Leaf Litter Vermi Composting: Converting Waste to Resource

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Abstract: Waste is not waste unless someone wastes it. Solid waste collection and its management is one of the burning issues of environment today in most nations worldwide. Although many methods have been proposed and implemented for proper solid waste disposal but some of these treatment and disposal strategies can cause severe environmental issues. The present manuscript intends to give an overview of studies on use of garden leaf litter waste around us as a substrate for vermicompost formation. Vermicomposting is aerobic process in which detritivorous earthworms play an important role in decomposition of organic waste converting it to nutrient rich medium for plant growth known as vermicompost. They do so by interacting with wide range of microorganisms and variety of other fauna acting as decomposers and this interaction results in stabilization of organic matter leading to alteration of its physical and biochemical properties. In recent years, vermicomposting technique has advanced considerably because it is eco-friendly, economically feasible and socially acceptable approach for waste management. In simple words, it is a way of converting waste to wealth. Furthermore, the end product of vermicomposting (Vermicast) - the nutrient rich compost is an efficient soil conditioner.

1. INTRODUCTION

Population status and dynamics suggests India to be amongst the developing economies countries of the world, whose population is exponentially growing. The increasing population is a direct reason responsible for enhanced production of municipal solid waste (MSW). Amount of solid waste generated in the cities of India has increased to 48 million tons in 1997 from 6 million tons in 1947 with an annual growth rate of 4.25%, and it is likely to reach 300 million tons by 2047 [1–3]. Wastes can be classified into inorganic and organic, depending on their treatability. Inorganic wastes like certain types of plastics are non-biodegradable. Organic waste contains all such
carbonaceous wastes like agricultural wastes, food scraps, garden wastes that are biodegradable. Fallen dry leaves from trees (also called as leaf litter) [4–7], covers the major part of the garden waste Huge quantity of waste generated in gardens, not only creates the storage problem but is also responsible for eutrophication of surface water bodies through nutrient leaching. In many cases, the leaf litter waste is mostly collected and piled up in heaps and is set on fire which results in the loss of organic nutrients and many important nutrients from forest floor. Besides this, accumulation of dead forest litter is also responsible for the incidence of surface forest fires. These uncontrolled surface forest fires cause danger to the forest and neighboring human habitations. Leaf litter waste in urban areas is often piled in open where it degrades naturally, thus occupying land resource. But these practices sometimes create problems such as blockage of urban water drainage and sewers The burning of leaf litter also leads to release of pollutants in air causing air pollution. The rural populations in India make use of leaf litter as fuel that causes indoor air pollution [8]. But this leaf litter waste can be a good source of nutrients for the soil if proper waste management process is adopted. Leaf litter can maintain soil fertility as it is a good supplier of organic matter. For sustainable environmental management, recycling of waste is required. Converting the negative waste into beneficial product is an important aspect of resource recycling [9–11].

Composting is the wonderful approach to manage any type of biowaste. It is an aerobic or anaerobic process involving several microfloras like bacteria, fungi and actinomycetes that help in breakdown of organic matter to nutrients like humus. Vermicomposting is an upgraded form of composting and differs from composting in several ways and is also faster than composting The word ‘vermi’ is derived from the Latin word vermis which means a worm. Thus, vermicomposting is a process in which decomposition is done by worms and the decomposed material is used as compost. Any species of earthworms viz. epigeic, anecic or endogeic can be used. If it has natural ability to colonize and decompose organic waste for nutrient recovery. Vermicomposting is a bio-oxidative process in which detrivorous earthworms act along with microorganisms and other fauna to decompose and stabilize organic waste, thus modifying its physical and biochemical properties [12–15]

