Review Article

Vermicomposting by Bio-Recycling of Animal and Plant Waste: A Review on the Miracle of Nature

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Abstract | Inorganic fertilizers and pesticides have eliminated beneficial microorganisms, depleted soil fertility, and lowered natural resistance in crops, making them more susceptible to disease and having detrimental consequences for the environment and human health. To address these issues, we must turn to ecologically friendly alternatives like vermicompost tea and vermicompost, which not only increase crop growth and production while lowering diseases and pests over time, but also protect environment and human health. Vermicomposting is the process of breaking down and stabilizing solid organic waste to produce fine organic rich manure that can be readily stored, processed, and put into agricultural areas with no negative repercussions. In the vermicomposting process, earth worms and mesophilic microbes collaborate to digest solid agricultural waste under controlled circumstances, resulting in a stable form of organic matter. Earthworms produce vermicompost, which contains growth-regulating hormones, macro-micro nutrients, plant-immobilized microflora, growth regulators and promoters and cellular portion degrading enzymes (cellulose, proteases, lipase, amylases, chitinase), which degrade organic substrates even after they have been secreted. Earthworms change the chemical and physical characteristics of organic substrates, over time reducing the C:N ratio, increasing the surface area exposed to bacteria, and improving the microbial degradability of organic materials. This study aims to demonstrate how organic amendments, rather than chemical fertilizers, might improve soil health and plant development. Plant nutrition, growth, photosynthesis, and chlorophyll content in the leaves are all improved by the absorption of macro- and micronutrients in vermicompost. End users, such as farmers, may benefit significantly from the vermicompost generated, since it can be used to replace chemical fertilizers and get higher price for organic products by utilizing locally available composting material.

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1. Introduction

Earthworms produce vermicast from biodegradable materials, the term vermicomposting was coined to describe the complete process of vermicompost. The degradation/digestion of raw materials improves the bioavailability of fundamental nutrients. Vermicast also contains plant growth promoting materials such as ethylene, auxin, and gibberellin, as well as enzymes such as cellulose, nitrogenase, and phosphatase, according to several research (Aslam and Ahmad, 2020; Aslam *et al*., 2020). When biodegradable matter goes through the earthworm's intestines, nutrients are produced. Both of these hormones and nutrients are also thought to promote plant development while limiting pathogen invasion, which causes a variety of illnesses. Vermicast's organic fertilizing and soil conditioning properties come highly recommended. Concerned researchers have recently reported on their most recent experiments (Wang *et al*., 2007; Bellitürk *et al*., 2020; Aslam and Ahmad, 2020; Aslam *et al*., 2020) found vermicomposting to have plant-beneficial effects. The authors of this paper present a brief but comprehensive introduction to vermicomposting (Figure 1) as well as particular components of the operation that affect all frontline participants involved for earthworm nutrition enrichment.

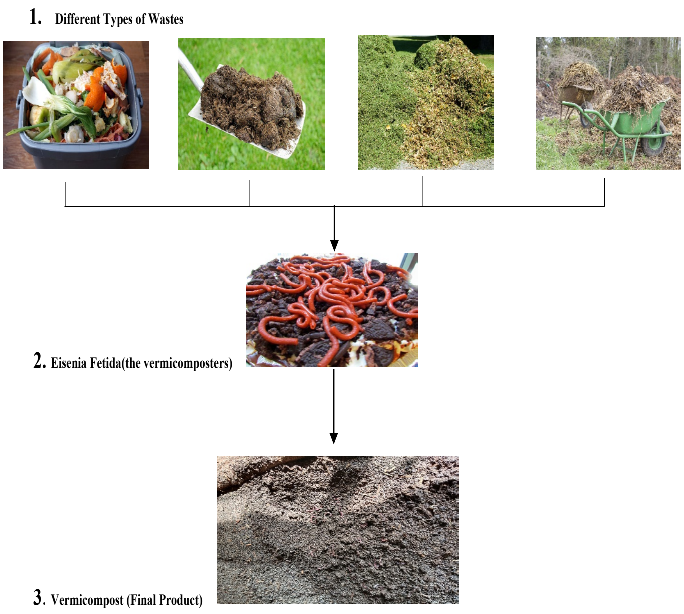

Figure 1: Vermicomposting.

