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REVIEW: VERMICOMPOST, ITS IMPORTANCE AND BENEFIT IN AGRICULTURE

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ABSTRACT. Vermicomposting is described as "bioxidation and stabilization of organic material involving the joint action of earthworms and mesophilic micro-organisms". Under appropriate conditions, worms eat agricultural waste and reduce the volume by 40 to 60%. Vermicompost produced by the activity of earthworms is rich in macro and micronutrients, vitamins, growth hormones, enzymes such as proteases, amylases, lipase, cellulase and chitinase and immobilized microflora. The enzymes continue to disintegrate organic matter even after they have been ejected from the worms. Reduced use of water for irrigation, reduced pest attack, reduced termite attack, reduced weed growth; faster rate of seed germination and rapid seedlings growth and development; greater numbers of fruits per plant (in vegetable crops) and greater numbers of seeds per year (in cereal crops) are only some of the beneficial effects of the vermicompost usage in agricultural production. Earthworms and vermicompost can boost horticultural production without agrochemicals. In spite of the benefits associated with vermicompost, its use is not widespread yet. This review attempts as increasing awareness of this local soil amendment.

Introduction

In recent years, the disposal of organic wastes from domestic, agricultural and industrial sources has caused increasing environmental and economic problems and many different technologies to address this problem have been developed. The growth of earthworms in organic wastes has been termed vermiculture and the processing of organic wastes by earthworms is known as vermicomposting (Edwards, 2004). There is a marked trend towards the use of novel technologies, mainly based on biological processes, for recycling and efficient utilization of organic residues. Therefore, it is possible to conserve the available resources and to recover the natural products, and in some cases, to combat the disposal problems and minimize the pollution effects. Vermicomposting has been arising as an innovative biotechnology for the conversion of agro-industrial wastes into value added products, which can be utilized for improving the soil structure and fertility in organic farming (Garg, Gupta, 2009).

Reduced use of water for irrigation, reduced pest attack, reduced termite attack, reduced weed growth; faster rate of seed germination and rapid seedlings growth and development; greater numbers of fruits per plant (in vegetable crops) and greater numbers of seeds per year (in cereal crops) are only some of the beneficial effects of the vermicompost usage in agricultural production (Anonymous, 2009).

Pure vermicompost is not so good for agricultural production, because it contains too much nutrients (Olle 2016a, Olle, 2017).

The beneficial effects in using vermicompost based substrates in agriculture (Olle, 2016b): it accelerates growth; increases crop yields; creates a favorable environment for beneficial micro-organisms; permanently improves soil structure; increases plant secretion; in case of plants with longer growing season, additional fertilization with biohumus or its leotion is sufficient, provision of mineral fertilizers is not necessary in this case; 100% natural, ideal for use in organic farming and in artificial environments.

Therefore the author decided to give a literature overview article about vermicompost, its importance and benefit in agriculture.

What is vermicomposting?

Vermicomposting is generally defined as the solid phase decomposition of organic residues in the aerobic environment by exploiting the optimum biological activity of earthworms and microorganisms (Garg, Gupta, 2009).

Vermicomposting is described as "bioxidation and stabilization of organic material involved by the joint action of earthworms and mesophilic micro-organisms". Vermicompost produced by the activity of earthworms is rich in macro and micronutrients, vitamins, growth hormones, enzymes such as proteases, amylases, lipase, cellulase and chitinase and immobilized microflora. The enzymes continue to disintegrate organic matter even after they have been ejected from the worms (Barik *et al*., 2011).

Vermicomposting involves the composting of organic wastes through earthworm activity. It has proven successful in processing sewage sludge and solids from wastewater, materials from breweries, paper waste, urban residues, food and animal wastes, as well as horticultural residues from processed potatoes, dead plants and the mushroom industry (Dominguez, Edwars, 2004).

Vermicomposting is a decomposition process involving the joint action of earthworms and microorganisms. Although microorganisms are responsible for the biochemical degradation of organic matter, earthworms are crucial drivers of the process, by fragmenting and conditioning the substrate and dramatically altering its biological activity. Earthworms act as mechanical blenders and by comminuting the organic matter they modify its physical and chemical status, gradually reducing its C:N ratio, increasing the surface area exposed to micro-organisms and making it much more favourable for microbial activity and further decomposition. Greatly during passage through the earthworm gut, they move fragments and bacteria-rich excrements, thus homogenizing the organic material. The end-product, or vermicompost, is a finely divided peat-like material with high porosity and water holding capacity that contains most nutrients in forms that are readily taken up by the plants. These earthworm casts are rich in organic matter and have high rates of mineralization that implicates a greatly enhanced plant availability of nutrients, particularly ammonium and nitrate (Dominguez, Edwars, 2004).

The vermicomposting process different phases during the process are as follows (Garg, Gupta, 2009): (1) Initial pre-composting phase: The organic waste is pre-composted for about 15 days before being fed to earthworms. During this phase, readily decomposable compounds are degraded and the potential volatile substances are eliminated which may be toxic to earthworms. (2) Mesophilic phase: During this phase, earthworms, through their characteristic functions of breaking up organic matter, combine it with the soil particles and enhance microbial activities and condition organic waste materials for the formation of organic manures. (3) Maturing and stabilization phase.

History

Earthworm has caught imagination of philosophers like Pascal and Thoreau (Adhikary, 2012). Civilizations, including Greece and Egypt valued the role earthworms played in soil. The ancient Egyptians were the first to recognize the beneficial status of the earthworm. The Egyptian Pharaoh, Cleopatra (69–30 B.C.) said, "Earthworms are sacred." She recognized the important role the worms played in fertilizing the Nile Valley croplands after annual floods. Removal of earthworms from Egypt was punishable by death. Egyptian farmers were not allowed to even touch an earthworm for fear of offending the God of fertility. The Ancient Greeks considered the earthworm to have an important role in improving the quality of the soil. The Greek philosopher Aristotle (384–322 B.C.) referred to worms as the intestines of the earth (Medany, 2011).