Traditionally vermicompost has been prepared by using animal manure (especially of the rumens) as the substrate and has been known to be a fertilizer cum soil conditioner. In recent years, leaf litter has also been used as substrate for vermicomposting and its end product as biofertilizer on various crops [16–19]. Mostly mature fallen (Senescent) leaves are used for vermicomposting. Senescence in leaves is a natural phenomenon occurring as a result of numerous molecular events at the time of ageing Several researchers have made great contributions in establishing protocols for vermicomposting of leaf litter of different species of plants like Mango (Gajalakshmi et al., 2004); Neem (Gajalakshmi and Abbasi, 2004); Acacia (Ganesh et al., 2009); Coconut (Gopal et al., 2009); *Polyalthia longifolia* Palash also known as Bastard teak tree ,Banana ,in order to assess the
variation in the nutrient quality of compost and vermicompost, carried out both composting and vermicomposting of leaf litter of different plant species like *Pinus roxburghii*, *Eucalyptus* hybrid, *Populus deltoids* and leaves of *Parthenium hysterophorus*, *Shorea robusta* in combination with municipal solid waste, using earthworm *Eisenia foetida* and concluded vermicomposting as a better technology than composting.

The literature survey revealed that for vermicompost preparation, 8-10 species of earthworms have been considered suitable out of 3000 species present in soil. Among these, *Eisenia foetida* and *Eudrilus eugeniae* are the two earthworm species best utilized for vermicomposting process. These species are epigenic and live on the upper surface of soil feeding on different kinds of organic material including vegetable waste and produce better vermicompost when compared to species that feed on plain soil. Furthermore, these species are very active and cause rapid decomposition of organic wastes producing vermicompost in a short span of time as compared to other species. Other species of earthworms which have been used for vermicomposting include *Eisenia andreii*, *Lumbricus rubellus*, *Perionyx excavatus*, *Perionyx sansibaricus*. Organic waste is broken down within gizzard, a thick-walled muscular organ presents in the eighth or ninth segment of earthworm body. The partially decomposed matter is further exposed to different enzymes including chitinase, cellulase, protease etc. that cause further digestion of biomolecules into simple forms. Approximately 80 – 90% of the ingested material is excreted as vermicast while only 5-10% is absorbed by earthworms for their growth and maintenance.

Precomposting is often done as a pretreatment before Vermicomposting to produce high agronomic value and pathogen free vermicast. All the pathogens, volatile gases produced by the organic waste in the substrate are toxic to earthworm and thus are eliminated by this pretreatment (Nair et al., 2006; Prez- Godinez et al., 2017; Zhang et al., 2021). According to Chaudhari (2019) vermicomposting can be considered as powerful tool to bring second green revolution in India as vermicompost is a rich source of numerous nutrients, phenolics, plant growth regulators and also humus. Vermicompost improves physical structure of the soil and enhance the uptake of nutrients by plants. Growth promoting effects of vermicompost have been widely recognized across the globe.

Vermicompost has been shown to possess higher concentrations of all major as well as micro nutrients as compared to simple compost. Pathogen reduction and enhancement in beneficial microbes in final vermicompost through earthworms have also been reported earlier (Nair et al., 2006). Adequate quantity of vermicompost addition in degraded soil not only enhances the nutrient quality but also different enzymatic activities of the soil and better turnover of the nutrients. Higher proportion of microorganisms like nitrifying, phosphate-solubilizing and potassium-solubilizing bacteria has been observed in soils amended with vermicompost. Hence regular and adequate use of
vermicompost in soil improves the soil quality, maintains nutrient recovery and microbial count which are necessary for plant growth.

Some studies related to use of leaf litter of some plant species mixed with or without cattle dung or pressed mud or any other material for producing vermicompost are summarized in Table 1.
Table 1. Summary of literature on the use of leaf litter of different plant species as vermicompost substrate

