1. GENERAL INTRODUCTION

Earthworm is often referred to as farmer’s friend Earth’s intestine and Nature’s plough (Darwin 1881). Certain species of earthworms such as Eudrilus eugeniae, Eisenia foetida play a significant role in decomposing organic matter and mineral cycling (Edwards and Lofty 1977). Vermicomposting is the biodegradation of organic waste through earthworm activity to produce organic manure called vermicompost. A plethora of literature is available on the response of earthworms to different types of vegetable substrates in the field but information is scanty on the effect of diet on earthworms during the vermicomposting process (Dominguez et al., 2000).

Increased use of fertilizers reduces the quality of food produced as well as soil fertility. But combination of inorganic and organics will reduce the environmental hazard due to higher fertilizer use efficiency as well as improvement of the quality of crops. Current status of lack of availability of organic substances make us switch over to other cheap organic resources. The organic matter stimulates plant growth, improves plant resistance under unfavorable condition. Previous reports are available on the effects of combined application of organics with inorganic fertilizers. Sanflippo et al (1990) by their experiments indicated the presence of growth promoting substances in humic acid possibly corresponding to insole acetic acid or its precursors. A significant amount of both free and conjugated gibberellic like substances was also observed in humic acid. Fly ash additions to the soil also increased the extractable concentration of all plant nutrients.
In India, large amount of cattle dung and aquatic biomass remain unutilized. Organic wastes can be converted to various end products (Hobson et al., 1974) or recycled for food, feed, fuel and fertilizer (National Academy of Sciences, USA, 1981). The effects of organic fertilizers on earthworm populations and the ability of earthworms to promote the rapid decomposition of organic materials have been described for decades. Recently, earthworm biotechnology has been found useful for the management of anaerobically stabilized effluent from the dried grape industry (Athanasopoulos, 1993).

A combination of recycling and resource recovery through biogas and vermiculture could yield fuel (methane), fertilizer (biogas plant-effluent), and feed (worm casts as fertilizer for plants (Krishnamoorthy & Vajranabhalah, 1986) Macro invertebrates play a definite and prominent role in regulating soil processes but among them termites and earthworms play a vital role in maintaining soil fertility and in bringing about efficient nutrient cycling. An earthworm is more familiarly known to the student of biology as an organism provided for dissection, to the angler as bait for fishing and to the common man as ‘Yet another creature’. Darwin (1837), though popularly known for his theories on evolution, was one of the pioneers who highlighted the role of earthworms in soil health.

A gardener is a person who has a good sense of humus. Humus is the product of biological action on organic matter. Earthworms form a major component of the soil system and these seemingly unimportant creatures-true optimists, par excellence- have been silently ploughing the land for millions of years and assisting in the recycling of organic nutrients for the efficient growth of plants. Earthworms therefore represent a key component in the biological
strategies of nutrient cycling in soils and the structure of their communities gives a clear indication of the type of soil system they inhabit (Lavelle, 1988). These little creatures are known to have originated during the Precambrian era, and recent reports (Piearce, et al., 1990) have described a fossil of an embryonic earthworm, with part of its cocoon wall in tact, found beneath a late Bronze Age midden at Potterne, Willshire, UK.

Unfortunately, the advent of chemicals and their large-scale application in the name of fertilizers and biocides has drastically changed the structure of soils and has in most cases eliminated soil organisms. The discontinuous distribution of earthworms in certain soils under pasture or cultivation is a result of earthworms exhibiting endemism (Lavelle et al., 1989). Human interference in natural ecosystems through modern practices of agriculture, silviculture and horticulture, involving large-scale application of fertilizers and biocides, has been responsible for the destruction of endemic soil fauna.

It must be realized that only soils along with its faunal components constitutes living soil. Earthworms can be called biological indicators of soil fertility, for soils with earthworms readily support healthy populations of bacteria, fungi, actinomycetes, protozoans, insects, spiders, millipedes and a host of other organisms that are essential for sustaining a healthy soil. Earthworms not only inhabit the soil, but by virtue of their activity, contribute to the physical and chemical alterations in the soil, leading to soil fertility and plant growth. Soils inhabited by earthworms have casts, which are in turn, richly inhabited by microorganisms.
Beddard (1912) described earthworms as segmented bristle-bearing worms contributing at large to the biomass of soil invertebrates, particularly in the temperate and the tropical regions of the world. Their role in the turning over of the soil drew the attention of Aristotle (Shipley, 1970) who called earthworms the ‘Intestines of the earth’. Darwin (1881) discovered the role of earthworms in the breakdown of dead plant material in soil and forest litter, and in the maintenance of soil structure, aeration and fertility. His finding that earthworms play a beneficial role in soil formation and fertility was acknowledged by Hensen (1877), Muller (1884) and Urguhart (1887).