1.1 Earthworms

Earthworms are soil creatures that are long, cylindrical, slender, segmented, and bilaterally symmetrical, with a brilliant brownish body swathed in a smooth cuticular crust. After 1/2 month, earthworms weigh between 1400-1500 mg and breed hermaphroditically. The earthworm's body is made up of 65 percent protein, 14 percent carbs, and 14 percent fat, with ash accounting for the remaining 5 percent. Depending on the environment, an earthworm's life cycle might span anywhere from 3 to 7 years. The earthworm gut is a long tube that connects the mouth to the throat, oesophagus, gizzard, digestive glands, and anal cavity. Amino acids, nutrients, organic elements, polysaccharide, protein, and symbiotic microbes are all found in earthworm mucus (micro-fungi, protozoa and bacteria). The earthworm gut's increased organic C:N and moisture content provide excellent conditions for bacterial endospore germination and dormant microorganism activation. Amylase, cellulase, protease, lipase, chitinase, and urease are among the digestive enzymes present in the earthworm food canal. The functions of mannose and cellulase have been shown to be influenced by gut bacteria (Munnoli *et al*., 2010). Earthworms comminute the substrate, increasing the surface area available for microbial decomposition, which is essential for efficient vermicomposting. When this fractioned organic matter passes through the gut, it interacts with intestinal-associated bacteria and digestive enzymes before partly digesting and entering the intestines as casts, during which the microbes start the decay phase and contribute to the maturation stage (Aslam *et al*., 2020, 2021; Joshi *et al*., 2020).

Earthworm-microflora interactions are complex, and certain microorganisms are consumed by earthworms as a source of food. These microorganisms include protozoa, a few yeasts, and fungus including *Fusarium oxysporum*, *Alternaria solani*, and *Drawida calebi*. The earthworm species *Lumbricus terrestris* and *Eisenia fetida* digest *Bacillus cereus* var mycoides, however neither *Serratia marcessens* nor *Escherichia coli* were found in the earthworm gut (Edward *et al*., 1985; Aslam *et al*., 2020, 2021; Ahmad *et al*., 2021).

1.2 The earthworm Eisenia fetida qualities

The earthworm *Eisenia fetida* (Savigny, 1926) is a lumbericidae species belonging to the Annelida phylum (Pavlíček and Csuzdi, 2012). Such earthworms have a yellowish belly with red, black, or brown body. It is divided into segments with lengths varying from 23 to 130 mm and numbers ranging from 80 to 110. The genital belt expands to 7-9 sections between segments 24, 25, 26, or 32 during puberty. The adult worm weighs around 1.5 g and has a reproductive

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cycle of 50-55 days. Adult worms create a cocoon each 3 days, with 1/3 of infants emerging after 23 days. Taking into account the reality that not every baby survives (Dominguez and Edwards, 2011).

Eisenia fetida (Figure 2) is a fertilizer-maker with ability to live in many environment types. It favours to eat with a lot of dung, soil, debris, wood, vegetables, bananas and lot of wastes. These worms have a high food consumption and digestion rate, and they are rich in organic matter. Such earthworms consume the comparable of 1/2 their body weight in raw garbage every day (Khan, 2005).

Figure 2: ***Eisenia fetida*.**

1.3 Vermicomposting

By using the vermicomposting method, discarded organic residue may be transformed into nutrient-rich organic humus that is both helpful and environment friendly. There are no negative consequences to the process of breaking down and stabilizing organic waste via the use of vermicomposting, which results in a fine organic rich manure that can be kept and applied to farmland with relative ease (Aslam *et al.*, 2020). Earth worms and mesophilic bacteria work together in a controlled setting to break down solid agricultural waste in a process known as vermicomposting. This procedure yields a long-lasting form of organic materials (Aslam and Ahmad, 2020). Earthworms create vermicompost, which contains macro- and micronutrients, hormones that regulate development, growth stimulants and regulators, microflora immobilized in plants, and enzymes that degrade cellular components (lipase, chitinase, amylases, proteases, and cellulose). Even after they have been secreted, these enzymes continue to destroy organic substrates (Rehman *et al.*, 2020). Proline, glycine betaine, ascorbic acid, salicylic acid, and other PGPRs are essential (Ahmad *et al.*, 2019). Nitrogen, potassium, phosphorus, calcium, magnesium, and iron are all required by plants that may live in arid environments (Ahmad *et al.*, 2019; Ali *et al.*, 2018). A drop in the C:N ratio, an increase in the surface area accessible to bacteria and a boost to microorganisms' ability to break down organic matter are all effects of earthworms altering organic substrate qualities physically and chemically. Fine organic frictions as well as bacterial faces are predicted to be found in the stomach of the earthworm. As a result, the organic substrates were uniform in composition. Vermicomposting produces a fine powder that has been fractionated. Ammonium and nitrate, two of the most important plant nutrients, are easily available in humus because of their high-water storage capacity and high porosity (Nenthra *et al.*, 1999).

