STANDARDIZATION OF TECHNIQUES FOR PRODUCTION AND ENRICHMENT OF VERMIWASH

By

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THESIS

submitted in partial fulfilment of the requirement for the degree of

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Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE
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DECLARATION

*I, hereby declare that this thesis entitled "**Standardization of Techniques for Production and Enrichment of Vermiwash**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.*

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We, the undersigned members of the Advisory Committee of Ms. Thankamony, K., a candidate for the degree of Master of Science in Agriculture with major in SoilScience and Agricultural Chemistry agree that the thesis entitled ***"Standardization of Techniques for Production and Enrichment of Vermiwash"*** *may be submitted by Ms. Thankamony, K. in partial fulfilment of the requirement for the degree.*

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EXTERNAL EXAMINER

Dedicated to

My late Appappan
and
Grand parents

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1. INTRODUCTION

Agriculture provides food, nutrition, livelihood, income, employment and environmental securities in the agrarian economy. But the very existence of this primary sector depends on the equilibrium of the agro-sphere, an appropriate concept to operate the nutrient dynamics and plant productivity in relation to agro-ecological considerations and soil health. In view of the future demographic projections, anthropogenic stress on the natural resources is going to increase with tremendous potential strain on sustainability. The soil which is the most important natural bio-physical reserve is under severe stress to support the future needs of high energy input agriculture. The concerns about the contamination of water and environment have also increased in recent years. All these aspects point towards the increasing need to make ever more efficient use of environmental resources to provide food, water and infrastructure support for these growing populations.

The relevance of sustainable agriculture comes exactly here. Recycling of organic resources into soil in whatever way and form it is possible, is the basic step to augment and sustain the nutrient supply and plant productivity. Due to urbanization, industrialization and agricultural intensification there is alarming increase both in the production of solid, liquid and industrial wastes and also in the handling of these materials in a safe manner. Organic waste utilisation in agriculture therefore assumes paramount importance.

Estimate of agricultural waste availability in India suggests that the average value of crop waste is 350 metric tonnes and that of the animal wastes, is 650 metric tonnes. Thus around 1000 metric tonnes of agricultural wastes are available in the country. This constitutes farmyard manure (200 MT), crop residues (30 MT), green manure (25 MT) and rural waste (10 MT). The nutrient consumption in India in 2001-02 is 52 kg N, 25-54 kg P_2O_5 and 6.20 K_2O ha^{-1}. With the intensification of agriculture this may go up and the projected demand for fertilizer by 2025 AD is expected to be 30 metric tonnes. About 25 per cent of this demand can be met by utilizing various types of farmwastes (GOI, 2004).

Among the different options of organic waste utilisation, application of vermitechnology is the most ecofriendly one. It involves the use of earthworms as natural bio-reactors. In the process of converting the organic waste into vermicompost, the mucus secretions of worms and the associated microbes act as growth promoters along with other nutrients. It improves physical, chemical and biological properties of the end product, the vermicompost, over the ordinary compost. Vermiwash, the aquous extract of live column of vermicompost with high earthworm activity, is another nutrient rich product of vermi technology. It contain number of enzymes, hormones and vitamins and a good load of microbial flora and therefore prooves to be a potential organic enricher. Production and supply of this nutritional organic preparation together with the/or widespread application help and promote quality agriculture with the production of good food for healthy life. The present study is an earnest effort to investigate the potential of vermitechnology in converting organic farm waste of contextual relevance to value added soil enrichers. Following were the objectives:

1. to standardize the substrate controlled micro-environment for worm production and proliferation.
2. to identify the suitable enrichment techniques of vermiwash.
3. to evaluate the soil and crop responses of enriched vermiwash.

2. REVIEW OF LITERATURE

2.1. Earthworm - Importance in soil fertility studies

Darwin (1881) first reported the role of earthworms in the maintenance of soil structure, aeration and fertility. The beneficial influence of earthworms on soil qualities were studied by Rhee (1969) and efforts were made to ameliorate poor soils using these organisms which reclaiming flooded areas that were subsequently drained and put to cultivation. Edwards and Lofty (1977) found out that the earthworms belonged to Megascolidae and Lumbricidae and are valuable to agriculture. The beneficial effect of earthworms was related to improvement of soil properties (Edwards and Lofty, 1980) Earthworm specii in soil were indicators of the soil type and its properties (Kaleemurrahman and Ismail, 1981). According to Bhawalkar (1989) earthworms were the natural bioreactors, as they effectively harness the beneficial soil microflora. The interactions between earthworms and microorganisms regulated the rate of soil carbon turnover .Logsdon and Linden (1992) reported that the plant growth and development depended on soil structure affected by earthworms. According to Bhawalkar and Bhawalkar (1993) the physical comminution of soil organic particles, the amelioration of soil pH, the enhancement of microbial activity in soil and contribution to soil fertility by earthworms.

Rajagopal (1996) revealed that the burrowing and channeling habit of earthworms reflected in the improvement of soil aeration, drainage and structure. Pore size distribution as well as total porosity were increased, influencing hydraulic conductivity, infiltration of water and root growth. Sarawad *et al.* (1996) pointed out that physical property of vertisol improved with vermicompost as compared to fertilizer application. Singh and Rai (1996) found out that earthworms improved the poor structure of soil and made them friable.

Fragoso *et al.* (1997) studied the earthworm diversity and activity, which affected the physical properties of soils including structural heterogeneity, stability, distribution of organic matter, water infiltration and its retention of water. Zvonkova and Tiunov (1997) reported that soil adjoining earthworm channels (drilosphere, 2-3 cm) had rich organic matter. The European lumbricid earthworms had effect on soil macro porosity and hydraulic conductivity (Francis and Fraser, 1998). Jegou *et al.* (1998) studied the effects of earthworms on the transfer of organic carbon in soil.

Parkin and Berry (1999) reported that earthworm derived Carbon and Nitrogen deposited in the drilosphere facilitated the enrichment of nitrogen by transforming bacterial populations. The elevated nitrogen transformation resulted in the enrichment of NO_3 in the earthworm burrow. Bulk density, porosity, water holding capacity and infiltration rate of soil significantly improved with the application of organic manures (Malewar *et al.*, 2000). Singh and Kumar (2000) reported that the earthworms could be called the biological indicators of soil fertility. Since the earthworms most definitely supported healthy populations of bacteria, fungi, actinomycetes and scored as the host of other organisms that were essential for sustaining a healthy soil.

Willoughby and Kladivko (2002) revealed that the deep burrowing earthworm species, *Lumbricus terrestis* (night crawler) had significant impact on water infiltration rates in soils.Chan (2003) reported the ability of earthworms in incorporating lime into the subsoil by ingestion and subsequent deposition as casts and thereby ameliorating the acidity. Earthworms incorporated surface organic matter, thus improved soil aggregate stability and nutrient availability (Selvaseelan and Maheswari, 2003).

2.2. Castings

Gaur (1982) reported that the actinomycete population in worm casts was over six times more than in original soil. Tiwari *et al.*, (1989) found out that higher phosphatase activity in earth worm casts. Casts were effective in enhancing nitrogen metabolism in plants (Tomati *et al.*, 1990). The clay-organic materials were deposited in the channel walls, whereas the coarser sandy materials were deposited within the earthworm channels or surface castings (West *et al.*; 1991). Ismail (1993) investigated that enzymes and gut microorganisms took active part in earthworm digestion and after absorption of nutrients for its own metabolism, the earthworm ejects castings through the anus. According to Gaur and Sadasivam (1993), the castings of earthworms were rich in nutrients (N, P, K, Ca and Mg) and also bacterial and actinomycete population. Endogeic species of earthworms which generally made horizontal burrows deposit their casts inside their burrows, while the anecic made vertical burrows casts liberally on the surface soil, especially in compact soils (Habibullah and Ismail, 1995).

The fertility value of casts could enhance the presence of polysaccharides and humates and metal chelating agents involved as co-factors in several enzymatic activities (Tomati and Galli, 1995). Earthworms modified soil, physical, chemical and biological properties and enhance nutrient cycling by ingestion of the soil, humus and production of casts (Rao *et al.*, 1996). Tomati *et al.* (1996) reported an increase of three metals in casts, Zn, Fe and Mo, which involved in metallo-enzyme proteins.

According to studies conducted by Acharya (1997) greater availability of N, P, K, Ca, Mg and Mo were found in earthworm castings than in soil. Giraddi and Lingappa (1997) found out that the role of endogeic species in intensifying agro-ecosystems was likely to be more important for soil function especially because they acted as ecosystem engineers and through their mutual interactions with microflora, selective ingestion of soil particles, high rate of ingestion and production of casts.

Palaniappan and Annadurai (1999) revealed that the concentrations of exchangeable Ca, Na, Mg, K, available P and Mo were higher in earthworm casts than in surrounding soil. Earthworm activities included micronising soil particles, re-distribution of nutrients, reduced nutrient run off from soil surface, increasing availability of N, P, K to plants and increasing mixing of various nutrients (Bhatnagar and Palta, 2002). Earthworm casts had higher organic contents, stability, available P, K and microbial biomass. This properties had implications for soil fertility and wider eco system function (Scullion, 2002). Greater availability of N, P, K, Ca, Mg, K and Mo are found in earthworm castings than found in the soil (Ahmed *et al.*, 2003). Chaoui *et al.* (2003) studied the effect of earthworm casts that were used to improve the fertility and physical characteristics of soil. In nature, earthworm casts consisted of excreted masses of soil, mixed with residues of comminuted and digested plant residues. (Tomati and Galli, 2003).

2.3. Feeding Habits

According to Ganeshamurthy *et al.* (1998) the increased availability of the micronutrients Fe, Mn, Zn and Cu in the worm casts was due to processes occurring during the passage of the soil through the earthworm gut. Earthworm's gizzard was a novel colloidal mill in which the feed is ground into particles smaller than 2μ giving thereby an enhanced surface area for the microbial processing (Sharma, 2002).

Horn *et al.* (2003) noticed that the special microenvironment of the earthworm gut was ideally suited for N_2O producing bacteria. This study also supported the hypothesis of the *in-situ* conditions of the earthworm gut that activated N_2O producing soil bacteria during gut passage. Ihssen *et al.* (2003) found out that the N_2O emitted by earthworms was due to the activation of ingested denitrifiers and other nitrate-dissimilating bacteria in the gut lumen.

2.4. Physiology and activity of earthworm

Earthworm's body cavity (Coelom) had apertures, which regulated the coelomic fluid to different segments of body for making these turgid, which helps in locomotion (Bahl, 1947). Earthworm tissue contained 50-75 per cent proteins, 7-10 per cent fats, Ca, P and other mineral (Senapati *et al.*, 1985).

2.5. Rearing of earthworm

The fecundity of two earthworm species, *Lanpito mauritii* (Kinberg) and *Perionyx excavatus* recorded higher in biogas slurry (Ponnuraj *et al.*, 1998). When different bio-wastes used for worm production, cattle shed waste was found to be superior in term of earthworm population (Talukdar *et al.*, 2001). Lee *et al.* (2002) revealed that earthworm biomass in cattle dung was higher and it also provided a more nutritious and friendly environment to the worm species *Eisenia fetida*. When pig manure solids used as a substrate, Gunadi *et al.* (2003) observed a very high significant correlation for worm fecundity (*Eisenia fetida*) (savigny).

2.6. Verimicompost preparation

Hegde *et al.* (1997) studied that organic waste like rice straw and sugarcane trash could be effectively used for the preparation of vermicompost along with *Eudrillus euginae* (Kinberg). Ravankar *et al.* (1998) *reported* that congress weed and cotton stalks mixed with cattle dung using *Eisenia foetida* produced a nutrient rich manure.

Utilization of prominent weeds like *Senna uniflora, Parthenium hysterophorus, Achyranthus aspera, Pennisetum* and *Euphorbia geniculata* was possible in the vermicompost production using earthworm species, *Eudrillus euginae* (Bridar and Patil, 2001). Ramalingam (2001) proved that sugarcane trash individually and in combination with press mud using *Perionyx* excavatus could be used for vermicomposing .Bhattacharya and Chattopadhyay(2002) proved vermicomposting of fly ash and cowdung with *Eisenia foetida.* The amount of insoluble phosphorus from flyash was trade into more soluble forms and thus increased bio-availability of nutrients

Gajalakshmi *et al.* (2002) found out that the noxious aquatic weed; water hyacinth (Eichhornia crassipes, Mart. Solms) could be successfully used for vermicomposting.

2.7 Enrichment of vermicompost

Zacharia (1995) reported the superiority of vermicomposting of vegetable garbages enriched with *Eudrillus euginae,* and beneficial microorganisms. The inoculation of vermicompost with Nitrogen-fixing Azotobacter *Chroococeum* strains, *Azospirillum lipoferum* and the phosphate solubilizing *Pneudomonas striata* increased the nitrogen and phosphorus contents. According to Sailajakumari (1999) inorganic phosphate could be reduced to half of its recommended doze by priming vermicompost with rock phosphate. Das *et al.* (2001) reported that manure quality was improved with the combined inoculation of earthworms and cellulolytic microorganisms on vermicompost. Preetha (2003) studied the biotic enrichment of organic wastes from ayurvedic preparations using earthworms and microbes.

2.8 Vermiwash collection techniques

A low cost technology for the collection of vermiwash in homesteads was proposed by Padmaja *et al.* (1998). Umamaheswari *et al.* (2003) designed and fabricated an indigenous vermiwash-collecting device.

2.9 Response of crops to vermicompost / vermiwash application

Maximum yield of bhendi due to 100 per cent vermicompost application was reported by Govindan *et al.* (1995). Vermicompost reduced the requirement for chemical fertilizers in cowpea and bitter gourd (Jiji *et al.*, 1996). Protein, Carbohydrate and crude fibre percentage as well as lycopene content of tomatoes showed a significant increase with vermicompost application (Pushpa, 1996). Rajalekshmi (1996) proved that the presence of earthworms in the organic wastes, retained more soil moisture in the field at maximum flowering stage of chilli crop. Sagaya and Gunathilagaraj (1996) observed that highest N,P and K content in the plants raised in bed with earthworms. Ushakumari *et al.* (1996) studied the effect of vermicompost in the yield of bhendi. Vasanthi and Kumaraswamy (1996) reported that the grain yields in rice were significantly higher in treatments which received vermicompost. Arunkumar(1997) reported that the number of leaves were higher in chilli plants which received vermicompost. The studies prooved a significant correlation between yield and vermicompost application. Composted coir-pith with neem cake increased the biometrical and yield parameters of cowpea and soyabean (Joseph *et al.*, 1998). Phebe (1998) studied that the addition of vermicompost showed that the highest ascorbic acid content and the lowest level of acidity in snake gourd.

According to Mba (1999), there was a highly significant correlation between application of vermicompost and the leaf vegetable yield of *Telfairia occidentalis* (Fluted pumpkin)

Ranijasmine (1999) has reported that the application of vermiwash produce significant effect on growth and quality of tomato. Vermicompost application increased the tuber production in sweet potato (Sureshkumar, 1999). Ushakumari *etal.*(1999)studied the effect of vermicompost on yield increase in okra (Abelmoscheus esculuntus Moench).

Earthworm processed pig manure and food wastes enhanced the growth of tomato seedlings significantly (Atiejeh *et al.*, 2000).

Sreenivas *et al.* (2000) reported that the TSS of ridge gourd was found increased with increased rates of vermicompost. Surekha and Rao (2000) studied the influence of vermicompost and FYM on the incidence of pest complex in bhindi. The study revealed that vermi compost followed by FYM, prevented the build up of the pest under study.

Samawat *et al.* (2001) investigated the effects of vermicompost on the growth characteristics of tomato. The study found out that fruit weight was significantly affected by the interaction. The hormone like activity of humic acid from the vermicompost increased the growth of tomato and cucumber plants (Atiejeh *et al.*, 2002).

Topoliantz *et al.* (2002) showed that improved soil phosphorus availability was positively correlated with earthworm inoculation in an experiment conducted using earthworms *Pentoscolex corethrurus* and *Vigna unguiculata subspecies sesquipedalis*. Wieczorek *et al.* (2002) revealed that the soil application of bio-compost based on the earthworm, *Eisenia foetida* protected tomatoes against *Fusarium oxysporum f.sp lycopersici*. It was also limited the infection of cucumber seedlings with *pythium ultimatum*.

According to Anitha and Prema (2003), the yield effects were significant due to te application of vermicompost on amaranthus when compared with control. Thangavel *et al.* (2003) investigated the effect of vermiwash and vermicast in paddy. Significant effect was noticed in the case of content and uptake of potassium. Yadav and Vijayakumari (2003) investigated that application of vermicompost in chilli brought significant changes in the maximum number of fruits per plant, fruit weight per plant, single fruit weight, fruit length and fruit diameter.

3. MATERIALS AND METHODS

The study entitled 'Standardization of techniques for the production and enrichment of vermiwash' was conducted at College of Horticulture, Vellanikkara during September 2003 to August, 2005.

The research work consisted of three experiments as follows:

1. Standardization of substrate controlled environment for worm multiplication.
2. Enrichment techniques of vermiwash.
3. Rapid soil-crop response studies

3.1 Experiment I - Standardization of substrate controlled environment for worm multiplication

This experiment was meant for standardizing the substrate controlled environment for rapid growth, activity and multiplication of earthworms.