The debate goes on and through the centuries, much before the green revolution, these quiet machines have been carrying out the marvelous function of pouching the soil and fertilizing it. They have helped the angler to have his day and have helped people in the remote habitats of China, India and Iran prepared decoctions for some ailment or the other. As awareness grows about the importance of earthworms to soil fertility and plant growth, every individual the farmer the agriculturist, the horticulturist, the gardener, the common man, the house wife and the child who goes to school must be educated on the valuable contribution that earthworms impart to throbbing life on earth.

Most earthworms are terrestrial organisms, which live in the soil. But some species, like pontodrilus bermudensis lead a comfortable life in estuarine waters. Though taxonomic classification is desirable to identify a given species of earthworm, a classification based on ecological strategies is more suitable for harnessing earthworms for the benefit of mankind. Even such classifications may prove unsuitable, as particularly in tropical climates, these worms may be found under moist, rotting logs at the bases of paddy plants, on damp roofs,
terraces and trees, and even beneath the traditional domestic grinding stone as sufficient organic matter gets deposited in such areas due to constant use.

Earthworms are generally classified as saprophages, but based on their feeding habits they are classified into detrivores and geophages (Lee, 1985). Anecies feed on the leaf litter mixed with the soil of the upper layers and are said to be geophytophagous. They may also produce surface casts generally depending on the bulk density of the soil. Endogeic earthworms are geophagous. They live deep within the soil deriving nutrition from the organically rich soil they ingest. The contrasting behavior, morphology and physiology of soil dwelling non pigmented forms and surface-living red–pigmented forms, represent evolutionary roles arising from r and k selection with subsidiary adaptive radiation (Satchell, 1980).

Solid waste is defined as the organic and inorganic waste materials produced by different sources which have lost their value in the eyes of their owner. It is estimated that the per capita waste generated in India is about 0.4 kg/day with the compostable matter approximately 50-65%. Most cities in developing countries have to contend with inefficient systems of collection and processing of solid waste. Most common practice of waste processing is uncontrolled dumping which causes mainly water and soil pollution. Besides dumping or sanitary landfilling, the final disposal of solid wastes can be carried out by other methods like incineration and composting. Earthworm farming (vermicululture) is another bio-technique for converting the solid organic waste into compost. Vermicompost is a high-grade nutrient rich compost of significant value as a biofertilizer, soil conditioner and tonic for plantation.
In India, approximately 134kg/ha nutrients are removed every year from the soil due to raising of different crops. But the amount of input (N, P and K) through chemical fertilizers is only 74/kg/ha. The net result is that soil is regularly being depleted of these essential nutrient elements on a continuous basis. Aquaculture techniques also involve both management of soil and water for husbandry of fish, which is basically the same as in aquaculture. Fishpond performance mainly depends upon the water retentivity of the soil and its inherent fertility. For proper management of pond soil and water, nutrient elements need to be added from an external source of all the organic manures. Raw cattle dung has had the widest application over decades in India, South East Asia and other countries (Alikunhi 1957; Jhingran and Sharma, 1980; Degani et al; 1982).

There is controversy in the literature concerning the relative merits of inorganic and organic fertilization. During 1960, there was a trend in Taiwan to use inorganic fertilizers because they are easy to manage and hygienic (Lin, 1968), but organic fertilizers are still popular due to high cost of inorganic fertilizers following the increase in the price of oil and also in favour of integrated livestock fish farming. In Israel both types of fertilizers are used for fish culture but it has been reported that yields with inorganic fertilizers rarely exceed 10kg/ha/day compared to 30kg/ha/day in the organic fertilization. (Schroeder, 1977, 1978)

In the present study, Vermicompost was used as a biofertilizer (organic manure) in the field level model ponds and the growth of the fish was assessed with selected population densities. The performance level of the eutrophicated
system was compared separately by adding organic or inorganic fertilizer in identical environmental condition.

