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INSIGHT OF VERMICOMPOST AND ITS SCOPE IN FODDER CROPS

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SUMMARY

Vermicompost is one of the most popular organic fertilizers that is produced by the activity of Earthworms. Vermicompost is a nutrient-rich (Macronutrients) and microbiota enriched product, making it an excellent soil amendment. It enhances soil fertility, promotes crop productivity and supports sustainable agricultural practices. It also helps to enhances soil structure via soil aeration, water retention and root penetration. Vermicomposting occurs in the presence of oxygen. This reduces odour and pathogen. Earthworms ingest organic matter, break it down and excrete a nutrient-rich. microbe-dense vermicompost. The entire process of vermicomposting involves a complex inter play of earthworms, microorganisms and decomposing organic matter. The microbial communities within earthworm gut and cast are found to be highly efficient and capable of digesting wide range of organic material and polysaccharides (cellulose, sugars, chitin, lignin, starch). In addition of macro and micronutrients, the vermicompost found to be rich in phosphate solubilizers, nitrogen-fixer fixing bacteria, enzyme producers and plant growth promoting bacteria. Likewise, enzymes like urease, β-glucosidase, phosphatase have been reported in vermicompost. Thus, the present review will feature, various methodology for the preparation of vermicompost, microbiome of vermicompast, physical properties of vermicompost, impact of vermicompost on plant health, antifungal features impact of vermicompost on soil health, its role in disease resistance, application methods enzymatic profiling, conventional compost vs Vermicompost and its application in forage, crops. The realization attained from the literature assessed herein will further help to understand the role of vermicompost in forage crop.

Key words: Disease resistance, Earthworms, Enzymes (Urease, β-glucosidase, Phosphatase), Soil fertility, Microorganisms, Vermicompost

Vermicomposting is a bioconversion process in which organic waste is decomposed by earthworms (Pathma and Sakthivel, 2012). Vermicomposting is also emerged as an effective method for the valorization of industrial, domestic, municipal, and agricultural wastes (Enebe *et al.,* 2023). It is recognized as an organic fertilizer characterized by its high nutrient content and play vital role as a soil conditioner. It facilitates the recycling of organic waste into more bioavailable forms with elevated nutrient and mineral content alongside beneficial microorganisms under controlled temperature and aeration conditions (Oyewole *et al.,* 2014). Zhao *et al.,* (2019) reported that vermicompost could enhance soil fertility and crop growth while mitigating continuous cropping challenges in greenhouse environments. The water-soluble nutrients present in the vermicompost enhance the availability of essential elements and contribute to improved soil structure, including enhanced drainage properties (Thakur *et al.,* 2021). Further, vermicompost is also enriched with nutrients. Due to its high nutrient availability and microbial activity, vermicompost improved soil fertility, stimulated plant growth and suppressed plant pathogens and pest populations (Pathma and Sakthivel, 2012). Jangra *et al.,* (2019) also documented that vermicompost comprised of nutrients, plant growth regulators, and beneficial microorganisms such as bacteria, fungi and actinomycetes. The beneficial effects of vermicompost encompass the stimulation of root and shoot growth, promotion of seed germination, enlargement of leaf area, enhancement of root branching, increase in fruit yield, improvement of nutritional quality, encouragement of plant flowering, influence on biomass, modulation of photosynthetic pigments and regulation of photosynthesis and respiration rates (Usmani *et al.,* 2019). Vermicompost has the potential to stimulate the growth and activity of plant growth-promoting rhizobacteria (PGPR) and mycorrhizal fungi leading to enhanced plant nutrient absorption and resilience to environmental challenges (Subramanian and Raghavan, 2013).

