which was on par with that of April (7.0) and May (7.0). The lowest pH was recorded on June (6.9), which was on par with that of April and May.

Table 4.11 pH variations of elephant dung at different months of sampling

Period of sampling	pH
January	7.1[bc]
February	7.2 [ab]
March	7.3 [a]
April	7.0 [cd]
May	7.0 [cd]
June	6.9 [d]

The treatment values in a column followed by same superscript do not differ significantly

4.3. VERMICOMPOSTING OF ELEPHANT DUNG

The experiment was done to identify the best substrate and suitable microbial agents for vermicomposting. Influence of temperature, microbial population at thermophilic, mesophilic and maturity stage of composting, rate of earth worm multiplication, pH of compost and nutrient status of the compost were studied as a part of this experiment.

4.3.1 Influence of Temperature on Composting

Daily variations of temperature of treatment combinations were recorded as detailed in section 3.3. The observations are given in Appendix 4. Irrespective of the treatment combination, temperature was declined as days advanced. The highest temperature of 39.8°C was recorded by S_5M_2 on 2nd day of composting and lowest temperature by S_6M_0 (24.7^{0}C) on 62nd day of composting. On the first fifteen days the highest temperature was recorded by S_5M_2 (39.8^{0}C) and the lowest temperature by S_1M_0 (28.8^{0}C). In the next 30 days the highest temperature of 34.9^{0}C was recorded by S_5M_2 and the lowest by S_4M_1 (26.2^{0}C). In the next eight days the highest temperature was shown by S_5M_0 (30.8^{0}C) and the lowest by S_4M_2 (25.4^{0}C). In the next ten days, the highest temperature by S_2M_3 (28.7^{0}C) and the lowest temperature by S_6M_0 (24.7^{0}C). With these results, the four different stages of composting were identified and detailed under section 5.3.1

4.3.2 Microbial enumeration at Different Stages of Composting

4.3.2.1 Thermophilic stage

Microbial count during thermophilic stage of composting are given in table 4.12. The highest bacterial colony was observed on S_5M_2 with the population of 66.5 x 10^6cfu $10g^{-1}$.It was followed by $S_5M_3$with the population of 53.5 x 10^6cfu $10g^{-1}$ which was on par with S_4M_3 and S_5M_0. They were on par with S_4M_0, $S_4M_1$and S_5M_1.

Table 4.12 Microbial enumeration at thermophilic stage of composting

Treatment combinations*	Microbial population(cfu $10g^{-1}$)		
	Bacteria (10^6)	Fungus (10^4)	Actinomycetes (10^5)
S_1M_0	31.5 de	16.0 bcdef	4.5 ns
S_2M_0	26.5 def	14.5 bcdef	2.0 ns
S_3M_0	22.0 de	13.0 defg	6.5 ns
S_4M_0	41.5 cd	13.0 defg	5.0 ns
S_5M_0	47.0 bc	22.0 ab	4.0 ns
S_6M_0	15.0 hijk	8.0 ghi	10.0 ns
S_1M_1	18.0 ghij	10.5 fghi	8.5 ns
S_2M_1	31.0 de	17.0 bcdef	6.0 ns
S_3M_1	24.0 efg	16.0 bcdef	11.0 ns
S_4M_1	41.5 c	17.5 bcde	6.0 ns
S_5M_1	44.0 c	18.0 bcd	2.5 ns
S_6M_1	25.0 defg	18.0 bcd	6.0 ns
S_1M_2	12.0 jk	13.5 cdefg	3.0 ns
S_2M_2	19.0 fghij	18.0 bcd	6.5 ns
S_3M_2	21.0 fgh	11.0 efghi	10 ns
S_4M_2	26.5 def	20.0 bc	7.5 ns
S_5M_2	66.5 a	27.0 a	2.0 ns
S_6M_2	26.5 def	4.5 i	3.5 ns
S_1M_3	20.5 fghi	5.5 hi	1.0 ns
S_2M_3	32.5 d	7.0 ghi	1.0 ns
S_3M_3	09.5 k	7.5 ghi	4.5 ns
S_4M_3	47.5 bc	18.0 bcd	6.0 ns
S_5M_3	53.5 b	15.5 bcdef	7.5 ns
S_6M_3	13.0 ijk	11.5 defgh	6.0 ns

The treatment values in a column followed by same superscript do not differ significantly

*Details being furnished in page 20

It was followed by S_2M_3, which was on par with S_2M_1 and S_1M_0. They were on par with S_4M_2, S_6M_2 and S_2M_0. They were on par with S_6M_1, S_6M_1, which was on par with S_3M_0. S_3M_2, which was on par with S_1M_3. S_1M_3 was on par with S_2M_2, $S_1M_1$and S_6M_0.The least colony count was observed on S_3M_3 which was on par with S_1M_2.With respect to the substrate FYM: elephant dung in 1:8 proportion recorded maximum bacterial colony where as S_3 (elephant dung: banana pseudostem-1:1) and S_6 (elephant dung : Banana pseudostem (1:8) proportion recorded the lowest count.

The treatment S_5M_2 recorded the maximum fungal colony of 27.0 $x10^4$cfu $10g^{-1}$. It was followed by S_5M_0 which was on par with S_4M_2.The least count was observed in S_6M_2 having 4.5 $x10^4$cfu $10g^{-1}$.It was observed that S_5 Treatment (FYM:elephant dung-1:8) proportion recorded maximum fungal colony. The colony with least population was observed in S_1 (FYM:elephant dung 1:1 proportion). There was no significant difference between the treatments for actinomycetes count. However the highest population was recorded in S_3M_1 and lowest in S_1M_3 and S_2M_3.

4.3.2.2 Mesophilic stage of composting

Microbial count at mesophilic stage of composting is given in table 4.13. The highest bacterial count was observed in S_5M_1 with population of 77.0 $x10^6$cfu$10g^{-1}$ Next treatment recording the highest population was S_5M_3 which was on par with S_5M_0 which in turn on par with S_4 M_3, S_4M_0 and S_5M_2. There was no significant difference between S_5M_2 and S_2M_1. S_2M_1 was on par with S_2M_3, S_6M_2 and S_2M_2. The least population was observed on S_6M_3 ($20.0x10^6$ cfu $10g^{-1}$) which was on par with S_3M_3 and S_1M_2. Regarding the influence of substrate S_5 (FYM:elephant dung 1:8) proportion recorded maximum bacterial colony followed by S_2 (FYM:ED 1:1 proportion.). The least count was observed in S_3 combination (elephant dung: banana pseudostem 1:1 proportion).

Table 4.13 Microbial enumeration at mesophilic stage of composting

	Microbial population(cfu $10g^{-1}$)		
Treatment combinations*	Bacteria(10^6)	Fungus(10^4)	Actinomycetes(10^5)
S_1M_0	37.0 fghi	20.5 bcde	5.5 efg
S_2M_0	33.5 ghi	16.5 bcdefg	6.0 defg
S_3M_0	30.5 dhijk	15.0 defgh	13.0 a
S_4M_0	54.0 d	17.0 cdefg	6.0 ddefg
S_5M_0	64.0 bc	33.0 a	3.5 fg
S_6M_0	26.0 jkl	07.5 i	13.0 a
S_1M_1	24.0 kl	18.5 bcde	12.5 ab
S_2M_1	48.5 de	16.0 cdefg	6.5 def
S_3M_1	29.5 ijk	22.0 bc	11.5 abc
S_4M_1	38.5 fgh	20.5 bcde	8.5 bcde
S_5M_1	77.0 a	24.0 b	5.5 efg
S_6M_1	32.0 ghijk	24.0 b	7.0 def
S_1M_2	20.0 l	16.0 cdefgh	6.5 def
S_2M_2	44.0 efg	14.0 efgh	3.5 fg
S_3M_2	25.0 jkl	18.0 bcdef	10.0 abcdd
S_4M_2	35.5 fghi	21.0 bcd	13.5 a
S_5M_2	51.5 d	36.5 a	7.5 cdef
S_6M_2	40.0 efg	11.5 fghi	4.5 efg
S_1M_3	32.5 ghij	17.0 cdefg	3.5 fg
S_2M_3	42.5 ef	11.5 fghi	2.0 g
S_3M_3	20.0 l	9.5 hi	7.0 def
S_4M_3	55.5 cd	20.5 bcde	8.5 bcde
S_5M_3	67.5 b	18.5 bcde	7.5 def
S_6M_3	20.0 l	11.0 ghi	10.0 abcd

The treatment values in a column followed by same superscript do not differ significantly. *Details being furnished in page 20

The highest fungal colony was observed in S_5M_2 (36.5x 10^4 cfu $10g^{-1}$), which was on par with S_5M_0. The lowest count was observed in S_6M_0, which was on par with S_3M_3. There was no significant difference between S_6M_1, S_5M_1 and S_3M_1.It was also found that S_4M_2, S_1M_0, S_4M_1, S_4M_3, S_5M_3.S_1M_1 and S_3M_2 were on par with respect to fungal count. It was also found insignificance in S_3M_2, S_2M_0.S_1M_3, S_4M_0, S_2M_1 and S_1M_2 were on par treatments. S_2M_3 and S_6M_3 were also on par with respect to fungal count. The substrate, FYM:elephant dung (1:8) recorded maximum fungal colony and lowest in elephant dung : banana pseudostem in 1:8 proportion.

There was significant difference in actinomycetes population at mesophilic stage of composting. The highest population (13.5x10^5 cfu $10g^{-1}$) was recorded in S_4M_2 which was on par with S_3M_0, S_6M_0 and S_1M_1. The lowest count was recorded in S_2M_3 (2.0x10^5 cfu $10g^{-1}$) which was on par with S_2M_2, S_5M_0 and S_1M_3.The lowest actinomycetes population was observed in FYM: elephant dung (1:1) proportion and highest count in elephant dung: banana pseudostem in 1:1 proportion.

4.3.2.3 *Maturity stage of composting*

Data pertaining to microbial count at maturity stage of composting are presented in table 4.14. The highest bacterial colony of 54.0 x10^6 cfu $10g^{-1}$ was observed in S_5M_1, which was on par with S_5M_2. The lowest population was recorded in S_3M_3 and S_1M_1 with a population of 16.0x10^6 cfu $10g^{-1}$. It was insignificant among S_4M_0, S_6M_1, S_2M_0, S_3M_1, S_4M_2, S_6M_3, S_6M_2 and S_1M_3 treatments. S_1M_3 and S_2M_3 were on par. S_2M_3, S_2M_2 and S_1M_1 were on par. S_1M_2 was on par with S_2M_1, S_3M_3 and S_3M_0. The highest bacterial population was observed in FYM:elephant dung (1:8) proportion followed by treatment with FYM: elephant dung in 1:1 proportion. The lowest bacterial population was observed in elephant dung: banana pseudostem in 1:8 proportion.

Table 4.14 Microbial enumeration at maturity stage of composting

	Microbial population(cfu $10g^{-1}$)		
Treatment Combinations*	Bacteria (10^6)	Fungus (10^4)	Actinomycetes (10^5)
S_1M_0	33.0 ^{cde}	12.0 ^{bc}	8.0 ^{ns}
S_2M_0	26.5 ^{defg}	9.5 ^{bc}	3.0 ^{ns}
S_3M_0	18.5 ^{gh}	8.0 ^{bc}	3.0 ^{ns}
S_4M_0	32.0 ^{cdef}	9.0 ^{bc}	4.0 ^{ns}
S_5M_0	41.0 ^{bc}	16.0 ^{ab}	4.5 ^{ns}
S_6M_0	18.0 ^{gh}	6.0 ^{c}	4.0 ^{ns}
S_1M_1	16.0^{h}	10.0 ^{bc}	6.5 ^{ns}
S_2M_1	20.5^{gh}	8.0 ^{bc}	5.0 ^{ns}
S_3M_1	26.0^{defgh}	12.5 ^{bc}	6.0 ^{ns}
S_4M_1	35.0 ^{cd}	15.5 ^{ab}	6.0 ^{ns}
S_5M_1	54.0 ^{a}	12.0 ^{bc}	4.5 ^{ns}
S_6M_1	26.5 ^{defg}	11.5 ^{bc}	3.0 ^{ns}
S_1M_2	22.0 ^{fgh}	11.0 ^{bc}	5.0 ^{ns}
S_2M_2	22.5 ^{fgh}	12.5 ^{bc}	2.0 ^{ns}
S_3M_2	19.5 ^{gh}	11.5 ^{bc}	4.0 ^{ns}
S_4M_2	26.0 ^{defgh}	11.5 ^{bc}	2.0 ^{ns}
S_5M_2	50.0 ^{ab}	21.5 ^{a}	5.5 ^{ns}
S_6M_2	25.0 ^{defgh}	13.5 ^{abc}	6.5 ^{ns}
S_1M_3	25.0 ^{defgh}	9.5 ^{bc}	5.0 ^{ns}
S_2M_3	24.0 ^{efgh}	8.5 ^{bc}	2.5 ^{ns}
S_3M_3	16.0 ^{h}	10.5 ^{bc}	4.0 ^{ns}
S_4M_3	34.0 ^{cde}	14.5 ^{ab}	4.0 ^{ns}
S_5M_3	46.5 ^{ab}	14.5 ^{ab}	6.0 ^{ns}
S_6M_3	25.0 ^{defgh}	10.0 ^{bc}	5.5 ^{ns}

The treatment values in a column followed by same superscript do not differ significantly. *Details being furnished in page 20

S_5M_2 recorded the highest fungal count of 21.5 x 10^4 cfu $10g^{-1}$ .It was on par with S_5M_0, S_4M_1, S_4M_3 and S_5M_3. Next treatment recording highest count was S_6M_2, which was on par with S_3M_1, S_2M_2, S_1M_0, S_5M_1, S_3M_2, S_4M_2, S_6M_1, S_1M_2, S_3M_3, S_1M_1, S_6M_3, S_2M_0, S_1M_3, S_4M_0, S_2M_3, S_3M_0 and S_2M_1. The lowest count of $6.0x10^4$ cfu $10g^{-1}$was seen in S_6M_0. Fungal population was higher in FYM:elephant dung (1:8) proportion and lower in FYM:elephant dung in 1:1 proportion.

There was no significant difference in actinomycetes populaton at maturity stage. The highest population (8.0 x 10^5 cfu $10g^{-1}$) was recorded in S_1M_0 and lowest (2.5x 10^5 cfu $10g^{-1}$) was recorded in S_2M_3.

4.3.3 Influence of Substrate & Microbes on Earthworm Count

Data for the rate of earth worm multiplication at the final stage of composting are furnished in table 4.15. The earth worms were introduced @ 60/kg of substrate. The earth worm count was multiplied two to eight fold in different substrate combination after 60 days of vermicomposting. The maximum multiplication rate of (8.2) was noticed in S_5M_2 and lowest rate (2.72) was noticed in S_4M_3. FYM: elephant dung in 1:8 proportion recorded highest multiplication rate and lowest was recorded in FYM: banana pseudostem (1:8) proportion.

4.3.4 pH Variations of Compost at Maturity Stage

pH variations of compost at maturity stage are given in table 4.16. There was no significant difference for pH variation for compost combinations. Microbial influence also does not show any significant variation. But the substrate level has influenced the compost pH variation significantly. The highest pH of 7.3 was recorded in S_6 (elephant dung: banana pseudostem-1: 8 proportion) followed by S_3 (elephant dung: banana pseudostem- 1:1 proportion). The lowest pH of 6.2 was recorded by S_2 (elephant dung: BPS-1:1) which was on par with that of S_1, S_5 and S_4.