3.1.1. Study materials

Materials used as substrates for worm rearing and proliferation included banana pseudostem, coconut leaf, green leaf (Glyricidia) and cowdung. Earthworms, *Eudrillus euginae* procured from ABARD Unit of Vermicompost attached to the College of Horticulture was used. To increase the degradation of the substrates, the fungal inoculum, *Schizophyllus communae* was incorporated in all treatments, and kept the substitutes for pre-processing for 20 days prior to the charging of worms.

To collect the vermiwash, a device was fabricated at the ABARD Unit of vermicompost (Plate 1 and 2). It consisted of a plastic container of size 48 x 44 sq.cm. with a sloppy inner floor for the easy flow of vermiwash. A plastic fruit basket of convenient size was placed at the bottom of the basket for the easy

Plate 1. Overall view of Experiment 1 with Vermi wash Production Units

Plate 2. Single Vermi wash Production Unit with substrates before and after composting

draining of the vermiwash and it was collected through a tap provided one inch above the basal part of the unit. In order to retain the relative humidity and to regulate the temperature inside the device, gunny bag lining was provided around the inner sides of the plastic bucket. Sufficient number of holes were provided on the lid of the device for proper aeration.

3.1.2. Technical details

Design	:	CRD
Replication	:	3
Treatments	:	8

T_1 - Banana pseudostem and cowdung in the ratio 6:1

T_2 - Coconut leaf and cowdung in the ratio 6:1

T_3 - Green leaf and cowdung in the ratio 6:1

T_4 - Banana pseudostem, coconut leaf and cowdung 3:3:1

T_5 - Banana pseudostem, green leaf and cowdung 3:3:1

T_6 - Coconut leaf, green leaf and cowdung in the ratio 3:3:1

T_7 - Banana pseudostem, coconut leaf, green leaf and cowdung in the ratio 2:2:2:1

T_8 - Banana pseudostem and cowdung in the ratio 8:1

As per the treatment 15 kg of substrates were chopped, mixed and filled in each device. Earthworms were added at 1000 numbers per device after a pre-composting period of 20 days. The fungal inoculum *Schizophyllum communae* @ 1 kg together with 3 kg of cowdung and topsoil slurry in the ratio 1:1 were also added to each treatment.

3.1.3. Observations

3.1.3.1. Variations of pH and temperature

The variations in temperature were noted using the multichannel temperature recorder at 13.00 hrs. daily during the entire period of vermicomposting. Simultaneously the atmospheric temperature was also recorded (Appendix I).

3.1.3.2. Nutrient contents

Major nutrients N, P and K of the compost materials were analysed and the pH per the methods given in the Table 3.1. For the pH measurement the substrate materials were made into small pieces, crushed well and agitated properly to prepare a 1:1 suspension of each . Then C:N ratio was also worked out.

Table 3.1. Physico-chemical analysis of the substrates

Property	Method	Reference
pH	1 : 1 suspension	Jackson, 1958
C	Schollen-Berger's modified method	elWalkoel and Riley, 1956
N	Microkjldhal digestion and distillation	Jackson, 1958
P	Diacid Extract Spectrophotometry	
K	Diacid Extract Flamephotometry	

The count of micro-organisms was taken by Serial Dilution Plate Technique (Johnson and Curl, 1972) using different media as detailed in Table 3.2 below. The chemical composition of media used is provided in Appendix II.

Table 3.2. Media used for counting of micro-organisms

Sl. No.	Microbes	Medium	Reference
1	Fungus	Martin's Rose Bengal Agar	Martin, 1950
2	Bacteria	Nutrient Extract Agar	Rao, 1986
3	Actinomycetes	Kenknight	Rao, 1986
4	Nitrogen fixing organisms	Jensen's medium	Jensen, 1942
5	Phosphate solubilizing organism	Pikovaskya's medium	Rao and Sinha, 1963

3.2 Experiment II - Enrichment techniques of vermiwash

Three techniques of enrichment as detailed below were replicated thrice in CRD.

3.2.1. Substrate enrichment technique (SET)

Based on first experiment the best substrate was selected and preprocessed in accordance with the established principle of aerobic composting. An organic enriching media (OEM) comprising of poultry manure, bonemeal and neem cake in 1:1:1 ratio was prepared into a fine powder form (Plate 3 & 4) to enrich the preprocessed substrate. OEM at three levels as below were tried.

SET_1 - OEM at 1 per cent level of the substrate

SET_2 - OEM at 5 per cent level of the substrate

SET_3 - OEM at 10 per cent level of the substrate

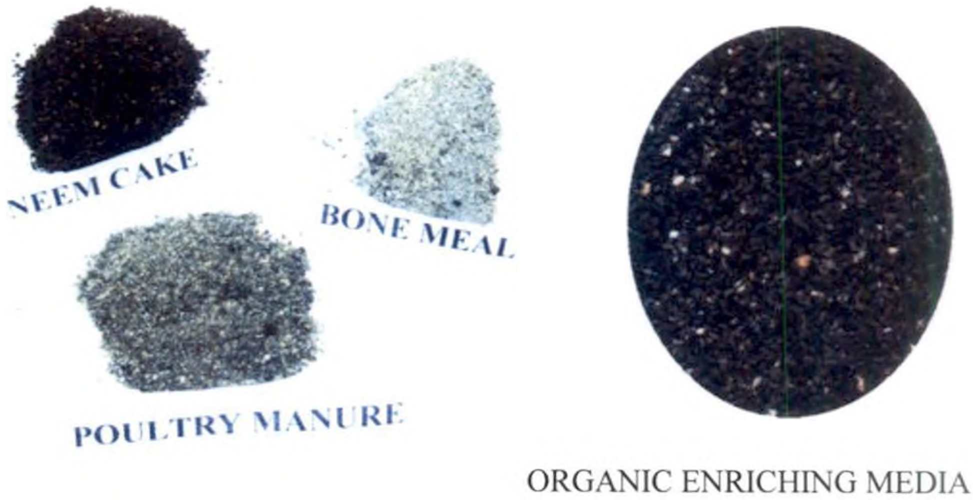


Plate 3. The Enrichers used for the study

Plate 4. The best enriched vermi wash selected from Experiment II

pH	: 7.80	Phosphorus (%)	:	0.10
Nitrogen (%)	: 1.43	Potassium (%)	:	0.41

3.2.2. Vermiwash enrichment indirect technique (VET)

In this experiment OEM at 1, 5 and 10 per cent levels of the substrate were tried one day prior to the extraction of vermiwash anticipating indirect enrichment through dissolution. Three treatments viz.,

VET_1	-	OEM @ 1%
VET_2	-	OEM @ 5%
VET_3	-	OEM @ 10%

3.2.3. Vermiwash enrichment direct technique (VDT)

It also included three treatments as below:

VDT_1	-	OEM @ 1%
VDT_2	-	OEM @ 5%
VDT_3	-	OEM @ 10%

Here the extract of OEM @ 1, 5 and 10 per cent of the substrate was added directly to the vermiwash and filtered to get equivalent quantities of enriched vermiwash as in other techniques..

3.2.4. Physico-chemical analysis of vermiwash

For the standardization of vermiwash, various analyses were carried out. Chemical analysis for C, N, P and K were carried out for enriching media as well as vermiwash, following the standard procedures detailed in Table 3.1. The micronutrient Zn was determined by atomic absorption spectrophtometry using DTPA extract.

3.3 Rapid crop response studies

The agronomic performance of the best enriched vermiwash of Experiment II was tested using amaranthus (*Amaranthus tricolor* L.) in a pot culture experiment with the following technical details (Plate 5 and 6).

3.3.1. Soil

The soil used for the study was laterite of the order oxisol belonging to Vellanikkara series. The physico-chemical properties of the soil were determined following standard procedures given in the Table 3.3.

Table 3.3. Methods used for soil analysis

Sl. No.	Characters	Method	Reference
1	PH	1 : 25 soil water suspension	Jackson, 1958
2	Field capacity	Field method	Mishra and Ahmed, 1987
3	CEC	Neutral normal ammonium acetate	Jackson, 1958
4	Organic C	Walkley and Black titration	Walkley and Black, 1956
5	Available N	Alkaline permanganate distillation	Subbaiah and Asija, 1956
6	Available P	Bray-I extractant ascorbic acid reductant – Spectrophotometry	Bray and Kurtz, 1945
7	Available K	Neutral Normal Ammonium acetate – Flame photometry	Jackson, 1958

Plate 5. Overall view of Pot culture study

Plate 6. Experimental plant of Amaranthus

3.3.2. Treatments

T_1 - Absolute control

T_2 -. Crop with recommended doze of NPK as per POP

T_3 - Crop with direct application of vermiwash to soil to supply the recommended doze of NPK keeping the moisture content @ field capacity.

T_4 - Crop with direct application of vermiwash to soil to supply the recommended NPK keeping the moisture content @ 50 per cent field capacity.

T_5 - Crop with foliar spray of vermiwash to supply the recommended doze of N and remaining P and K as basal.

T_6 - Crop with foliar spray of urea to supply the recommended doze of N and the remaining P and K as basal.

3.3.3. Planting details

Surface soil collected at 0-15 cm depth was dried and ground with a wooden mallet. About 10 kg of soil was transferred to pots of size 24 x 36 sq.cm. Before the initiation of the experiment a nursery was raised and maintained for 21 days. Three uniform size seedlings were transplanted in the properly maintained pots.

Details of the nutrient management of the crop is provided in Appendix III.

3.3.4. Observations

Physico-chemical properties of the soil viz., pH, CEC, available N, available P and available K were determined by standard procedures described in Table 3.3.

Biometric observations such as height and number of leaves were taken at an interval of 10 days. Fresh weight of the produce was also taken at harvest.

N, P and K content of the plants were analysed by the standard procedures cited in Table 3.1. to estimate the crop uptake

Crude protein content (percent) was determined by multiplying leaf nitrogen content with 6.25

3.5 Statistical analysis

The data obtained was statistically analysed by the method of analysis of variance (ANOVA) (Panse and Sukhatme, 1985). and using DMRT by M STAT-C programme. Correlations were worked out using the method of Snedacor and Cochran, (1967).

4. RESULTS

4.1 Experiment 1 - Standardization of substrate controlled environment for multiplication of worms

4.1.1. Physico-chemical properties of substrates

Physico-chemical properties of substrate materials used for composting as well as worm multiplication are given in the Table 4.1.

Table 4.1. Physico-chemical properties of substrate materials used in the experiment

Characteristics	pH	Total carbon (%)	N (%)	P (%)	K (%)	C: N ratio
Cow dung	6.25	32.22	0.59	0.35	0.55	56.3
Banana pseudostem	7.79	38.90	0.89	0.42	1.02	43.17
Coconut leaves	5.96	29.82	1.40	0.20	0.62	21.32
Glyricidia green leaves	6.44	81.30	3.00	0.10	0.70	27.11

In general, the pH of substrate materials were in the neutral to alkaline range with the least value of 6.25 recorded by cowdung and the highest of 7.79 by banana pseudo stem. Coconut leaf and green leaf recorded values of 6.81 and 7.14 respectively.

The highest amount of the total carbon was noticed in glyricidia green leaves (81.30 per cent) whereas the lowest was noted in coconut leaves (29.82 per cent). Cowdung and banana pseudostem registered values of 33.22 and 38.90 per cent respectively.

Maximum nitrogen content was observed in Glyricidia green leaf with a value of 3.00 per cent and minimum in cowdung with a value of 0.59 per cent. Banana pseudo stem registered a value of 0.89 and coconut leaf 1.40 per cent.

Regarding phosphorus, it was maximum in banana pseudo stem with a value of 0.42 per cent, while in glyricidia gave the minimum value of 0.10 per cent. Cowdung and coconut leaf registered values of 0.35 and 0.20 per cent, respectively.

With reference to potassium, maximum and minimum values were obtained for banana pseudostem and cowdung with 1.02 and 0.55 per cent respectively while 0.62 and 0.70 per cent was observed in coconut leaf and green leaf respectively.

The C:N ratio of the substrate materials were 56.33, 43.17, 21.32 and 27.11 respectively for cowdung, banana pseudo stem, coconut leaf and green leaf.

4.1.2 Variations in temperature (°C)

The influence of various treatments on temperature (°C) over vermicomposting were observed at 10 days interval upto 60 days. The details are given in Table 4.2.

Table 4.2. Variations in temperature (°C) at different stages of composting

Treatments \ Days	10	20	30	40	50	60
	Initial stage		Middle stage		Final stage	
T_1	29.26^{e}	28.27^{e}	28.47^{a}	28.43^{a}	28.83^{bc}	28.07^{a}
T_2	30.93^{bc}	29.80^{abc}	29.59^{a}	28.82^{a}	29.49^{a}	28.48^{a}
T_3	31.16^{ab}	30.13^{ab}	29.72^{a}	28.53^{a}	29.11^{abc}	28.27^{a}
T_4	30.53^{cd}	29.47^{bc}	29.34^{a}	28.74^{a}	29.26^{ab}	28.66^{a}
T_5	30.22^{d}	29.16^{cd}	29.17^{a}	28.53^{a}	28.86^{bc}	28.35^{a}
T_6	31.22^{ab}	30.47^{a}	31.44^{a}	28.75^{a}	28.83^{b}	28.60^{a}
T_7	31.61^{a}	30.29^{a}	29.63^{a}	28.60^{a}	28.78^{bc}	28.40^{a}
T_8	29.38^{e}	28.58^{de}	28.81^{a}	28.59^{a}	28.72^{c}	28.21^{a}

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

Though significant differences in temperature were observed at 10, 20 and 50 days intervals, the highest temperature observed in T_7 (banana pseudostem, coconut leaf, green leaf and cowdung (3:3:3:1), 31.61°C at 10th day of composting, a value very near to the atmospheric temperature of 30.86°C (Appendix I) corresponding to the target date. Similarly, the lowest value of T_1 (29.26 °C) was also near to the ambient temperature of that day. This pattern of variations was more or less same almost throughout the period of investigation between and within different treatments. Moreover, at the final stage, the 60th day of composting, there was no significant variations of temperature among the different treatments. These observations indicate no distinct stages of composting as that of the aerobic process.

4.1.3 pH

Changes in pH at initial, middle and final stages of composting are provided in Table 4.3. In general, different substrate materials recorded an acidic range of pH between 6.53 and 6.84 at the initial stage which gradually raised the peak values around 8 at the middle stage and subsequently stabilised at maturity stage to near neutral value of 7 to 7.5. The treatment effects were also not significant at the initial and final phase of composting. During the middle stage, where significant differences were observed, the maximum value of pH (8.11) was observed in T_4 (banana pseudostem, coconut leaf and cowdung 3:3:1) which was on par with T_7 (banana pseudostem, coconut leaf, green leaf and cowdung 2:2:2:1) registering the value of 8.07. However, the treatments T_1, T_8, T_3 and T_6 were also found to be on par except T_5.

Table 4.3. Changes in pH of compost at different stages of composting

Treatments	Initial stage	Middle stage	Final stage
T_1	6.60^{a}	8.01^{ab}	7.11^{a}
T_2	6.69^{a}	7.63^{bc}	7.03^{a}
T_3	6.58^{a}	7.88^{ab}	7.34^{a}
T_4	6.84^{a}	8.11^{a}	7.57^{a}
T_5	6.66^{a}	7.79^{ab}	7.48^{a}
T_6	6.67^{a}	7.85^{ab}	7.30^{a}
T_7	6.64^{a}	8.07^{a}	7.68^{a}
T_8	6.53^{a}	7.91^{ab}	7.53^{a}

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

4.1.4. Microbial count

Effect of treatments on microbial count (CFU $10\ g^{-1}$) at different stages of composting are given in the Table 4.4 (a), (b) and (c).