Methods for the preparation of vermicompost

Plethora of literature is available for vermicomposting. Different authors have demonstrated different methods for the production of vermicompost. Thakur *et al.,* (2021) prepared vermicompost by using coconut husk and a layer of polythene sheet or tiles placed at the base of the cement ring followed by layer of organic waste (15-20 cm). Rock phosphate was sprinkled onto the waste material, followed by an application of cow dung slurry. The ring was then filled completely in successive layers and the top of the ring was sealed with soil or cow dung and left for decomposition a period of 15 to 20 days, so that, the exothermic reaction from the decomposition process reduced. After that approximately, 500 to 700 earthworms were introduced. Water was sprinkled every three days to maintain adequate moisture to regulate the earthworms' body temperature. The vermicompost from agricultural waste gets ready in approximately two months, whereas using sericulture waste as the substrate, it gets ready in about four weeks. The resultant vermicompost is characterized by its lack of foul odor, black coloration, and light weight. Similarly, Ahmad *et al.,* (2021) prepared vermicompost by using bed (approximately 10L x 3B x 3H feet) constructed using bricks with the size adjustable based on the quantity of material available and specific requirements. The bed surface was moistened by sprinkling water, followed by spreading of thick layer of dry leaves or paddy straw (2-3 inch) at the base of the bed, an another sprinkling of water was given to moisten the dry material, then uniform 1-1.5 feet thick layer of farmyard manure or cow dung was spread over the leaves or straw and water was sprinkled to ensure adequate moisture. The cow dung used was aged 10-15 days, as fresh cow dung generates heat that can harm earthworms while overly decomposed dung lacks sufficient nutrients. Subsequently, kitchen waste such as vegetable leaves, fruit rinds, and grasses, chopped into small pieces was added. Another 1-1.5 feet layer of cow dung was uniformly spread and adequately moistened. Approximately, one kilogram of vermiculture, containing about 800-1,000 earthworms was then distributed over the cow dung layer. This was layered again by a (2-3 inch) layer of leaves uniformly spread over the farmyard manure (FYM) followed by water sprinkling. The vermicompost bed was then covered with jute or gunny bags. Aslam *et al.,* (2020) observed that to maintain optimal moisture and temperature conditions in the vermicompost bed, water was regularly sprinkled over the gunny bags, ensuring moisture levels of about 35%-40% and temperatures ranging from 15°C-30°C . If the vermicompost unit has to be established in an open area, a shed or roof should be provided to create shady conditions, also to protect the earthworms from direct sunlight and rain.

Microbiome of Vermicompost

Vermicompost augments soil biodiversity by fostering beneficial microbes which in turn promotes plant growth both directly and indirectly. Direct promotion occurred through the production of plant growth-regulating hormones and enzymes while indirect benefits arose from the suppression of plant pathogens, nematodes, and other pests. This dual action improved plant health and minimized yield loss (Rehman *et al.,* 2023). Vermicomposting is characterized as a non-thermophilic and biooxidative process that involves the utilization of earthworms along with associated microorganisms (Rada ,2015). Earthworms plays a crucial role in breaking down the large soil particles and leaf litter, thereby increasing the availability of organic matter for microbial degradation. They transformed organic wastes into valuable vermicompost by grinding and digesting the material with the aid of aerobic and anaerobic microbes (Maboeta and Van Rensburg, 2003). The intestine of earthworms harbored a diverse array of microorganisms, enzymes, and hormones that facilitated the rapid decomposition of partially digested material, leading to the production of vermicompost within a relatively short period, typically around 4 to 8 weeks (Nagavallemma *et al.,* 2004). The final product of vermicomposting is enriched with diverse microbial communities such as phosphate solubilizers, nitrogen-fixing bacteria, enzyme producers, and plant growth-promoting bacteria (Chitrapriya *et al.,* 2013). Bacterial genera such as *Pseudomonas* sp., *Paenibacillus* sp., *Azoarcus* sp., *Burkholderia* sp., *Spiroplasm* sp., *Acaligenes* sp., and *Acidobacterium* sp. has been identified as key decomposers of various organic compounds associated with earthworm intestines and vermicasts (Singleton *et al.,* 2003). Likewise, Vaz-Moreira *et al.,* (2008) reported firmicutes species like *Bacillus benzoevorans*, *B. cereus*, *B. licheniformis, B. megaterium, B. pumilus, B. subtilis, B. macroides, Actinobacteria including Cellulosimicrobium cellulans,* *Microbacterium sp., M. oxydans*, and Proteobacteria such as *Pseudomonas sp*. and *P. libaniensis* in the vermicomposts. Pinel *et al.,* (2008) discovered a novel symbiont, *Verminephrobacter eiseniae*, within the nephridia of *E. foetida*. Other bacterial species including *Ochrobactrum* sp., *Massilia* sp., *Leifsonia* sp., and members of families Aeromonadaceae, Comamonadaceae, Enterobacteriaceae, Flavobacteriaceae, Moraxellaceae, Pseudomonadaceae, Sphingobacteriaceae, Actinobacteria, and Microbacteriaceae have been also identified in the alimentary canal of earthworms (Byzov *et al.,* 2009). The microbial communities within earthworm guts and casts are reported to be highly active and capable of digesting a wide range of organic materials and polysaccharides such as cellulose, sugars, chitin, lignin, starch, and polylactic acids (Zhang *et al.,* 2000, Aira *et al.,* 2007, Vivas *et al.,* 2009). Further, Khyade (2018) reported the analysis of single-strand conformation polymorphism (SSCP) profiles and revealed the presence of diverse bacterial groups including Alphaproteobacteria, Betaproteobacteria, Bacteroidetes, Gammaproteobacteria, Deltaproteobacteria, Verrucomicrobia, Planctomycetes, and Firmicutes in fresh soil, gut, and casts of earthworms (*L. terrestris* and *Aporrectodea caliginosa*). Notably, representatives of classes Flavobacteria, Sphingobacteria (Bacteroidetes), *Pseudomonas* sp., unclassified Sphingomonadaceae (Alphaproteobacteria), and *Alcaligenes* sp. (Betaproteobacteria) have been identified in worm casts (Byzov *et al.,* 2009). Ravindran *et al.,* (2016) reported that vermicompost is rich in microorganisms, likely due to the favorable environment within the digestive tract of earthworms, which supported microbial growth. The organic waste ingested by earthworms provided energy for microbial proliferation. Ravindran *et al.,* (2016) also reported the highest microbial counts at 21 days of vermicomposting, while fecal coliforms were not detected. Zhang *et al.,* (2020) reported the presence of *Dokdonella* sp., strictly aerobic and urease-negative rods with an optimal growth temperature of 40°C, in vermicompost.