Table 4.15 Earth worm count as influenced by different substrates and microbial combinations

a)

Treatment combinations*	Earth worm count/kg of substrate at harvest stage	Treatment combination	Earth worm count/kg of substrate at harvest stage
S_IM_1	200.01	S_4M_1	163.37
S_IM_2	184.02	S_4M_2	181.51
S_IM_3	185.62	S_4M_3	175.67
S_2 M_1	426.19	S_5 M_1	464.74
S_2 M_2	422.01	S_5 M_2	494.67
S_2 M_3	412.62	S_5 M_3	457.27
S_3M_1	278.17	S_6M_1	198.29
S_3M_2	288.92	S_6M_2	204.22
S_3M_3	292.37	S_6M_3	197.13

b) *Details being furnished in page 20

Substrate	S_1	S_2	S_3	S_4	S_5	S_6
Earth worm count/ kg of substrate	189.88	420.27	286.49	173.52	472.26	199.88

c)

Microbes	M_1	M_2	M_3
Earth worm count/ kg of substrate	288.46	295.89	286.79

Table 4.16 pH of compost at maturity stage as influenced by different substrates and microbial combinations

a)

Treatment combinations*	pH	Treatment combination	pH
S_1M_0	6.2 ^{NS}	S_1M_2	6.2 ^{NS}
S_2M_0	5.7 ^{NS}	S_2M_2	6.7 ^{NS}
S_3M_0	6.6 ^{NS}	S_3M_2	6.8 ^{NS}
S_4M_0	6.6 ^{NS}	S_4M_2	6.3 ^{NS}
S_5M_0	6.8 ^{NS}	S_5M_2	7.0 ^{NS}
S_6M_0	7.0 ^{NS}	S_6M_2	7.2 ^{NS}
S_1M_1	6.4 ^{NS}	S_1M_3	6.2 ^{NS}
S_2M_1	6.1 ^{NS}	S_2M_3	6.7 ^{NS}
S_3M_1	6.9 ^{NS}	S_3M_3	6.8 ^{NS}
S_4M_1	6.6 ^{NS}	S_4M_3	6.5 ^{NS}
S_5M_1	6.8 ^{NS}	S_5M_3	6.2 ^{NS}
S_6M_1	7.0 ^{NS}	S_6M_3	7.8 ^{NS}

The treatment values in a column followed by same superscript do not differ significantly *Details being furnished in page 20

b)

Substrate	S_1	S_2	S_3	S_4	S_5	S_6
pH	6.3 ^{bc}	6.2 ^{c}	6.8 ^{ab}	6.5 ^{bc}	6.7 ^{bc}	7.3 ^{a}

c)

Microbes	M_0	M_1	M_2	M_3
pH	6.4^{NS}	6.6 ^{NS}	6.7 ^{NS}	6.7 ^{NS}

The treatment values in a row followed by same superscript do not differ significantly

4.3.5 Maturity Days of Compost

Data regarding maturity days of different treatment combination are given in table 4.17. There was no significant difference between treatment combinations on the maturity days of composting. Maturity days ranged from 45.5 days in S_1M_2 to 60 days in S_6M_0. Coming to the influence of substate, S_1 recorded minimum maturity period of 47.0 days and S_6 recorded maximum maturity period of 59.5 days. Comparing the substrate combination of elephant dung, the minimum maturity period was recorded by S_2 which was on par with S_5 combination. Considering the influence of microbes native microbes, and treatment without microbes were on par recording maximum maturity period. Consortium of Aspergillus flavus & Bacillus subtilis have showed minimum maturity period, which was on par with *Pleurotus platypus* introduced treatment.

4.3.5.1 Correlation of temperature during different stage of composting with maturity period.

A correlation analysis was done to assess whether temperature during thermophilic, mesophilic, cooling and maturity stages of compost has any influence on maturity period of composting. The results are furnished in table 4.18. A highly significant positive correlation was obtained with thermophilic temperature and significant positive correlation with mesophilic temperature. Non-significant negative correlation was obtained for cooling temperature and non-significant positive correlation for temperature at maturity stage of compost.

Table 4.17 Maturity days of compost as influenced by different substrates and microbial combinations

a)

Treatment combination*	Maturity days	Treatment combination	Maturity days
S_1M_0	48.5 ^{NS}	S_1M_2	45.5 ^{NS}
S_2M_0	55.5 ^{NS}	S_2M_2	51.5 ^{NS}
S_3M_0	57.5 ^{NS}	S_3M_2	56.5 ^{NS}
S_4M_0	54.5 ^{NS}	S_4M_2	51.0 ^{NS}
S_5M_0	57.0 ^{NS}	S_5M_2	56.5 ^{NS}
S_6M_0	60.0 ^{NS}	S_6M_2	56.5 ^{NS}
S_1M_1	46.0 ^{NS}	S_1M_3	48.5 ^{NS}
S_2M_1	53.5 ^{NS}	S_2M_3	56.5 ^{NS}
S_3M_1	57.5 ^{NS}	S_3M_3	58.5 ^{NS}
S_4M_1	53.5 ^{NS}	S_4M_3	55.0 ^{NS}
S_5M_1	54.0 ^{NS}	S_5M_3	58.5 ^{NS}
S_6M_1	58.5 ^{NS}	S_6M_3	59.0 ^{NS}

The treatment values in a column followed by same superscript do not differ significantly

*Details being furnished in page 20

b)

Substrate	S_1	S_2	S_3	S_4	S_5	S_6
Maturity days	47.00 ^{e}	55.25 ^{cd}	58.5 ^{b}	54.5^{d}	56.5 ^{c}	59.5 ^{a}

c)

Microbes	M_0	M_1	M_2	M_3
Maturity days	55.5 ^{a}	53.83 ^{b}	52.92 ^{b}	56.0 ^{a}

The treatment values in a row followed by same superscript do not differ significantly

Table 4.18 Correlations between temperature recorded at different stages of composting and days of compost maturity

Temperature	Thermophilic Stage	Mesophilic Stage	Cooling Stage	Maturity Stage
Maturity Days	0.625**	0.356*	-0.19^{NS}	0.159^{NS}

** Highly significant * significant NS- non significant

4.3.6. Nutrient Contents of Compost

The nutrient value of compost at the maturity stage are furnished in the table 4.19.

4.3.6.1 Carbon

The highest carbon content was recorded in S_6M_0 (14.52%). The next treatment recording highest carbon was S_3M_0, which was on par with S_2M_0. The lowest carbon content was recorded in S_1M_2 (7.36%) which was on par with S_4M_2. S_6M_3, S_5M_0, S_5M_3 were insignificant with respect to carbon percent. It was found that S_3M_1, S_2M_3, S_3M_3 were on par. It was also found that there was no significant difference between the treatment combinations of S_6M_2, S_1M_0, S_1M_3, S_2M_1. S_3M_2, S_4M_3, S_5M_1. It was also found that S_5M_2, S_6M_1 were insignificant with S_2M_1 and S_5M_1. S_4M_1 was on par with S_4M_0, S_1M_1. S_1M_1 and S_4M_2 were insignificant with respect to carbon content. On considering the influence of microbes, it was found that those treatments without the addition of microbes recorded the highest carbon content. With regard to the substrate, it was noted that substrate combination with elephant dung: banana pseudostem (1:8) recorded the highest carbon content.

4.3.6.2 Nitrogen

No significance on different treatment combinations for nitrogen status was observed. There was no variation due to microbial influence on different compost

combinations. But substrate combination created significant difference for N content. S_5 (FYM: elephant dung-1:8) recorded highest N content which was on par with S_2 (FYM: elephant dung-1:1) and S_3 (elephant dung : banana pseudostem-1:1). Lowest value recorded for S_4 (FYM: banana pseudostem-1:8) which was on par with S_1 (FYM: banana pseudostem-1:1 proportion.).

4.3.6.3 Phosphorous

The P content of compost ranges from 0.45 percent in S_6M_0 to 0.90 percent in S_2 M_3.The highest P content was recorded in S_2M_3, which was on par with S_5M_3. The lowest P content was recorded in S_6M_0 (0.45%) which was on par with S_6M_1 and S_4M_2. It was found that there was no significant difference between S_5M_1 and S_1M_1 with respect to P status. S_1M_3, S_6M_3, S_5M_2, S_3M_3, S_2M_2, S_3M_1, S_4M_1, and S_1M_2 were on par treatments. On considering the substrate influence, the treatment with FYM: elephant dung in 1:8 proportion recorded the highest P content. With respect to microbial influence the treatment with native microbes recorded the highest P content.

4.3.6.4 Potassium

The highest K content was recorded in S_4M_1 with 1.04 percent. The next best treatment was S_5M_3 with 0.87 percent, which was on par with S_3M_1. The treatment recording the lowest K status was S_3M_2 (0.39%) which was on par with S_5M_0. The potassium content of different compost combinations ranged from 0.39 percent in S_3M_2 to 1.04 percent in S_4M_1. It was found that S_6M_0, S_5M_1, S_1M_1, S_4M_0 were on par. It was also found that S_6M_2, S_3M_0, S_4M_3, S_2M_2, S_6M_1, S_2M_1 were on par. No significant difference was noted for S_2M_0,S_2M_3,S_1M_3,S_6M_3,S_1M_2,S_5M_2 and S_3M_3. With respect to substrate combination FYM: elephant dung (1:8) and ED: banana pseudostem (1:8) had higher K content. *Pleurotus platypus* introduced treatment had higher K content.

4.3.6.5 Calcium

The calcium content ranged from 0.025 percent to 0.945 percent. Highest calcium status for S_5M_1 (0.945) which was on par with S_3M_3.No significant difference could be found between S_3M_1, S_6M_1 and S_5M_3. S_1M_2. S_2M_2, $S_4M_1$and S_2M_3 were on par. Lowest calcium content in S_3M_0 (0.03%) which was on par with S_1M_0, S_6M_0, S_2M_0, S_4M_0 and S_5M_0. FYM: elephnt dung (1:8) proportion recorded highest calcium status. *Pleurotus platypus* introduced treatment recorded highest calcium status. It was also found that treatment without microbes and earth worms has recorded very low calcium status.

4.3.6.6 Magnesium

There was no significant difference between treatment combinations on magnesium status. Highest Mg status was recorded in S_4 (FYM: banana pseudostem (1:8) proportion. Lowest magnesium status was recorded in S_6 (elephant dung: BPS-1:8) and S_1 (FYM: BPS-1:1).

4.3.6.7 Sodium

Sodium ranged from 0.09 percent in S_5M_3 to 0.25 percent in S_4M_1 and S_6M_1. The highest Na status was recorded in S_4M_1 and S_6M_1.The lowest Na recorded in S_5M_3 with 0.09 percent. No significant difference in S_6M_2, S_4M_2 and S_6M_3.S_6M_3 was on par with S_2M_1, S_1M_2 and S_3M_2. It was followed by S_3M_3, which was on par with S_2M_0 and S_3M_1. S_3M_1 and S_1M_1 was insignificant with Na content. $S_3M_1$was on par with S_1M_3, S_2M_2, S_3M_0, S_4M_0, and S_4M_3. S_4M_3 was on par with S_1M_0, S_5M_2 and S_5M_0 which in turn on par with S_5M_1 and S_6M_0.Considering the substrate combination, FYM: banana pseudostem (1:8) and elephant dung: banana pseudostem (1:8) proportion recorded highest sodium content. Consortium of *Bacillus subtilis & Aspergillus flavus* and *Pleurotus platypus* recorded the highest Na content

Table 4.19 Effect of different treatment combination on the the nutrient contents of biotically enriched elephant dung, in %

Treatment combination*	Carbon	Nitrogen	Phosphorous	Potassium	Sodium	Calcium	Magnesium
S_1M_0	10.33 defg	1.06 NS	0.49 jk	0.41 jkl	0.14 efgh	0.05 k	0.04 NS
S_2M_0	12.29 b	1.24 NS	0.51 ijk	0.52 gh	0.17 cdef	0.04 k	0.04 NS
S_3M_0	12.42 b	1.25 NS	0.71 cd	0.59 ef	0.15 defgh	0.03 k	0.04 NS
S_4M_0	8.85 hij	1.06 NS	0.52 hij	0.73 d	0.16 efgh	0.04 k	0.05 NS
S_5M_0	11.60 bcd	1.34 NS	0.51 ijk	0.40 ki	0.13 efgh	0.03 k	0.03 NS
S_6M_0	14.52 a	1.12 NS	0.45 k	0.76 d	0.10 gh	0.04 k	0.04 NS
S_1M_1	8.78 hijk	1.08 NS	0.78 bc	0.73 d	0.16 defg	0.35 ij	0.03 NS
S_2M_1	9.86 defgh	1.19 NS	0.50 ijk	0.56 fg	0.19 abcde	0.40 hi	0.05 NS
S_3M_1	10.74 cde	1.38 NS	0.55 ghij	0.83 bc	0.17 cdef	0.86 bc	0.05 NS
S_4M_1	9.05 ghij	1.21 NS	0.53 ghij	1.04 a	0.25 a	0.47 gh	0.04 NS
S_5M_1	9.86 defgh	1.22 NS	0.79 b	0.75 d	0.11 fgh	0.95 a	0.03 NS
S_6M_1	9.52 efghi	1.29 NS	0.49 jk	0.56 fg	0.25 a	0.83 bcd	0.03 NS
S_1M_2	7.36 k	1.08 NS	0.55 ghij	0.44 ijkl	0.19 abcde	0.50 g	0.03 NS
S_2M_2	9.73 defgh	1.16 NS	0.54 ghij	0.56 fg	0.16 defg	0.49 g	0.03 NS
S_3M_2	9.86 defgh	1.25 NS	0.66 de	0.39 i	0.19 abcde	0.80 cd	0.04 NS
S_4M_2	7.63 jk	0.91 NS	0.49 jk	0.79 cd	0.23 abc	0.57 f	0.04 NS
S_5M_2	9.66 efgh	1.65 NS	0.59 fgh	0.44 ijkl	0.14 efgh	0.89 ab	0.04 NS
S_6M_2	10.60 def	1.17 NS	0.50 ijk	0.65 e	0.24 ab	0.76 d	0.04 NS
S_1M_3	9.81 defgh	0.94 NS	0.59 fg	0.47 hij	0.16 defg	0.30 j	0.03 NS
S_2M_3	10.06 cd	1.40 NS	0.90 a	0.49 hi	0.19 abcde	0.43 gh	0.04 NS
S_3M_3	10.82 cd	1.25 NS	0.56 ghi	0.42 ijkl	0.18 bcde	0.94 a	0.03 NS
S_4M_3	9.78 defgh	0.92 NS	0.64 ef	0.59 ef	0.16 defg	0.68 e	0.03 NS
S_5M_3	11.21 bcd	1.34 NS	0.87 a	0.87 b	0.09 h	0.82 bcd	0.03 NS
S_6M_3	12.09 bc	1.20 NS	0.59 fgh	0.46 hijk	0.21 abcd	0.68 e	0.03 NS

The treatment values in a column followed by same superscript do not differ significantly *Details being furnished in page 20

Discussion

5. DISCUSSION

The results of various experiments conducted on utilization of elephant dung for vermicompost production were studied, presented in the chapter 4 and discussed below.

5.1 IDENTIFYING THE ROLE OF MACRO AND MICROFAUNA ON THE *IN-SITU* DECOMPOSITION OF ELEPHANT DUNG

5.1.1 *In-situ* Decomposition of Elephant Dung

5.1.1.1 Influence of temperature, moisture and C: N ratio on degradation stages of dung during different months of sampling

At all the stages of degradation, the dung temperature was always higher than atmospheric temperature. This is an indication of natural process of decomposition that is going on within the dung with the release of energy by way of heat. Rate of decomposition is more rapid in a temperature range of 30^0 to 40^0C. Above or below this temperature, the process of decomposition is markedly reduced. The temperature of the degrading dung is ranging from 28-32^0C (fig1) which also indicates that the process of decomposition is going on at the site under field conditions. The highest moisture was recorded in June and the lowest in January (fig 2). The environmental conditions highly influenced the moisture within the dung. There were intermittent rains during the months of May (1.5cm) & June (4.5cm) leading to an increase in moisture content of the dung during dry periods. On an average, the moisture content of dung ranged from 8.40 to 14.70 percent at monthly intervals (fig 2).