1.4 Bio-recycling of animal waste into vermicompost

Earthworms reduce biomass production early in their growth, but they improve nitrogen mineralization and increase the rate of ammonium-nitrogen conversion to nitrate. Earthworms have the most effect on organic wastes by speeding up the maturation process, as evidence given by increased lettuce and tomato seedling growth (Atiyeh *et al.*, 2000). When compared to non-vermicomposted chicken litters, many vermicomposting poultry litters show a two- to three-fold increase in useable phosphorus and a two-fold rise in potassium. These findings were backed up by the fact that worm biomass is significantly larger in layer cage litter and broiler cage litter than in deep litter. Layer cage litter contained the most cocoons, while broiler deep litter contained the fewest. For the bioconversion of chicken litters into value-added compost, vermicomposting outperforms efficient microorganism-based (EM) composting, according to this report (Joshi *et al.*, 2020). *E. coli* thrive in compost extracts devoid of indigenous bacteria in a laboratory experiment as long as bioavailable nutrients are abundant. The information can be used to evaluate the risk of various forms of manure-based compost and soil additives used in fruit and vegetable production, as well as the composition of microbial communities on *Escherichia coli* (Neher *et al.*, 2019). Poultry litter has a high nutrient content, which can contribute to eutrophication and phytotoxicity in the ecosystem. The use of earthworms to balance the nutrients in the soil can help to solve these problems. The purpose of this research is to see if a new earthworm known as *Drawida sulcata* can convert chicken litter, cow dung, and *Tectona grandis* leaf litter into vermicompost (VC). D. *sulcata* is a hardy species that flourishes in an alkaline pH environment during the vermicomposting process (Yuvaraj *et al*., 2019). Changes in organic matter, nutritional content, and shapes were studied in fresh and 3-month stabilized FYM. During the maturation process, complete N, water-soluble compounds, and lignin content grew dramatically, whereas C, fat, hemicellulose plus cellulose, and the C/N ratio fell significantly. Many of these traits may be used as measures of maturity. There are no significant differences among the various tests used to assess the content and types of humified substances. After a three-month stabilization phase, the FYM can be found to be insufficiently humid. The content of nutrient elements increases with maturation, while availability decreases (Levi-Minzi *et al*., 1986). The formation of vermicompost from manure causes a pH shift toward neutral, a decrease in electrical conductivity, considerable improvements in oxidation capacity, and significant reductions in potentially dangerous water-soluble chemical species (Mitchell, 1997). Poultry manure can be used as a fertilizer, a methane source, and an energy source. A study proves the various options for using various poultry wastes in depth. The amount of waste created by poultry is staggering. Cost-effective methods for recycling waste into useful products, on the other hand, have yet to be discovered (Thyagarajan *et al*., 2013). Microbial activity increased throughout the first 60 days before gradually dropping, as determined by a dehydrogenase assay. The compost made by inoculating earthworms had a higher total nitrogen content. The gaps, on the other hand, were negligible. The overall P, K, and Cu contents of compost made with earthworm inoculation were close to those of non-inoculated treatments (Bansal and Kapoor, 2000). Dehydrogenase activity, which measures microbial activity, increased for the first 75 days of incubation before declining. The finished product has a lower average heavy metal content than the initial feed mixture. Strong textile mill waste can be used as a raw substrate in vermicomposting when combined with up to 30% cow dung. The completed product has less heavy metal on average than the initial feed mixture. When coupled with up to 30% cow dung, strong textile mill waste can be used as a raw substrate in vermicomposting. The cocoons of various worm species were examined for growth and development in various feed mixtures (Kaushik and Garg, 2003). To promote earthworm survival at a feeding frequency of 1/8-weeks, poultry litter should be microbially pre-composted and bulking substance added to bring the C/N ratio to 50 or higher (simulating windrow vermicomposting). Unlike bin vermicomposting, earthworms are fed once a week, does not require microbial pre-composting and results in favorable earthworm growth (Tohidinejad *et al*., 2011).