Table 4.4. Effect of treatments on microbial count (CFU 10 g^{-1}) at different stages of vermicomposting

(a) Initial stage

Treatment	Bacteria (10^5)	Fungi (10^4)	Actimomycetes (10^5)	Nitrogen fixers (10^3)	Phosphate solubilisers (10^3)
T_1	34.82^{b}	21.39^{b}	12.08^{a}	6.28^{b}	14.10^{a}
T_2	25.35^{b}	16.79^{b}	3.46^{c}	4.72^{b}	4.72^{d}
T_3	31.04^{b}	17.85^{b}	9.76^{ab}	11.67^{a}	10.47^{abc}
T_4	24.47^{b}	17.10^{b}	6.80^{abc}	6.45^{b}	7.11^{cd}
T_5	27.72^{b}	20.74^{b}	6.44^{bc}	7.17^{ab}	8.25^{bcd}
T_6	26.70^{b}	14.34^{b}	4.39^{bc}	4.07^{b}	9.37^{bc}
T_7	35.07^{b}	23.70^{b}	6.41^{bc}	7.77^{ab}	12.07^{ab}
T_8	45.61^{a}	33.04^{a}	13.88^{c}	6.42^{ab}	14.41^{a}

(b) Middle stage

Treatment	Bacteria (10^5)	Fungi (10^4)	Actimomycetes (10^5)	Nitrogen fixers (10^3)	Phosphate solubilisers (10^3)
T_1	204.0^{ab}	25.63^{a}	145.8^{ab}	20.84^{bc}	8.72^{a}
T_2	144.0^{c}	21.15^{a}	102.4^{b}	19.76^{bc}	3.51^{a}
T_3	194.7^{ab}	23.76^{a}	121.6^{ab}	44.50^{a}	6.09^{a}
T_4	192.6^{ab}	21.70^{a}	115.7^{ab}	20.14^{c}	5.35^{a}
T_5	211.7^{ab}	23.79^{a}	129.7^{ab}	43.34^{a}	5.93^{a}
T_6	164.9^{bc}	21.56^{a}	111.2^{ab}	17.67^{c}	3.02^{a}
T_7	230.0^{a}	32.13^{a}	151.3^{a}	33.07^{ab}	7.28^{a}
T_8	217.6^{a}	38.36^{a}	131.4^{ab}	22.55^{bc}	8.54^{a}

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

(c) Final stage

Treatment	Bacteria (10^5)	Fungi (10^4)	Actimomycetes (10^5)	Nitrogen fixers (10^3)	Phosphate solubilisers (10^3)
T_1	97.36^{ab}	29.33^{ab}	50.05^{ab}	19.02^{ab}	3.91^{ab}
T_2	72.4^{b}	22.49^{b}	32.73^{b}	8.97^{c}	0.95^{c}
T_3	86.52^{ab}	29.10^{ab}	46.61^{ab}	25.97^{a}	3.60^{ab}
T_4	78.97^{ab}	27.67^{ab}	40.77^{ab}	11.07^{c}	2.02^{bc}
T_5	86.43^{ab}	23.54^{b}	29.93^{b}	9.27^{c}	2.17^{bc}
T_6	82.54^{ab}	21.24^{b}	29.93^{b}	8.64^{c}	2.13^{bc}
T_7	107.60^{a}	37.00^{ab}	66.50^{a}	19.84^{ab}	3.63^{ab}
T_8	104.3^{a}	44.33^{a}	48.48^{ab}	19.02^{ab}	5.51^{a}

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

4.1.4.1. Initial stage

At this stage significant differences were found in the population of bacteria, fungi, actinomycetes, nitrogen, fixers and phosphate solubilizers, among the treatments. With respect to the bacteria, the highest value of 45.61 x 10^5 CFU $10g^{-1}$ was observed in T_8 (banana pseudostem and cowdung in the ratio 8:1), while the lowest value was 25.35 x 10^5 CFU $10g^{-1}$ in T_2 (coconut leaf and cowdung in the ratio 6:1). Other treatments were on par with T_2. For fungi, the highest and lowest values were obtained for T_8 and T_6 with 33.04 x 10^4 CFU $10g^{-1}$ and 14.34 x 10^4 CFU $10g^{-1}$, respectively. The rest of the treatments were on par with T_6 (coconut leaf, green leaf and cowdung in the ratio 3:3:1). For actinomycetes, maximum values was obtained in T_8 (13.88 x 10^5 CFU $10g^{-1}$) and minimum in T_2 (3.46 x 10^5 CFU $10g^{-1}$). The highest and lowest count for nitrogen fixers were observed respectively, in T_3 (green leaf and cowdung in the ratio 6:1) with a value of 11.67 x 10^3 CFU $10g^{-1}$ and T_6 with 4.07 x 10^3 CFU $10g^{-1}$. The treatment T_6 was on par with T_1, T_2 and T_4. Significant differences were not observed in the values recorded by the treatments T_5, T_7 and T_8. With reference to phosphate solubilizers, the maximum count of 14.41 x 10^3 CFU $10g^{-1}$ in T_8 closely followed by T_1 (14.10 x 10^3 CFU $10g^{-1}$) and these values were on par with each other. The lowest value was noted in T_2 with 4.72. Significant variations in the population of phosphate solubilizers were recorded by the treatments T_3, T_4, T_5, T_6 and T_7.

4.1.4.2. Middle stage

During this stage the treatment effects on microbial counts were significant except for fungi and phosphate solubilizers. The respective counts of all group of microbes were also very high here. With respect to bacterial population, the highest count was observed in T_7 with a value of 230 x 10^5 CFU $10g^{-1}$. This was found to be on par with T_8 with a mean value of 217.6 x 10^5 CFU $10g^{-1}$. The treatments T_1, T_3, T_4 and T_5 were on par with each other. The lowest value of 144 x 10^5 CFU $10g^{-1}$ was noted in T_2. In the case of actinomycetes, the maximum population was observed in the treatment T_7 with a mean value of 151.3 x 10^5 CFU $10g^{-1}$, whereas the lowest mean value was 102.4 x 10^5 CFU $10g^{-1}$ in T_2. The values expressed by T_1, T_3, T_4, T_5, T_6 and T_8 were on par.

Regarding the nitrogen fixers, the count was maximum in T_3 (44.50 x 10^3 CFU $10g^{-1}$) which was on par with the value recorded (43.34 x 10^3 CFU $10g^{-1}$) by T_5. The lowest value of 17.67 x 10^3 CFU $10g^{-1}$ in T_6 was on par with T_2. No significant variations in the values recorded by T_1, T_2 and T_8 were noticed. No significant variations were observed in the population of fungi and phosphate solubilizers.

4.1.4.3. Final stage

At the maturity stage, though the microbial counts were lesser compared to the middle stage, variations were significant among treatments. The highest bacterial population was showed by T_7 with a value of 107.60 x 10^5 CFU $10g^{-1}$ which was on par with T_8. The values recorded by the treatments T_1, T_3, T_4, T_5 and T_6 found no variations, while the lowest mean was noted in T_2. In the case of fungi, T_8 was found superior over other treatments values. The treatments T_1, T_3, T_4, and T_7 were on par with each other. The lowest count was seen in T_2 followed by T_5 and T_6 where the differences were found to be non-significant. The population of actinomycetes was maximum in T_7, while it was minimum in T_5 and T_6 with mean values of 66.50 x 10^5 CFU $10g^{-1}$ and 29.93 x 10^5 CFU $10g^{-1}$ respectively. This value did not differ significantly from that of T_2. Nitrogen fixers were the highest in T_3 (25.97 x 10^3 CFU $10g^{-1}$) and the lowest in T_2 (8.97 x 10^3 CFU $10g^{-1}$). The treatments T_1, T_7 and T_8 were on par with each other. The microbial counts as recorded by T_2, T_4, T_5 and T_6 were found on par with T_2. The highest count of phosphate solubilizers was observed in T_8 with 5.51 x 10^3 CFU $10g^{-1}$ and the lowest population was seen in T_2 having a value of 0.95 x 10^3 CFU $10g^{-1}$. There was no significant variations in the observed values registered by T_1, T_3 and T_7. The counts of T_4, T_5 and T_6 were found on par with each other.

4.1.5. Earthworm count

The number of earthworms as influenced by different treatments was taken at 15^{th}, 30^{th} and 45^{th} day after inoculation. The data are given in the Table 4.5.

There were significant differences among the treatment at the all three intervals. In general T_5 at the 15^{th} day registered the minimum (890.67) and T8 at 15^{th} day, the maximum value (1064.00). The other treatments did not differ significantly.

Table 4.5. Number of earthworms as influenced by different treatments

Treatments	15 days after inoculation	30 days after inoculation	45 days after inoculation
T_1	960.33^{ab}	1122.00^{bc}	1388.33^{ab}
T_2	896.66^{ab}	940.00^{d}	943.00^{e}
T_3	941.33^{ab}	1004.39^{cd}	1091.55^{cde}
T_4	1025.66^{ab}	1050.34^{bcd}	1097.68^{cde}
T_5	890.67^{b}	1108.66^{bc}	1226.00^{bc}
T_6	896.33^{ab}	942.00^{d}	1000.33^{de}
T_7	1037.67^{ab}	1173.67^{b}	1142.35^{cd}
T_8	1064.00^{a}	1362.60^{a}	1408.67^{a}

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

On 30^{th} day after inoculation, treatment T_8 (1362.60) was found superior to all. The lowest value was registered in T_2 (940.00) followed by T_6 (942.00). However T_1 and T_5 were found on par with each other whereas significant variations were observed among T_7, T_4 and T_3. At 45th day of inoculation, T_8 showed the highest mean value of 1408.67 when compared to other treatments. The treatments T_3 and T_4 were on par with respective values of 1091.55 and 1097.68. However the treatments T_1, T_5, T_6 and T_7 were varied significantly. The lowest mean value was expressed by T2(943).

4.1.6. Nutrient content of vermicompost

Effect of treatments on the nutrient contents of vermicompost are presented in the Table 4.6.

Table 4.6. Effect of treatments on major nutrient content of vermicompost

Treatment \ Percentage	Total Carbon	N	P	K
T_1	10.89^{f}	1.07^{abc}	0.28^{ab}	1.28^{b}
T_2	17.99^{a}	0.84^{abcd}	0.21^{b}	0.80^{b}
T_3	12.69^{cd}	0.78^{bcd}	0.17^{b}	0.83^{b}
T_4	15.77^{b}	0.69^{d}	0.15^{b}	0.79^{b}
T_5	11.78^{de}	0.96^{abcd}	0.16^{b}	0.83^{b}
T_6	16.53^{b}	0.71^{cd}	0.22^{b}	0.68^{b}
T_7	14.57^{c}	1.19^{a}	0.36^{a}	0.87^{b}
T_8	12.58^{ef}	1.09^{ab}	0.25^{b}	1.30^{a}

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

The maximum content of total carbon was observed in T_2 (17.99%) while the minimum was noted in T_1 (10.89%). The rest of the treatments differ significantly among themselves. The highest nitrogen content of 1.19 per cent was expressed by T_7, while the lowest value of 0.69 in T_4. The treatments T_2 and T_5 were on par, while significant variations were observed among others. Regarding phosphorus, the highest value 0.36 per cent was found in T_7 followed by T_1 with 0.28 per cent. The other treatments were on par with the lowest mean value of 0.15 per cent in T_4. The treatment, T_8 recorded the highest value for potassium with 1.30 per cent, while the lowest was 0.68 per cent in T_6, which was on par with other treatments.

4.1.7 C:N ratio and maturity period of vermicompost

The effect of various treatments on the C:N ratio as a measure of compost maturity are provided in the Table 4.7.

Table 4.7: Effect of different treatments on C:N ratio and maturity compost

Treatments	C:N ratio	Maturity periods (days)
T_1	10.18^{d}	41.00^{d}
T_2	21.42^{a}	$55..33^{ab}$
T_3	16.27^{b}	49.00^{bc}
T_4	22.86^{a}	52.08^{bc}
T_5	12.28^{bc}	48.67^{bc}
T_6	23.29^{a}	54.00^{ab}
T_7	12.25^{bc}	47.00^{a}
T_8	11.55^{c}	44.21^{d}

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

The lowest mean values were recorded by T_1 (10.18) closely followed by T_8 (11.55), T_5 (12.28) and T_7 (12.25). These treatments showed maturity period below 50 days. Whereas the highest C:N ratio was found in T_6 closely followed by T_4, and T_2 with values of 23.29, 22.86 and 21.42 respectively. These treatments were on par as well. The period of maturity in these cases was above 50 days in general.

4.2 Experiment 2 - Enrichment Techniques of Vermiwash

4.2.1 Physico-chemical properties of enrichers

Various physico-chemical properties of organic enrichers used in the investigations are given in the Table 4.8.

Table 4.8. Physico-chemical properties of substrates and enrichers used in the composting process

Substrates/ Enrichers	PH	Total Carbon (%)	N (%)	P (%)	K (%)	C:N ratio
Neem cake	4.90	54.5	5.00	1.20	1.08	10.9
Poultry manure	6.60	13.3	1.50	1.40	0.80	20.0
Bonemeal	8.00	2.8	2.10	20.30	0.01	5.8
OEM 1:1:1	7.80	48.2	1.00	0.40	0.20	48.2

Neemcake and poultry manure were in acidic range with pH of 4.90 and 6.60 respectively. Bonemeal recorded a pH of 8.00. With respect to the OEM (1:1:1:1) a pH of 7.80 was observed.

The highest content of total carbon was present in neemcake with a value of 54.5 per cent. The poultry manure and bone meal recorded 13.3 and 2.8 per cent respectively. However OEM (1:1:1) observed a total carbon content of 48.2 per cent.

The highest content of nitrogen (5%) was observed in neemcake, while poultry manure and bone meal registered 1.50 and 2.10 per cent respectively. For OEM 1:1:1, the nitrogen content was 1.00 per cent.

Bonemeal recorded the highest value of 20.30 per cent while, poultry manure noted 1.40 and neemcake contained 1.20 per cent of phosphorus. The OEM 1:1:1 recorded 0.40 per cent of phosphorus

Regarding the potassium content, 1.08 per cent was observed in neemcake, 0.80 per cent in poultry manure, while it was only in traces (0.01 per cent) in bonemeal. OEM 1:1:1 recorded phosphorus content of 0.40 per cent

Neemcake, poultry manure, bonemeal and OEM recorded C:N ratios of 10.9, 20.0, 5.8 and 48.2 respectively.

4.2.2. Temperature variations with enrichment technique

Temperature variations at different stages of enriched vermicompost taken at 10 days interval are presented in the Table 4.9.

In general the SET treatments observed slightly higher temperature at the initial stage compared to VET and VDT treatments. However, towards the final stage the treatment differences further narrowed down and were comparable to the atmospheric temperature.

Table 4.9. Temperature (°C) variations of enriched vermicompost as influenced by treatments at different intervals

Treatment / Days^{-1}	Initial stage	Middle stage	Final stage
SET_1	30.60^{b}	30.10^{b}	29.12^{ab}
SET_2	31.40^{b}	30.39^{b}	29.42^{ab}
SET_3	32.80^{a}	30.70^{a}	30.57^{ab}
VET_1	31.30^{b}	29.49^{c}	29.49^{abc}
VET_2	32.43^{c}	28.25^{c}	29.10^{ab}
VET_3	32.23^{c}	28.73^{c}	29.00^{bc}
VDT_1	31.40^{c}	29.01^{cd}	29.52^{abc}
VDT_2	30.13^{c}	29.05^{cd}	29.82^{bc}
VDT_3	31.74^{a}	29.23^{cd}	29.95^{bc}

SET - Substrate Enrichment Technique
VET - Vermiwash Enrichment indirect Technique
VDT - Vermiwash enrichment Direct Technique
The treatment values in a column followed by the same superscript do not differ significantly

4.2.3. Earth worm counts in enriched compost

Periodical earthworm counts as influenced by different enrichment treatments are given in the Table 4.10 . The worms flourished and increased in numbers during 10th to 40th day of composting without significant difference. But the treatment effects were found significant at 50th and 60th day of composting. The SET treatment values (1, 5 and 10 percent) recorded the worm count of 1421, 1000 and 997 respectively in the treatments SET_1, SET_2 and SET_3. The mean earthworm counts of VET treatments (1, 5 and 10 percent) and their respective values of 1215,1142 and 1010 in VET_1, VET_2 and VET_3. For the VDT treatment (1, 5 and 10 percent) observed the earthworm counts of 1369, 1384 and 1864 in VDT_1, VDT_2 and VDT_3. VDT_2 and VDT_3 were found on par.

Table 4.10. Earthworm counts as influenced by enrichment techniques

Treatment \ Days	10	20	30	40	50	60
SET_1	1083	1173	1132	1178	1421^{b}	659^{bcde}
SET_2	1144	1142	1110	1289	1000^{c}	701^{bcd}
SET_3	1177	1155	957	1169	997^{d}	806^{cde}
VET_1	1052	1114	1346	1063	1215^{bc}	976^{ab}
VET_2	1259	1121	1239	1118	1142^{cd}	1403^{aa}
VET_3	1109	1218	1141	.1152	1010^{c}	781^{abcd}
VDT_1	1119	1196	1125	1169	1369^{b}	899^{abc}
VDT_2	1197	1256	1119	1201	1384^{a}	738^{c}
VDT_3	1193	1399	1196	1201	1864^{a}	1403^{a}

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

With respect to 60^{th} day of composting, SET treatments values (1, 5 and 10 percent) observed the worm counts of 659 ,701 and 306 in SET_1, SET_2 and SET_3 respectively. VET treatments VET_1, VET_2 and VET_3 (1, 5 and 10 percent) respectively) registered the counts of 976,1403 and 781 .The VDT values for the earthworm counts were 899, 738 and 1403 respectively for the treatments T_7, T_8 and T_9.

4.2.4. Physico-chemical properties of vermiwash

Important properties which determine the pH and nutrient contents of vermiwash is provided in the Table 4.11.

Table 4.11. Physico-chemical properties of vermiwash as influenced by different enrichment techniques

Treatment	pH	N (%)	P (%)	K (%)	Zn (ppm)
SET_1	8.64^{ab}	0.181^{c}	0.168a	0.176^{de}	133.0^{a}
SET_2	8.63^{ab}	0.242^{c}	0.148a	0.262^{bcde}	119.3^{a}
SET_3	8.23^{cd}	0.317^{c}	0.185a	0.158^{e}	113.3^{a}
VET_1	8.50^{bc}	0.091^{c}	0.081a	0.213^{cde}	137.0^{a}
VET_2	8.69^{a}	0.194^{c}	0.073a	0.229^{bcde}	114.0^{a}
VET_3	8.69^{ab}	0.198^{c}	0.108a	0.375^{bc}	114.0^{a}
VDT_1	8.45^{bc}	0.505^{bc}	0.109a	0.357^{bcd}	144.0^{a}
VDT_2	8.29^{cd}	0.897^{b}	0.047a	0.652^{a}	152.0^{a}
VDT_3	8.01^{d}	1.425^{a}	0.096a	0.410^{b}	169.0^{a}

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

With respect to the pH, wide variations were found among the treatment means. The VET treatment T_5 recorded the highest pH of 8.69 and T_1, T_2 and T_6 were on par among themselves. No variations can be found among T_3 and T_8. The treatments T_4 and T_7 did not differ significantly. The lowest mean value was observed as 8.01 in T_9.