Even though there was no significant difference on C: N ratio during different periods of sampling, the highest C: N ratio of 49.11 was recorded in

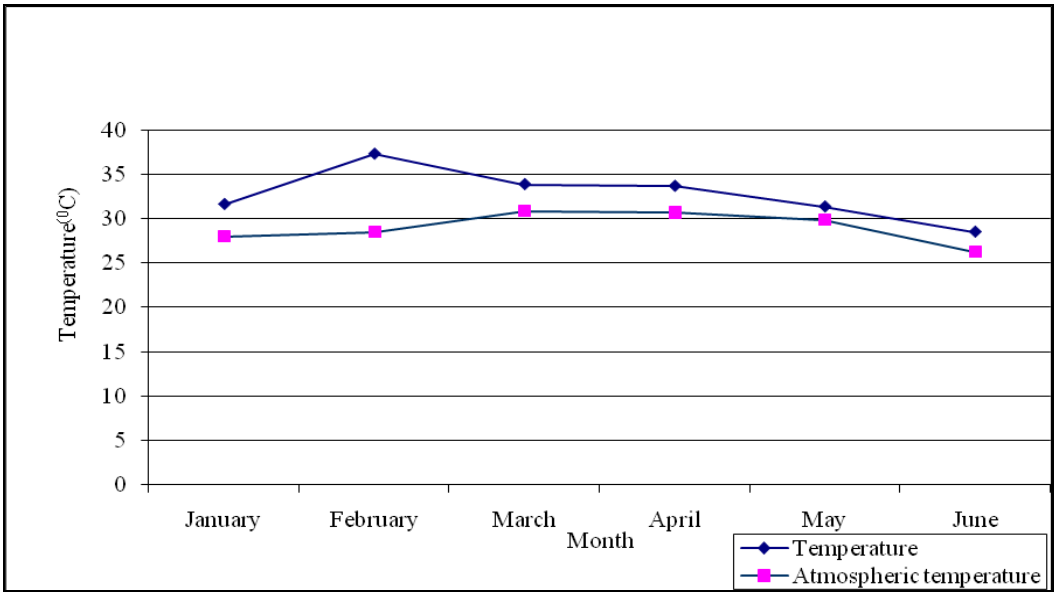


Fig. 1 The dung temperature at different months of sampling versus atmospheric temperature

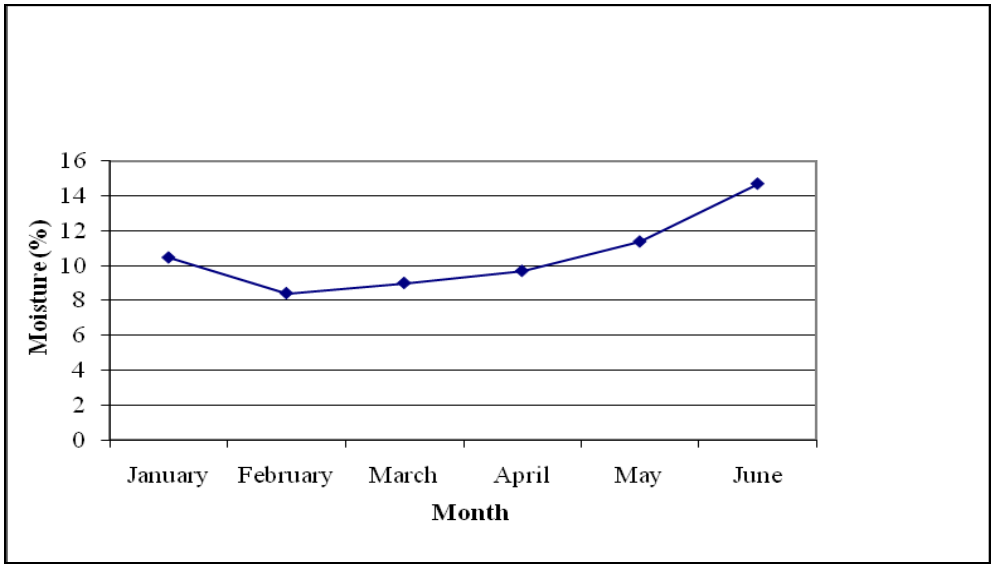


Fig. 2 Moisture contents of degrading dung at different months of sampling

January and lowest value of 48.31 was recorded in May, indicating a reduction as the months advances.

5.1.1.2 Effect of C: N ratio & microbial population at different degradation stages of dung

Considering the C: N ratios, the highest C: N ratio was recorded at four months old sample (E_4) followed by eight months old sample (E_3). The fresh faecal bolus (E_6) was on par with E_2 and also found that E_5 (body washings) were on par with E_1 (fig 3). The fresh faecal bolus and body washings have recorded lower C: N ratio due to the presence of more nitrogen content in the sample because of the presence of more urine in fresh samples.

At the advanced stage of decomposition of dung, the C: N ratio was getting reduced due to more microbial activity leading to the loss of carbon as CO_2 (Hamoda *et al*., 1998). It was also observed that micro fauna was high at early stage which was getting reduced due to reduction in substrate.

In advanced stage *viz* E_1 and E_2, the microbial population is very less. But for early stage of decomposition *viz* E_3 and E_4 and also fresh sample E_5 and E_6, the microbial population was high. As compared to fungi & actinomycetes, the bacterial population was high especially at early stage of decomposition. So these organisms are getting more organic matter to flourish which may not be available at advanced stage of decomposition (Rao, 1999). Gradually the substrate of carbon is getting reduced due to the utilization by microbes.

Microbial population especially bacteria was showing a declining trend during advanced stage of decomposition (fig 4). It has been furnished under section 4.1.2 that bacteria are having predominant role in lignocellulose degradation. So, at early stages of dung degradation *viz* E_3 and E_4, lignocellulolytic break down is taking place leading to reduction in C: N ratio and

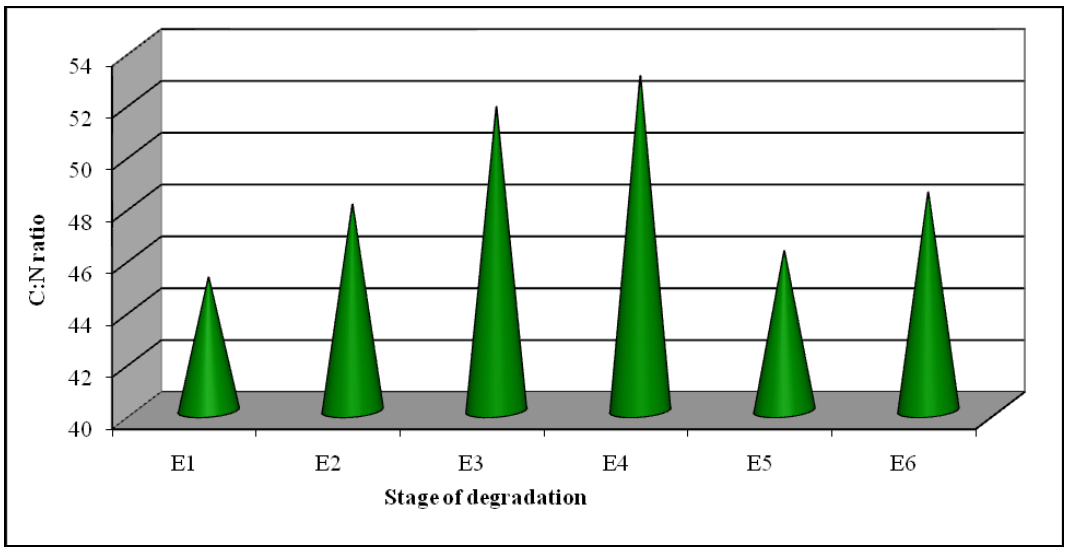


Fig.3 C: N ratio of dung at different stages of degradation

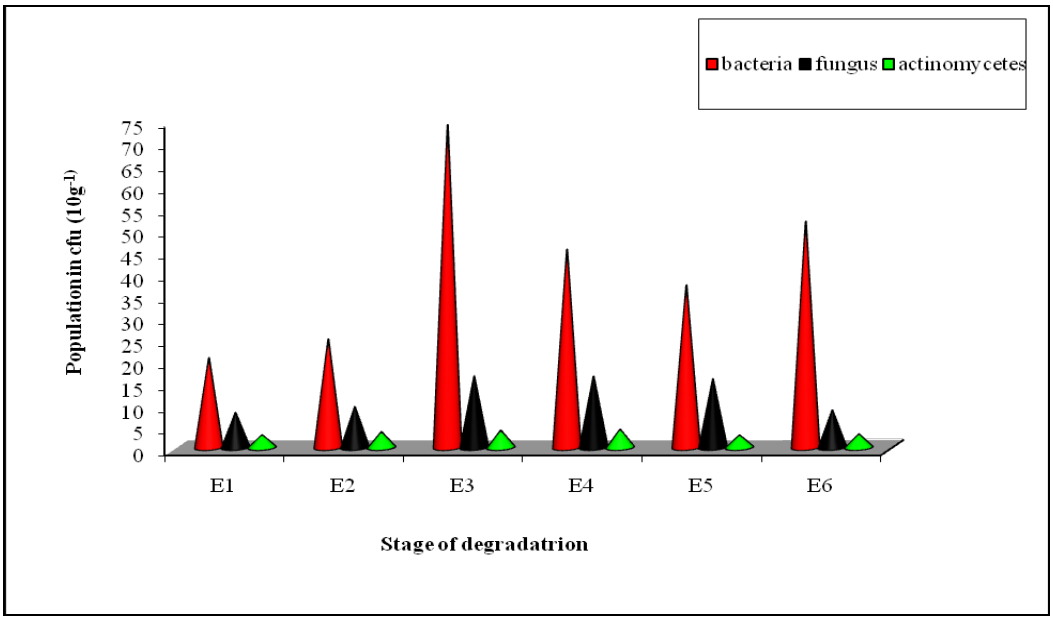


Fig. 4 Microbial enumeration (in cfu) within dung

reducing the substrate of bacteria resulting in their lower multiplication rate during advanced stage of decomposition (E_1 and E_2).

5.1.1.3 *Macro fauna at the degradation stages of dung*

As mentioned in section 4.1.1.3 in the early stage of decomposition, termites, millipeds and centipeds were the dominant macro fauna observed. But at the advanced stage, mainly earwigs and silver fish were noticed. The field monitoring was done during dry months and so there were more termite colonies in the field. Freyman *et al.,* (2008) has reported that termite can quickly remove large amount of mammalian dung especially during the dry season when an average of $1/3^{rd}$ of the dung deposited in given habitat has been removed by the termites within one month. Weir (1971) reported that dung beetles were responsible for the burial and removal of all dung during the wet season. So it may be the reason for low prominence of dung beetle during the study period.

5.1.2 Isolation of Native Microbes from Dung

As detailed under the section 4.1.2 it was found that bacteria were having prominent role in lignocellulose solubulization than fungi (fig. 5 and 6). Bacteria had predominant role in lignocellulose degradation due to wider tolerance of temperature and pH by bacteria (Hanafy *et al.,* 2007). Wahyudi *et al*., (2010) also reported the presence of lignocellulose degraders in the dung of elephant. He reported that micro fauna from buffallo's caecum were superior isolates compared to that from elephant dung and superior isolate was identified as *Entrococcus casseliflavum*. From the study it was found that M_2 (*Aspergillus flavus* & *Bacillus subtilis*) were found to be efficient in elephant dung degradation than native microbes isolated from dung. It was also reported that *Bacillus subtilis* was found to be superior for solid waste management as it has reduced the solid waste to ¼th volume within 21 days of composting (Girija *et al*., 2011). The bacteria *Bacillus subtilis* and *Entrococcus casseliflavum* were isolated from cow and buffalo,

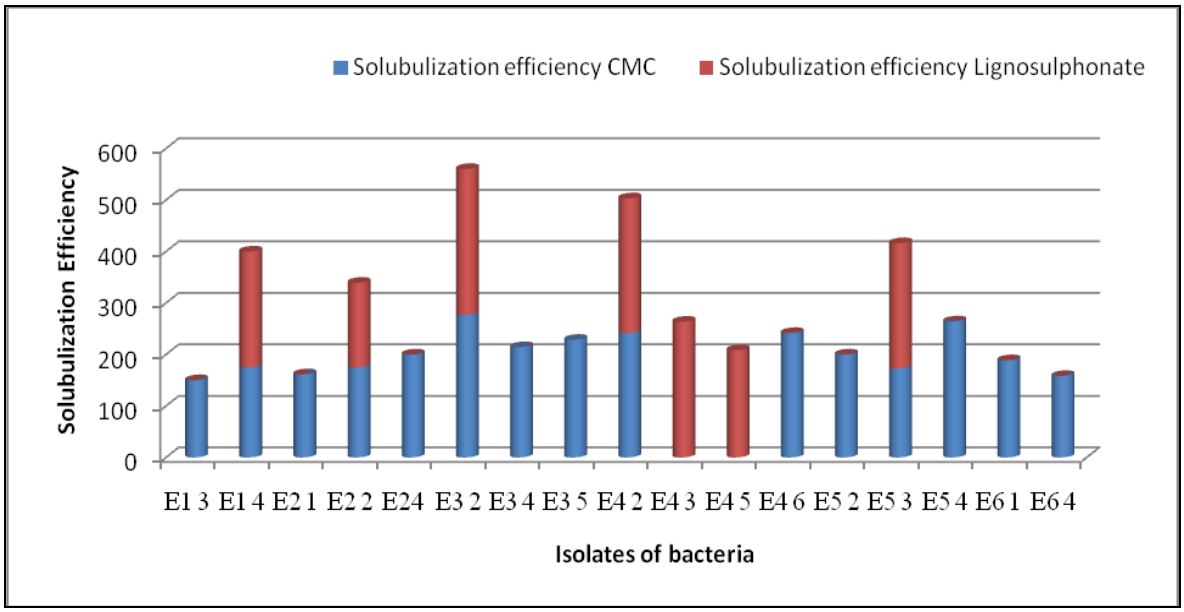


Fig. 5 Solubulization efficiency on CMC and lignosulphonate media by native bacteria

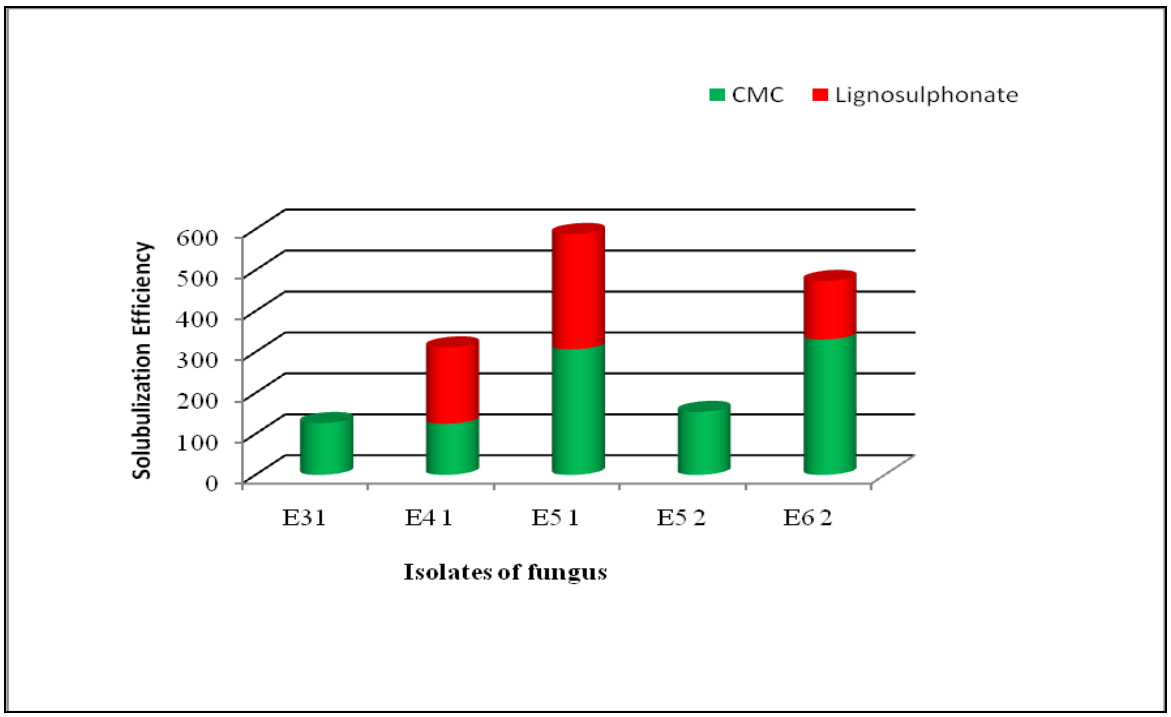


Fig. 6 Solubulization efficiency on CMC and lignosulphonate media by native fungi

which are ruminant herbivores having more digestion capacity than non ruminant elephants and hence microbes isolated from their digestive tract and dung have more efficiency for lignocellulose degradation.