1.5 Chemical properties of vermicompost

The term vermicompost refers to an organic matter that has been broken down by worms and contains nutrients that are easily absorbed. Calcium and potassium are two examples. Other examples are the ions PO42– and NO3-1. This organic manure is beneficial for microbial activity as well as the retention of nutrients since it has a high porosity, high capacity of water holding, and a large surface exposure area. The action of microbes in vermicompost results in the production of plant growth hormones such as cytokinin and auxins, in addition to other components of mulch.

The composing process' main goal is to improve the transformation of organic decay into stable organic compounds by interacting with helpful microbes at 45-60°C, which allows for purity of organic decay by removing dangerous germs (Zucconi and De Bertoldi, 1987). The thermophilic stage (where organic waste decomposition occurs more frequently at a specific temperature of 45 to 65 degrees Celsius) and the mesophilic stage (where organic waste decomposition occurs more frequently at a specific temperature of 45 to 65 degrees Celsius) are the two stages of composting (where the temperature is reduced to 20-35 degrees Celsius, and the remaining non-decomposed substance degrades at a moderate rate). The duration of each decomposition phase is influenced by the kind of organic waste, aeration, and moisture content.

In the formation of vermicompost, beneficial bacteria and earthworms collaborate to oxidize organic waste (Ahmad *et al*., 2022; Dominguez *et al*., 1997). Earthworms seem to degrade and intermingle organic matter by altering its chemical and physical properties, reducing the ratio of (C: N) over time, and increasing the surface area accessible to bacteria to accelerate their activity and breakdown. Earthworms seem to breakdown and mix organic materials in the first phase by increasing surface area for quicker decomposition of organic masses, and in the second phase, ingested wastes replaced with new substances, with bacteria managing the decomposition process

(Lores *et al.*, 2006). The amount and type of earthworms, the characteristics of organic waste, humidity, and medium ventilation all have a role in the decomposition process.

Initially, Darwin (1881) has emphasized attention of media of degradation of organic matter over significance of earthworms in in his published book "The vegetable Mould making via the process of earthworm" (Edwards, 2004; Aslam *et al.*, 2020). It was also observed that some earthworm epigeic species that absorbed organic materials may improve soil and agricultural production (Oliver, 1937; Barrett, 1942). The technique of vermiculture has extended more quickly but subsequently, scientific community does not consider it a serious technology (Bouche, 1977). At the beginning of scientific research in Germany, Graff (1974) had worked on vermiculture technology and further continued his research in USA beyond 1970s with his collaborated workers at New York State University who employed to degrade garbage sludge through earthworm (Edward *et al.*, 1985). Later the research sustained by the investment Agriculture research council of United Kingdom at Rothamsted Experimental unit (Mitchell *et al.*, 1977). Reynolds and Wetzel (2004) have stated eighty-three hundred species of earthworm within "*Oligochaet* Family and except half population of earthworm were terrestrial in habitat. The most common family included "*Lumbricidae*" is found in America in North side, Europe, Western Asia and various more regions of the world, *Eudrilidea* family inhabited in West Africa, similarly *Microchaetidae* family existed in some areas of Eastern Asia and as well in Australia, whereas *Glossoscolecidae* and *Megascolocidae* families dwelled in Southern and Central Asia.

Earthworms are macroscopic *oligochaete* clitellate that dwell in wet earth described by Dominguez and Edwards (2011). Structurally, earthworms have segmentation, symmetrically bilateral, possessing an exterior gland called clitellum for yielding an egg sac cocoon, and small number of bristle setae occur on every segment of earthworm, an excretory pore anus at the terminal region of their body and a sensory lobe named prostonium at anterior region of the mouth. They are sexually hermaphrodite and reproduce mostly by copulation and cross fertilization, most copulated species produce cocoons containing fertilized eggs varying in number from 1 to 20. Based on their feeding habits and burrowing patterns, earthworms are categorized into three types: Anecic, endogeic, and epigeic (Bouche, 1977). Endogeic and anecic creatures' dwell in the subsurface and eat both inorganic and organic minerals; their excrement, known as faeces, also contains organic minerals, whereas epigeic species live on the surface and eat surface trash as well as litter converters. They commonly take feeding over particular course organic matter and consume undecayed surface litter (Bellitürk *et al.*, 2020).