1.1. VERMITECHNOLOGY

Vermiculture

Vermicomposting and vermicasting are fast becoming familiar terms in farming as well as organic waste recycling for both industrial and domestic use. It has therefore become necessary to provide up-to-date scientific information on the basic and applied aspects of earthworms with specific reference to Indian conditions.

Vermibed

This comprises a layer of 15-20cm thick loamy soils above a thin, 5cm layer of broken bricks and coarse sand. Earthworms are introduced in the soil layer with little cattle dung and hay on as feed. The earthworms grow and multiply in this bed.

Vermiwash

A liquid fertilizer collected after the passage of water through a column of worm activation. It is very useful as a foliar spray.
**Farmyard Manure (FYM)**

Farmyard manure. It is made up of three types of substances—dung; urine of animals and straw or other plant refuse (Agro waste).

### 1.2 EARTHWORMS IN FOOD CHAINS

The abundant food resource in the form of earthworms is utilized by diverse predators and for organisms it is the principal food (Macdonald, 1983). Earthworms are preferred as feed by amphibian (Lescure, 1966), reptiles (Catling and Freedman, 1980), birds (Harlin, 1977) among the vertebrates, apart from fishes which fall prey to the worm on the look. Among invertebrates, centipedes may comfortably feed on cocoon’s hapless earthworm juveniles. With the worm now fighting for a place on the dining table, in the form of earthworm soups, vermiburgers and patties and with the immense potential of earthworm in medicine, it is essential to check the bioaccumulation of heavy metals in earthworms.

**Vermicompost**

The compost prepared by using earthworms is called vermicompost. Vermicompost is a very important aspect of organic farming package today. It is easy to prepare, has excellent properties and is absolutely harmless to plants. While vermiculture is the culture of earthworms, Vermicastings are faecal matter released by earthworms. The bulk density of the soil in anecic and
endogeic earthworms is one of the important determining factors in cast production. (Habibullah and Ismail, 1985; Krishna moorthy, 1989).

1.3 SUITABLE WORMS FOR VERMICULTURE

Of the three ecological varieties of earthworms, the epigeics in particular and the anecics in general, have largely been harnessed for use in the vermicomposting process. Epigeics like *Eisenia foetida* (Hartenstein et al., 1979 a, b) and *Eudrilus eugeniae* (kale and Bano 1988) have been used in converting eugeniae organic wastes (agro wastes and domestic refuse) into vermicompost. Though these surface dwellers are capable of working hard on the litter layer and can convert all the organic waste into manure they are of no significant value in modifying the structure of the soil. The aneciec, however, are capable of both organic waste consumption as well as in modifying the structure of the soil. Such burrowing species that are widely used in soil management like the earthworm, *Lampito mauritii* (Ismail, 1993) also effectively create a drilosphere apart from helping in compost production.

Of special significance are the uses of local varieties of earthworms in vermitech (Ismail, 1993). The recommends in site soil community especially earthworms comprising the epigeic and anecic varieties for the combined process of litter and soil management. It is apparent that a complex chain of interactions takes place between the activities of different kinds of soil organisms. Of the several species of earthworms commonly available in Tamil Nadu Ismail, 1986; Ismail et al., 1990), Ismail (1993; 1994 a, b,c, 1995 a)
recommends that though Perninex excavatus and Lampito mauritii together take care of the litter and other organic wastes, L.mauritii being an anecic earthworm also takes care of soil management by burrowing through it.

The advantages of using local varieties of earthworms are many „The hazards of using alien species are well known.” History is littered with examples of confrontations between indigenous and foreign organisms (Mac kenzie, 1991). Kale et al., 1982) have reported P.excavatus to be the Indian equivalent of E.foetida. It has however been observed that E.eugeniae and P. excavatus do not coexist comfortably in mixed cultures, indicating competition among the species of earthworms (Stockli, 1982) and it has time and again been justified by few scientists (Lavelle, et al., 1989; Murphy, 1993) though it is extremely unnecessary and undesirable to tamper with the local biodiversity (Ismail, 1995 b). Of the several species of epigeic earthworms used in vermicomposting, three species have been recommended and applied in laboratory and field situations. They are Perinoxy excavatus, Eudrilus eugeniae and Eisenia foetida. Reinecke et al., (1992) have worked out the suitability of these species of earthworms in vermicomposting in terms of their temperature requirements. In the present study Eudrilus eugeinae, Eisenia foetida and Lampito mauritii were used for composting different types of animal wastes.