5.2 BIOCHEMICAL ANALYSIS OF ELEPHANT DUNG

5.2.1 Physico chemical and Biochemical Analysis of Dung

Coming to the biochemical aspects, the dung was rich in crude fibre (21.4%) and lowest in crude fat (2.8%) [fig 7]. Among the structural constituents, it was rich in cellulose (35.8%) followed by hemicellulose (30.1%) and then lignin content (17.5%) [fig 8]. The feed mainly taken by elephant under Kerala conditions are palm leaf (*Caryota urens*) as staple roughage. The concentrate part of feed was rice, wheat, ragi or horse gram either singly or in cooked form (Anantha subramniam, 1979). He also reported that palm leaf was rich in crude fibre (31.0), crude protein (7.7%), nitrogen free extract (48.33%) and total ash (9.6%). Elephants are non ruminant herbivore. It was also reported that elephant has a digestibility of only 44% of what they consume (Sreekumar, 2009). So proper and complete digestion may not be taking place in the intestine of the elephant. Hence the dung was rich in crude fibre.

5.2.2. Variations of pH at Monthly Intervals

The pH of dung varied from neutral to alkaline range. The highest pH was recorded on March (7.3). The lowest pH was recorded on June (6.9) (fig 9). The high pH of dung was due to the presence of more base elements. The pH showed a declining trend during rainy season. As detailed under section 4.2.2, the total bases (K, Na, Ca^{2+}, Mg^{2+}) comes to around 1.46% which was higher than nitrogen status (0.86%). So these base elements may be leaching during rainy season.

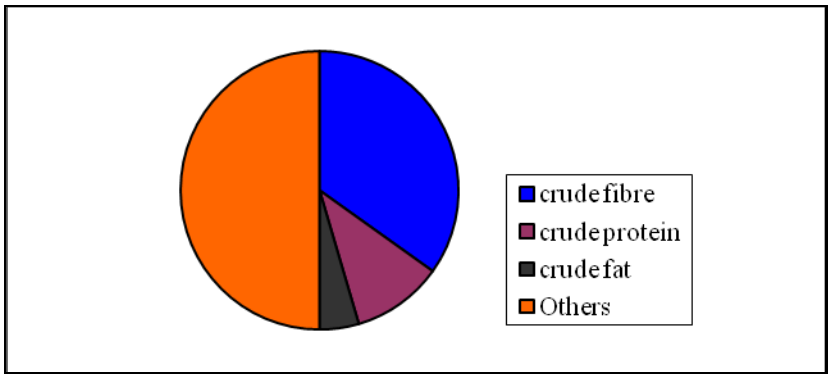


Fig. 7 Biochemical constituents of elephant dung

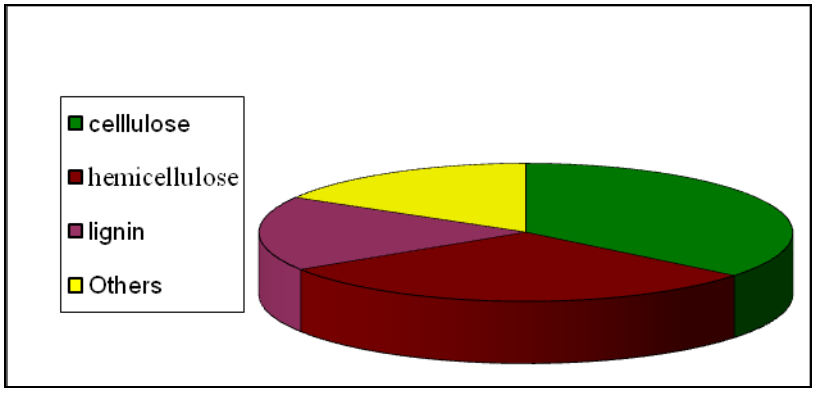


Fig.8. Structural constituents of elephant dung.

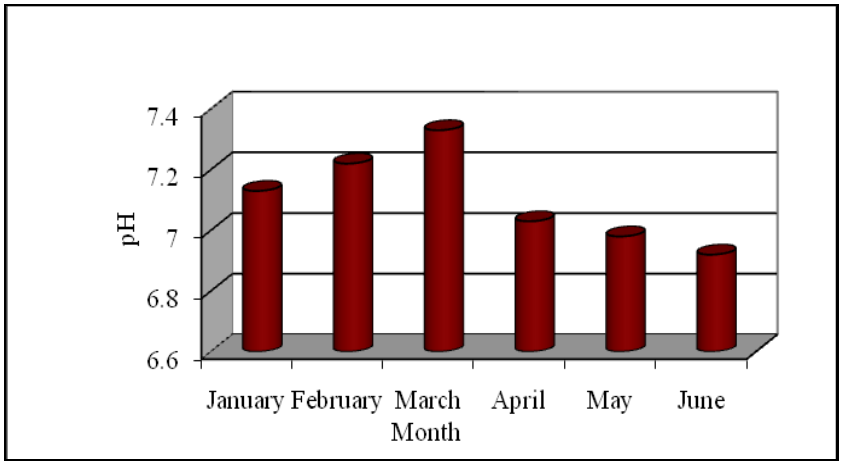


Fig .9 pH of elephant dung at monthly intervals of sampling

5.3. VERMICOMPOSTING OF ELEPHANT DUNG

5.3.1 Influence of Temperature on Composting

The whole flatuations in temperature as detailed under section 4.3.1 specify four stages of composting namely thermophilic, mesophilic, cooling and maturity stages. Supportive findings were given by Thomas (2001) and Preetha (2003). The highest temperature was recorded by S_5M_2 (39.8^0C) on 2nd day of composting and the lowest temperature by S_6M_0 (24.7^0C) on 62nd day of composting.

On the first fifteen days the highest temperature was recorded by S_5M_2 (39.8^0C) and the lowest by S_1M_0 (28.8^0C) [fig 10]. This period corresponds to thermophilic stage of composting. Irrespective of different treatment combinations, the highest temperature was recorded during thermophilic stage of composting. In all stages, thermophilic stage has great significance. The elevated temperature during the thermophilic stage is essential for rapid degradation of cellulose as the thermophilic fungi and actinomycetes involved in that process thrive at a high temperature (Tuomela *et al*., 2000). Among the treatment combinations S_5M_2 had higher microbial activity. The microbial consortium (M_2) was found to be efficient lignocellulose degrader (Girija *et al*., 2011). More over S_5 is the substrate combination of elephant dung and FYM in 8:1 proportion, had more lignocellulolytic substrate which inturn resulted in the proliferation of lignocellulose degraders. So it may be the reason for recording the highest temperature by that treatment during thermophilic stage of composting where as in S_6M_0 the no microbial agents were applied. Hence that treatment recorded lowest temperature and has taken longer maturity period for composting.

In the next 30 days, the highest temperature of 34.9^0C was recorded by S_5M_2 and lowest by S_4M_1 (26.2^0C) corresponding to mesophilic stage of composting (fig 11). In the next eight days, highest temperature by S_5M_0 (30.8^0C)

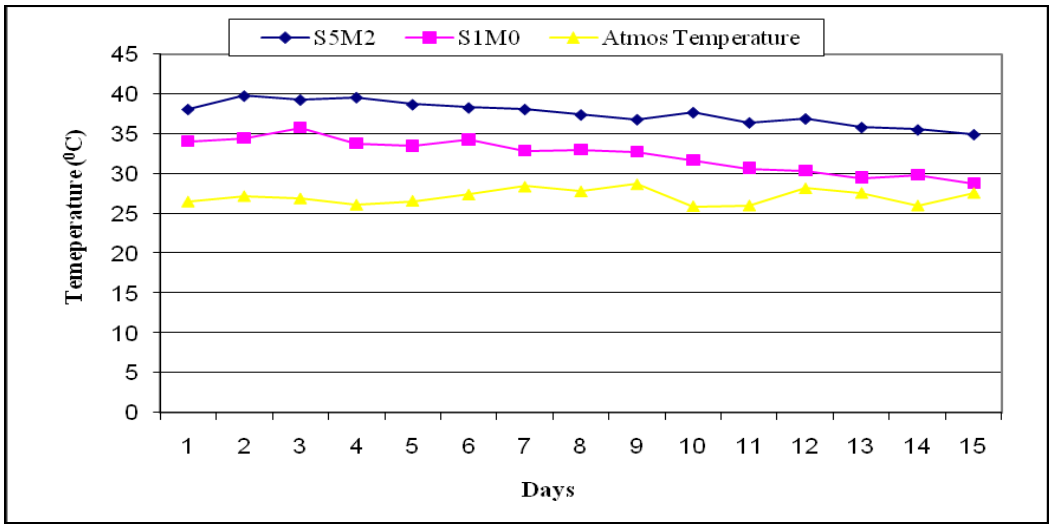


Fig. 10 Temperature variations during thermophilic stage of composting

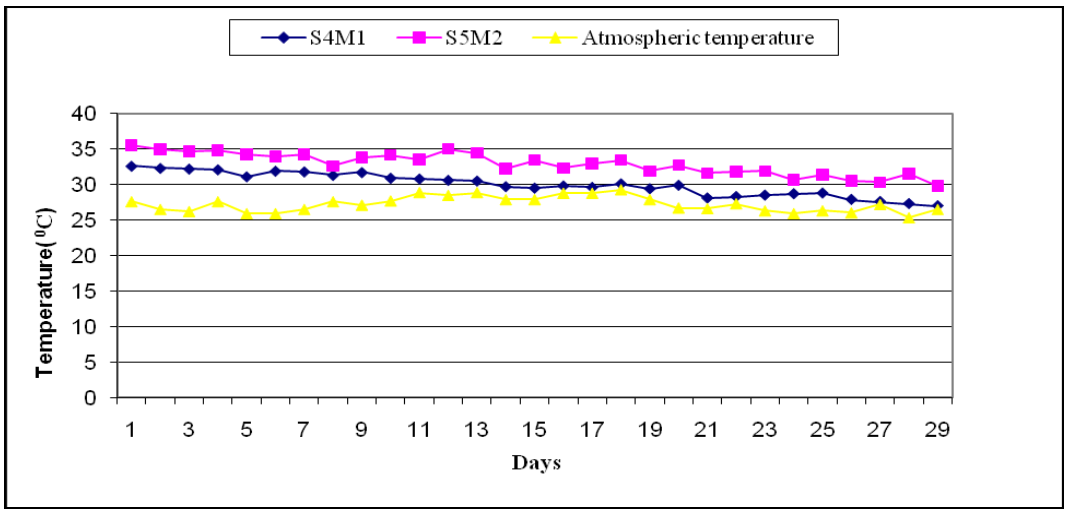


Fig. 11 Temperature variations during mesophilic stage of composting

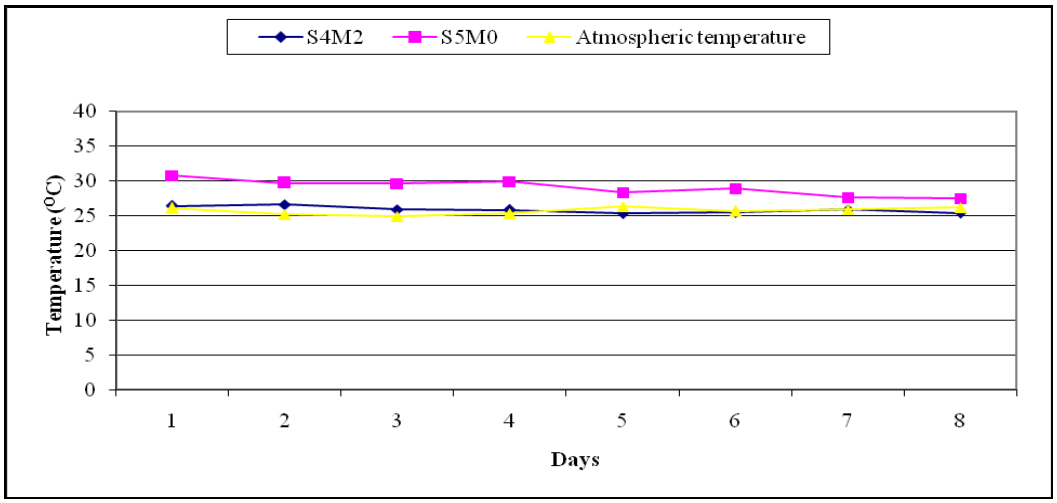


Fig. 12 Temperature variations during cooling stage of composting

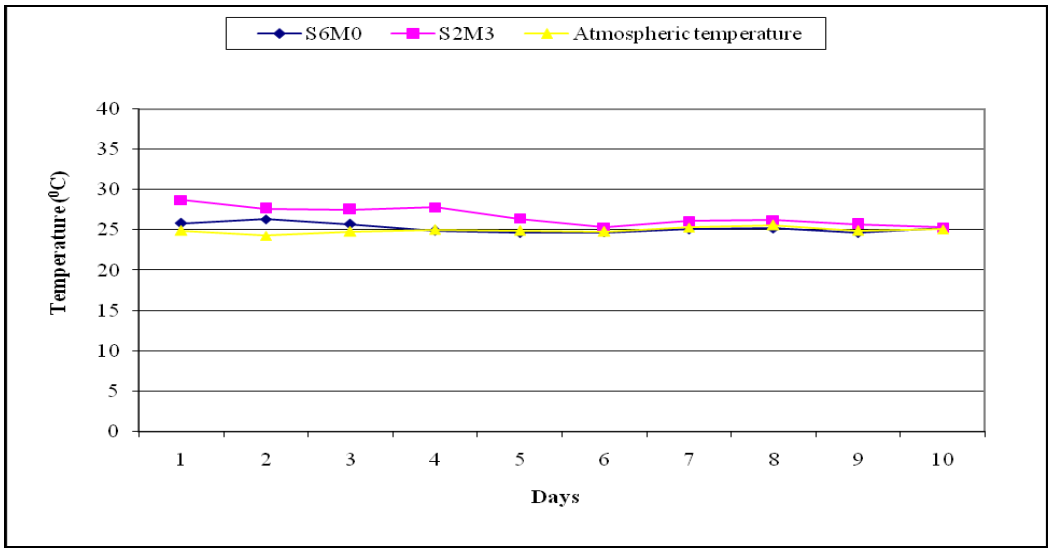


Fig. 13 Temperature variations during maturity stage of composting

and the lowest by S_4M_2 (25.4^{0}C) [fig 12]. This period represented cooling stage. In the next ten days the highest temperature was recorded by S_2M_3 (28.7^{0}C) and the lowest temperature by S_6M_0 (24.7^{0}C) [fig 13] represented maturity stage. After thermophilic stage, the microbial activity was also reduced which leads to maturation stage of composting and it falls within the ambient temperature (Zibilske, 1999). It was also revealed from the fact that the lowest temperature of 24.7^{0}C was attained by S_6M_0 on 62ndday of composting. So there existed an intrinsic relationship between temperature and stages of composting. Maturity of compost always coincides with temperature stabilization period.

5.3.2 Microbial Count at Different Stages of Composting

It was evident that in substrate combination of FYM: elephant dung in 1:8 proportion had recorded the highest microbial count (fig 13). The elephant's caecum and proximal colon harbour anaerobic microorganisms and fungi which ferment plant cell wall, carbohydrate, simple sugars, starch and protein (Sreekumar, 2009). Wahyudi *et al*., (2010) also reported the presence of lignocellulose degrading bacteria in elephant dung. Nisha (2007) revealed that bacterial population are predominant in vermiproducts followed by actinomycetes and fungi. Gopal *et al*., (2009) also reported that population of aerobic heterotrophic bacteria; filamentous actinomycetes and spore producing bacteria were higher in vermicomposted cow manure. At the maturity stage of composting, (fig 15) the population of microbes declined due to the decrease in dissolved organic carbon. The low and nearly steady state of temperature corresponding with the final stage is also explainable at this point. Observations made by Nair (1997) also supports this evidence. Pre processing of organic waste helps in breaking down the complex organic compound into intermediate simpler metabolite for synthesising new cellular materials of the microbe involved during the mesophilic stage of composting (Gaur and Sadasivam, 1993). It was also accepted that wormcast had a relatively higher microbial respiration rate than un- injested materials (Aira *et al.,* 1996).