Vermicomposting with distinct organic wastes include rice straw composite (RSC), rice straw (RS) and FYM (Farmyard manure) and other substrates by using *E. fetida* specie at 60% humidity was examined. The analysis revealed the vermicomposting with above mentioned substrates (RSC) and (FYM) except other substrates complete rapidly in 85-100 days and on contrary, other substrates gradually complete vermicomposting in 285 days. Ultimately, the ratio (1:1) of RSC: FYM substrate followed by FRM give best result (Venkatesan *et al.*, 2015).

Reinecke *et al.* (1992) examined the potential of three epigeic species namely (*P. excavatus, E. fetida, E. eugeniae*) for crop residues composting of wheat and paddy straw modified with FRM. The average per live weight and ratio of growth (mg wt., single worm in one day) of earthworm species were reported higher for *P. excavates* then E. *fetida*. Resultantly, *P. excavates* specie showed the better mineralization efficacy and growth which additionally support species suitability for wide scale process of vermiculture (Singh and Kulbaivab, 2009) (Table 1).

Suthar (2007) studied the potential of indigenous *Pertonyx excavatus* specie in lab conditions in which average number of cocoon productions was within (396.3± 23.3) and (692.8± 23.3). The decomposition of waste and production of earthworms was contributed firmly with substrate quality of their biological and chemical composition.

Swati and Reddy (2009) have compared the efficacy of two distinct species viz., *E. eugeniae* (EE) and *P. excavatus* (PE) in vermicomposting of rice straw. After 90 days, (EE) yielded (538±38) juveniles which was found 48.3% higher than (277± 25) juveniles produced by (PE) specie. (EE) Specie was capable to yield vermicast of (0.48±0.06g) in single day. Whereas (PE) specie was only capable to yield less

Table 1: Details of work done on vermicompost.

Material used	Species used	Reference
Sugar cane press mud + Horse manure	(*Eisenia fetida*)	Sangwan and Kaushik, 2007
Cattle dung	(*Eisenia fetida*)	Bansal and Kapoor, 2000; Edward *et al*., 1985; Edward, 1988; Kaushik and Garg, 2003.
Textile mill sludge	(*Eisenia fetida*)	Garg and Kaushik, 2005
Cow slurry	(*Eisenia fetida*)	Hand *et al*., 1988
Horse waste	(*Eisenia fetida*)	Garg *et al*., 2005
Water hyacinth	(*Eudrilus eugeniae* and *Perionyn excavatus*)	Gupta and Garg, 2008
Coffee pulp	(*Eisenia fetida*)	Orozco *et al*., 1996
Mango leaves	(*Eisenia fetida*)	Talashilkar *et al*., 1999
Guar gum	(*Eisenia fetida*)	Suthar, 2007
Pig waste	(*Eisenia fetida*)	Chan and Griffith, 1988
Poultry droppings	(*Eisenia fetida*)	Garg and Kaushik, 2005
Turnkey waste	(*Eisenia fetida*)	Edward *et al*., 1988
Sheep waste	(*Eisenia fetida*)	Edward *et al*., 1985.
Solid paper mill sludge	(*Eisenia andrei*)	Butt, 1993

(Dominguez and Edwards, 2011).

vermicast of (0.27±0.04g) in single day. So, (EE) was able to utilize paddy straw in 21.6% lower than to (PE) specie.

Singh and Sharma (2002) carried a study in which substrate of wheat straw was before decomposed for ½ mouth via inoculation with *Pleuroina sajorcaju*, *Azotobacter chroococcum*, *Aspergillus niger* and *Trichoderma harzianum* under distinct association followed via vermicomposting for one month thus quality of best composite was made when the substrate of vermicomposting was applied with whole four bio control microbes' inoculants. Suthar (2008) has used pre-harvest residues of such crops, wheat *Triticum aestivum*, and other crops in association with cow dung for vermicomposting via treating with *E. eugeniae* (EE). Vermicompost exhibited lesser concentration and greater contents of other main nutrients of plant in wheat vermicomposting. Study regarding to vermicomposting process was carried with distinct organic wastes i.e., wheat straws and other substrates by usage of five earthworm species namely (*P. excavatus, E. fetida, E. eugeniae, L. mauritti* and one local specie). Regarding to the (C:N) ratio, *P. excavatus, E. fetida* and *E. eugeniae* completely decompose the cotton stubble waste.