Physical properties of vermicompost

Vermicompost is characterized by its finely divided peat-like texture exhibited high porosity, excellent aeration, drainage, water-holding capacity, microbial activity, superior nutrient status, and buffering capacity. These physicochemical properties are reported to be conducive for soil fertility and plant growth (Pathma *et al.,* 2012). Uz and Tavali (2014) conducted the physico-chemical analysis of vermicompost and recorded 7.80 pH, 1450 µS/cm EC, 48.95% organic matter, 1.90% total nitrogen (N), 14.94 C/N (carbon to nitrogen ratio), 2.05% phosphorus (P), 0.8% potassium (K), 1.89% calcium (Ca), 0.92% magnesium (Mg), 500 ppm manganese (Mn) , 100 ppm Zinc (Zn), 44 ppm copper (Cu) , 1575 ppm iron (Fe). Kumar *et al.,* (2017) reported an increase in the nitrogen content from 0.84% in the raw biomass to 1.34% in the vermicompost prepared from cow dung and wheat straw, potassium levels from 0.84% to 1.34% and phosphorus levels from 1.27% to 1.83% in the vermicompost. The physico-chemical analysis of Vermicompost revealed 6.50 pH, 3.00 dS/m EC, 48.00% organic matter, 12.00% C/N (carbon to nitrogen ratio), 1.40% nitrogen (N), 1.0% phosphorus pentaoxide (P_2O_5), 1.0% potassium oxide (K_2O), 4% calcium (Ca), 0.60% magnesium (Mg), 0.55% iron (Fe), 0.45% sulphur (S) and also reported heavy metal analysis revealed 0.40 ppm cadmium (Cd), 6.30 ppm nickel (Ni), 25.30 ppm lead (Pb), 1.02 ppm mercury (Hg), 6.15 ppm chromium (Cr), 0.05 ppm Strontium (Sn) (Aslam and Ahmad 2020, Bellitürk *et al.,* 2020). Hafez *et al.,* (2021) observed that the vermicompost (VC) exhibited an organic matter content of 42%, an electrical conductivity (EC) of 3.8 dS/m, and a pH of 7.4. Its nutrient composition included total nitrogen (N) 2.1%, total phosphorus (P) 7.8%, and total potassium (K) 0.5%. The carbon (C) content was observed 18.3 ± 1.36%, while the polyphenol concentration was determined to be 8.4%. Przemienieck *et al.,* (2021) assessed the physical properties of vermicompost and reported 7.18 pH-H_2O, 7.0 pH-KCI, 2.42 mS/cm electrical conductivity (EC), 200 ppm nitrate (NO_3^-), 68.8 ppm ammonium (NH_3), 618 ppm phosphorus (P), 1796 ppm potassium (K), 1411 ppm calcium (Ca), 370 ppm Magnesium (Mn), 190 ppm Chlorine (Cl), 5.09% organic carbon (OC), 0.24% total nitrogen (N), 21/1 carbon to nitrogen (C/N) ratio in the vermicompost.