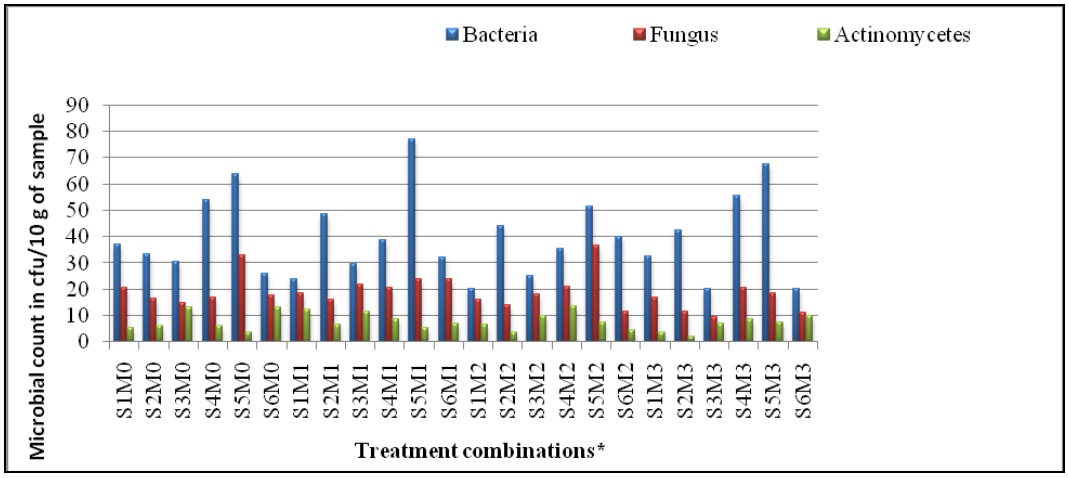


Fig. 14 Microbial enumeration at thermophilic stage as influenced by different treatment combinations

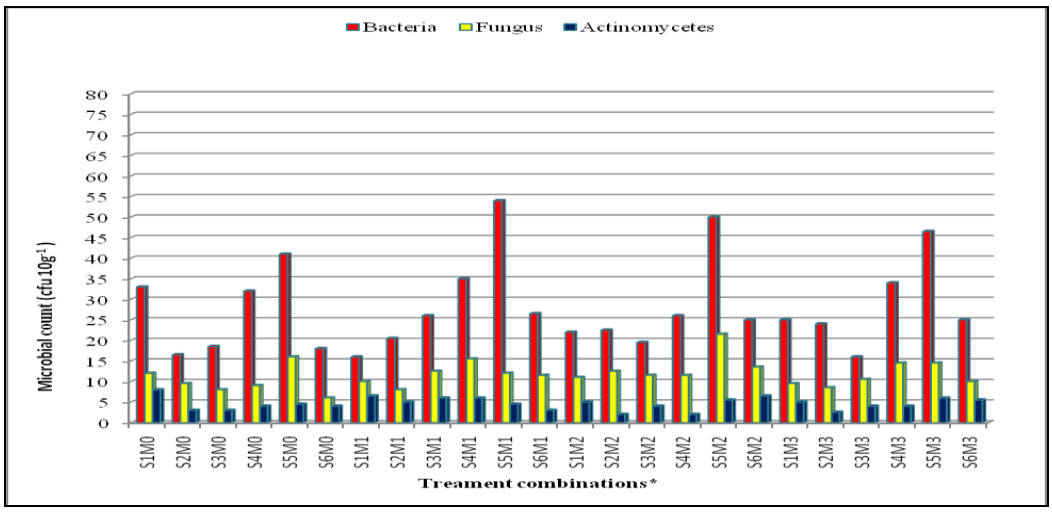


Fig. 15 Microbial enumeration at mesophilic stage as influenced by different treatment combinations

*Details are furnished in page 20

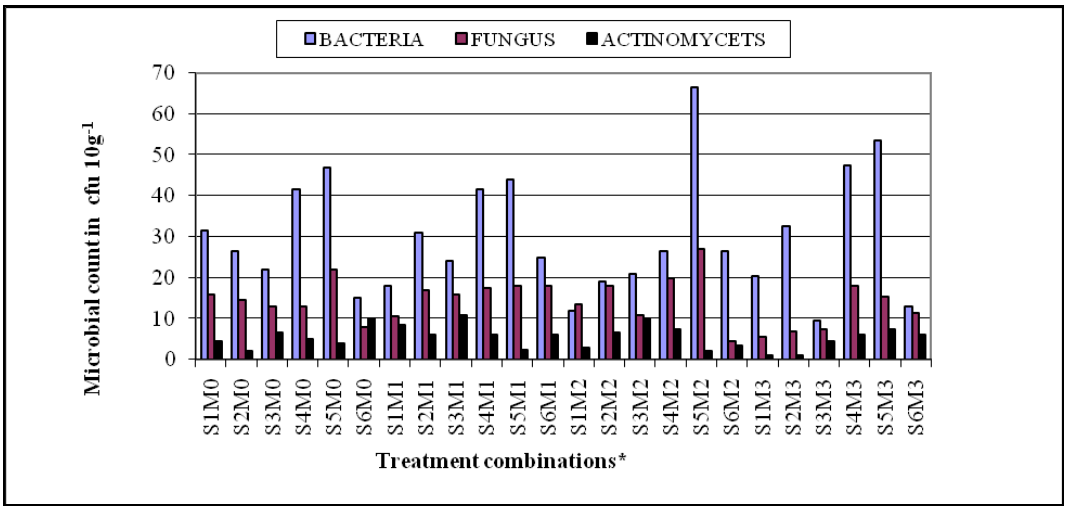


Fig.16. Microbial enumeration at maturity stage as influenced by different treatment combinations

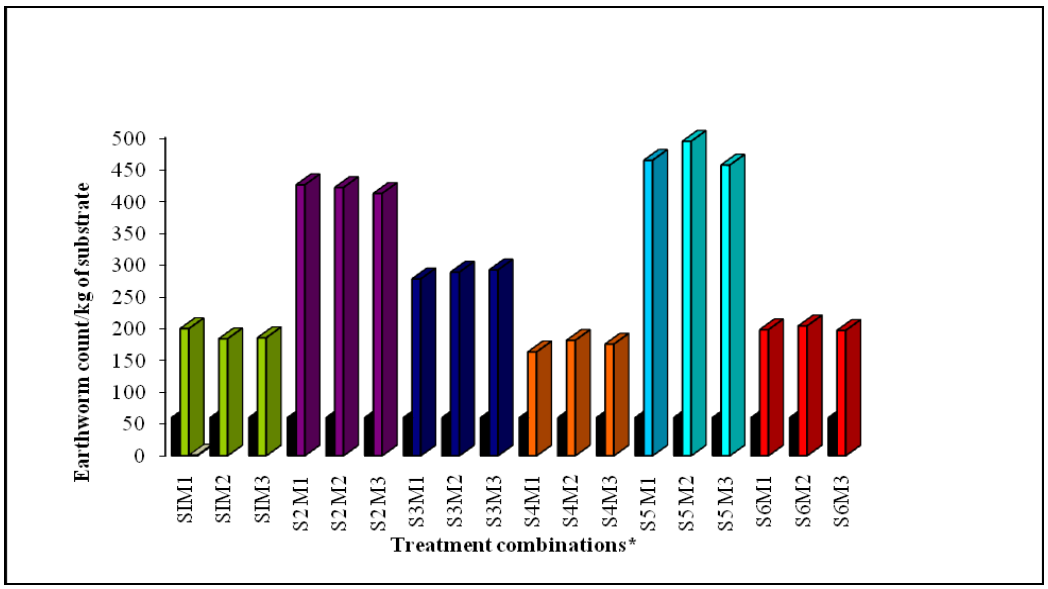


Fig. 17 Effect of different treatment combinations on earth worm multiplication

*Details are furnished in page 20

5.3.3 Influence of Substrate & Microbes on Earthworm Count

Earth worm species are able to consume wide range of organic waste such as sewage sludge, animal dung, crop residues and industrial refuse (Chan and Griffith, 1988). Suthar (2007) stated that factors relating to growth of earth worm may be considered in terms of physico-chemical and nutrient characteristics of waste feed stocks. FYM showed a high rate of multiplication due to the supply of easily metabolizable organic matter, non assimilated carbohydrate and low concentration of growth retarding substances. Neuhauser *et al*. (1988) and Manaf *et al.* (2009) also got similar results with another earth worm species, *Perionyx excavatus*. The earth worm population has showed seven to eight fold multiplication in FYM: elephant dung in 1:8 proportions (fig 17). It has been found that elephant dung (ED) is a rich source of cellulose (35.8%) as detailed under section 4.2.1. Cellulase, protease, chitinase, amylase enzymes were reported in earth worm gut by Lee (1985). So elephant dung may be the suitable substrate for earth worm multiplication. The substrate combination of FYM: banana pseudostem (1:8) recorded the lowest earth worm multiplication rate. It may be due to high moisture content of the substrate banana pseudostem (BPS) used.

5.3.4 pH Variations of Compost at Maturity Stage

As per the data provided in Appendix 3, pH of FYM was 6.8, banana pseudostem (BPS) 7.3 and elephant dung (ED), it was 7.1. The pH showed near neutral to alkaline in different compost combination ranging from 6.2 in FYM: ED (1:1) proportion to 7.3 in ED: BPS (1:8) (fig 18). Wilson (1989) reported that most well stabilized compost had a pH between 6.5 and 7.5. Gaur and Sadasivam (1993) also reported that most materials decomposing anaerobically will have a pH range that is conducive for microbiological growth. It was also noted that in all treatments where the earth worms were introduced pH, was significantly increased in comparison to the treatments where earth worms were not introduced.

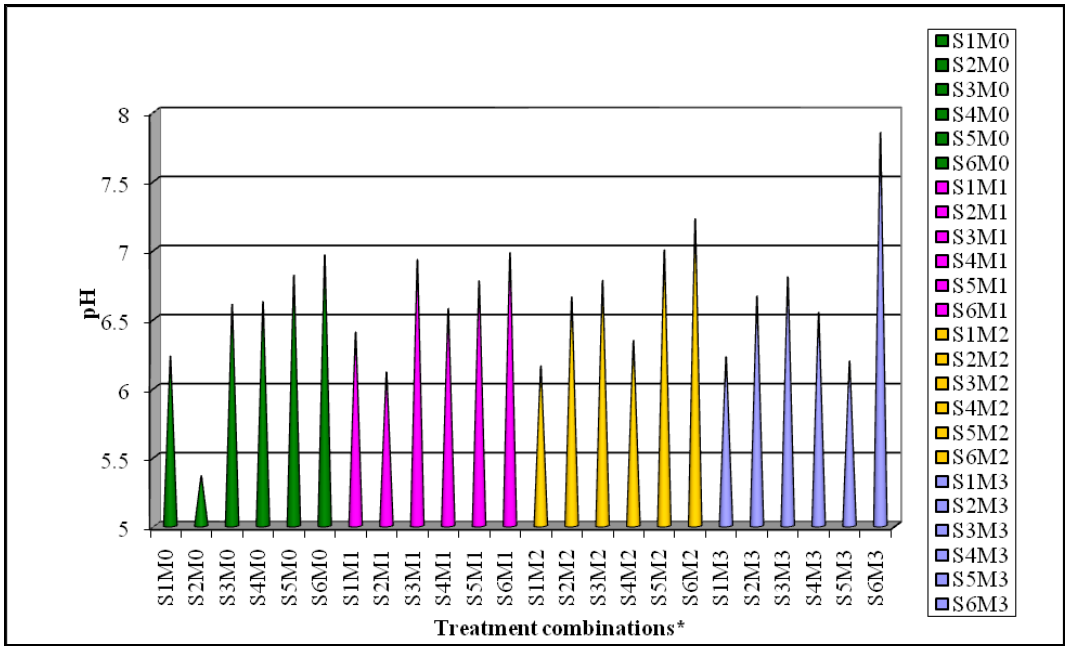


Fig. 18 Effect of different treatment combinations on pH of compost

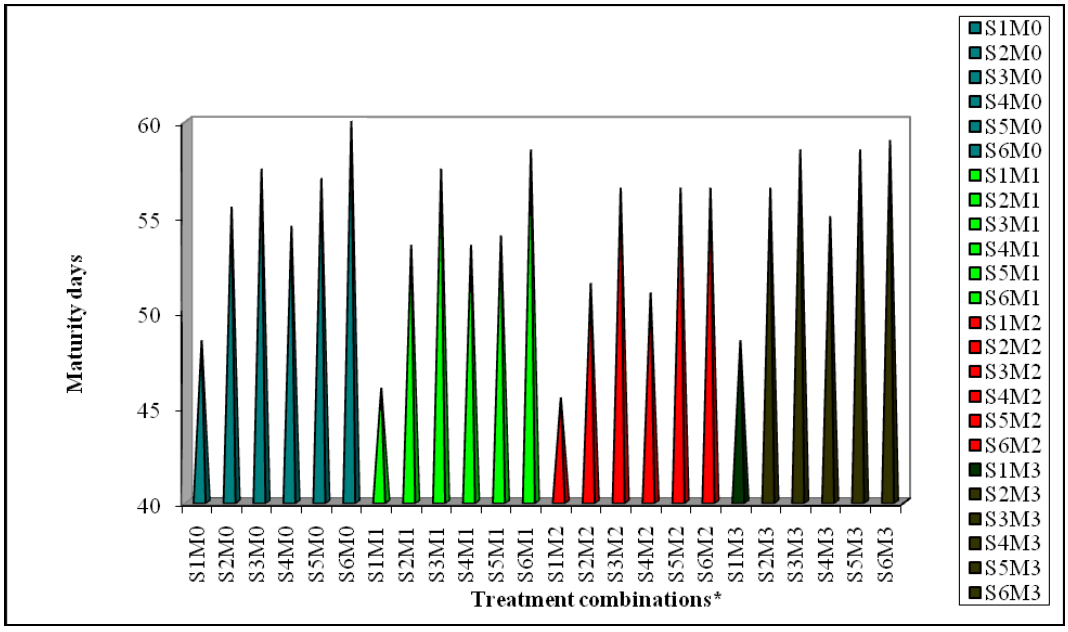


Fig. 19 Effect of different treatment combinations on maturity days of compost

*Details are furnished in page 20

It may be due to NH_4^+ excretion and addition from calciferous glands of the earth worms. (Lee, 1985).

Those treatment combinations, where banana pseudostem was used, showed higher pH values. It was also noted that BPS was high in pH and it may be the reason for higher pH noticed for the substrate with banana pseudostem.

5.3.5 Maturity Days of Compost

The different treatment combinations did not influence the maturity of compost (fig 19). This may be due to the fact that vermicomposting with different substrates were actually started after the cessation of pre composting with different microbes for fifteen days. Coming to the influence of substrate S_1 (FYM: BPS -1:8) recorded minimum maturity period of 47 days and S_6 (elephant dung: BPS-1:8) recorded maximum maturity period of 59.5 days. Considering the influence of microbes, native microbes and treatment without microbes were found to be on par recording maximum maturity period. Consortium of *Bacillus subtilis* & *Aspergillus flavus* had showed minimum maturity period, which was on par with *Pleurotus platypus* introduced treatments. Thermophilic bacteria played a major role in reducing the maturity period. So the addition of lignocellulose degraders hastened the decomposition reaction and helped in reducing the maturity period. It was also supported by the finding as detailed under section 4.3.5.1 that a highly significant positive correlation was obtained for thermophilic temperature with maturity days. This explains the role of microbes involved in the rapid degradation of lignocellulose thrive at high temperature (Tuomela *et al*., 2000). Native microbes isolated from dung were not efficient in lignocellulose degradation under in vivo condition. So they have taken longer maturity period which was on par with treatment without microbes. Findings by Wahyudi, *et al.,* (2010) also supports this evidence. It was detailed under section 4.1.1.1 that there was no significant difference for C: N ratio of the dung during the consecutive six month of field study which also indicated that native microbes are not efficient in

lignocellulose degradation. The combination of elephant dung with other substrate showed higher maturity period due to more cellulose content (35.8%) compared to substrate of FYM and BPS. The treatment without microbes recorded higher maturity period because microbes are involved in utilization of organic form of nutrients that helps in mineralization process. They are involved in reducing the carbon content and secretion of nitrogen there by lowering the C: N ratio. C: N ratio below 20 can be considered as stable humus (Jimenez and Garzia, 1992).