1.6 Earthworm species appropriate for vermicomposting preparation

Edwards (2011) has identified five distinct earthworm species to epigeic class appropriate for vermicompost preparation over the basis of following characters, maximum rate of feeding, digestion, and accumulation of organic wastes colonization capability in organic waste, low life cycle, acclimation in broad range environmental conditions, these fives species are *Dandrobaena veneta* (Savigny), *Eisenia fetida* (Bouche), *Eisenia andrei* (Savigny), *Eudrilus eugenae* (Kinberg) and *Perionyx excavates* (Perrier). For development the appropriate temperature of both species *Eisenia Andrei* and *Eisenia fetida* is twenty-five degrees Celsius and requirement of suitable moisture is eighty five percent, whereas such kind of species can also bear broad series of humidity. Over suitable moisture and temperature the duration of cocoon life cycle to maturity of earthworm is approximately 45-51 days. The hatching time to reach actual sexuality period differs from 21-30 days whereas copulation period occurs in the soil. Egg hatching initiates at two day later copulation, laying feasibility to be reported 72-82%. Cocoons laying differ from 2.5-3.8 single cocoon. Life span ranges 589-594 days in control conditions but actual life it differs relying upon the condition.

1.7 Useful effects of vermicomposting

Vermicompost has been reported for enhancement of soil pore spaces, better passage of air, water retaining capacity and well drainage than general compost owing to presence of large humus concentration. Therefore, 30-40% water usage efficacy was enhanced by vermicompost application. Local community waste was used for preparation of vermicompost in India which is considered 75% less expensive as compared to artificial chemical fertilizer achieved from organic product with environmental protection and dual economic advantages (Sinha and Herat, 2012).

Vermicompost has been shown to be five to six times more effective as a crop development enhancer than other large (C:N) manures, and 30-40% better than traditional chemical fertilizers (Sinha and Herat, 2012).

It includes N fixers, phosphate solubilizers and fungal mycorrhizal association. It has been considered possessing huge particular area of surface which offers locations of vermicompost for microbial activities and retention of nutrients (Ahmad *et al*., 2021). NPK are regulated on exchange regions and are easily accessible. It generally contains indole acetic acid, gibberellins, kinetins, plant growth regulators (PGRs) and plant growth promoters (PGPRs) (Atiyeh *et al*., 2002). Production of hormones of plant growth are occurred through disintegration in gut of earthworms and are transitory in environment however maintain under complication with fulvic and humic acid (Arancon *et al*., 2004) highly same to soil used regulators of plant growth (Muscolo *et al*., 1999). Antibiotics and Actinomycetes are also contained in Vermicompost which assist in increasing biological resistance within crops against diseases and pests. The application of vermicompost decreases dependence of artificial chemical sprays via 70% (Suhane, 2007).

1.8 Influence on soil characters

A trial in field was carried out in University of Ohio state, in which the vermicompost mixture along recommended rate of inorganic fertilizer added individually in the soil pots, later three months, there were large concentrations of extracted N, biomass of microbial N, actions of dehydrogenase enzymes and orthophosphates in vermicompost modified soil that the soil received equal (Arancon *et al*., 2005). In later years of experimental trial also great orthophosphates and microbial dry matter N was reported in soil where the combination of inorganic and vermicompost were added than in the soil obtaining merely inorganic fertilizer (Figure 3).

In second study, it was reported that enhanced concentrations of NPK noted where vermicompost was added (Nenthra *et al*., 1999). The variability in remaining of N and P nutrients among vermicompost + inorganic fertilizer so inorganic fertilizer and mixture would be leaded to large rate of nutrients leaching or microbe immobility of the minerals in the inorganic applied soils. The usage of inorganic fertilizer had the fastest rate of nutrients percolation when compared to vermicompost and inorganic fertilizer mixed treatments (Arancon *et al*., 2005). Same reduced in nutrient leaching was reported when vermicompost was applied by Wei *et al*. (1999). Leaching of nutrients might be owing to slowing down via microbial immobility. The immobility might be enhanced by the microbial dry weight rates where vermicompost was added in soil.

Application of vermicompost recovers nutrient availability and physiochemical properties in the soil and vermicompost comprises humus large contents (Adhikary, 2012), that assist in soil accumulate synthesis and eventually recovers water holding capability and aeration (Garg *et al*., 2006). Availability of humic acid delivers requisite locations for plant nutrients for instance, P K, S, Ca and Fe, that are readily available in stored forms to plants and discharged when plant required.