1.4 IMPACT OF CHEMICALS ON EARTHWORMS

A large number of pesticides used in agriculture are known to adversely affect earthworm populations resulting in an imbalance of the normal functioning of the various components of the ecosystem. The effect of sevin (an
enzyme) on the survivability and numbers of earthworms (Kale and Krishnamoorthy, 1982) has been reported.

Several authors (Bharathi and Subha Rao, 1984 b, 1986; Gupta and Sundararaman, 1987, 1988 a, 1991; Hans et al., 1993, 1994; and Senapati et al., 1987.) have worked on aspects pertaining to the role of pesticides on the life of earthworms. There is pronounced effect of pesticides on non-target organism like earthworms.

Presently many cities are facing the problem of disposal of solid waste generated within the cities. Solid waste arising out of domestic, commercial, industrial and agricultural products comprises biodegradable (organic) and non-biodegradable material. Due to the phenomenal growth in the quantum and diversity of the waste materials generated by the human activity potentially harmful effects on the environment and public health resulted. Due to increased pace of urbanization and industrialization, the environment pollution problems are becoming more complex and diverse requiring innovative technologies and management plans for remediation with adoption of advanced process technologies. Under industrialization programme release of toxic and hazardous wastes have also increased due to which thrust on end on pipe treatment has now shifted to waste minimization, waste utilization, recovery of resources from wastes cleaner process technologies and assessment of health aspects of pollution problems. Basically there are 3 types of disposal techniques practiced in organic solid wastes. Incineration as a disposal for city solid wastes is more expensive and requires more control over the operation because of air pollution.
India generates about 210 million tones of municipal solid wastes (MSW) each day. The quantum of wastes produced increases at a rate of 1.5 percent per year (Abbasi and Ramasamy 2001). Rapid urbanization and uncontrolled growth of population are the main cause for the production of MSW. Open dumping of MSW affects the land, air and water and also causes severe health problems to human beings. About 73 percent of the MSW are compostable (Paul et al 2003) and hence such wastes can efficiently be utilized for vermicomposting. In recent years, the earthworms have been used to convert solid waste such as MSW (Goswami et al 2001), press mud and sugarcane trash (Ramalingam 2001), weeds (karmegam & Daniel 2000), leaf litters (karmegam & Daniel 1999) and vegetable waste (Padma et al 2002) into useful compost. Hence, an attempt was made in the present study to utilize the service of *E. eugeniae* for the production of vermicompost from MSW and also to find out the effect of overcrowding on worm growth and the microbial changes that takes place in the substrate.

Earthworms are known to constitute more than 80% of the soil invertebrate biomass in subtropical and tropical, as well as in temperate zones (Kale, 1997; Nainawat and Nagendra, 2001). Earthworms have the ability to improve soil physical structure, contribute to the breakdown of organic matter and release plant nutrients (Edwards and Boheln, 1996). Extensive literature is available on earthworm ecology in temperate regions (Edwards and Bohlen, 1996). However, relatively less work is done in the tropical regions (kale, 1997; Tripathi and Bhardwaj, 2004). Only scanty reports are available on earthworm population from north-east India. (Chaudhri and Bhattacharjee, 1999; Chaudhuri etal., 2008). Ramanujam etal.,(2004) have reported 12 species of earthworms from Mizoram including one new species Eutyphoeus
mizoramensis Julka et al., 2005). The variations in response pattern could be attributed to the effects of human activities. The earthworms can be utilized as an effective tool in assessing the degree of anthropogenic influences such as afforestation and silvicultural practices (Chaudhuri and Sabyasachi Nath, 2011).

1.5 ECOLOGICAL CLASSIFICATION

Ecological classification of earthworms based on interspecific variations has been attempted by several workers.