| S.N.o. | Botanical name of Plant species (Common name) | Name of Earthworm species | Reaction mixture | Vermireactor | Time duration | Result |
|--------|---------------------------------------------|---------------------------|------------------|--------------|--------------|--------|
| 1.     | *Acacia auriculiformis* *(Acacia)*           | *Lamprothoe mauritii*     | Acacia leaf litter + Cow dung (7:5:1) | 4 series of rectangular reactors of same volume with identical width and different length and height: 50 x 10 x 2 cm 25 x 10 x 4 cm 12.5 x 10 x 8 cm 6.25 x 10 x 16 cm | 45-60 days | Greater the surface area:volume ratio of the reactor, higher was the vermicast output. High content of polyphenols and lignin in Acacia leaf litter was responsible for high rate of mortality and weight loss in earthworms feeding on them. |
| 2.     | *Azadirachta indica* *(Neem)*               | *Eudrilus eugeniae*       | Neem leaf litter + Cow dung (2:1) | 2 types of wooden boxes used: One with 62.5 worms l⁻¹ and other with 75 worms l⁻¹ of the reactor volume | 5 weeks | A slight increase in vermicast output (17g l⁻¹ d⁻¹) was observed in the reactor containing 75 worms l⁻¹ as compared to 16.4g l⁻¹ d⁻¹ in the reactor containing 62.5 worms l⁻¹. Application of vermicompost resulted in an increase in vegetative and reproductive growth of brinjal plants. |
|        |                                             | *Eisenia fetida*           | Only neem leaves | Rectangular wooden boxes (48 x 36 cm, height 20 cm). Reactors operated in 2 modes: 1.) PDCOP 2.) Batch | 16 months | Pseudo discretized continuous reactor operator (PDCOP) was more efficient and resulted in 3-4 times more production of vermicast as compared to conventional method (Batch reactors). All three species of earthworms showed persistent increase in body mass, good reproduction rate and |
|   | **Bambusa polymorpha** (Bamboo) | **Pontosc olex corethra rus** | **Drawida assamen sis** | **vermicast production.** |
|---|---------------------------------|------------------------------|------------------------|--------------------------|
| 3. | 4 types of reaction mixture:   | 4 types of reaction mixture: | Earthen pots (2.5L)   | Highest rate of growth   |
|   | Control soil (CS)              | Control soil (CS)            | containing 1600 g of   | and cocoon production   |
|   | Soil (S)+Cow manure (C),       | Soil (S)+Cow manure (C),     | substrate of different | was recorded in SL diets|
|   | 30:2 w/w (SC)                  | 30:2 w/w (SC)                | reaction mixtures      | for both the species of  |
|   | Soil (S) + Bamboo leaf         | Soil (S) + Bamboo leaf       |                        | earthworm.              |
|   | litter (L), 30:2 w/w (SL)      | litter (L) + Cow manure (C)  |                        |                         |
|   | Soil (S) + Bamboo leaf litter  | Soil (S) + Bamboo leaf litter|                        |                         |
|   | +Cow manure (C), 30:1:1 w/w    | +Cow manure (C), 30:1:1 w/w  |                        |                         |
|   | (SCL)                           | (SCL)                        |                        |                         |
|   | Earthen pots (2.5L)            | Earthen pots (2.5L)          | 150 days               |                         |
|   | containing 1600 g of substrate | containing 1600 g of         |                        |                         |
|   | of different reaction          | substrate of different       |                        |                         |
|   | mixtures                       | reaction mixtures            |                        |                         |
|   |                                |                              |                        |                         |
| 4. | 4 types of reaction mixture:   | 4 types of reaction mixture: | Mud pot of 2.5 L       | High rate of mineralization |
|   | T<sub>1</sub> - BL<sup>b</sup> + | T<sub>1</sub> - BL<sup>b</sup> + | capacity              | was observed in the    |
|   | CD<sup>c</sup> (1:1)           | CD<sup>c</sup> (1:1)         |                        | vermibed with SOL than |
|   | T<sub>2</sub> - BL<sup>b</sup> + | T<sub>2</sub> - BL<sup>b</sup> + |                        | in BL                    |