Impact of vermicompost on plant health

Vermicompost is a natural organic substance resulting from the degradation of plant and livestock waste by earthworms, enriched with beneficial microorganisms and recoverable plant nutrients (Arancon *et al.,* 2012, Olivares *et al.,* 2015). Vermicompost enriched with humic acids (HAs) plays a crucial role in stimulating plant growth and development (Vukovic *et al.,* 2021). The presence of humic acids (HAs) enhances microbial activity in the soil ultimately increasing N, P and K content in plants (Arancon *et al.,* 2004). Pant *et al.,* (2011) reported that the application of vermicompost tea enhanced plant yield, as well as increased the levels of total carotenoids and total thioglucosides in plant tissues. Similarly, Gholami *et al.,* (2019) investigated the effects of humic acid at varying concentrations (0, 0.3, 0.6, and 0.9 kg/ha) and vermicompost (0, 5, 7.5, and 10 t/ha) on the uptake of mineral elements (N, P, K, Fe, Zn, Mn, and Cu) and photosynthetic pigment concentrations in chicory, due to the presence of humic acids, the activity of microorganisms in the soil was improved that finally increased N, P and K content in plants. Chauhan *et al.,* (2024) revealed that the application of 75% of the recommended dose of fertilizer (RDF) and 25% of the recommended dose of nutrients (RDN) through vermicompost, combined with an NPK consortium via soil application, markedly increased Nitrogen (N), phosphorus (P) and potassium (K) uptake in maize compared to other treatments. The growth stimulation of crops is likely attributed to the presence of water-soluble bioactive compounds like phytohormones, humic and fulvic acids, minerals, amino acids or microbial by products present in vermicompost (Baldotto and Baldotto, 2014).

Antifungal features of Vermicompost

The sterilized water extracts (SWE) of bamboo vermicompost, filtered through a 0.22-µm cellulose acetate filter, significantly inhibited the mycelial growth of *Rhizoctonia solani* AG1-IB on Potato Dextrose Agar (PDA) medium. The presence of SWE in the PDA medium reduced the fungal growth rate from 23.8 mm 24/h to 20.3 mm 24/h (You *et al.,* 2019). Similarly, Yasir *et al.,* (2009) reported the filter-sterilized aqueous extract of vermicompost (VC) significantly inhibited the spore germination of *Fusarium moniliforme* compared to the autoclaved aqueous extract of VC, Specifically, the inhibition of spore germination was 75.8% in the filter-sterilized extract and 54.7% in the autoclaved extract.

Impact of Vermicompost on soil health

Earthworms secreted various hormones, enzymes and vitamins during casting which stimulated the activity of other beneficial soil microbes, thereby enhancing soil health. Their castings contained a high percentage of humus which facilitated the aggregation of soil particles resulting in improved porosity, aeration and water-holding capacity (Edwards and Arancon, 2022). Physically, soils enriched with vermicompost exhibited improved aeration, increased porosity, lower bulk density and greater water retention potential (Aslam *et al.,* 2020). Uz and Tavali (2014) reported changes in soil after the application of Vermicompost @ 40 t/ha observed 8.07 pH, 215.81-S/cm EC, 10.70 µg TPF/g dwt/h Dehydrogenase, 44.14 µg PNG/g dwt/h β-Glucosidase, 58.53 µg NH_4^+-N/g dwt h^{-2} Urease, 44.37 µg PNG/g dwt/h alkaline phosphatase enzymes. Lim *et al.,* (2015) reported that the application of vermicompost significantly increased plant dry weight and improved soil properties such as pH, organic matter content, and microbial activity. Aslam *et al.,* (2020) reported improved chemical properties of the soil, including electrical conductivity, pH, nutrient content, and organic matter status improvements, resulting from the application of vermicompost, led to enhanced plant growth and yield. The application of vermicompost improves soil microbial respiration rates, indicating enhanced soil microbial activity (Jha and Subramanian 2018).

Vermicompost and pest disease resistance

The scrutinization of the literature revealed that the vermicompost has the potential to prevent the diseases in plants. Chaoui *et al.,* (2002) elucidated the potential of vermicompost in mitigating plant diseases such as *Pythium damping-off*, root rot caused by *Rhizoctonia* sp and *Verticillium wilt* and revealed that vermicompost augments improved the microbial biomass and metabolic activity within the rhizosphere. Jangra *et al.,* (2019) investigated the impact of vermicompost on the chili after pest *Polyphagotarsonemus latus* and observed a substantial reduction in both the population and the number of eggs (5.05 eggs per leaf) laid by *Polyphagotarsonemus latus* when vermicompost was applied at a rate of 5 t ha^{-1}, compared to the control (6.18 eggs per leaf). Additionally, You *et al.,* (2019) evaluated the effect of bamboo waste-based vermicompost on damping-off disease in cucumbers found that vermicompost significantly reduced damping-off caused by *Pythium aphanidermatum*, *P. ultimum var. ultimum*, and *Rhizoctonia solani* AG1-IB compared to autoclaved vermicompost and a commercial nursery medium.