5.3.6. Nutrient Contents of Compost

5.3.6.1. Carbon

The loss of organic carbon was significantly affected by vermicomposting. The reduction in the organic carbon content from the substrate (48%) to final product (14.52%) has been noted. The percentage of reduction accounted to be 33%. Suthar (2006) reported that earth worm promotes microclimate condition in vermi reactors that increase loss of organic carbon from substrate through microbial respiration. Part of the carbon in decomposing residue was evolved as carbon dioxide and a part was assimilated by microbial biomass. Hand (1988) also reported that worms secrete enzymes, proteases, lipase, amylase, cellulase and kitinase in their gizzard which bring rapid biochemical conversion of cellulosic and proteinaceous materials in organic waste. All these factors contribute for the reduction of carbon content of the substrate. Kaviraj and Sharma (2003) also reported a 25-43% loss of organic carbon during vermicomposting of municipal or industrial waste. Preetha (2003) also reported a reduction of carbon content in lignocellulolytic rich waste. It was also interesting to note that in all treatments were earth worms have not been introduced carbon content ranged from 10.33% to 14.52% (fig 20).

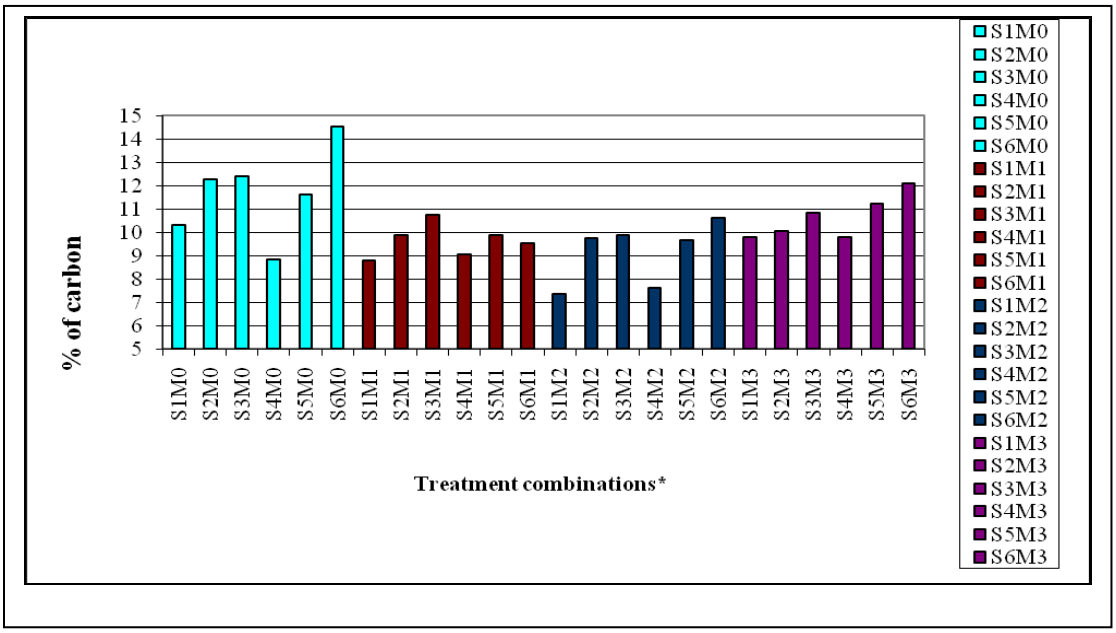


Fig. 20 Carbon content of compost as influenced by different treatment combinations

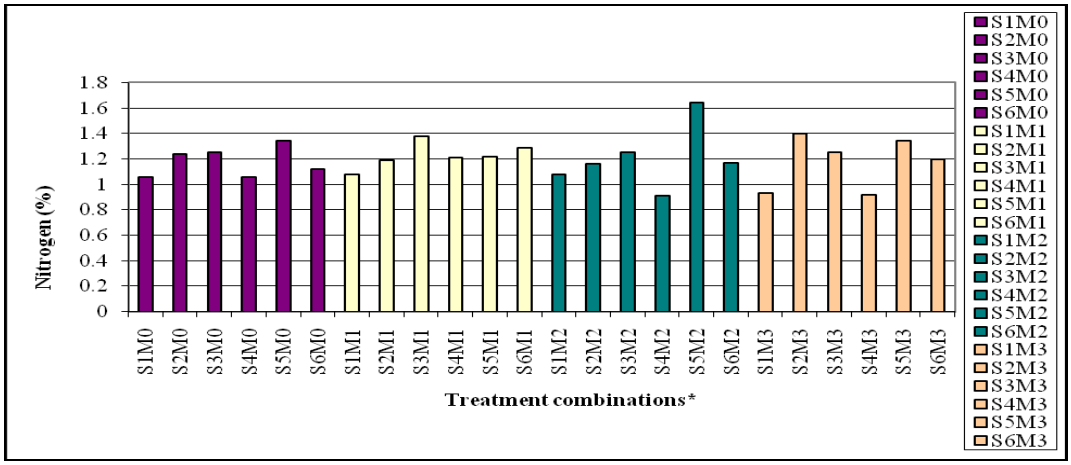


Fig. 21 Nitrogen content of compost as influenced by different treatment combinations

*Details are furnished in page 20

5.3.6.2. Nitrogen

Substrate combination of FYM recorded 0.51% N, BPS 0.83% N and ED 0.86% N as provided in Appendix 3. The highest value for N in compost obtained for S_5M_2 (1.64%) and the lowest for S_4M_2 (0.910%) (fig 21). Apart from the high nitrogen content of ED, the mineralization of dung during composting also increased the nitrogen content of resultant compost. In S_5 combination, seven fold increase of earth worm population was noticed and in S_5 combination in general has recorded high nitrogen content. It may be due to addition of nitrogen in the form of mucous, nitrogenous excretory substance, growth stimulating hormone and enzyme from earth worm reported as found by Tripathy and Bharadwaj (2004).The enrichment with microbes and earth worms helped to improve the nitrogen status of the compost material.

5.3.6.3. Phosphorous

P content of FYM was 0.43%. BPS 0.38% and that of ED was 0.34%. There was 1.5 to 2.5 fold increase in P content due to Vermicomposting (fig 22). But there was no release of P in the composted material irrespective of different substrate microbial combination. However the highest content was registered by FYM: ED (1:1) with the highest content which was closely followed by FYM: ED (1:8). Satchel and Martin (1984) found an increase of 25 per cent P from paper waste sludge after worm activity. Treatment where native microbes introduced had higher P status. So there is a clear role for native microbes in releasing/ solubulizing P from different substrate combinations. Many fungi and bacteria are potential solubilizers of bound phosphate. So the treatments with added microbes possessed an influence on increase in P content. Due to the direct action of worm gut enzymes and stimulation of micro flora the P content increased (Garg *et al*. 2006). An increase in total phosphorus as a result of bacterial and faecal phosphate activity of earthworms recorded (Edward and Lofty, 1972).

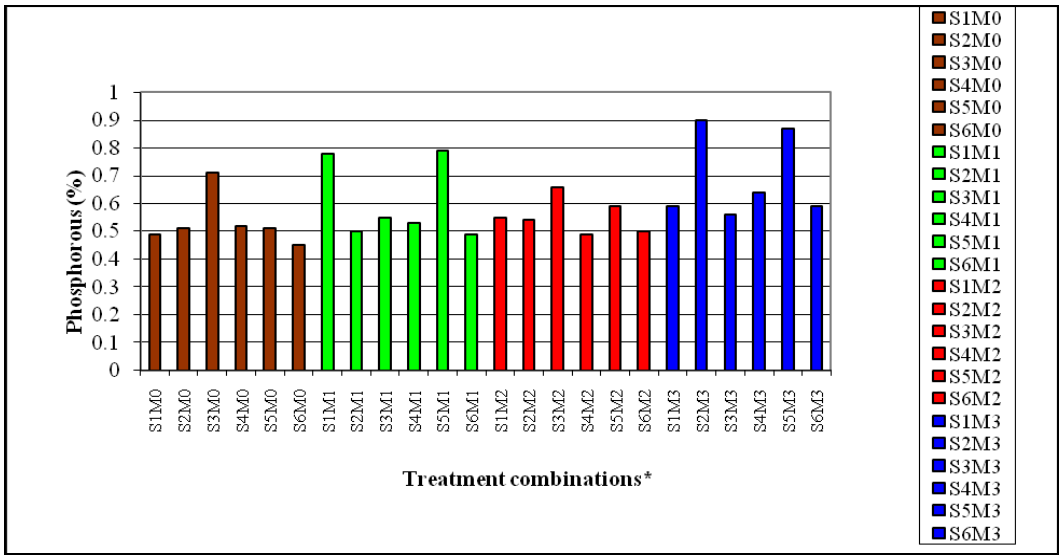


Fig. 22 Phosphorous content of compost as influenced by different treatment combinations

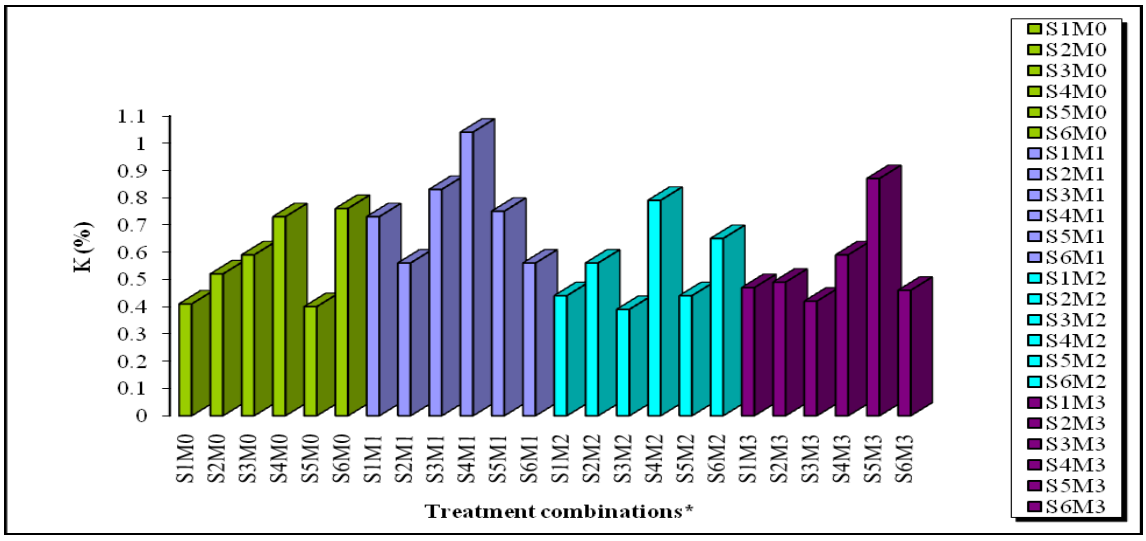


Fig. 23 Potassium content of compost as influenced by different treatment combinations

*Details are furnished in page 20

5.3.6.4. Potassium

The K content of substrate materials were 0.53% for FYM, 1.03% for BPS and 0.34% for ED. The highest K content recorded in S_4M_1 with 1.04% and lowest in S_3M_2 with 0.39% (fig 23). By considering the K status of substrate, no significant increase in compost has been found. Elvira *et al.*, (1998) reported that there was significant reduction in total K by the end of vermicomposting due to high water solubility and leaching of windrows. The K content of compost material depends on the inherent content of the same in substrate. Gaur *et al*., (1971) also reported that the chemical composition of compost varied depending on the source from which it was prepared. Among the substrate used, BPS has the highest K content. So substrate combinations with BPS in eight proportions have recorded higher K content. Those treatments where *Pleurotus platypus* has been introduced showed higher K content. It may be due to the presence of carrier material i.e., talc which is a k source.

5.3.6.5. Calcium

Calcium status of FYM was 0.18, BPS 0.57 and ED 0.19 per cent. It was strikingly noticed that in all the compost combination without earth worm has very low calcium status compared to earth worm introduced treatment (fig 24). It may be attributed due to the presence of calciferous glands in earth worms seen in association with oesophageal pouches. The calciferous glands contain calcigenous cells which secrete amorphous $CaCO_3$ which crystallizes in the lumen of oesophageal pouch to form spheroliths of calcite which are excreted in to the oesophagus (Lee, 1985). In all other combinations, there was increase in calcium status with respect to the substrate combination.

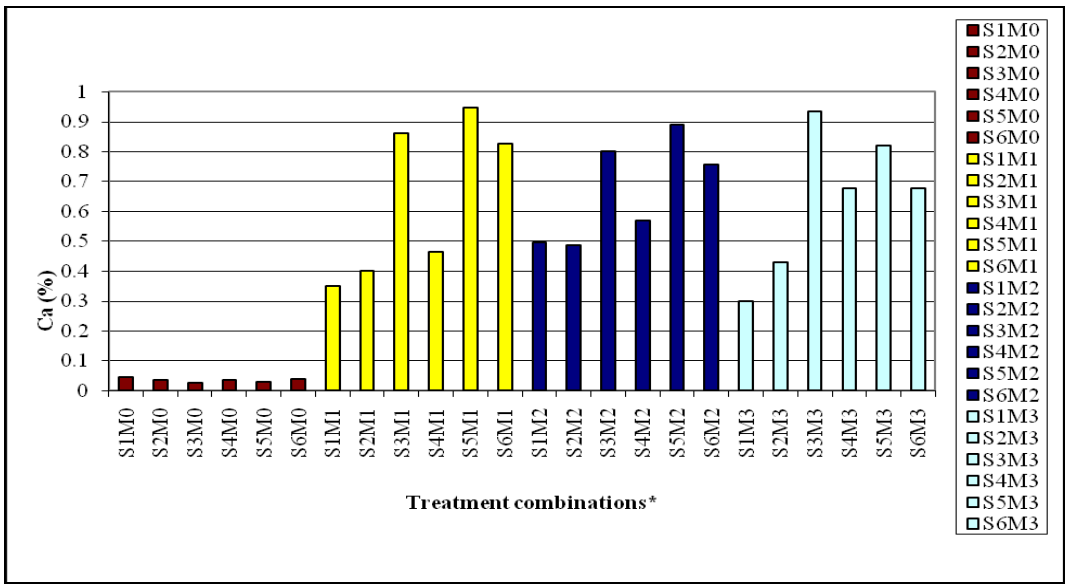


Fig. 24 Calcium content of compost as influenced by different treatment combinations

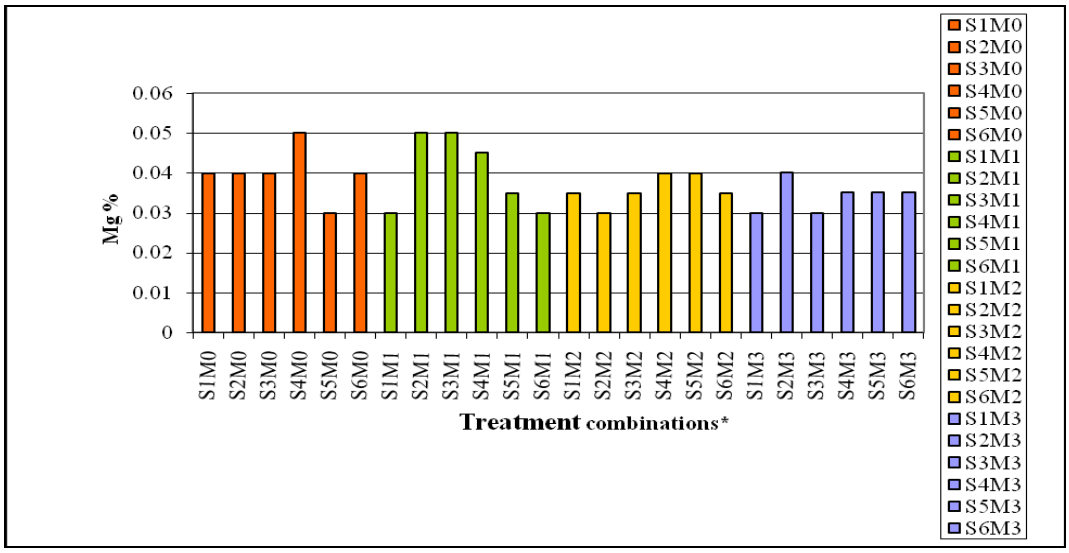


Fig. 25 Magnesium content of compost as influenced by different treatment combinations

*Details are furnished in page 20

5.3.6.6. Magnesium

There was no significant difference between treatments for magnesium content (fig 25). But comparing to calcium level there was no significant increase for magnesium status. It may be due to the antagonism between calcium and magnesium and selective function of earth worm in calcium metabolism. Similar report of antagonism was reported by Bindhu (2010) during vermicomposting of spent mushroom substrate.