Sinha and Herat (2012) observed further intake of Ca, Mg and K in vermicompost modified soil than general compost method. They applied on surface area of the vermicompost (Ahmad *et al*., 2007). Leite *et al*. (2010) detected that the NPK availability with the application of vermicompost was found 18, 39 and 78% respectively more as compared to compost. Carbonic mass, *Azotobacter* and Phospho-bacteria with addition of vermicompost were $8.8x10^{-3}$, $11.7x10^{-3}$ and 274 mg per kg of soil but similar with treatment of general chemical fertilizer were $0.8x10^{-3}$, $3.2x10^{-5}$ and 218 mg per kg correspondingly.

Sinha *et al*. (2010) discovered that earthworm species accumulate high levels of heavy metals such as manganese (Mn), iron (Fe), copper (Cu), lead (Pb), zinc (Zn), mercury (Hg), and cadmium in their body cells (Cd). They could primarily consume and accumulate exceptionally high quantities of Pb, Cd, and Zn in their bodily cells. Earthworm cells have been found to tolerate a Cd concentration of 100 mg/kg dry mass.

Bioaccumulation of 90-180 Pb per gram of dry mass in the tissues of earthworm species *Lumbricus* *terrestris* was reported by Sinha *et al.* (2010), whereas D. *rubida* and L. *rubellus* can aggregate Pb at 2600 and 7600 mg g^{-1} respectively in the body of their cells. Consequently, the residual released from poisonous heavy metals (Hartenstein *et al*., 1980). Production of vermicomnpost from excreta of L. *rubellus* earthworm fastened with fluoranthene and PAHs phananthrene (100 µg per kg of soil) later 8 weeks had 84% low of phenathrene was eliminated (Tripathi and Bhardwaj, 2004). But it has well-known that vermicompost process eliminates organic wastes and heavy toxic metals that the soil will not deteriorate ultimately owing to accumulation of vermicompost achieved from the pollutants contaminated with organic wastes and heavy metals.

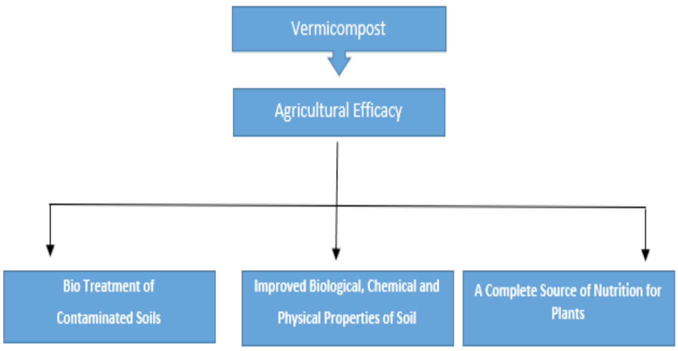

Figure 3: Vermicompost benefits.

1.9 Response on field crops

The rice crop yield was expressively enhanced by the use of vermicompost than the ordinary synthetic fertilizer treatment. The vermicompost was used at quantity of ten tons in a hectare biomass basis than 0.2 ton in a hectare of chemicals and yield attained was equal in application of both treatments. Large population of actinomycetes, mycorrhizal fungi and nitrogen fixers are helpful for enhancing uptake of nutrients from the soil. The earthworm once added in the soil will change organic decay into castings of worm for preparation vermicompost that provide improvement in yield, disease resistance and quality of crop. Availability of 460 per m^2 density population of earthworms (*Aporrectodea trapezoids*) in soil enhanced the germination and progression of wheat crop via thirty nine percent grain production and protein contents in grain via 12% and resistance of crop against biotic factors (Baker *et al*., 1997). Earthworm raid expressively enhanced production of grain of soybean and wheat by 51% and 48% correspondingly (Baker *et al*., 2006).