|   | CD<sup>c</sup> (2:1)           | CD<sup>c</sup> (2:1)         |                        | vermibed.                |
|   | T<sub>3</sub> - SOL<sup>e</sup> + | T<sub>3</sub> - SOL<sup>e</sup> + | Vermicompost produced  |                         |
|   | CD<sup>c</sup> (1:1)           | CD<sup>c</sup> (1:1)         | was rich in soil      |                         |
|   | T<sub>4</sub> - SOL<sup>e</sup> + | T<sub>4</sub> - SOL<sup>e</sup> + | nutrients and          |                         |
|   | CD<sup>c</sup> (2:1)           | CD<sup>c</sup> (2:1)         | microbial population,  |                         |
|   | T<sub>5</sub> - CD<sup>c</sup>  | T<sub>5</sub> - CD<sup>c</sup> | thus can be used for   |                         |
|   | (100%)                         | (100%)                       | land restoration.      |                         |
|   |                                |                              |                        |                         |
| 5. | Only Leaf litter,              | Eudrilus eugeniae            | Plastic bins           | Addition of cattle dung  |
|   | Leaf litter +                  | *Eisenia foetida*            | 15 days                | to leaf litter in the   |
|   | Cattle dung (1:1),             |                              | PC<sup>a</sup>         | ratio of 1:1 resulted    |
|   | Only Cattle dung               |                              | + 13 weeks VC<sup>d</sup>| in an increase in the   |
|   |                                |                              |                        | production of              |
|   |                                |                              |                        | vermicompost and        |
|   |                                |                              |                        | decomposition of the     |
|   |                                |                              |                        | leaf litter.              |
|   | Plant Combinations | Reaction Mixtures | Vermicomposting Conditions | Vericompost Properties |
|---|---|---|---|---|
| 6. | *Butea monosperma* (Palash) <br> *Santalum album* (Chandan) <br> *Syzygium cumini* (Jamun) <br> *Eucalyptus globulus* (Eucalyptus) | Mixture of leaf litter + Cattle dung (1:1) <br> *Eudrilus eugeniae* <br> *Eisenia fetida* | Plastic containers 15 days | Odour less, dark brown in colour and granular in appearance and consisted of many plant nutrients. |
| 7. | *Casuarina sp.* <br> *Tectona grandis* (Teak) | 4 types of reaction mixtures: <br> **Set A**: *T. grandis* leaf litter + cow dung (1:1) + *E. fetida* <br> **Set B**: *T. grandis* leaf litter + cow dung (1:1) + *E. eugenia* <br> **Set C**: Casuarina leaf litter + cow dung (1:1) + *E. fetida* <br> **Set D**: Casuarina leaf litter + cow dung (1:1) + *E. Eugenia* | Vermireactor s of size 20 cm X 30 cm 6 weeks | Good quality vermicompost produced when leaf litter and cow dung were mixed in equal proportion. *E. eugenia* showed better rate of vermicomposting then *E. fetida* |
| 8. | *Cocos nucifera* (Coconut) | 2 types of reaction mixture: <br> **CLV**: Coconut leaves + Cow Manure (10:1) | Cement tanks of dimensions 7.5 x 2.0 x 1.0 m (length x width x depth, respectively). 20 days PC* + 60 days VC** | In the vermicompost produced from the CLV mixture, there was an increased number of Plant beneficial microorganisms. |
|   | Species                                         | Ecosystems                  | Reaction mixture                  | Duration                      | Vermicompost produced                                                                 |
|---|------------------------------------------------|-----------------------------|-----------------------------------|------------------------------|----------------------------------------------------------------------------------------|
| 9. | *Diospyros melanoxylon* (Tendu)                | *Eudrilus eugeniae*         | Leaf litter + Cattle dung          | 30 days PC + 60 days VC     | Vermicompost produced was used as a biofertilizer that enriched soil and resulted in increased production of crop - Onion (*Allium cepa*). |