5.3.6.7. Sodium

Sodium content of substrate were 0.25% for elephant dung, 0.19% for FYM, and 0.31% for banana pseudostrem (Appendix 3). But comparing to the substrate combinations. compost recorded low sodium status (fig 26). It may be due to antagonism reaction of alkali and alkaline earth elements especially due to the presence of more calcium content in final product

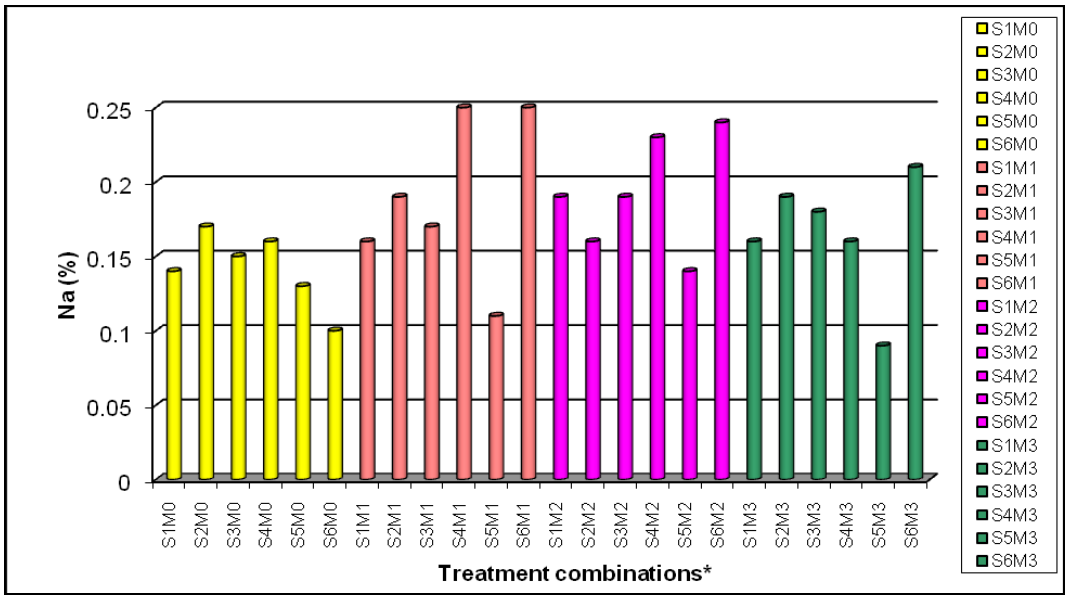


Fig. 26 Sodium content of compost as influenced by different treatment combinations

*Details are furnished in page 20

PRACTICAL UTILITY

A healthy elephant produces 100- 150 kg dung per day. As per the findings of the study, FYM: elephant dung (1:8) was found to be the best option for composting. The tank used for vermicomposting has a dimension of $1m^3$ and 300 kg capacity. So for one cycle 262.5 kg elephant dung and 37.5 kg FYM is required. Based on the observations, the B.C ratio was worked out and detailed as follows.

Capital cost

Pre-composting				**Vermicomposting**			
Particulars	No.Required	Unit cost(Rs.)	Total	Particulars	No.Required	Unit cost(Rs.)	Total
Cutter	1	5000	5000	Tank	1	1700	1700
Impliments		2500	2500	Thatchang		500	500
Polythene Sheets	1	500	500	Sieving Machine	1	2500	2500
Total			8000	Total			4700
Total capital cost: Rs.12700.00							

Operational cost

Pre-composting				**Vermicomposting**			
Particulars	Quantity Required	Unit cost(Rs.)	Total (Rs.)	Particulars	Quantity Required	Unit cost(Rs.)	Total (Rs.)
Cow dung	37.5Kg	55paise/kg	18.75	Earthworm (numbers)	1500	50paise /earthworm	750
Microbes	450g	0.1Rs/kg	45	Harvest & Packing (man hours)	24	100	100
Labour (man hours)	24	100	100				
Total			163.75	Total			850
Total operational cost: Rs. 1013.75							

Income

Particulars	**Quantity produced**	**Unit price**	**Total (Rs.)**
Compost	100kg	Rs.10/kg	1000
Earthworms	1500no’s	50paise/worm	750
Total Income			**Rs. 1750**

Recurring expense: Variable cost + Interest on capital cost (12%) + Depreciation charge (10%).

Recurring expense = Rs. 1013.75 + 254 +212

=Rs.1479.75

= Rs.1480 (Approximately)

Total Income = Rs.1750.0

B.C.ratio =1.2

Effective utilization of elephant dung after vermicomposting

- Recycling of elephant dung is possible with the use of biotically enriched elephant dung (plate 9) for grass cultivation so that grass is a better feed for elephants as there is scarcity of palm leaves.
- Vermicomposting of elephant dung is a viable agri entrepreneurship programme for the mahouts by utilizing family labour as it is a less cost effective, simple and viable technology.

Plate 9. Biotically enriched elephant dung

Summary & Conclusion

6. SUMMARY & CONCLUSION

Study on the "utilization of elephant dung for vermicompost production" was conducted at College of Horticulture, Vellanikkara during the period 2009-11 with three separate and continuing experiments as follows: 1. Identifying the role of macro and micro fauna on the in-situ decomposition of elephant dung. 2. Biochemical analysis of elephant dung. 3. Vermicomposting of elephant dung.

In order to study the role of macro and micro fauna on *in situ* decomposition of dung, a field study for six months was undertaken by identifying six stages of degradation of dung namely more than one year old (E_1), one year old (E_2), eight months old (E_3), four months old (E_4) and fresh samples constituting body washings (E_5) and fresh faecal bolus (E_6). Native microbes efficient in lignocellulose degradation were isolated and compared with effective lignocellulose degraders. Characterisation of physico chemical and biochemical properties of elephant dung was done. Vermicomposting of elephant dung was done by applying effective lignocellulose degraders during the pre composting period in different substrate combination with FYM and banana pseudostem. The salient findings are summarized below.

- Temperature within in the degrading dung was higher than atmospheric temperature indicating active microbial decomposition with the release of energy.
- Presence of micro flora was found to be less in twelve month and more than twelve month old dung as compared to eight month old dung.
- Higher microbial activity at the early stage of decomposition in turn resulted in reduction of C: N ratio of the dung material at the advanced stage.
- Lignocellulolytic nature of elephant dung favoured the multiplication of more bacteria as compared to fungi and actinomycetes.

- The mineral nutrient status of elephant dung was estimated to contain 48.18% C, 0.86% N, 0.34% P, 0.37% K^+, 0.19% Ca^{2+}, 0.05% Mg^{2+} and 0.25% Na^+ with a pH value of 6.9.
- The dung was found to be rich in crude fibre (21.4%) followed by crude protein (6.5%) and crude fat (2.8%).
- Cellulose, hemi cellulose and lignin fraction of dung were accounted as 35.8, 30.1 and 17.5 % respectively.
- During the composting process of elephant dung, there was clear distinction of four phases with reference to variation in temperature. Accordingly during the thermophilic stage (10-15 days), temperature ranged from 39.8^0C to 28.8^0C, mesophilic stage (20-44) days with 34.9^0C to 26.6^0C, cooling (45-52days) with 30.8^0C to 25.4^0C and maturity (53-62) with a stabilized temperature of 28.7^0C to 24.7^0C.
- At all the stages of composting the dominance of micro flora was found to be in the order bacteria> fungi> actinomycetes. Worm multiplication was influenced by the substrate controlled micro environment with the combination of FYM and elephant dung in the ratio 1:8 registering an eight fold increase in worm count at the time of compost harvest.
- There was a reduction of 34.4% in the organic carbon content of the elephant dung with FYM in 8:1 proportion after pre composting with effective lignocellulose degraders *Aspergillus flavus* and *Bacillus subtilis.*
- Though the different substrate microbial combination did not influence the nitrogen content of vermicomposted elephant dung, the substrate combination of elephant dung and FYM in the ratio 8:1 registered the maximum nitrogen content in the compost. Among the microbes *Pleurotus platypus* enriched the compost with highest nitrogen & potassium content.

- As compared to the introduced microbes the isolated native consortium augmented more phosphorous from elephant dung.
- The release of different nutrients in the compost was influenced by the original contents of the same elements in different substrates. As the banana pseudostem (BPS) contained 1.03 % K^+, the vermicompost generated from BPS always registered higher K^+ status as compared to other substrates such as FYM (0.54% K^+) and elephant dung (0.34 % K^+).
- *Aspergillus flavus* and *Bacillus subtilis* released significantly higher contents of Na^+, Ca^{2+} and Mg^{2+} and found to be more effective and efficient in lignocellulose degradation.
- The substrate combination of elephant dung (ED) and FYM (1:1) registered a compost maturity period of 54 days which was on par with ED: FYM (1:8) with 57 days.
- The compost from the substrate combination of ED: FYM (8:1) on an average recorded 10.78% C, 1.34% N, 0.66% P, 0.61% K^+, 0.67% Ca^{2+},0.04% $Mg^{2+}$and 0.12% Na^+ with a pH value of 7.3.
- The elephant dung and FYM in the ratio 8: 1 must be pre composted with *Aspergillus flavus* and *Bacillus subtilis* in order to reduce the maturity period of compost. Moreover the same treatment recorded high rate of microbial activity, maximum earthworm multiplication rate and high nitrogen, phosphorous and calcium status.
- Vermicomposting of elephant dung with FYM in the ratio 8:1 is a profitable venture in long run with a B.C ratio of 1.2.

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*originals are not seen

Appendices

APPENDIX

Appendix 1

Weather data during the period of 1st experiment

Period	Atmospheric Temperature (°C)	Rain fall (mm)
January	27.95	0.00
February	28.45	0.00
March	30.85	0.00
April	30.70	0.00
May	29.85	1.50
June	26.25	4.50

Appendix 2

Media Composition for microbial enumeration

Martins Rose Bengal Agar Media	**Potato Dextrose Agar Media**
KH_2PO_4 – 1.0 g $MgSO_4.7H_2O$ – 0.05 g Peptone – 5.0 g Dextrose – 10.0 g Rose Bengal – 0.03 g Agar – 20.0 g Distilled water – 1000 ml	Potato – 200 g Dextrose – 20 g Agar – 20 g Distilled water – 1000 ml
Kenknights Agar Media	**Lignosulphonate Media (pH 7.0)**
K_2HPO_4 – 1.0 g $NaNO_3$ – 0.1 g KCl – 0.1 g	K_2HPO_4 – 1.0 g KCl – 0.5 g $MgSO_4.7H_2O$ – 0.5 g

$MgSO_4.7H_2O$ – 0.1 g Glucose/ Cellulose – 20.0 g Agar – 20.0 g Distilled water – 1000 ml	Fe_2SO_4 – 0.1 g Ligninsulphonate – 2.5 g Agar – 20 g Distilled water – 1000 ml
Nutrient Agar Media	**Carboxy Methyl Cellulose (CMC) Media (pH 7.5)**
Agar – 20.0 g Peptone – 5.0 g Beef extract – 3.0 g NaCl – 5.0 g Distilled water – 1000 ml	K_2HPO_4 – 0.5 g KCl – 0.5 g $MgSO_4.7H_2O$ – 0.5 g $FeSO_4$ – Traces $NaNO_3$ – 0.5 g CMC – 5.0 g Agar – 20 g Distilled water – 1000 ml

Appendix 3

Physico -Chemical Parameters of substrate used for compost.

Parameters	C %	N %	P %	K %	Ca %	Mg %	Na %	pH
FYM	32.3	0.51	0.43	0.53	0.18	0.07	0.19	6.1
Banana pseudostem	38.3	0.83	0.38	1.03	0.57	0.30	0.31	7.2

Appendix 4

Daily variations of dung temperature as influenced by different treatments and atmospheric temperature as (^{o}C)

Days	S1M0	S2M0	S3M0	S4M0	S5M0	S6M0	S1M1	S2M1
1	34.1	33.4	34.6	34.9	34.1	33.8	35.2	34.1
2	34.5	33.6	33.9	34.8	34.5	34.9	35.5	34.7
3	35.8	33.8	34.8	34	34.5	35.8	35	34.2
4	33.8	34.9	33.6	33.9	34.6	36.2	34.9	33.9
5	33.5	33.8	33.9	34.3	33.9	34.5	34.6	33.6
6	34.3	33.7	33.2	34.5	33.6	33.9	34.5	33.5
7	32.9	33.9	33.5	33.5	33.3	34.1	33.2	33.4
8	33	34.5	34.2	33.2	33.8	33.9	33.1	33.8
9	32.8	34.8	34	33.9	33.5	34.9	33.6	33.2
10	31.7	34.7	33.2	33.1	33.2	34.6	33.4	33.8
11	30.7	33.7	33.6	33	33.1	33.8	33.5	32.6
12	30.4	33.5	33.4	32.8	33.4	34.2	33.3	32.9
13	29.5	33.3	33.1	32.6	32.6	35.3	32.5	32.5
14	29.8	32.6	32.9	32.5	32.2	34.9	32.6	32.4
15	28.8	32.8	33.5	33.1	32.5	34.1	32.7	32.1
16	29.4	32.9	32.9	33.7	33.4	33.7	32.9	33.2
17	30	32.6	32.9	32.9	33.2	32.9	32.6	31.5
18	29.7	32.4	32.7	32.8	32.9	32.6	31.9	31.7
19	29.3	31.6	33.2	32.2	33.2	32.7	32.1	31.6
20	28.8	31.6	33.6	33.3	32.1	33.2	31.6	31.3
21	27.9	31.8	33.5	32.3	32.7	32.7	31.2	31.5
22	28.6	31.5	32.9	32.2	31.8	32.6	31.8	30.8
23	29.1	30.6	32.6	32.5	31.9	31.7	31.4	30.2
24	28.3	30.7	32.5	31.7	31.6	31.4	30.9	30.9
25	28.5	30.4	31.9	31.9	32	30.9	30.6	30.7
26	27.9	30.8	31.5	31.8	31.5	30.1	30.3	30.5
27	27.5	29.6	31.5	31.6	31.6	29.8	30.8	29.8
28	27.6	29	31.5	31.2	31.8	28.6	29.9	30
29	28.4	30.5	31.6	31.6	30	28.8	30.5	29.8
30	28.4	29.2	30.5	31.9	30.5	27.3	31.1	29.5
31	27.9	29.2	30.4	30.3	30.3	28.4	30.7	29.6

Appendix Continue……

Days	S_2M_1	S_3M_1	S_4M_1	S_5M_1	S_6M_1	S_1M_2	S_2M_2	S_3M_2
1	34.1	34.4	34.1	33.5	34	35.8	35.5	35.4
2	34.7	34.9	34.5	33.8	34.1	35.7	35.4	35.7
3	34.2	34.5	34.6	33.7	33.9	35.4	35.2	35
4	33.9	34.2	34.2	33.9	33.8	35	34.8	34.2
5	33.6	33.8	33.8	33.8	33.5	34.5	34.9	34.9
6	33.5	33.4	33.1	32.9	34.7	34.8	34.1	34.5
7	33.4	33.8	33.6	32.8	32.5	33.9	34.2	34.1
8	33.8	33	33.5	32.5	32.6	33.8	33.9	34.2
9	33.2	33.7	33.1	32.9	32.7	33.9	33.8	33.5
10	33.8	33.5	33.3	33	32.2	33.4	33.2	33.9
11	32.6	32.9	32.5	32.5	33.9	33.7	33.6	33.8
12	32.9	32.6	33	32.8	33.5	32.8	33.5	33.2
13	32.5	32.5	32.8	33.8	33.6	32.4	33.8	33.4
14	32.4	32.2	32.6	32.8	33.7	32.1	33	32.7
15	32.1	32.4	32.3	32.9	32.9	32.5	32.2	32.8
16	33.2	33.9	32.2	32.4	32.6	32.5	33.4	32.2
17	31.5	33.5	32.1	32.5	32.3	31.6	32.6	32.4
18	31.7	33.7	31.1	32.9	32.2	32	32.5	31.9
19	31.6	32.6	31.9	32.7	32.8	32.1	32.7	31.8
20	31.3	31.8	31.8	32.5	32.1	31.8	32.3	31.1
21	31.5	31.9	31.3	31.5	31.7	31.7	32.9	31.5
22	30.8	31.4	31.7	31.6	31.4	31.5	32.8	31.6
23	30.2	31.7	30.9	31.2	31.8	31.9	32.6	31
24	30.9	31.5	30.8	31.9	31.5	31.2	32.5	30.5
25	30.7	31.3	30.6	31.8	31.9	31.5	32.9	30.9
26	30.5	30.9	30.5	31.7	30.8	31.6	31.4	30.8
27	29.8	30.2	29.7	30.9	30.7	30.5	31.2	30.7
28	30	30.8	29.5	30.1	30.2	30.9	31.6	30.4
29	29.8	30.5	29.8	30.2	30.7	30.8	31.5	30.5
30	29.5	30.4	29.6	30.6	30.8	30.5	31.1	29.6
31	29.6	29.9	30.1	30.4	30.9	30.1	31.2	29.5