The VDT treatments VDT_1, VDT_2 and VDT_3 were observed the highest values of 0.505, 0.897 and 1.425 per cent respectively. The SET and VET treatments did not differ significantly among themselves. Values recorded by SET treatments, SET_1, SET_2 and SET_3 with 0.181, 0.242 and 0.317 per cent respectively. For the VET treatments, VET_1, VET_2 and VET_3, the nitrogen contents were 0.091, 0.0194 and 0.198 per cent respectively. No significant differences were observed for the values of phosphorus and zinc. With respect to potassium content highest mean values were obtained for VDT_1, VDT_2 and VDT_3 with 0.357, 0.652 and 0.410 per cent respectively. The SET treatments registered lower values for potassium, whereas the VET treatments were in between SET and VDT treatments. Zinc, a reflective element of hormone activity did not differ significantly among treatments. However, the lowest value of 113.3 ppm was in SET_3 and the highest of 169.0 ppm, in VDT_3.

4.2.4 Chemical properties of plain vermiwash

Chemical properties of plain vermiwash are given in the Table 4.12

Table 4.12. Physico-chemical properties of plain vermiwash

Treatment	pH	N (%)	P (%)	K (%)	Zn (ppm)
Plain vermiwash	8.70	0.02	0.007	0.100	170.0

With respect to the chemical properties of plain vermiwash,the pHwas recorded as 8.70.The major nutrients N,P and K were 0.02,0.007 and 0.100 percent respectively while Zn was registered a value of 170 ppm.

4.3 RAPID CROP RESPONSE STUDIES

4.3.1. Crop performance

The influence of various treatments on plant height, number of leaves and yield of amaranthus are given in the Table 4.13.

Table 4.13. Effect of different treatments on plant height, number of leaves and yield of amaranthus

Treatments	Height (cm)	No. of leaves	Yield (g^{-1} pot)
T_1	46.67^c	13.00^c	31.37^e
T_2	70.70^b	19.00^{bc}	54.87^b
T_3	120.33^a	20.67^{bc}	69.33^c
T_4	118.00^a	30.67^a	83.05^{ab}
T_5	85.50^b	24.33^{ab}	71.69^{bc}
T_6	85.67^b	31.67^a	95.70^a

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

With respect to the plant height, soil application of vermiwash (T_3 and T_4) with mean values of 120.33 cm and 118.00 cm were found superior when compared to the absolute control value of 45.67 cm,(T_1). The foliar spray treatments, T_5 and T_6 did not differ significantly.

Foliar application of one per cent urea (T_6) was observed producing the highest number of leaves, 31.67 followed by 30.67 in soil application of vermiwash at 50 per cent field capacity (T_4). When compared to the absolute control (T_1) with a value of 13.00, the treatments, T_2 and T_3 were found on par while T_5 was significantly different from other treatments.

The highest yield was recorded by foliar application of one per cent urea (T_6) with the mean value of 95.70 g pot^{-1} compared to absolute control (T_1) with 31.37 g pot^{-1}. The treatments with soil applications of vermiwash (T_3 and T_4) recorded the yield of 69.33 g pot^{-1} and 83.05 g pot^{-1}, respectively. Foliar application of vermiwash (T_5) registered a mean value of 71.69 g pot^{-1}, while POP recommendation expressed the yield of 54.87 g pot^{-1} (T_2).

4.3.2 Physico-chemical characteristics of soil

The different characteristics of soil before and after the experiment are given in the Table 4.14 (a) and (b).

4.3.2.1. Before the experiment

The pH of the soil was found to be 6.29. The CEC was observed as 6.2 [cmol(+) kg^{-1}]. The organic carbon content was 0.79 percent. Available nitrogen, phosphorus and potassium were 268.01, 13.12 and 72.04 kg^{-1}ha respectively. Field capacity was found to be 23.69 per cent.

Table 4.14. Physico-chemical characteristics of soil

(a) before experiment

Sl. No.	Characteristics	Values
1	PH	6.29
2	Organic carbon (%)	0.79
3	Available nitrogen (kg ha^{-1})	268.0
4	Available phosphorus (kg ha^{-1})	13.12
5	Available potassium (kg ha^{-1})	12.04
6	Cation, Exchange capacity (Cmol+kg^{-1})	6.20
7	Field capacity (%)	23.69

(b) after experiment

Treatments	PH	CEC (Cmol+kg^{-1})	Organic carbon (%)	Available nitrogen (kg^{-1} ha)	Available phosphorus (kg^{-1} ha)	Available potassium (kg^{-1} ha)
T_1	6.10^{b}	5.98^{b}	0.81^{d}	261.18^{e}	12.49^{c}	72.03^{d}
T_2	6.31^{ab}	6.82^{b}	1.21^{c}	288.48^{d}	14.49^{bc}	87.17^{bc}
T_3	6.75^{a}	7.62^{a}	1.39^{a}	326.18^{b}	16.28^{bc}	93.32^{abc}
T_4	6.76^{a}	7.88^{a}	1.40^{a}	340.66^{a}	18.44^{b}	85.24^{c}
T_5	6.70^{a}	7.84^{a}	1.32^{b}	315.83^{c}	21.68^{ab}	95.41^{ab}
T_6	6.74^{a}	7.36^{a}	1.33^{b}	336.26^{a}	21.73^{a}	96.73^{a}

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

4.3.2.2. After experiment

The effects of different treatments on the physico-chemical characteristics evaluated after the experiment reveals significant differences between the treatments.

The pH was increased to 6.76 in the treatment T_4, while T_3, T_5 and T_6 were on par with T_4. The lowest was seen in 6.10 in absolute control while T_2 significantly differed from others.

Maximum CEC of 7.88 [cmol(+) kg^{-1}] was observed in the soil application of vermiwash (T_4) and minimum in the T_1 (absolute control) with 5.98 (cmol + kg^{-1}). No significant differences were observed in CEC values.

With respect to the organic carbon, maximum amount of 1.40 per cent was observed in T_4. It was found on par with T_3, T_5 and T_6. The lowest amount was expressed by the absolute control, T_1 with 0.81 followed by 1.21 by POP recommendation (T_2).

The highest nitrogen content of 340.66 kg ha^{-1} was observed in T_4, when compared to the absolute control T_1 with 261.18 kg ha^{-1}. The treatments T_4 and T_6 did not differ significantly, while wide variations were seen among other treatments.

When compared to the absolute control, the other treatments showed higher values for available phosphorus. Maximum amount of phosphorus was obtained in T_6 with 21.73 kg ha^{-1}, while the lowest was observed 12.49 kg ha^{-1} in T_1. Significant variations were found among T_4 and T_5. The treatments T_3 and T_2 did not differ significantly from each other.

With reference to the available potassium, T_6 was found superior over all other treatments with 96.73 kg ha^{-1}. The lowest was observed in T_1 (absolute control) with 72.03 kg ha^{-1}. The other treatments T_2, T_3 and T_4 were significantly different from each other, while T_5 was found on par with T_6.

4.3.3. Nutrient uptake studies

Effects of various treatments in the uptake of nutrients by the test crop are presented in the Table 4.15.

Table 4.15. Effect of different treatments on crop nutrient uptake

Treatments	Nitrogen (g^{-1} plant)	Phosphorus (g^{-1} plant)	Potassium (g^{-1} plant)
T_1	0.143^b	0.001^a	0.329^b
T_2	0.304^b	0.005^a	0.953^b
T_3	0.617^a	0.004^a	1.307^b
T_4	0.918^a	0.009^a	1.687^a
T_5	0.548^a	0.008^a	1.576^a
T_6	0.947^a	0.115^a	1.796^a

The treatment with foliar application of one per cent urea observed the highest uptake of nitrogen with a mean value of 0.947 g $plant^{-1}$ when compared to the absolute control T_1 with 0.143 g $plant^{-1}$. The treatments T_3, T_4 and T_5 were found on par, while T_1 and T_2 also did not differ significantly.

The treatment means did not differ significantly for the uptake of phosphorus.

The highest amount of potassium uptake was seen in T_6 (1.687 g $plant^{-1}$) which was in par with T_4 and T_5 with 1.796 g $plant^{-1}$ and 1.794 g $plant^{-1}$ respectively. No significant variations were found in the case of treatments T_1, T_2 and T_3.

4.3.5. Crude protein content

Treatments	Crude Protein Content(%)
T_1	12.5^{d}
T_2	14.68^{c}
T_3	$16.5b^{b}$
T_4	14.83^{bc}
T_5	16.63^{b}
T_6	21.85^{a}

he influence of various treatments on the crude protein content of the amaranthus were studied and given in the Table 4.18. The treatment effects were highly significant. The maximum content of 21.85 per cent was obtained in the foliar application of one per cent urea (T_6) which was found to be superior over all other treatments. The lowest amount was observed in the absolute control T_1 with 12.5 per cent. The foliar application of vermiwash (T_5) registered 16.63 per cent, while the soil application of vermiwash noted 16.56 and 18.43 per cent of crude protein in T_3 and T_4 respectively while a value of 12.5 per cent was observed with POP (T_2).

4.3.6. Correlation studies

Coefficient of correlation of yield with plant height, number of leaves, available NPK and plant uptake of NPK are provided in the Table 4.16. All the characters studied showed significant positive correlation with yield. Uptake of N, available N and number of leaves showed maximum correlation with respective values of 0.99, 0.95 and 0.94. The lowest R value of 0.60 was observed with uptake of P.

Table 4.16. Correlation on yield with different characters

Characters	*R value*
Plant height	0.66*
Number of leaves	0.94*
Available nitrogen	0.95*
Available phosphorus	0.81*
Available potassium	0.66*
Plant uptake N	0.96*
Plant uptake P	0.65*
Plant uptake K	0.97*

* *Significant at 5 per cent level*

5. DISCUSSION

The results of various experiments conducted on standardization of substrate controlled micro-environment for worm multiplication as well as production of vermiwash and the response of crop to enriched nutrient application were studied and presented in the Chapter 4. The details are discussed below:

5.1 Standardization of substrate controlled environment for worm multiplication

5.1.1. Physico-chemical composition of substrate materials

Given the external conditions are alike, substrate controlled micro-environment is the most decisive factor which determines the effectiveness of vermicomposting, since worm castings are the vermicompost. Nature and chemical composition of the substrate materials decides the proliferation of worms as well as nutritional quality of the compost. The physico-chemical properties of the substrates which the worm have to feed therefore, assume primary considerations. Table 4.1. under item physico-chemical properties of substrate materials involved in composting describes these quality aspects of the substrates. The substrate materials are carbonaceous in nature with C: N ratios falling between 56.33 for cowdung and 21.32 for coconut leaves. The proportionate contents of macronutrients of substrate materials are illustrated in Fig.I. The materials that are rich in nitrogen, the order of glyricidia < coconut leaves < banana pseudostem < cowdung. Potassium occupies the position next to nitrogen with respect to the total nutrient composition followed by phosphorus.

It is evident that the main composting substrates viz. glyricidia green leaves, dried coconut leaves and chopped banana pseudostem do contain major nutrients in highly disproportionate manner, when compared to cowdung, a biocompost. *The importance of chopping the rude plant parts and mixing them* with cowdung as done in the present study is to provide a favourable microclimate through a finer physical environment as well as properly blended nutritional

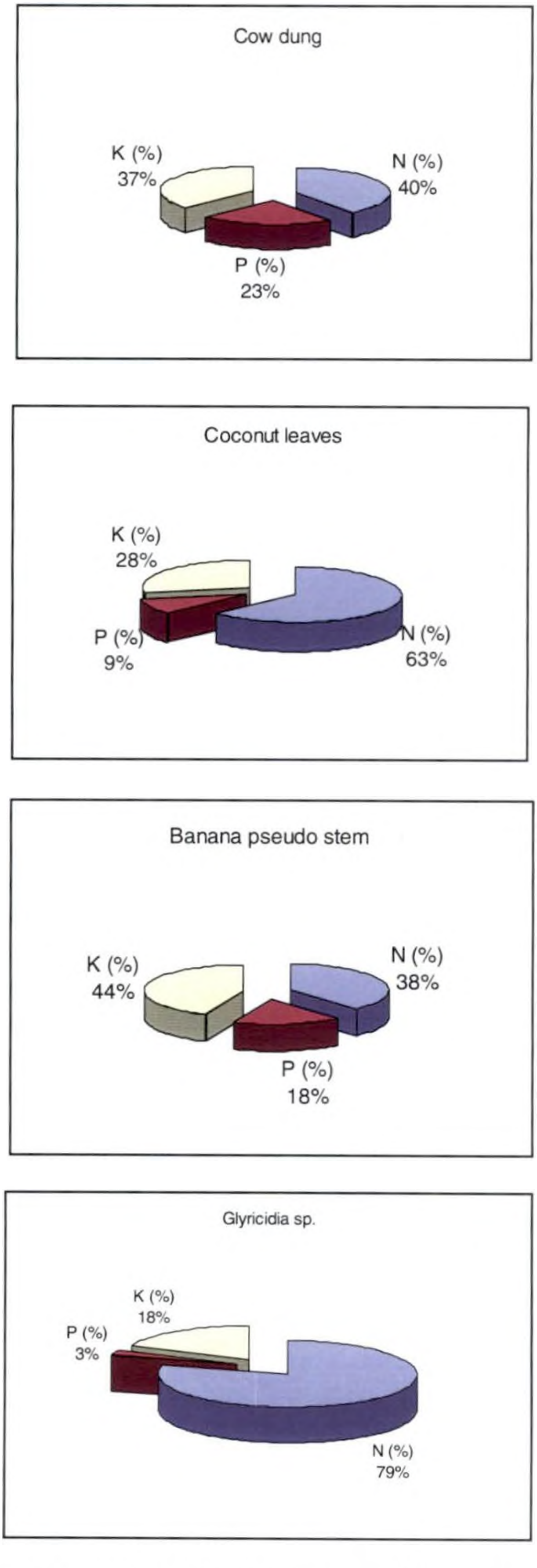


Fig. 1 Proportionate contents of substrate materials used for composting

medium of substrates. As opined by Chawla (1984) protein of high quality and availability mixed with fibre largely indigestible by ruminants as found in fresh cowdung with wide C:N ratio (56.33) and almost neutral pH makes it, an ideal one for creating a comfortable substrate controlled environment for any composting prices. Cowdung being the most traditional organic manure and is widely available to the farmers, it is locally acceptable as well. The other substrates like glyricidia leaf and banana pseudostem are also mostly alkaline in nature with good amount of nitrogen (3.00%) and potassium (1.02%) respectively. The fourth substrate of the study, the chopped and dried coconut leaves contains fairly good amount of nitrogen (1.40%), phosphorus (0.20%) and potassium (0.62%). With the lowest C: N ratio of 21.3 and with the highest proportional K content (63%) coconut leaves imparts an active nutritional function as well in the compostable substrate controlled environment for composting (Anitha and Prema, 2003).

5.1.2. Temperature controlled environment

Variations in temperature as influenced by different treatments are given in the Table 4.2. and Fig. 2, 3 and 4. As seen from the results, the temperature of all the treatments showed only very small difference with in the range of initial levels of 29.00-31.31 to 29.26°C to 31.61°C during the middle stage. Towards the final stage it coalesced with the atmospheric temperature around 29°C.

Apart from these small variations, the fluctuations in temperature in general did not tend to indicate any distinct stages like mesophilic, thermophilic and maturity stages as in aerobic composting where organic wastes undergo decomposition, the insulating effect of the materials leads to conservation of heat and a marked rise in temperature of the substrates takes place (Preetha, 2003). But worms are thermosensitive in nature and excessive heat during the decomposition of organic matter results in their mortality. To avoid this the substrate materials were subjected to pre-processing as described under section 3.1.1. of methodology, observing the principles of aerobic composting. This precaution was also essential to make the temperature controlled environment of organic matter decomposition independent of the substrate controlled one (Thomas, 2001). As vermicomposting is the intrinsic interaction between the active worm population and the innocuous organic environment the suitability of the substrate assumes paramount importance. The insignificance in variations of temperature as observed in this study is therefore indicative of the suitability of the substrates for building up an active worm population.

5.1.3. pH

The stage-wise observations on pH of vermicompost as influenced by different treatments are provided in the Fig.5. and the corresponding data in the Table 4.3.

The results are further supportive to the suitability of the substrate combination irrespective treatment differences for effective vermicomposting. Stabilized neutral pH values were shown by all treatments towards the final state. Though the substrates showed variations in pH, their combined effects were complimentary to each other and at maturity phase the pH was maintained around the widely reported neutrality of pH 7.03 to 7.68.

Decomposition will occur most readily in a neutral medium because most microorganisms grow best under neutral conditions. Under aerobic conditions a material that is initially neutral will experience a decrease in pH during the start of composting. This will normally be followed by an increase in pH at later stages. Finally, the matured compost materials attained a neutral range of pH. The findings of Wilson (1989) are in line with these observations. The action of innumerable number of micro-organisms favoured with neutral pH further accelerate the flourishing of worm population and resultant decomposition.