| 10. | *Eucalyptus globulus* (Eucalyptus)             | *Eudrilus eugeniae* *Eisenia fetida* | Cattle dung + Leaf litter (100%) + Cattle dung (1:1) | 15 days PC + 14 weeks VC | Increased rate of vermicomposting in a reaction mixture containing Leaf litter and cattle dung in 1:1. |
| 11. | *Hevea brasiliensis* (Rubber plant)           | *Eisenia fetida*            | Rubber leaf litter + Cow dung (1:1) | -                           | Vermicompost produced when applied to the *Ananas comosus* (Pineapple) plantations showed increase in yield and restoration of degraded acidic soil |
| 12. | *Mangifera indica* (Mango)                    | *Eudrilus eugeniae*         | Leaf litter + Saw dust + River sand + Soil | 2 types of circular plastic containers: One with 62.5 animals l⁻¹ and the other with 75 animals l⁻¹ of the reactor volume | Earthworms grew well in both types of reactors, increasing their zoomass by ~103% and producing ~157 offsprings. A slight increase in vermicast output (~14.9 g l⁻¹ d⁻¹) was observed in the reactor containing 75 worms l⁻¹ as compared to ~13.6 g l⁻¹ d⁻¹ in the reactor containing 62.5 worms l⁻¹. |
| 13. | *Musa paradisiaca* (Banana)                   | *Eisenia fetida*            | 6 types of reaction mixtures: Rectangular plastic containers | 9 month s | Vermicast produced had earthy odour and blackish in colour. |
| 14. | *Polyalthia longifolia* | *Perionyx ceylanensis* | VR<sub>1</sub>: 1000 g CD  
VR<sub>2</sub>: 800 g CD + 200 g BL  
VR<sub>3</sub>: 600 g CD + 400 g BL  
VR<sub>4</sub>: 400 g CD + 600 g BL  
VR<sub>5</sub>: 200 g CD + 800 g BL  
VR<sub>6</sub>: 1000 g BL | Having 28 cm x 20 cm x 14 cm dimensions and 10 L capacity. | Reaction mixture containing 20-40% (VR<sub>2</sub> and VR<sub>3</sub>) of the leaf litter showed best results in terms of mineralization rate and earthworm growth. |
| 15. | *Populus nigra* L. (Poplar) | *Eisenia fetida* | 2 types of reaction mixture:  
Leaf litter: Peat (1:8)  
Horse manure: Peat (1:8) | Plastic containers of 250 millilitre capacity | - | Polwar leaf vermicompost showed higher calcium ion concentration and pH values than the horse manure vermicompost. Application of polwar leaf vermicompost extract to the wheat seeds and potato shoots showed increased root weight compared to the seeds and shoots grown on tap water. |
| 16. | *Santalum album* (Sandalwood) | *Eisenia fetida*  
*Eudrilus eugenia* | 2 types of reaction mixture:  
100% leaf litter  
Leaf litter: Cattle dung (1:1) | Plastic bins of 30 x 15 cm size | Both the earthworm species were successful decomposers of Sandalwood leaf litter. Vermicompost produced was odour less, black and granular in appearance. |
| 17. | Syzygium cumini (Jamun) | Eudrilus eugenia, Eisenia foetida | 100% leaf litter + Cattle dung (1:1) | Plastic containers of 15 litre capacity | 15 days PCa + 14 weeks VCd | Both the earthworm species were observed to be the efficient degrader of Jamun leaf litter. Better vermicomposting was achieved only in a reaction mixture containing leaf litter and cattle dung in 1:1 proportion. |
| 2 types of reaction mixture: | Green Jamun leaf litter + Cattle dung (1:1), Senescence Jamun leaf litter + Cattle dung (1:1) | Plastic bins | 10 days PCa + 13 weeks VCd | Vermicompost formed from both the reaction mixtures showed similar trend in pH and temperature variation. |

PCa = Precomposting; VCd = Vermicomposting; BLb = Bamboo leaf litter; CDc = Cow dung; SOLe = Silver oak leaf litter; LPLf = Polyalthia longifolia; SCTg = Sugarcane trash; PMh = Pressmud
Figure 1: Species of Earthworm

Figure 1 shows number of studies carried out on different species of earthworms for vermicomposting of leaf litter.

Das = Drawida assamensis; Eeu = Eudrilus eugeniae; Efo = Eisenia fetida; Lma = Lampito mauriti; Pco = Pontos colexcorethrurus; Pex = Perionyx excavates

Figure 2 shows number of plant species whose leaf litter was used for vermicomposting by different species of earthworms.
Figure 2: Number of Plants Species

Fig. 2. No. of plant species whose leaf litter has been used for vermicomposing by different species of earthworms.

Das = *Drawida assamensis*; Eeu= *Eudrilus eugeniae*; Efo= *Eisenia fetida*; Lma = *Lampito mauritii*; Pco= *Pontos colexcorethrurus*; Pex= *Perionyx excavates*

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