Sinha and Heart (2012) observed agronomic influence of vermicompost and related to chemical fertilizer and animals' excrement manure added individually and in embellishments to the wheat. The wheat grain yield enhanced up to 20% by the treatment of vermicompost than application of chemical fertilizer. When similar concentration of synthetic chemical fertilizer was added with vermicompost at rate of (25 Qha^{-1}) the yield enhance was 12% greater as compared to special vermicompost application (Figure 4). Ahmad *et al.* (2022) recorded 40% enhance in wheat production with application of vermicompost at 6 tons ha^{-1} than inorganic fertilizers. Sinha and Valani (2011) reported 240% rapid maize development with integration of vermicompost with synthetic chemical fertilizer. They observed that the growth of plant was nearly two times when the rate of vermicompost was increased two-fold from two hundred to four hundred gram. Maize with double concentration of vermicompost obtained maturity stage in much lesser duration. When the plant grows with 200 g of vermicompost, male reproductive organs such as spike appear at the end of three months, while when the plant grows with 400 g of vermicompost, spike appear in forty days in those grown on 400 g spikes appear in thirty-nine days. Female reproductive structures developed in ninety-six and eleven days with a two-hundred-gram application of vermicompost, respectively, and sixty-nine and seventy-five days with a four-hundred-gram application.

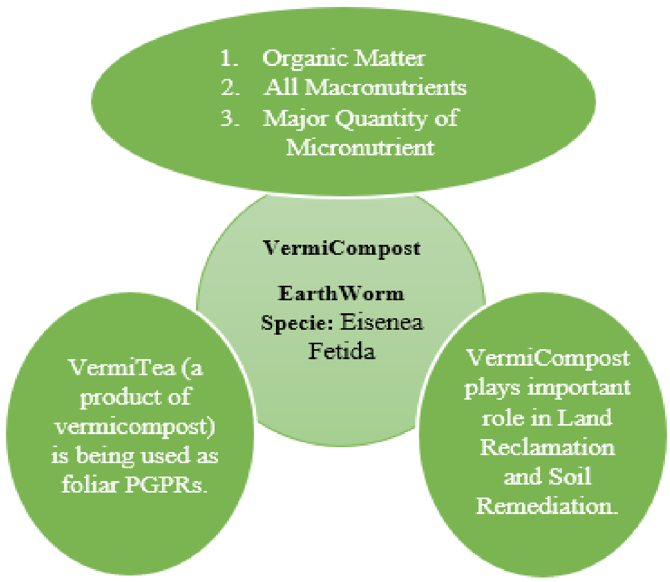

Figure 4: Vermicomposting byproducts and it's Nutrition.

1.10 Effect of crop residue and earthworm species over nutrient concentration of vermicompost

Davis *et al.* (2004) investigated the role of most earthworm species in the decomposition of big leaf litter and the mull structure. They discovered that earthworms boost nitrate production by encouraging bacteria to work harder. The presence of earthworm has noticeably effect on transformation of N mineral in tissue or cow excrement. Mineralization of nitrogen was higher in the availability and therefore N was converted into nitrate form which is owing to suitable condition for nitrification process via *E. fetida* species. Lunt and Jacobson (1994) analyzed the chemical composition of vermicomposting and explored that soil cast of forest was larger in organic carbon, exchangeable calcium and nitrogen mineral and large moisture contents equal as compare from the cast of field soil. Wang *et al*. (2007) examined the impact over presence of nitrogen and determined that non availability of nitrogen in organic matter can be accessible through vermicomposting.

Conclusions and Recommendations

Vermicomposting, according to this research, is the process of converting waste into black gold, which includes enzymes such as urease, cellulase, protease, chitinase, lipase, and amylase, as well as macro and micronutrients such as nitrogen (N), phosphorus (P), potassium (K), iron (Fe), zinc (Zn), sulphur (S), growth regulators and promoters.

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Novelty Statement

Vermicompost is an abundant and complete supply of nutrients for all crops. Earthworms are utilized as feed for poultry and fisheries once vermicompost has been fully produced. In Pakistan, no research on this topic had been conducted. For the first time in Pakistan, Dr. Zubair Aslam, Associate Professor, Department of Agronomy, Faculty of Agriculture, University of Agriculture, Faisalabad, presented this technology in 2019. Chemicals commonly employed in agriculture are now wreaking havoc on our ecosystem and causing stress in plants, wildlife, and humans. A healthier lifestyle will come from this organic diet for crops, trees, wildlife, and fisheries. This method is environmentally sustainable, commercially feasible, and publicly appropriate for plant, fishery, and bird feeding.

Author's Contribution

This review paper was planned and written by all the authors in an equal contribution. The final text has been reviewed and approved by all the authors.

Conflict of interests

The authors have declared no conflict of interest.

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