Classification based on habitat

Evans and guild (1948) have distinguished earthworms into surface dwelling and deep dwelling species. Bouche (1977) proposed an ecological classification of earthworms into three generalized life forms.

i. Epigecis

Epigeics are the species that live above the mineral soil surface. They are phytophagous. Eg. Eisenia foetida (Savigny).
ii. Anecics

Anecies are the species that live in burrows in mineral soil layers. They are geophytophagous. Eg. Lampito mauritii (Kinberg).

iii. Endogeics

Endogeics are the species that inhabit at mineral soil horizons feeding on soil more or less enriched with organic matter. They are geophagous. Eg. (Phretima prosthuma).

1.6 BASIC CHARACTERISTICS OF SUITABLE SPECIES

Farmers or gardeners need only those species which can quickly convert organic waste to vermicompost. Therefore a worm should have following characteristics.

1. Worm species should be tolerant to disease.
2. The culturing techniques should be simple enough to adopt.
3. Worm should be efficient convertor of plant or animal bio-mass to body proteins, so that its growth rates are high.
4. It should have high consumption, digestion and assimilation rate (composting qualities).
5. The worm should have wide adaptability (tolerance) to environmental
factors (capability to live in varying temperature conditions).
6. The worms should have feeding preference and adaptability for wide range of organic materials (high and rich organic matter).
7. The worm should produce large numbers of cocoons that should not have long hatching time, so that multiplication and organic matter conversion is fast.
8. Growth rate, maturity from young one to adult stage should be fast.
9. Worms on introduction in substrate should have least inactivity period. (= Vermistabilization period).
10. The worms should feed near the surface of organic matter.

**Role of earthworms**

Earthworms one of the macro fauna of soil has been considered as the farmer’s friend. Earthworms can generally be called as biological indicators of soil fertility. They act as good comminutors (pulverisers) of organic materials so as to promote microbial activity during composting. Their castings are usually rich in nutrients. Vermiculture is a rich source of organic fertilizers whatever the earthworms eats are transformed into organic fertilizers.

**1.7 EARTHWORMS AND THEIR APPLICATIONS IN ORGANIC AGRICULTURE**

The aim of the green revolution, as justified by its promoters, was to enhance crop production. It is now realized that agriculture does not only refer to crop production but also to various other factors that are responsible for crop
production. These had been previously completely overlooked. Factors, such as soil destruction, topsoil erosion and the adverse effect of the prolonged use of chemical fertilizers on soil health have been neglected. The United States has already lost one-third of its topsoil in the last 200 years. Soil erosion in other countries is equally alarming and devastating. The effects of pesticides on soil and human health have also been ignored. Nearly 25 million farmers in the tropical countries of the world are poisoned every year by chemical agriculture, in the name of conventional agriculture, has affected the basic concepts of agriculture by transforming it into an ugly culture which today has euphemistically been given the name agribusiness. This has altered the physiological processes of crops, diminished food quality, destroyed soil biota and promoted resistant varieties of insect pests.

In contrast to conventional agriculture, traditional agriculture establishes a religious relationship of the farmer with the earth. In the past, animals were part of the agricultural system and farmers were aware of the benefits of using their solid and liquid wastes and used this to their advantage. Moreover, crops like millets, bajra ragi previously used by traditional farmers have been neglected in favour of crops like sunflower and soyabean. The reduced production of coarse cereals has affected fodder production, which was used to support farm animals, and also served as much to conserve soil moisture and promote rich density and diversity of soil organism including earthworms.

Alternate agriculture practices have time and again proved that they are not only resource conserving but also productive. Such viable alternatives include organic farming eco farming, biodynamic farming as well as traditional
farming practices. These practices work in harmony with nature making use of various indigenously available resources, the chief of them being soil faunal components which establish a synchrony in nutrient cycles.

Vermicompost and or in situ vermiculture associated with other biological inputs have been applied to grow vegetables and other crops successfully. These approaches have proved to be economical as well as productive.

Due to an increasing demand for animal protein and organic manure the large amount of organic waste must be utilized for raising worms without causing pollution. Further, the feasibility of using vermiculture as a biotechnology for waste disposal among others necessitates the use of correct species for specific type of wastes. As the concern is largely with number and biomass, a thorough knowledge about the growth and reproduction potential of the relevant species is yet another pre requisite for vermiculture and vermicomposting.

To accomplish the above objectives the present study was undertaken to observe the growth of *E. foetida*, *E. eugeniae* and *L. mauritii* during composting for a period of 60 days and physico chemical characterization & microbial studies followed by field application studies were made in the present study.