At this point it is worthwhile to note that the low pH inhibits earthworm activity as evident from the Table 4.7. Maximum earthworm count is in the alkaline pH. Treatment variations are found to be significant only at middle stage with T_2 registering the lowest pH and T_7, the highest. The minor variations in pH

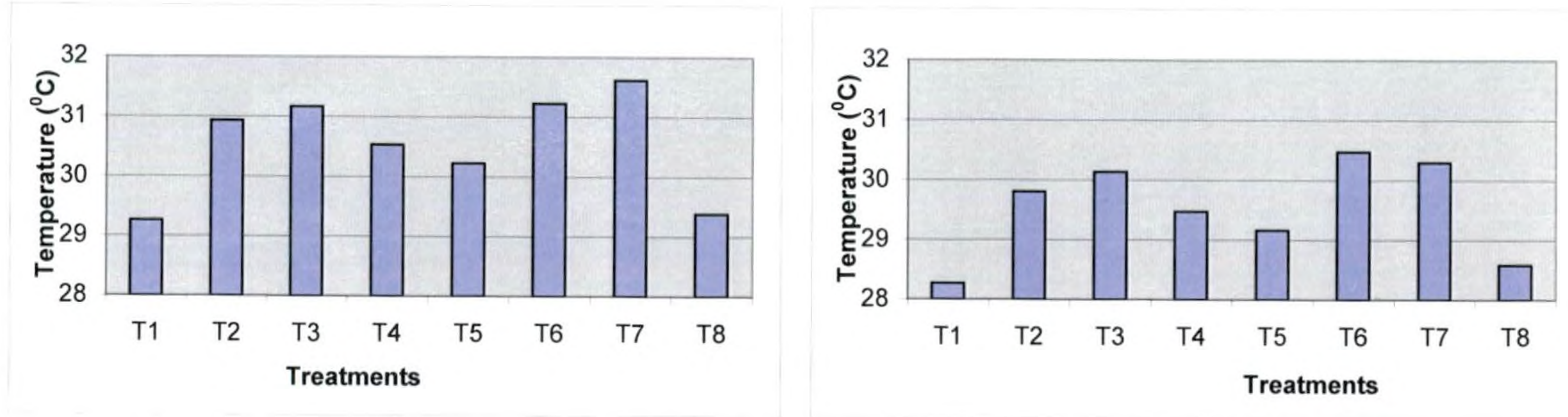


Fig 2. Variations in Temperature (^{0}C) as influenced by different treatments at initial stage (10 and 20 days) of composting

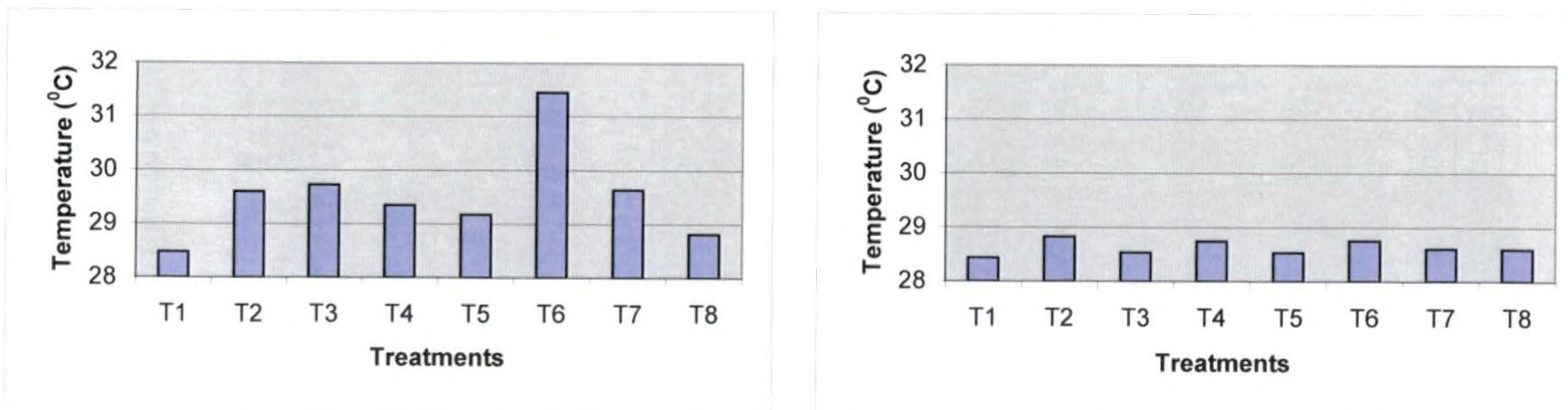


Fig 3. Variations in Temperature (^{0}C) as influenced by different treatments at middle stage (30 and 40 days) of composting

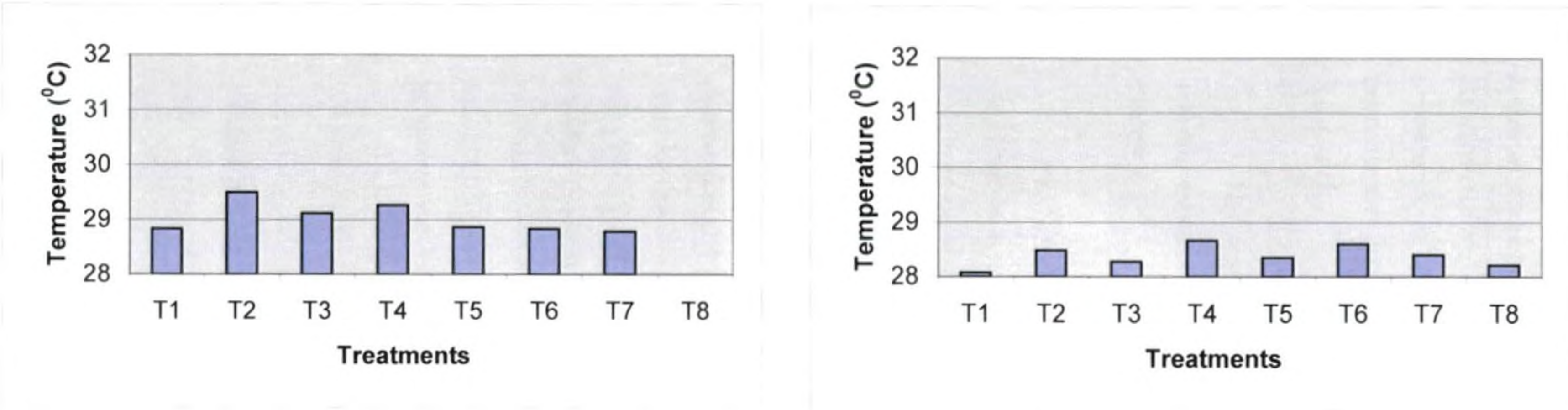


Fig 4. Variations in Temperature (^{0}C) as influenced by different treatments at final stage (50 and 60 days) of composting

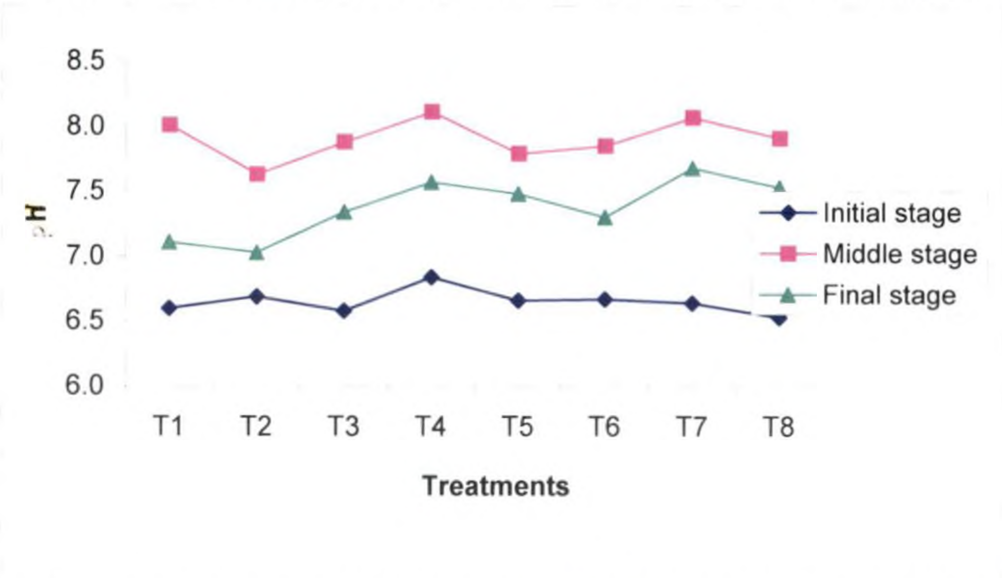


Fig 5. Changes in p^H of vermicompost as influenced by different treatments and stages of composting

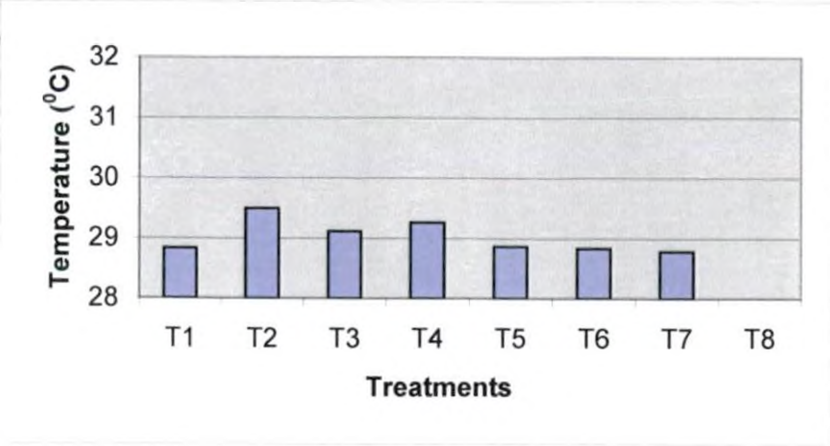
may be attributed to the physico-chemical properties of substrates and the different combinations of the same. Supportive findings were reported by Gaur and Sadasivam (1993).

The variations in pH with respect to the treatment effects are projected in Fig.5. There is steady progress from acidic to neutral and then from neutral to alkaline with corresponding increase in the days of composting. The build up of worm population over the period of composting also showed a similar trend. The inference from these findings is that the wormcastings which are rich in calciferous glands and alkaline elements contribute much towards the alkaline pH of the compost material. At this juncture, it may be noted that the ordinary compost differs from vermicompost. While the former registers the pH of substrate materials involved in the composting process, the latter record the modified and resultant reaction of the active worm population.

5.1.4. Microbial analysis

The counts of bacteria, fungi, actinomycetes and beneficial micro-organisms such as nitrogen fixers and phosphate solubilizers were taken from vermicompost samples collected from the initial, middle and final stages of composting. The data are given in the Table 4.4.(a,b and c) and detailed in 4.1.4.1, 4.1.4.2. and 4.1.4.3. Graphical illustration is also provided in Fig.6.

When composting begins the mesophilic flora predominates and are responsible for most of the metabolic activity that occurs. The mesophilic microbes pre-disposes a favourable environment for the other flora to get themselves activated. This results in the oxidation process and the resultant temperature, which attracts the thermophilic flora to multiply. In the present study this phase of decomposition occurs under the pre-processing stage included for partial decomposition of organic wastes prior to the introduction of worms. Pre-processing of organic wastes helps in the breaking down of complex



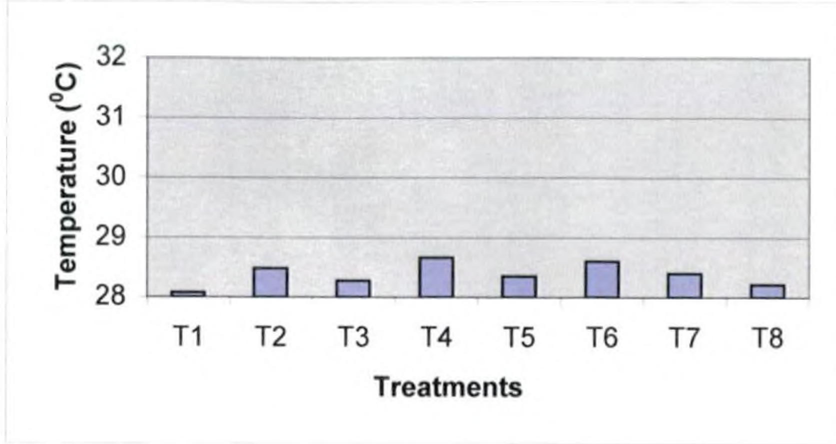


Fig 4. Variations in Temperature (°C) as influenced by different treatments at final stage (50 and 60 days) of composting

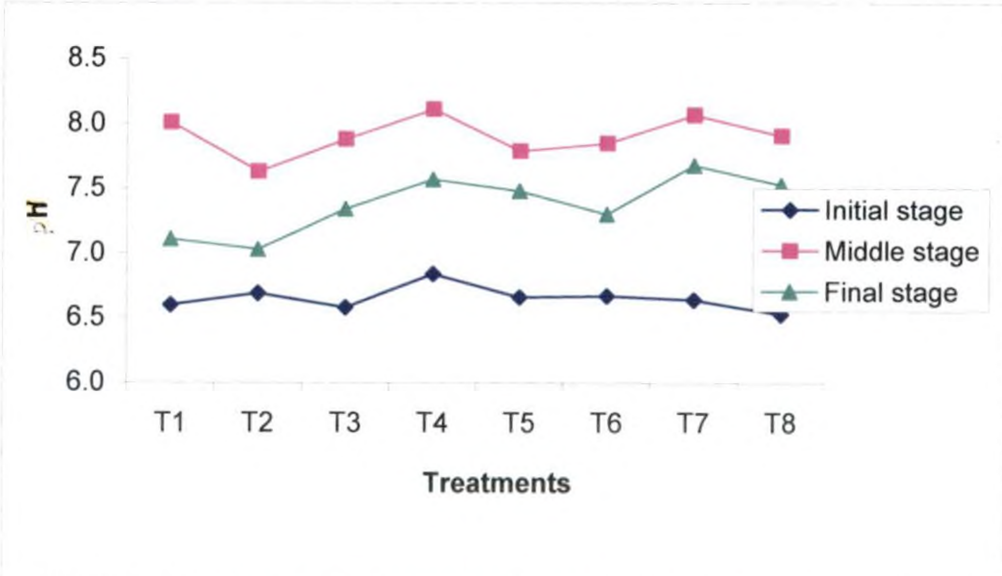
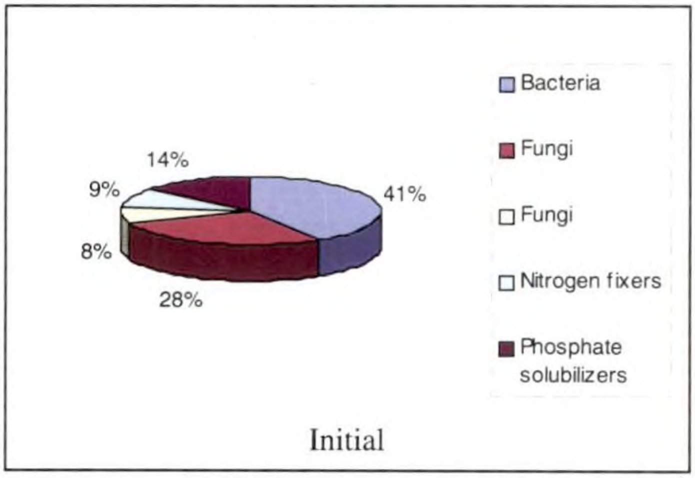
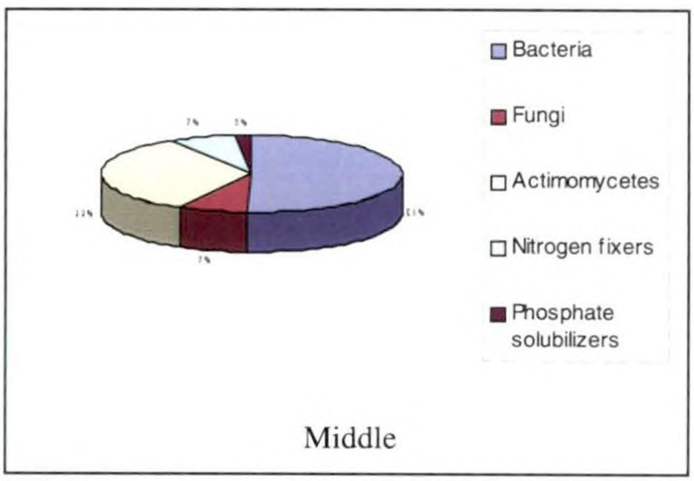


Fig 5. Changes in p^H of vermicompost as influenced by different treatments and stages of composting





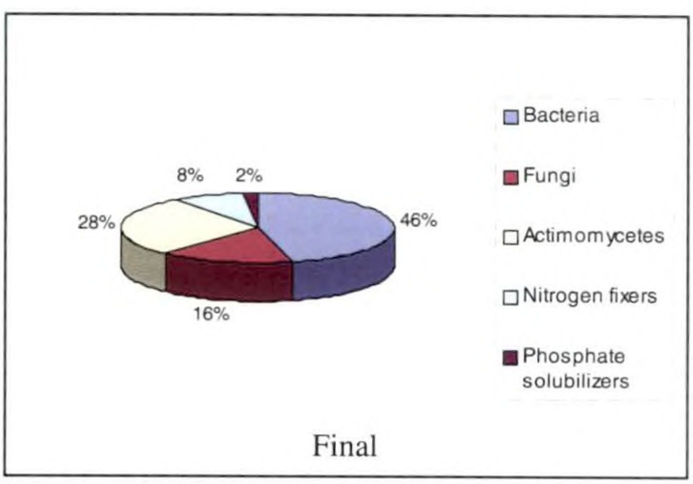


Fig.6. Comparative count of microorganisms at specific stages of composting

compounds into intermediate simpler metabolites for synthesizing new cellular materials of the microbes involved during the mesophilic microbes involved during the mesophilic (Gaur and Sadasivam, 1993) and thermophilic stages of aerobic composting (Gaur *et al.*, 1995). Lipid and lignin degrading bacteria get flourished at this stage which help in the breakdown of long chain polysaccharides, lignin and hemicellulosic substances. The sequential series of biochemical processes happening at both the initial and middle stages have given congenial conditions for the introduction of earthworms.