Application method of vermicompost

Vermicompost water extracts are also known as vermicompost "teas," i.e vermicompost tea (VCT) exhibited effects similar to those of vermicompost (Khomami *et al.,* 2019). It could potentially be utilized as a natural foliar fertilizer. The elevated levels of nutrients in VCT can be assimilated by foliar tissues thereby influencing plant growth and production (Chaichi *et al.,* 2018). The VCT can be made by soaking vermicompost in water (1:10 ratio), can be applied to soil or foliar sprayed at 200-500 liters per hectare, offering immediate nutrient uptake and pest resistance (Pant *et al.,* 2009). Vermicompost can be applied by spreading it across the field surface at a rate of 5-10 t ha^{-1}, ensuring uniform nutrient distribution (Suthar, 2009). These application methods and rates optimize the benefits of vermicompost in sustainable farming.

Different earthworms involved in vermicomposting

Epigeic earthworms such as *Eisenia foetida, Lumbricus rubellus, L. castaneus, L. festivus, Eiseniella tetraedra, Bimastus minusculus, B. eiseni, Dendrodrilus rubidus, Dendrobaena veneta, and D. octaedra,* are proficient bio-decomposers and nutrient providers. They demonstrate resilience to disturbances, contribute significantly to litter breakdown and early decomposition processes, making them highly effective organisms for vermicomposting applications (Pathma *et al.,* 2012).

Enzymatic profile of vermicompost

The application of vermicompost leads to an increase in the activity of enzymes such as acid phosphatases, inorganic pyrophosphatase, dehydrogenases, β-glucosidases and urease (Przemieniecki *et al.,* 2020b). Alidadi *et al.,* (2016) conducted the analysis of the enzymatic composition of vermicompost and observed the presence of dehydrogenase (29.64 ± 0.41 mg/g 24/h) enzyme. Turp *et al.,* (2023) reported the enzymatic analysis of vermicompost and observed urease (220 µg NH_4 g/h), β-glucosidase (95 µg PNP g/h), alkaline phosphatase (91 µg PNP/g/h), arylsulfatase (83 µg PNP g/h), acid phosphatase (60 µg PNP g/h).

Conventional compost VS. Vermicompost

Vermicompost is generally more nutritious than cow dung. Argentine farmers utilizing vermicompost reported it to be seven times richer in nutrients and growth-promoting properties compared to conventional composts (Munroe *et al.,* 2007, Pajon *et al.,* 2007). This superiority is largely attributed to the humus content in vermicompost, which is excreted by earthworms, whereas humus formation in conventional composting occurs over a prolonged period through the slow decay of organic matter. Additionally, even in small quantities, the humic acid in vermicompost stimulates plant growth (Canellas *et al.,* 2002). In-addition, vermicompost retained nutrients for a longer duration compared to conventional compost, which often lacked sufficient macro and micronutrients. Furthermore, vermicompost delivered essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) to plants more rapidly, whereas conventional compost took a longer time to release these nutrients. Vermicompost also exhibited higher porosity, better aeration, improved drainage, and greater water-holding capacity than conventional compost, primarily due to its humus content (Hajam *et al., 2023*).

Application of vermicompost and its impact on forage crops

The results showed that application of vermicompost @ 5 t/ha along with 75% of the recommended dose of inorganic fertilizers gave higher green (Maize 26.2 t/ha and Cowpea 8.10 t/ha) and dry fodder (Maize : 4.46 t/ha and Cowpea : 1.62 t/ha) yields and also resulted in increased fodder quality (Backiyavathy and Vijayakumar, 2006). The application of 10 t ha^{-1} vermicompost along with 75% recommended dose of fertilizers increased the green fodder and dry matter yield of sunflower by 60.8 and 66.2%, respectively, over the control on a pooled mean basis (Sheoran and Rana 2005).

CONCLUSION

Vermicompost is a biologically active organic amendment rich in both micro- and macronutrients, making it a valuable soil enhancer. It harbours diverse beneficial microorganisms, including phosphate solubilizers, nitrogen-fixing bacteria, enzyme producers, and plant growth-promoting microorganisms, which contribute to nutrient cycling and soil fertility. The microbial consortia within earthworm gut and castings facilitate organic matter decomposition, leading to increased enzymatic activities. Additionally, vermicompost exhibits antifungal properties that suppress plant pathogens. Its nutrient-rich composition and microbial diversity make it a promising biofertilizer for fodder crops and an effective component in conventional, integrated, and organic farming systems, promoting sustainable agricultural practices.

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