Appendix Continue……

Days	S_4M_2	S_5M_2	S_6M_2	S_1M_3	S_2M_3	S_3M_3	S_4M_3	S_5M_3	S_6M_3	Atm temp
1	35.8	38.1	34.5	35.9	35.5	35.4	35.8	35	35.9	26.5
2	35.9	39.8	34.9	35.5	35.4	35.3	35.4	35.4	35.8	27.2
3	35.6	39.3	34.8	35.7	35.9	35.7	34.9	35.9	35.4	26.9
4	35.7	39.6	34.7	35.4	35.5	35.1	35.3	35.7	35.2	26.1
5	34.1	38.7	33.9	35.1	34.5	34.7	34.9	35.4	35	26.6
6	34.5	38.3	33.8	35.2	34.1	34.9	34.2	34.8	35.4	27.4
7	34.2	38.1	33.7	34.8	34.2	34.2	34.6	34.9	34.6	28.4
8	33.9	37.4	33.2	34.9	34.6	34.3	34.1	34.9	34.8	27.8
9	33.5	36.8	32.9	34.5	34.2	34.9	33.8	34.4	34.5	28.7
10	33.8	37.7	32.5	34.2	34.9	34.6	33.5	33.7	34.2	25.9
11	33.7	36.4	32.7	33.2	33.8	33.9	33.4	33.7	34.8	26
12	33.4	36.9	32.9	33.5	33.9	33.6	33.2	34.3	34.9	28.2
13	32.6	35.8	32.5	33.2	33.7	33.1	33.2	32.4	33.9	27.6
14	32.8	35.5	32	31.3	33.2	33.8	32.9	33.4	33.7	26
15	33	34.9	31.4	31.5	33.1	32.8	32.8	32.9	33.8	27.6
16	32.9	34.6	31.8	30.1	32.7	32.8	32.6	32.6	33.5	27.6
17	32.7	34.8	31.5	29.8	32.9	32.7	32.1	33.2	33.1	26.5
18	32.5	34.2	31.5	29.5	32.2	31.8	32.5	32.9	33.5	26.2
19	32.6	33.9	31.4	29.4	32.7	32	32.1	32.5	32.9	27.6
20	31.6	34.2	30.9	28.9	32.5	32.7	31.9	31.7	32.8	25.9
21	31.3	32.6	30.8	28.5	31.5	32.5	31.7	31.9	32.4	25.9
22	31.5	33.8	30.5	28.6	31.9	31.6	30.3	30.9	32.8	26.5
23	31.2	34.1	30.3	28.3	31.8	31.5	30.5	31.2	32.2	27.6
24	31.7	33.5	30.1	27.7	31.7	31.9	30.2	31.3	31.8	27.1
25	30.2	35	29.9	28.1	31.5	31.4	29.8	30.8	31.9	27.7
26	30.6	34.4	29.7	27.9	31.2	30.5	29.7	30.4	31.5	28.9
27	30.5	32.2	29.7	28.5	32	30.8	28.9	30.1	31.6	28.5
28	30.4	33.4	29.6	26.9	32.1	30.1	28.7	29.9	31.7	28.9
29	30.9	32.3	29.4	27.5	31.5	30.5	28.6	28.9	30.7	27.9
30	29.9	32.9	29.5	28.3	31.6	30.6	28.5	28.7	30.9	27.9
31	29.1	33.4	28.5	28.4	31.1	30.9	29.3	29.5	30.7	28.8

Appendix Continue……

Days	S_1M_0	S_2M_0	S_3M_0	S_4M_0	S_5M_0	S_6M_0	S_1M_1
32	27.6	28.6	30.3	30.6	30.6	28.3	30.9
33	26.9	28.7	31.2	30.9	30.5	29.4	29.8
34	27.3	29.9	31.1	30.8	30.8	28.4	29.9
35	28.1	28.9	30.7	30.5	30.2	28.3	29.7
36	26.4	28.6	30.2	30	30.5	27.7	29.5
37	27.7	28.8	29.9	30.1	30.7	26.9	29.6
38	28.1	27.8	29.8	30.5	30.4	27.1	29.4
39	27.9	27.9	29.6	29.2	30.3	26.5	30.7
40	28.1	27.5	29.4	29.3	30.6	26.4	29.8
41	26.9	27.9	28.5	29.4	30.1	25.8	28.6
42	27.3	28.2	28.6	28.5	30.9	25.8	28.9
43	26.1	28.3	28	29.2	30.8	24.9	28.6
44	26.3	27.2	28.1	28.9	29.7	25.3	28.5
45	26.5	27.9	27.3	28.1	29.6	24.6	28.9
46	26.7	27.6	27.6	28.2	29.9	25.9	28.8
47	25.9	28.3	27.5	28.3	28.3	26.3	27.9
48	26.1	26.6	27.3	28.9	28.9	25.7	28.5
49	25.3	27.1	26.9	27.3	27.6	26.3	27.9
50	25.9	27.3	26.7	27.6	27.5	25.5	27.6
51	26.2	28.1	26.5	27.3	27.6	25.9	27.8
52	25	26.6	26.2	27.7	26.9	25.8	28.2
53	25.2	26.3	26.4	26.9	26.7	26.3	29.2
54	25.6	26.2	25	26.8	26.7	25.7	29.6
55	25.1	25.9	24.3	26.5	26.9	24.9	27.6
56	24.7	25.7	24.7	26.2	26.7	24.6	26.5
57	24.4	25.4	24.5	26.4	25.6	24.7	26.4
58	24.9	25.9	24.2	26.8	24.5	25.1	26.7
59	24.2	25.3	25.1	26.9	24.9	25.2	26.5
60	24.4	24.9	24.8	26.1	24.8	24.6	25.5
61	24.3	25.8	24.3	24.6	24.6	24.1	25.4

Appendix Continue……

Days	S_2M_1	S_3M_1	S_4M_1	S_5M_1	S_6M_1	S_1M_2	S_2M_2	S_3M_2
32	29.3	29.8	29.4	29.7	29.8	30	31.5	29.1
33	29.1	29.5	29.9	29.4	29	30.7	30.1	29.5
34	28.9	29.4	28.1	29.1	29.4	29.1	30.9	29.7
35	28.9	29.2	28.3	29.2	29.6	29.9	30.8	29.2
36	29	28.6	28.5	29.5	29.9	29.8	30.4	28.5
37	28.5	28.6	28.7	28.5	29.8	29.5	30.7	28.3
38	28.7	28.6	28.8	28.8	29.7	29.3	30.6	28.2
39	28.2	28.2	27.9	28.9	29.3	29.4	29.9	28.1
40	28.4	28.5	27.6	28.6	29.5	29.5	29.8	28.5
41	27.6	28.6	27.3	28.3	29.4	28.2	29.6	27.2
42	27.9	28.7	27.8	27.3	28.5	28.5	29.7	27.6
43	27.8	28.9	26.2	27.2	28.6	28.7	29.5	27.3
44	27.7	27.9	26.4	27.6	28.4	28.3	29.1	27.9
45	27.6	27.8	26.1	27.7	28.1	28.1	28.3	27.1
46	26.5	27.6	26.4	25.9	28.2	27.9	28.2	26.8
47	26.4	26.7	27.1	27.8	28.6	27.8	28.6	26.4
48	26.6	26.9	26.9	27.6	27.6	27.7	28.4	26.4
49	26.3	26.8	26.7	27.9	27.8	27.6	28.6	26.7
50	27.3	26.7	25.8	26.5	27.2	27.5	28.6	26.5
51	26.9	26.9	25.7	26.8	27.1	27.4	27.9	25.8
52	25.9	25.9	25.6	26.3	27.1	27.6	27.8	25.7
53	26.2	25.8	24.9	26.1	26.9	26.9	27.7	25.6
54	26.7	25.6	24.8	26.3	26.6	26.8	27.6	25.4
55	25.9	25.4	24.3	26.2	26.3	26.7	27.5	25.3
56	25.8	25.7	24.9	25.6	26.2	26.5	26.3	25.2
57	26.4	24.5	24.5	25.9	26.5	27	26.2	24.7
58	26.8	24.5	24.7	25.8	26.8	26.9	26.1	25.1
59	24.7	24.2	25.2	25.5	26.7	26.5	26.4	25.3
60	25.9	24.1	25.7	25.3	25.9	26.3	25.7	25.2
61	25.8	24.5	26.1	24.9	25.8	25.7	25.1	25.4

Appendix Continue……

Days	S_4M_2	S_5M_2	S_6M_2	S_1M_3	S_2M_3	S_3M_3	S_4M_3	S_5M_3	S_6M_3	Atm temp
32	29.8	31.9	28.6	28.3	31.3	30.9	29.4	29.3	30.7	28.8
33	29.4	32.7	28.7	27.7	30.2	30.5	29.5	28.9	30.2	29.3
34	29.6	31.6	28.6	27.3	30.9	30.6	29.7	29.1	30.9	27.9
35	28.4	31.8	28.4	27.4	30.7	30.7	29.2	28.3	30	26.7
36	28.5	31.9	27.5	28.2	30.7	29.4	30.1	28.4	29.8	26.6
37	28.7	30.7	27.6	28.3	30.4	29.8	28.1	27.9	29.7	27.3
38	28.6	31.4	27.4	27.4	30.5	29.8	28.9	27.7	29.9	26.3
39	28.5	30.5	27.1	27.2	30.6	29.7	28.3	28.1	29.4	25.9
40	26.8	30.3	27.6	27.3	30.7	29.5	28.9	27.9	29.3	26.3
41	26.9	31.5	26.8	26.9	30.4	29.1	28.5	27.3	29.4	26
42	26.7	29.8	26.9	26.3	29.8	29.6	28.6	27.7	29.4	27.2
43	267	30.7	26.7	26.5	29.6	28.4	28.1	27.6	28.4	25.3
44	26.4	29.4	26.6	27.4	29.4	28.6	27.6	28.1	28.6	26.1
45	26.6	28.5	26.3	26.4	29.7	28.1	27.9	26.9	28.6	25.2
46	25.9	29.2	26	26.3	29.9	28	27.5	26.6	28.7	24.9
47	25.8	29.3	26.9	26.2	29.5	28.9	27.6	26.8	28.4	25.3
48	25.3	28.9	26.4	26.2	29.4	28.6	27.1	26.7	27.9	26.3
49	25.5	28.6	26.8	25.7	28.8	28.4	27	26.6	26.7	25.7
50	25.9	28.4	25.9	25.3	28.9	28.9	26.4	27.1	26.8	25.9
51	25.4	27.8	25.6	26	28.3	28.9	26.4	26.3	26.5	26.2
52	24.9	28.2	25.9	25.3	28.7	27.9	26.9	25.9	27.3	24.7
53	24.8	27.6	25.7	25.2	27.6	27.5	26.8	26.3	27.2	24.9
54	24.4	27.3	25.8	24.9	27.5	26.7	26.5	26.3	27.1	24.3
55	24.6	26.7	25.3	24.5	27.8	25.8	25.9	26.6	26.6	24.8
56	24.8	26.3	25.1	26.3	26.4	25.9	25.8	25.9	26.3	25
57	24.6	26.1	25.4	25.7	25.3	26.3	25.4	25.9	26.4	24.9
58	24.3	25.7	25.7	26.7	26.1	26.1	25.6	26.3	26.2	24.8
59	24.4	25.4	25.9	25.7	26.2	25.4	25.8	25.4	26.8	25.3
60	24.7	26.2	25	24.9	25.7	25.3	25.1	25.9	26.2	25.6
61	24.4	25.1	25.3	25.6	25.3	25.1	25.4	25.3	25.9	24.9

Abstract

UTILIZATION OF ELEPHANT DUNG FOR VERMICOMPOST PRODUCTION

By

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ABSTRACT OF THE THESIS

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COLLEGE OF HORTICULTURE

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ABSTRACT

The study on **Utilization of elephant dung for vermicompost production** was undertaken at College of Horticulture Vellanikkara during the period 2009-11. The experiment was done to understand the influence of macro and micro fauna on the *in situ* decomposition of elephant dung and to investigate the manurial value of biotically enriched elephant dung. In order to attain the objective three separate experiments were conducted in a phased manner.

The first experiment included the **investigation of the role of macro and micro fauna on the in situ decomposition of elephant dung and isolation of native microbes efficient in lignocellulose degradation**. In order to study the effect of macro and micro fauna on the in situ decomposition of elephant dung, a field monitoring was undertaken by identifying six stages of degradation of dung *viz*. more than one year old (E_1), one year old (E_2), eight months old (E_3), four months old (E_4), and fresh sample constituting of body washings (E_5) and faecal bolus (E_6). The results revealed that the temperature of degrading dung was always higher than atmospheric temperature indicating that natural decomposition was a continuos process. Higher microbial activity was observed in fresh dung which resulted in lowering the C: N ratio of old dung. Among the native microbes isolated from the dung, bacteria were found to have a predominant role in lignocellulose degradation.

The second experiment mainly included the **characterization of physico chemical and biochemical properties of elephant dung**. The manurial value of elephant dung was estimated as 48.18% C, 0.86% N, 0.34% P, 0.37% K^+, 0.19% Ca^{2+}, 0.05% Mg^{2+} and 0.25% Na^+ with a pH value of 6.9. Dung was rich in crude fibre (21.4%) and low in crude fat (2.8%). Cellulose, hemi cellulose and lignin fractions were accounted as 35.8, 30.1 and 17.5 per cent respectively.

The third experiment was **vermicomposting** which was done to identify the suitable microbial decomposers for pre-composting and the best substrate controlled environment for the same. The experiment was conducted in factorial

CRD with two factors and two replications. *Eudrillus euginae* was used as the compost worms. The different factors involved are the microbes and substrates at different levels. The factor without microbes was compared with *Pleurotus platypus*, combination of *Aspergillus flavus* and *Bacillus subtilis* and native microbes. Different substrate levels used for vermicomposting included FYM and banana pseudostem in 1:1 and 1:8 proportion, FYM and elephant dung in 1:1 and 1:8 ,elephant dung and FYM in 1:1 and 1:8. Based on the daily observation of the compost pile of elephant dung, four stages of composting namely thermophilic (10-15 days), mesophilic (25-30 days), cooling (5-8 days) and maturity (5-10 days) were identified. After thermophilic stage worms were introduced and found that substrate combination of FYM: ED (1:8) recorded seven to eight fold multiplication in earth worm population and a maturity period of 56 days which was on par with the substrate composition of FYM: ED (1:1), recording 54 days (on an average). The biotically enriched dung also recorded the manurial value of 10.78% C, 1.34% N, 0.66% P, and 0.61% K^+. 0.67% Ca^{2+}. 0.04% $Mg^{2+}$and 0.12% Na^+ with a pH value of 7.3. Among the microbes used, consortium of *Aspergillus flavus* and *Bacillus subtilis*, was found to be efficient in lignocellulose degradation which was on par with *Pleurotus platypus*.

The FYM & elephant dung in the ratio 1: 8 must be pre composted with *Aspergillus flavus* and *Bacillus subtilis* in order to reduce the maturity period of compost. Moreover the same treatment recorded high rate of microbial activity, maximum earth worm multiplication rate and high nitrogen, phosphorous and calcium status with minimum maturity days for composting. Regarding the practical utility of work, it was found that a benefit cost ratio of 1.2 was estimated for vermicomposting of elephant dung using a tank ($1m^3$) of 300 kg capacity and with the introduction of 1500 earthworms for a period of 50- 60 days with the help of effective lignocellulose degraders, *Aspergillus flavus* and *Bacillus subtilis*