It is well known that earthworms will not generally ingest plant litter until it is partly decomposed and it has been established that fungi and microorganisms ingested with decomposting wastes are important components of the diet (Gaur *et al.*, 1995). There is also evidences that microflora and many microorganisms passing through the earthworm gut are unharmed. Fungi also have their role in almost equal proportions in all the stages but predominate in maturity stage. These group of organisms are saprophytic and convert partially decomposed organic forms to stable products. Once decomposition process start stabilized, there leaves little raw substrates to get disintegrated and therefore microbial activity also diminishes to that extent. The low and nearly steady state of temperature corresponding wth the final stage is hence explainable. This is in line with the observations made by Nair (1997).

The population of different beneficial microbes such as nitrogen fixers and phosphate solubilizers showed considerable variations in their relative number during different phases of vermicomposting. The phosphate solublizers needed an acidic range of pH to flourish. In the initial stage, which is equivalent to the mesophilic stage, such acidic range was prevalent. Phosphate solubilization decreased by an increase in pH. It is due to the production of ammonia. Nitrogen fixing and phosphate solubilizing bacteria were isolated from the vermicompost Mba (1994; 1997) and Nair *et al.* (1997).

The treatment differences mainly indicated the suitability of different substrates congenial for worms and microbial multiplication and consequent organic matter decomposition. From the study it is inferred that banana pseudostem favours the flourishment of the microbial population as compared to coconut leaf, since the microbial population were always higher in those treatments where banana pseudostem forms the major substrate component. Similarly a general decreasing tendency in microbial population was noticed in those treatments where coconut leaf formed the major substrate component. This may because of the fact that the coconut leaf is more carbonaceous in nature and not easily decomposable as compared to the banana pseudostem which is more alkaline (pH 7.79) and succulent in nature.

The general pattern of pH variation as evident from Fig.5. is also reflective to the initial increase from acid range to alkaline level and its consequent stabilization at the neutral level towards the maturity phase. It is exactly in accordance with the established processes of composting. There is an intrinsic relationship of temperature, microbial population and pH variation with time during composting. The reports by Gaur *et al.* (1995) and Nair (1997) are also corroborative with these observations.

As observed above, it can be concluded that vermicompost is a product of combined activity of earthworms and various microorganisms in desirable substrate environment. Evidences also supported that composting involves an active phase and a maturation phase. The active phase is characterized by intense activity as indicated by respective counts of different organisms involved in the process.

5.1.5. Earthworm count

The activity of earthworm *Eudrillus eugeniae* in the vermicomposting system as accounted in terms of worm count are detailed in the Table 4.6. and Fig.7.

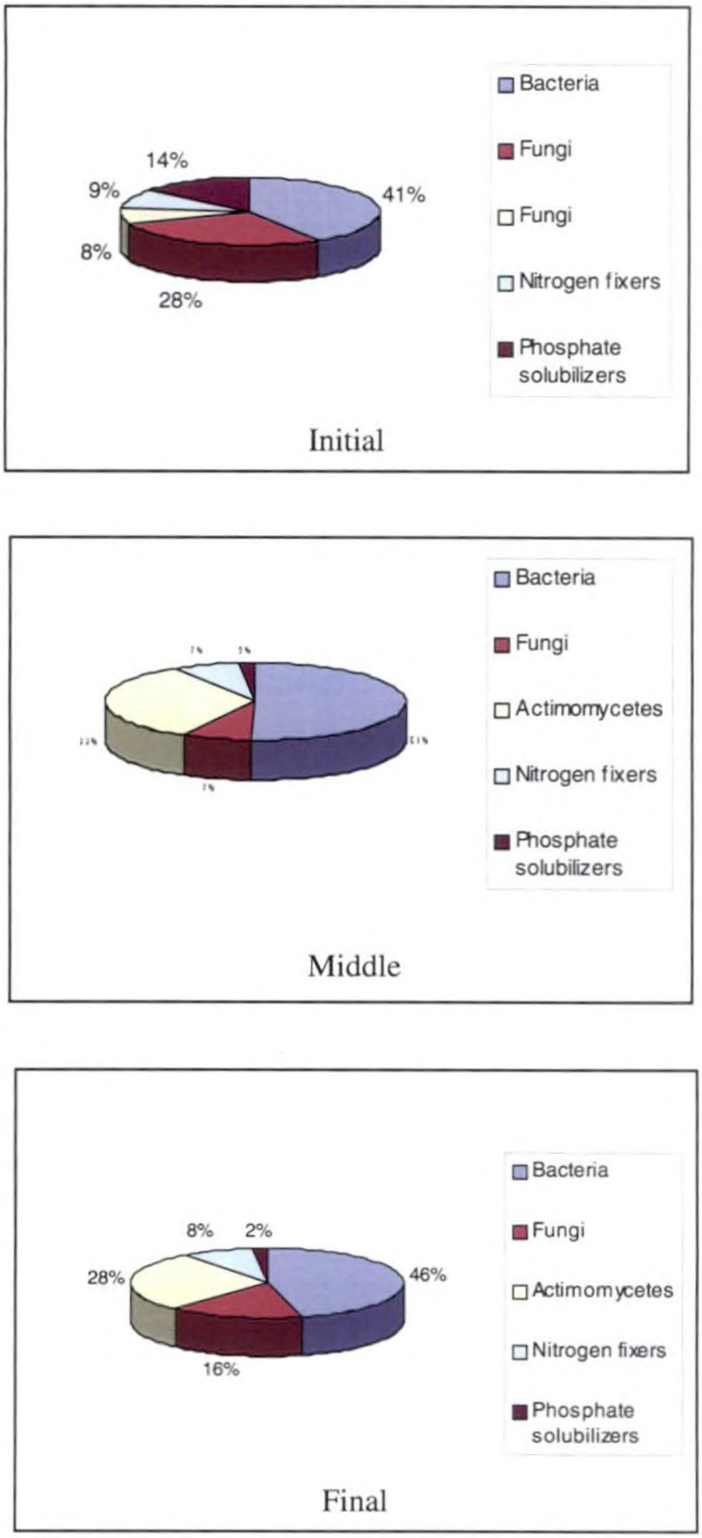


Fig.6. Comparative count of microorganisms at specific stages of composting

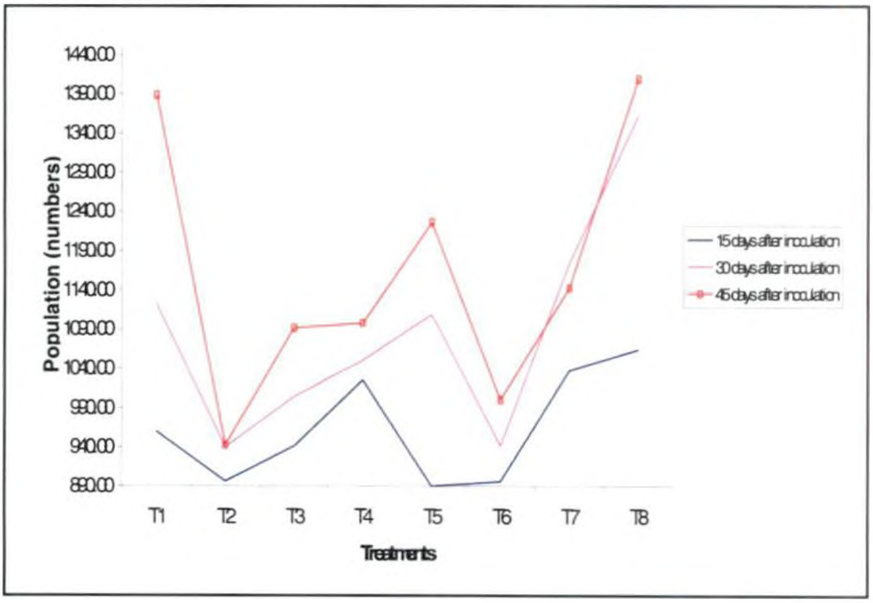


Fig.7. Earthworm population as influenced by different treatments and stages of composting

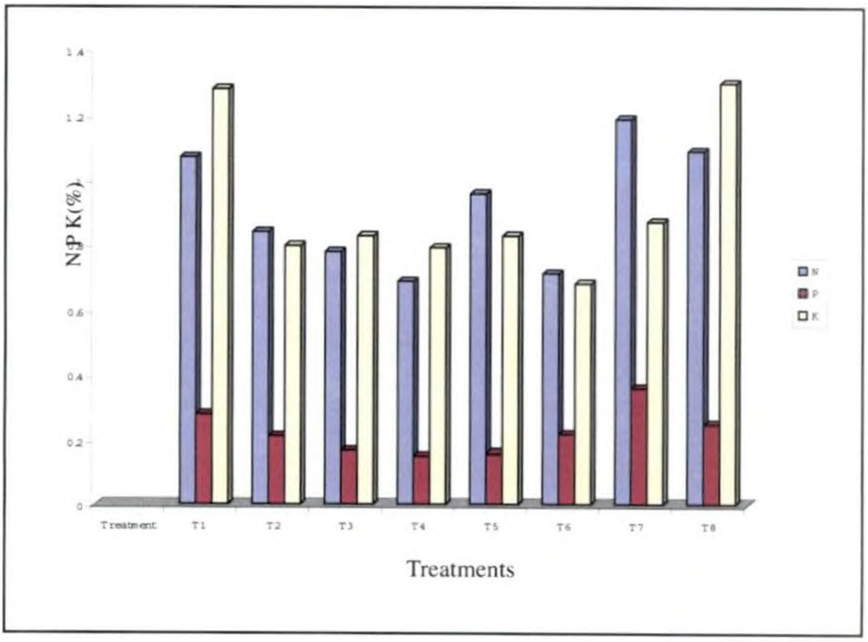


Fig. 8. Effect of treatments on major nutrient content of vermicompost in terms of N,P and K

Earthworms are detrivorous their diet comprises mainly organic detritus in various stages of decay and incorporation into the soil. Although the bulk food ingested is dead plant tissue, living microorganisms, fungi, macro fauna and mesofauna and their dead tissues are also ingested.

After 20 days of pre-processing of substrates, 1000 adult worms were inoculated in each treatment. In the first stage, the number of earthworms varied between 890.67 to 1064.00. Considerable increase in the population of earthworms was observed in almost all treatments. The substrate combination having banana pseudostem as one of the ingredients showed maximum number of earthworms. The earthworms are thermo and pH sensitive in nature and so the combination of banana pseudostem and cowdung in the ratio 8:1 (T_8) was found to be more congenial for worm multiplication and proliferation as discussed under section 5.1.2. and 5.1.3. The same treatment registered the highest numbers at all the stages of composting. The production is closely related to food quality basically a substrate controlled criterion and have implications for protein production from earthworm tissue. Similar studies are reported by Prabhakumari *et al.* (1995), Jiji *et al.* (1995) and Sailajakumari (1999).

Even the substrate combination containing good portion of coconut leaves becomes conducive for worm multiplication as indicated by the increase in the population of earth worms ($T_4$and T_7) as indicated by the treatment. This may be due to high lignin content and soothening effect of banana pseudostem on the coconut leaves as discussed above. This finding signifies the potential of converting farm waste of lesser decomposability as that of lignified coconut leaves and its ilk through proper blending with succulent substrates like banana pseudostem.

The optimum temperature range for the growth and multiplication of earthworm was found to be in the range of 28°C to 30°C. When a substrate controlled environment becomes sensitive to temperature fluctuations, it is always better to have an ingredient as that of banana pseudostem in the substrate combination for ameliorative roles. Succulent 'substrates manipulates the microenvironment to the advantage of worm population.

5.1.6. Nutrient contents of vermicompost

The influence of different treatments on the nutrient content of vermicompost is provided in Table 4.6 and Fig.8.

5.1.6.1. Nitrogen

The treatment T_7 containing suitable proportion of banana pseudostem, coconut leaf, glyricidia leaf and cowdung (2:2:2:1 ratio) recorded the highest N content of 1.19 per cent. As observed by many workers (Syres and Springett (1984), Bano *et al.* (1987) and Shuxin *et al.* (1991), the chemical composition of the compost depend upon the sources from which it is prepared. The substrate combination of the best treatment was in such a way that the bulk plant components were in equal proportion which tends to converge the nutrient contents of the end product, the compost, towards the average value of the respective substrates. Therefore the highest content of N noted with the target treatment is explainable.

Moreover, the observations of Haimi and Huhta (1990) on the increased nitrogen content by earthworm activity also merit consideration here. They opined that it may be due to the earthworm carcasses. But later it was confirmed that microbial activation by the earthworms are more important in nitrogen cycling than the additional nitrogen, brought into the soils in the earthworm biomass. Microorganism in the gut of some earthworm species using mucus secreted from the gut as an energy sources may fix atmospheric nitrogen in quantities that are significant for the earthworms metabolism and as a source of N for plant growth. A significant proportion of carbon assimilated by earthworm is secreted as intestinal and cutaneous mucus with greater C: N ratios than those of the resources used. As a result N assimilated in excess have to be excreted which may also add to the soil or to compost.

5.1.6.2. Phosphorus

As cited in the Table 4.8, the maximum P content was also recorded by T_7. The substrate controlled phosphate solubilizing organisms enhance the conversion of insoluble P during composting. Inorganic compounds turn to soluble form through production of acid and H_2S under aerobic and anaerobic condition and mineralises organic compounds with the release of inorganic P (Dey, 1988). It is also reported that the magnitude of transformation of P from the organic to inorganic state and thereby its available forms was found to be considerably higher in the case of organic wastes inoculated by earthworms (Pushpa, 1996). These findings together with the substrate controlled P concentration effect as in the case of N can explain the observed value.

5.1.6.3. Potassium

Table 4.6 reveals that the maximum of 1.30 per cent K was obtained in T_8, where banana pseudostem was mixed with cowdung in the ratio 8:1. T_7 recorded a value of 0.87 per cent which was comparable to majority of other treatments. It can be explained by the substrate controlled K concentration factor as the treatment T_8 contained the highest portion of banana pseudostem which had proportionately. The highest K content (44%) Fig.1. It is known that K is not bound to any organic compound in the plant and organic matter decomposition is not an index of K availability (Mengel and Kirkby, 1987). Moreover, different microorganisms have no role in K mineralization as in the case of N and P and therefore, no complimentary effect over the substrate contributions is found possible. This gives ample explanation to the high K observed in T_8 and not in T_7, the best for N and P.

5.1.7. C: N ratio and maturity period

Effects of various treatments on C: N ratio and maturity period are given in the Table 4.7 and Fig.9. C: N ratio is an important parameter that determines the value of compost as manure. The rate at which organic matter decomposes is determined principally by relative amounts of carbon and nitrogen present. C: N ratio is the most conventional index, which reflects organic matter decomposition and stabilization during composting. As composting proceeds the micro flora use carbon for energy and the N for cell building. The C: N ratio become narrower with time since the N remains in the system while the carbon as the energy source and the carbonaceous materials are converted to microbial biomass, Co_2 water and humus. Nitrogen is the major nutrient required by microorganisms in the assimilation of carbon compounds from the organic wastes. Decomposition involves the reduction of relative proportion of elements to a point where available carbon has been totally consumed and bacterial activity ceases. In this study it can be seen that the C: N ratios were ranged from 10.18 to 23.29. The C: N ratio of Banana pseudostem : Cow dung (BS: CD) in the ratio 6:1 and 8:1 (T_1 and T_8) respectively got a low value of 10.18 and 11.55. Cowdung act as a good substrate for proliferation of microorganisms and facilitating enhanced carbon mineralization and thus C: N ratio values get decreased. Similar findings are reported by Chawla (1984) and Press *et al.* (1996).

On perusal of that data, it was observed that the vermicompost materials, which attained the least C: N ratio, registered less time for composting. This is evident from the details accounted in Table 4.9 that is also illustrated in Fig.9. Immature composts with a high C: N ratio cause N immobilization. Excessively low C: N ratio cause ammonium toxicity. Both extremes interfere with plant growth. All immature composts induce high microbial activity in soil for sometimes after incorporation, potentially causing oxygen deficiency and a variety of indirect toxicity problems to plant roots. Immature compost also can be odoriferous which cause problems during utilization. Similar observations were

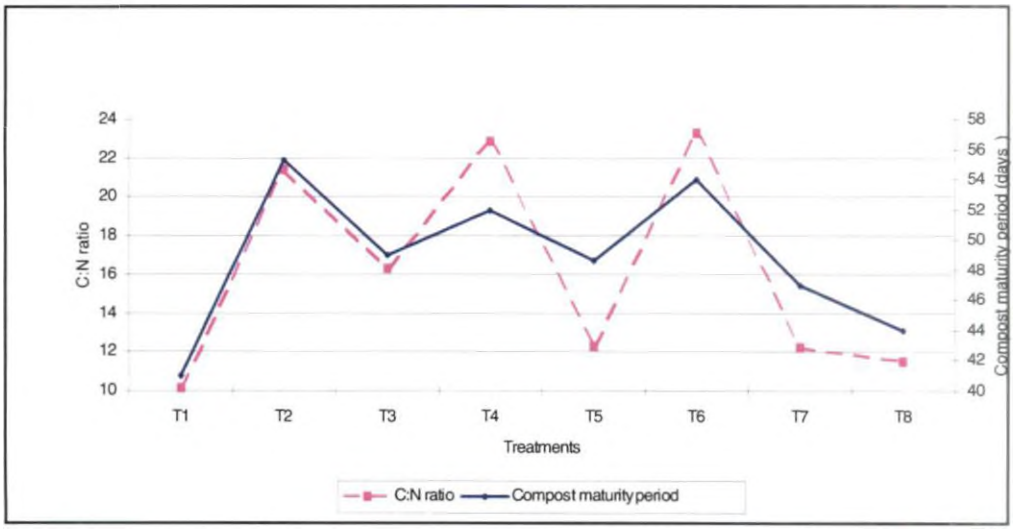


Fig.9. Effect of different treatments on C:N ratio and maturity period of vermi compost

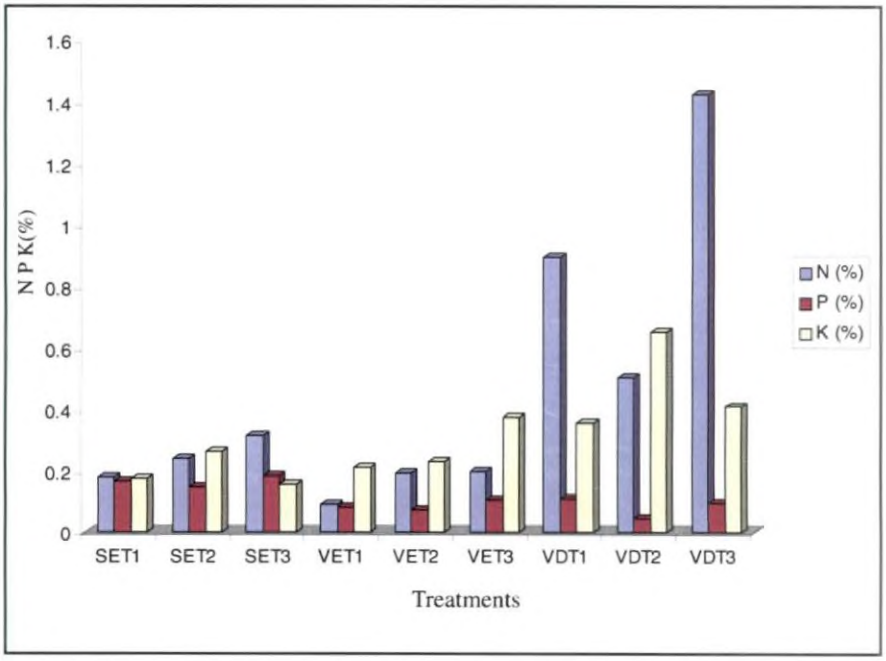


Fig.10. Influence of different treatments on the nutrient content of vermiwash

made by Zucconi (1981). The disease suppressive characters of composts are affected by maturity. High concentrations of soluble organic nutrients present in immature composts support growth of *Salmonella*, *Pythium* etc. Concentrations of the available nutrients declined as compost matured. At lower ratios N will be supplied in excess and will be lost as ammonia gas causing foul odour. Higher ratios means no sufficient nitrogen for optimal growth of microbes, compost cool, degradation proceed at slow rate. Activity of beneficial microflora that colonizes composts after peak heating is also affected by maturity. This is supported by Hoitink and Fahy (1990). A number of organic and inorganic substances that may accumulate in the liquid phase of composting during composting process have the potential for including a phytotoxic response particularly in seedlings. Toxic levels of organic acids often are produced in compost with a high C: N ratio. Chanyasak *et al.* (1983) also reported the high and toxic concentration of ammonia may occur in composts with a low C: N ratio.

With respect to maturity period the banana pseudostem and cowdung in the ratio 6:1 followed by the same in 8:1 showed a lowest maturity period of 41.00 and 44.21 days respectively. In contrast to this, the treatments with coconut leaf as the ingredient of substrate for composting, recorded the maximum composting period. This is due to the comparatively high C: N values as indicated by the treatments T_2, T_4 and T_6. While the selected treatment (T_7) had taken 47 days to attain maturity. Compost maturity mainly depended upon the substrate materials used. Stabilized temperature and pH indicated the maturity of compost along with C: N ratio. From this it may be concluded that certain period of maturation was necessary for organic matter to become stable compost material. This is in accordance with Nair (1997).

5.1.8. Selected vermicompost

The treatment T_7 (banana pseudostem : coconut leaf : green leaf : cowdung in the ratio 2:2:2:1) selected as best treatment for the further enrichment studies.

The physico-chemical properties of the same recorded the pH value of 7.68 with maximum amount of N, P and K with 1.19, 0.36 and 0.87 per cent respectively. The C: N ratio was found 12.25 which is an indicator of maturity. The higher N and P content may be due to the higher microbial count, favoured the environment for growth and multiplication of worms. According to Zacharia (1995), the vermicompost having NPK values of 1.08, 0.46 and 0.95. Hence the study was substantiated.

5.2 Enrichment techniques of vermiwash

5.2.1. Physico Chemical properties of enrichers

Physico-chemical properties of various enrichers involved in the composting process are given in the Table 4.10 under the section 4.2.1 are discussed as follows:

Though the materials neemcake and poultry manure are acidic and bonemeal, alkaline, the resultant mixture OEM recorded neutral pH values at all levels of application. Thus OEM was found to be the best enricher for raising the pH values of resultant vermiwash. The near neutrality of the OEM can be taken as a criterion for considering it as a safe material of compost enrichment. Appreciably good content of N, P and K further adds to the acceptability of the material as an excellent organic nutrient source. The different levels of the OEM also inherit uniform nutrient proportion, a very desirable character for a material to be recognized as a known nutrient source.

Poultry manure ferments quickly. If let exposed, it may lose upto 50 per cent of its nitrogen. Oil cakes are generally rich in manurial ingredients of N, P and K. Bone meals are rich in P. Though they are insoluble in water, they are quick acting organic manures with their nitrogen quickly available to plants. Organic wastes are poor in nitrogen and so they were enriched by incorporating bonemeal, non-edible cakes and poultry manure. Similar reports were already made by Jaggi (1991).

5.2.2. Temperature

The influence of different treatments on temperature variations are given in the Table 4.11. The data showed that there were significant variations among the treatment effects throughout the total composting period of 60 days.

The SET treatments (T_1, T_2 and T_3) recorded the maximum temperature when compared to VET (T_4, T_5, T_6) and VDT (T_7, T_8, T_9) treatments. The higher temperature is due to the enrichers. The heat producing capacity of an enricher in composting media is a function of its C: N ratio than any other characteristics. These enrichers liberate energy at a faster rate, for the multiplication of microbes and promote to assume the critical bacterial load for the accomplishment of the middle stage. The observed like in temperature of SET treatments at all stages attributed to the nutrient quality and heat producing ability of the enrichers. Similar findings are observed by Preetha (2003).

5.2.3. Earthworm count

Stage-wise quantification of composting earthworms (in numbers) as influenced by different treatments are provided in the Table 4.10. Here the poultry manure contained OEM did not favour the growth and multiplication of *Eudrilus euginae*.

Almost all treatments observed a higher earthworm count, except SET_2 and SET_3 (T_2 and T_3). VDT treatments, T_7, T_8 and T_9 showed remarkable increase in earthworm count due to the environment congenial for worm multiplication. SET 1 per cent (T_1) got a earthworm count of 1421. Here the enrichers support the growth of the earthworms. The higher worm count may also due to the temperature stabilization in the maturity phase. Environmental factors affect the multiplication rate of earthworms. At the maturity phase of composting, the temperature decreased and stabilized later. The temperature range of 28.36 – 30.57°C was recorded in the maturity phase. Eventhough the temperature decreased, the substrate itself acted as a source of Co_2 evolution. So the worms could not proliferate in the particular system. Viljoem and Reinecke (1992); Jiji (1997) reported similar findings.

5.2.4. Chemical properties of vermiwash

The pH variations of vermiwash as influenced by various treatments were provided under Table 4.11. The vermiwash was alkaline in nature. In the present study the pH ranged from 8.01 to 8.69. Vermiwash with pH 8.7 had been reported by Ranijasmine (1999).

Influence of different treatments on the nutrient content of vermiwash were presented in the Table 4.11. and graphically represented in the Fig.10. Significant differences were obtained in the content of nitrogen and potassium, while no significant variations were observed for phosphorus and zinc. The VDT treatments (T_7, T_8 and T_9) showed higher nitrogen content.

The significant increase was observed may be due to the high degree of decomposition reduced the volume and thereby increasing the nutrient content. Neem cake enriched the nitrogen content in the composting process. Poultry manure mixed with carbonaceous materials, reduces the ammonification from the composting. Nitrogenous excretions from the worms also can enrich the composts from organic wastes. Bhawalkar (1993) made similar observations. The chemical composition of vermicompost/vermiwash varies depending upon the sources from which it is prepared. Increased content of N in the vermicompost is due to the earthworm carcasses. Microbial flora also increases the nitrogen content. Haimi and Huhta (1990) made similar observations. The higher potassium content is due to the available and exchangeable K in the casts. The end product of composting technique is a microbiologically processed stable organic matter which is qualitatively superior to the initial substrate. The acceptability and utility of compost in agriculture is basically determined by its nutrient content and other desirable characters. This is in accordance with Nair (1997).

5.2.5 Studies on selected vermiwash

The treatment VDT @ 10 per cent (T_9) was selected as the best enriched vermiwash. The selected vermiwash had a pH of 8.01 with 1.425, 0.096 and 0.410 per cent of N, P and K respectively. The neemcake, bonemeal and poultry manure were good sources of organic manure. Hence the plain wash, low in nutrient was enriched by incorporating bonemeal, neem cakes and poultry manure (Table4.11). The selected treatment is also acceptable for furthur studies as the collection and preparation techniques are also easy.

5.3 Rapid crop response studies

5.3.1.1.Effect of different treatments on the height, number of leaves and yield

5.3.1.2.Height

With respect to the height, maximum value was observed in the soil application of vermiwash at 50 per cent field capacity (T4). One of the main functions of nitrogen in plants is to promote vegetative growth. Increase in plant height due to increase in nitrogen fertilization have been reported by Ramachandra and Thimmaraju (1983). Increased in plant height due to the rapid meristemetic activity triggered by plant nutrients especially nitrogen and the higher rate of metabolic activity coupled with rapid cell division brought about by phosphorus. Similar reports are made by Meera (1998).

5.3.1.3. Number of leaves

The improved biometric characters by way of improved biological N fixation, increased availability and uptake of nutrients through solubilization and increased absorption, stimulation of plant growth through hormonal action or decomposition of organic residues. This results in a better establishment of plants with higher number of leaves and photosynthetic area. Soil applications of vermiwash recorded the maximum values.

The vegetative growth in vermicompost treated plants is enhanced by the release of plant growth promoting compounds by earthworms into their casts (Neilson, 1965). This can increase the polymerisation of aromatic compounds thereby accelerating the humification and growth characters (Arunkumar, 2000). The significant influence of vermicompost in enhancing biometric characters may be due to the improved plant metabolisms resulting in a higher utilization of plant nutrients leading to an increased vegetative growth. Similar effects were found in the case of vermiwash which indicated favourable response in the present study (Table 4.13).

5.3.1.4. Yield

Mean yield (g pot^{-1}) of plants under different treatments are given in the Table 4.16. and Fig.11. Foliar application of one per cent urea recorded the highest yield (T_6), is followed by the soil application of vermiwash at 50 per cent field capacity (T_4).The former found superior to rest of the treatments. Urea is the fertilizer which contain 46 per cent nitrogen and readily available to plants. The response of urea in plant is very rapid and its the efficiency as a foliar fertilizerspray was already proved. Enam and Borijan (2000) and Borijan and Enam (2001) already reported the effect of foliar application of urea on yield and grain protein content in wheat. In the case of organic manures, they are very low in nutrients. Only the enrichment increased the nutrient efficiency. This positive influence of vermicompost/vermiwash may be due to the growth promoting

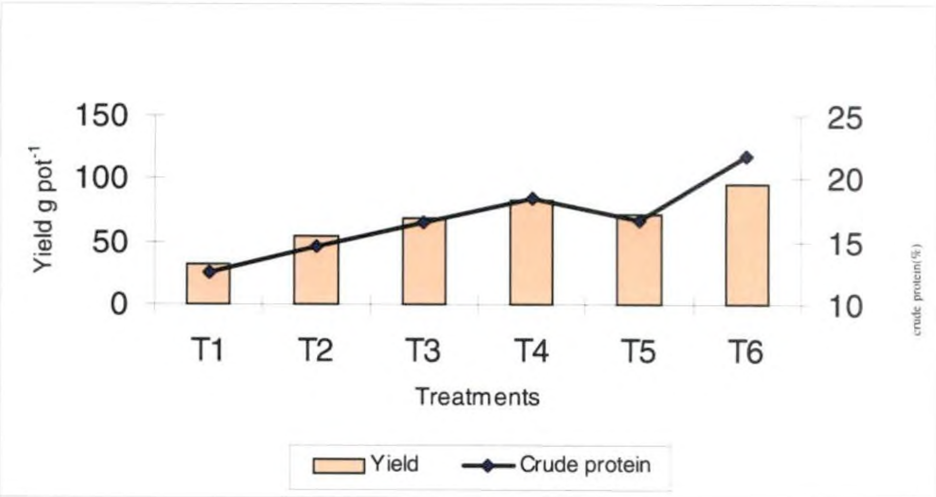


Fig.11. Yield and crude protein content of amaranthus

effects.. By the application of vermicompost yield was increased in chilli (Zacharia, 1995 and Rajalekshmy, 1996). Pushpa, (1996) and Ranijasmin, (1999) in tomato; Sagaya and Gunathilaguraj (1996) and Arunkumar (2000) in amarathus, Meera (1998) in cowpea, Ushakumari *et al.*(1999) in okra. The higher availability of N and P due to physical environment created by worms by promot the growth as well as yield of plants. Foliar application of vermiwash is not so effective as the organic fertilizer is not easily assimilated by the crop.

5.4 Studies on soil characteristics

The studies on soil characteristics are given in the Table 4.14 (a and b) .The details are discussed as follows.

The objective of manuring is to improve the nutritional status of the soil by increasing the pool of nutrients present so as to raise the yield from a lower to higher level. The pH of the soil was seen to be increasing considerably after the experiment. The highest pH of 6.76 was observed in the soil application of vermiwash at 50 per cent field capacity (T_4). The worm casts are very much close to neutral pH range than the surrounding soil and the possible factors may be NH_4^+ excretion and addition from calciferous glands (Mulongoy and Bedoret, 1989). Conversion of organic nitrogen of NH_3 and further to NH_4^+ temporarily reduces the pool of H^+ in the soil. Earthworm significantly raised the pH of the humus and the effect of earthworms on the soil pH was probably due to an increase in the concentrations NH_4^+ nitrogen (Haimi and Huhta, 1990). The enhanced soil pH is favourable for N fixation. Since at low pH, N fixation will be initiated by high H^+ concentration as well as high Fe or Al in laterites(Mohan *et al.*, 1987). Bhawalkar and Bhawalkar (1993) also reported that pH of the intestinal content of the earthworms is remarkably stable around neutral to slightly alkaline. The califerous glands in them fix $CaCo_3$ and prevent any fall in pH (Kale and Krishnamoorthy, (1980).

With respect to the organic carbon it was initially 0.79 per cent and there was significant increase in the organic carbon content of the soil after the experiment. Organic carbon was more in the treatments receiving vermiwash as soil application (T_4 and T_3). The results showed that as and when vermiwash used as an organic source, the organic carbon content significantly increased. This is in line with Khaleel *et al.* (1981). The vermiwash used in the present study was prepared from banana pseudostem, green leaf, coconut leaf and cowdung. The higher humifying capacity of worm is due to the accelerated humification process by the gut microflora, while the organic wastes pass through the earthworm gut. Similar observations are made by Pushpa (1996).

CEC is increased from 6.2 in the pre-experiment soil to 7.88 in the soil application of vermiwash. Available nitrogen also increased to 340.66 kg ha^{-1}. For nitrogen content in the soil, both foliar application of urea as well as soil application of vermiwash at 50 per cent field capacity produce significant differences over other treatments. The microbial activation and excretions by earthworms are important in nitrogen cycling. Microorganisms in the gut of earthworm species use mucus secreted from the gut epithelium as an energy source and act as source of nitrogen for plant growth.

Bijulal (1997) found out that the major effect of vermicompost application was reduction in P fixation and this increasing P availability in acidic soils. The increased phosphatase apparently produced in the gut of earthworms are considered to be important increasing the liability of organically bound P in soils. Similar observations were made by Satchell (1983). Higher levels of P uptake in rice treated with vermicompost was observed by Kale *et al.* (1992). The presence of phosphorus solubilizing organism in the vermicompost/vermiwash increases the phosphorus status of the soil. Increase in the available P content wasto the application of vermicompost. The alkaline nature of vermiwash might have ameliorated the acidity of the soil of the experimental field and thereby increased the content of available P in the soil at harvest of crop. Similarly significant differences were observed in the available potassium content of the soil before and after experimentation..

Vermiwash contains K in highly soluble form. So it is inferred that the earthworms increases the availability of potassium by shifting the equilibrium among the forms of K from relatively unavailable forms to more available forms. Similar findings are reported by Basker *et al.* (1992) and Ranijasmine (1999).

5.4.1. Uptake of major nutrients by plants

The uptake of major nutrients by plant is given in Table 4.15. Both soil and foliar application of vermiwash, do not produce significant differences on the uptake of nitrogen by plant. This is due to the N fixing organisms, which can supplement soil available nitrogen by their metabolic reactions. Nitrogen content in urea is also readily available form. It can cause an increase in the uptake of nitrogen. Vermiwash is also effective in enhancing nitrogen metabolism in plants. Similar reports are made by Tomati *et al.* (1990).

James *et al.* (1967) reported that a higher rate of metabolic activity with rapid cell division brought out by vermicompost application can be resulted in high uptake of nutrients and thus it might have resulted in increased utilization of nitrogen. When the nutrient solutions are directly sprayed into the leaves of the plants, the mineral ions slowly perpetrate through the stomata and cuticle of leaves, reach the interior of the leaf and thereby become available for absorption by the meosphyll cells. Nutrient uptake by leaf tissue is more effective as the nutrient solution forms of a thin film on the leaf surface. The rate of uptake is controlled by the diffusion of plant nutrients from the water film on the leaf surface through the cuticle and cell wall material to the plasmalemma The present study is also supported by Ranijasmine (1999). There is no significant differences on the uptake of P by plants.

The uptake of potassium produces significant differences between treatments. Foliar application of one per cent urea, followed by foliar application of vermiwash found to be superior over other treatments. Vermiwash contain K in highly available form. Zacharia (1995) reported the superiority of vermicompost application in the uptake of potassium by chilli. The same effect may be prevalent with the use of vermiwash also. Increased availability of K by earthworm activity. This was due to vermiwash as an organic source. The increase in K uptake due to increased K availability consequent to shifting of the equilibrium among the forms of K from relatively unavailable forms to more available forms in soil. Sharma *et al.* (1984); Bharadwaj (1995); Vasanthy and Kumaraswamy (1996) made similar observations.

5.4.2. Crude protein content

Effect of various treatments on the crude protein content of amaranthus are given in the Table 4.16 and Fig.11.

As a leafy vegetable more nitrogen is available to amaranthus and it is metabolised via NH_4^+ into glutamic acid. Carbohydrates provided by photosynthates are incorporated in this process of amino acid synthesis. Glutamic acid is further converted to other amino acids which are stored as proteins (Tisdale *et al.*, 1995). High levels of N nutrition would have favourably influenced the crude protein content of leaves on account of increased assimilation. Application of N promotes crude protein content as previously reported by Maurya (1987) in cucumber, Haris (1989) in snakegourd and Arunkumar (2000) in amaranthus. Application of organic sources improved the protein content in economic plant part which is understandable from the study.

5.4.4.1. Correlation studies

The correlation studies are given in the Table 4.17. The coefficient of correlation between yield and uptake of N and K were 0.96 and 0.97 for phosphorus, though it is positive not significant (R value being 0.6). There was progressive increase in yield with uptake of K. K had the influence on uptake and utilization of nitrogen (Subbaiah *et al.*, 1983, John, 1989).

A highly significant positive correlation existed between yield and plant height and number of leaves (R values 0.66 and 0.94 respectively). Zacharia (1995) also reported that the yield was significantly and positively correlated with height of plants and number of leaves in chilli. The available nutrients of soil showed a highly positive and significant correlation with yield. From the strength of the correlation it could be observed that all the soil nutrients were influencing the yield at maximum level (R values are 0.95, 0.81, 0.66). Beneficial effects of higher level of potassium in soil increasing the N and P uptake thereby increasing the yield of amaranthus.

The sequential processes and end result of the present investigation is summarised in Plate 7. It narrates the flow chart of strictly an organic enrichment process towards the accomplishment of quality food and healthy life, through vermi-technology. Value added vermicompost is initially produced from value less or rather noxious organic detritus involving thousands of nature's earnest bioreactors, the earthworms. They also act as bio enrichers During ingestion, they metabolise carbon, assimilate nitrogen, solubulize phosphorus, liberate micronutrients, secrets hormones and vitamins and ultimately they themselves dissolves as nourishments. An active column of this enriching media formed out of a complementarily blended substrate combination of banana pseudostem, dried coconut leaf, glyricidia green leaf and cowdung in the rate of 2:2:2:1 proves to be the best substrate controlled environment, for vermicompost and vermiwash production. Organic enriching medium comprising of poultry manure, bone meal and neemcake (1:1: 1)further allot to the nutritional value of the vermiwash, an organic nutrient solution for fertigation found effective at 50 per cent field capacity on the test crop amaranthus.

The flowchart can be explained as follows (Plate 7)

RECYCLING OF AGROWASTES THROUGH VERMICOMPOSTING

↓

ENRICHMENT OF COMPOST WITH SUITABLE ORGANIC MANURES

↓

COLLECTION OF VERMIWASH RICH IN NUTRIENTS, BENEFICIAL MICROBES, HORMONES AND ENZYMES

↓

FERTIGATION TO AMARANTHUS

↓

GOOD QUALITY LEAFY VEGETABLES FOR HEALTHY LIFE

Plate 7. Recycling of organic wastes for good quality leafy vegetables through vermi composting

6. SUMMARY AND CONCLUSION

Study on the 'Standardization techniques for production and enrichment of vermiwash' was conducted at College of Horticulture, Vellanikkara during the period 2003-2005. The experiment included the standardization of the substrate controlled environment for worm production and proliferation, identification of to identify the best enrichment techniques for vermiwash and the evaluation on the effectiveness of enriched vermiwash on crop and soil.

To standardize the substrate controlled environment for worm production, different types of agrowastes were used as substrate materials in the composting process. The wastes included cowdung, banana pseudostem, coconut leaves and glyricidia. Maximum C:N ratio was observed in fresh cowdung with 56.3 and the lowest in coconut leaves with 21.1, while banana pseudostem and glyricidia recorded C:N ratios of 43.17 and 27.11 respectively. The substrates were used in different proportions and then inoculated with fungal inoculum *Schizophyllus communae* to increase the degradation. After 20 days of pre-composting using the vermiwash production units, earthworms (*Eudrilus eugeniae*) were introduced in each unit. The observations on temperature, pH, microbial population and earthworm counts were recorded at specific intervals. The nutrient content was analysed and the best substrate in terms of earlier maturity and richer nutrient contents was identified for the enrichment techniques.

Three types of enrichment techniques were tested with an Organic Enriching Media (OEM). The OEM consisted of neemcake, bonemeal and poultry manure in the ratio of 1:1:1 and it was applied @ 1, 5 and 10 per cent of the total quantity of substrate. The techniques were SET (Substrate Enrichment Technique), where the OEM at different levels was applied along with the substrate, VET (Vermiwash Enrichment Indirect Technique) where the different levels of OEM was applied one day prior to the separation of vermiwash and VDT (Vermiwash Enrichment Direct Technique) where the different levels of OEM was added to the plain vermiwash. The observations on temperature, pH, earthworm count and nutrient composition were assessed. The selected enriched vermiwash was taken for the crop response studies using amaranthus as test crop. Observations on biometric characters, soil nutrient contents, nutrient uptake by the crop and yield were taken. The salient features are summarised below:

Standardization of substrate controlled environment for worm multiplication

- During the composting process the maximum temperature of 31.61oC and minimum of 28.07 oC was observed at 10 and 60 days after composting respectively. These levels of temperature almost coincided with the atmospheric temperature and so three distinct stages as in aerobic composting were not observed.
- With respect to the pH, the substrate materials recorded on acidic range (6.53-6.84) at initial stage, which gradually increased to alkaline range (7.63-8.11) in the middle stage and subsidised to a neutral range (7.30-7.68) at the final stage.
- Regarding the microbial count (CFU), the count of bacteria, fungi, actinomycetes and the beneficial microbes such as nitrogen fixers and phosphate solubilizers were taken at the initial, middle and final stages. Irrespective of substrate combinations, maximum count of phosphate solubilizers were observed at the initial stage. The highest count of bacteria nitrogen fixers and actinomycetes were in middle stage, while fungal population was almost equal in three stages.
- The microbial population was always higher in those treatments where the banana pseudostem forms the major substrate component. A general decreasing tendency in microbial population was noticed in those treatments where coconut leaf formed the major substrate component.
- The C:N ratio of the substrate materials were 56.33, 43.17, 21.32 and 27.11 in cowdung, banana pseudostem, coconut leaves and glyricidia respectively. After vermicomposting the substrate combination of banana

pseudostem: glyricidia : coconut leaf : cowdung in the ratio of 2:2:2:1 registered a C:N ratio of 12.25 which was found to be ideal for worm multiplication and proliferation. It matured within an interval of 47 days, , P and K values of 1.19, 0.25 and 1.30 per cent respectively.

- At the 15th, 30th and 45th day after inoculation of earthworms for composting, all the treatments recorded significant differences in their population. The combination of banana pseudostem, green leaf and cowdung in the ratio 3:3:1 (T_5) recorded the minimum at 15th day (890.67) and the combination of banana speudostem and cowdung in the ratio 8:1 (T_8) recorded the maximum (1408) at the 45th day.
- Neemcake, poultry manure and bonemeal were used as enrichers. An organic enriching media (OEM) comprising of these enrichers in 1:1:1 ratio was prepared into a fine powder form. OEM at 1, 5 and 10 per cent of the substrate was tried.

Enrichment techniques of vermiwash

- Among the three enrichment techniques, VDT was found to be the best with the production of vermiwash of pH 8.01 and N, P and K 1.425, 0.096 and 0.410 per cent respectively.
- The temperature of the VDT treatment with OEM @ 10 per cent (VDT_3) was 31.74 °C, 29.23 °C and 28.95 °C respectively in initial, middle and final phases of composting.
- Earthworm counts were maximum in VDT treatments. Among these, the highest mean value of 1864 was recorded by VDT_3, while the mean values of 1369 and 1384 were registered respectively in VDT_1 (OEM @ 1%) and VDT_2 (OEM @ 5%).
- The selected vermiwash VDT_3 (OEM 10%) recorded, pH of 8.01, N, P, K and Zn with the values of 1.425, 0.096, 0.410 per cent and 169.0 ppm respectively.

Rapid crop response studies:

- Maximum yield of 95.70 g pot^{-1} was obtained in the treatment T_6, where foliar application of urea one per cent was given. The same was closely followed by the treatment where the soil application of vermiwash was done at 50 per cent field capacity of the soil.
- pH, CEC and organic carbon content of the post harvest soil showed an increase from initial values. The treatment T_4 receiving the soil application of the vermiwash at 50 per cent recorded the maximum value for pH (6.76), CEC [(7.88 (cmol(+)kg^{-1})] and organic carbon (1.4%).
- Available N, P and K in the post harvest soil showed an increase from the initial status. The maximum values of N (340.66 kg ha^{-1}) was recorded by T_4, while P and K values were maximum in the treatment receiving foliar application of urea (T_6) and their respective values were 21.73 kg ha^{-1} and 96.73 kg ha^{-1}.
- Regarding the uptake of nutrients, maximum N uptake was observed in the treatment T_4 with 0.918 g pl^{-1}, while maximum uptake of P and K were noted in the treatment, T_6 with 0.115 and 1.796 g pl^{-1} respectively. With respect to the crude protein content, maximum content was observed in the treatment T_6 with 21.85 per cent.

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***Originals not seen**

Appendix I

Atmospheric temperature values at 10 days interval for a period of 60 days of composting

Days after composting	Temperature (°C)
0	29.00
10	30.86
20	30.36
30	30.31
40	29.98
50	30.56
60	29.51

Appendix II

The composition of different media

I. Media for fungus (Martin Rose Bengal 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.

II Ken Knight Medium

K_2HPO_4	-	1.0 g
$NaNO_3$	-	0.1 g
KCl	-	0.1 g
$MgSO_4\ 7H_2O$	-	0.1 g
Glucose/Cellulose	-	20.0 g
Agar	-	20.0 g
Water	-	1000 ml.
pH is adjusted to	-	7.0 - 7.2

III Jensen's media for nitrogen fixers

$CaHpO_4$	-	1.0 g
$K_2H\ PO_4$	-	1.0 g
$MgSO_4\ uH_2O$	-	0.2 g
NaCl	-	0.2 g
$FeCl_3$	-	0.1 g
Water	-	1000 ml
pH is adjusted to	-	6.5 - 7.0

IV Nutrient Agar media

Agar	-	20.0 g
Peptone	-	5.0 g
Beef extract	-	3.0 g
NaCl	-	5.0 g
Distilled water	-	1000 ml
pH is adjusted to -		

V Pikovaskya's medium

Glucose	-	10.0 g
$Ca_3\ (PO_4)_2$	-	5.0 g
$(NH_4)_2\ SO_4$	-	0.5 g
KCl	-	0/02 g
$MgSO_4\ 7H_2O$	-	0.1 g
$MnSO_4$	-	Traces
$FeSO_4$	-	0.5 g
Yeast extract	-	0.5 g
Agar	-	15.0 g
Distilled water	-	1000 ml.

Appendix III

Nutrient management of amaranthus

Treatment No.	*Mode of application and details*
1	Absolute control – crop without manuring
2	As per Package of Practice Recommendation of 50 N : 50 P : 50 K kg ha^{-1} Urea - 1.08 g/pot (N) Rajphos - 0.70 g/pot (P) MOP - 2.16 g/pot (K)
3	Soil application of vermiwash at field capacity Total quantity applied per pot - 5.250 lit.
4	Soil application of vermiwash at 50% field capacity Total quantity applied per pot - 2.625 lit.
5	Foliar spray of vermiwash Total quantity applied per pot - 3.500 lit. No. of sprays given at 4 days interval - 18 sprays
6	Foliar spray of 1% urea Total quantity applied per pot - 8.19 g. No. of sprays given at 7 days interval - 10 sprays

STANDARDIZATION OF TECHNIQUES FOR PRODUCTION AND ENRICHMENT OF VERMIWASH

By

THANKAMONY. K.

ABSTRACT OF THE THESIS

submitted in partial fulfilment of the requirement for the degree of

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ABSTRACT

The study on the 'Standardization of Techniques for Production and Enrichment of Vermiwash' was conducted at College of Horticulture, Vellanikkara, during the year 2003-2005 with the objective to standardize the substrate controlled environment for worm multiplication, to identify the enrichment techniques of vermiwash and to evaluate the efficiency of enriched vermiwash on crop and soil.

The standardization of substrate controlled environment was based on the principle of aerobic composting. For this, plastic drums of 50 litre capacity with appropriate fabrications and arrangements were taken. Agro wastes such as banana pseudostem, coconut leaf, green leaf and cow dung in different combinations were kept for pre-composting with the addition of fungal inoculums. The earthworms were inoculated @ 1000 numbers per unit. In contrast to the aerobic composting, then are no distinct stages in vermicomposting based on temperature. Microbial count for bacteria, fungi, actinomycetes, nitrogen fixers and phosphate solubilizers were observed at initial, middle and final stages respectively. The population of phosphate solubilizers were maximum in the initial stage (pH range of 6.53 to 6.84) and nitrogen fixers, in the middle stage (pH range of 7.63 to 8.11).

The earthworm population was found to be controlled by a substrate controlled criterion. Even the substrate combination containing good portion of coconut leaves becomes conducive for worm multiplication by the proper blending with succulent substrates like banana pseudostem. As the substrate combination, banana pseudostem : glyricidia leaves : coconut leaves : cowdung in the ratio 2:2:2:1 registered the least C:N ratio of 12.25 which attained maturity within 47 days, it was identified as the best substrate controlled environment for vermicompost production. The selected treatment which comprised of Banapseudostem : Greenleaf : Coconut leaf : Cowdung in the ratio 2:2:2:1

registered a pH of 7.68 and nutrient contents of 1.19, 0.36 and 0.87 per cent respectively. It had a relatively good load of microflora as the banana pseudostem favours the flourishment of the microbial and worm population.

The selected substrate combination was taken for the further enrichment techniques. An Organic Enriching Media (OEM) was prepared using neemcake, poultry manure and bonemeal. Vermiwash was collected after the compost maturity. The plain vermiwash was enriched by mixing OEM @ 10 per cent of substrate. The resultant and best enriched vermiwash registered nutrient contents of N (1.425%), P (0.096%), K (0.410%) and Zn (169.0 ppm) with a pH value of 8.01.

With respect to the crop response studies, foliar application of one per cent urea recorded the highest yield of 95.70 g pot^{-1}. The soil application of vermiwash at 50 per cent field capacity also proved better than foliar application of vermiwash. The crude protein content was also higher in foliar application of urea as well as in soil application of vermiwash at 50 per cent field capacity. For fertigation, the vermiwash was found to be very 'effective on the test crop of amaranthus.