Sir Surpala (10 Cent. A.D., the ancient Indian scientist) recommended to add earthworms to the soil to receive sufficient yield of fruits as pomegranates (Sinha, 2014b).

Earthworms are truly justifying the beliefs and fulfilling the dreams of Sir Charles Darwin who called them as unheralded soldiers of humankind and friends of farmers and said that there may not be any other creature in world that has played so important a role in the history of life on earth (Sinha *et al*., 2014a). They are also justifying the beliefs of great Russian scientist Dr. Anatoly Igonin (Sinha *et al*., 2014a), who said: Nobody and nothing can be compared with earthworms and their positive influence on the whole living Nature; they create soil and improve soils fertility and provide critical biospheres functions: disinfecting, neutralizing, protective and productive (Sinha *et al*., 2014a).

Composition and quality of vermicompost

The agro-industrial wastes are huge source of plant nutrients and their disposal means the ultimate loss of the resourceful material. Some agro-industrial processing wastes explored for vermicomposting are presented in Table 1.

Table 1. Potential agro-industrial processing wastes (Garg, Gupta, 2009)

Agricultural wastes
Rice husk, cereal residues, wheat bran, millet straw *etc*.
Food processing waste
Canning industry waste, breweries waste, dairy industry waste, sugar industry waste press mud and trash, wine industry waste, oil industry waste-non edible oil seed cake, coffee pulp, cotton waste *etc*.
Wood processing waste
Wood chips, wood shavings, saw dust
Other industrial wastes
Fermentation waste, paper and cellulosic waste, vegetal tannery waste
Local organic products
Cocofiber dust, tea wastes, rice hulls *etc*.
Fruits and vegetable processing waste

Vermicompost is a peat like material containing most nutrients in plant available forms such as nitrates, phosphates, calcium, potassium, magnesium *etc*. It has high porosity, water holding capacity and high surface area that provides abundant sites for microbial activity and for the retention of nutrients. The plant growth regulators and other plant growth influencing materials *i.e.* auxins, cytokinins and humic substances etc. produced by the microbes have been found in vermicomposts. The nutrients status of the vermicompost obtained from different organic materials is given in Table 2 (Garg, Gupta, 2009).

Table 2. Chemical composition of vermicompost (Garg, Gupta, 2009)

Characteristics	Value
Organic carbon, %	9.15 to 17.88
Total Nitrogen, %	0.5 to 0.9
Phosphorus, %	0.1 to 0.26
Potassium %	0.15 to 0.256
Sodium %	0.055 to 0.3
Calcium & magnesium (Meq/100 g)	22.67 to 47.6
Copper; mg kg^{-1}	2.0 to 9.5
Iron, mg kg^{-1}	2.0 to 9.3
Zinc, mg kg^{-1}	5.7 to 9.3
Sulphur, mg kg^{-1}	128.0 to 548.0

Vermicomposting technology is a suitable tool for efficient conversion of agro-industrial processing wastes, which serves as a rich source of plant nutrients. These waste materials are packed with a tremendous source of energy, protein and nutrients, which would otherwise be lost if they are disposed as such in the open dumps and landfills. Moreover, with the use of vermicompost as organic amendments in the agriculture, recycling of the nutrients back to the soil takes place, in turn, maintaining the sustainability of the ecosystem (Garg, Gupta, 2009).

Roles of vermicompost

Beneficial roles of vermicompost (Adhikary, 2012): (1) Red worm castings contain a high percentage of humus. Humus helps soil particles form into clusters, which create channels for the passage of air and improve its capacity to hold water. (2) Humus is believed to aid in the prevention of harmful plant pathogens, fungi, nematodes and bacteria. (3) A worm casting (also known as worm cast or vermicast) is a biologically active mound containing thousands of bacteria, enzymes, and residues of plant materials that were not digested by the worms. (4) Castings contain nutrients that are readily available to plants. (5) The activity of the worm gut is like a miniature composting tube that mixes conditions and inoculates the residues. (6) Worm castings are the best imaginable potting soil for greenhouses or houseplants, as well as gardening and farming. (7) Plant Growth Regulating Activity: Some studies speculated that the growth responses of plants from vermicompost appeared more like "hormone induced activity" associated with the high levels of nutrients, humic acids and humates in vermicompost. (8) Ability to Develop Biological Resistance in Plants: Vermicompost contains some antibiotics and actinomycetes that help in increasing the "power of biological resistance" among the crop plants against pest and diseases. Spray of chemical pesticides was significantly reduced by over 75% where earthworms and vermicompost were used in agriculture. (9) Ability to Minimize Pests Attack: There seems to be strong evidence that worm castings sometimes repel hard-bodied pests. (10) Ability to Suppress Plant Disease: Studies reported that vermicompost application suppressed 20%–40% infection of insect pests *i.e.* aphids (*Myzus persicae*), mearly bugs (*Pseudococcus spp.*) and cabbage white caterpillars (*Peiris brassicae*) on pepper (*Capiscum annuum*), cabbage (*Brassica oleracea*) and tomato (*Lycopersicum esculentum*). (11) Vermimeal Production: With the increasing demand for animal feed protein bolstered by the continuing growth of human population and food source, the production of vermimeal be considered as the most economically feasible application of vermiculture.

The beneficial impacts of vermicompost on soil (Sinha, 2014b):

1. Increase the 'Soil Organic Matter' (SOM), soil structure and prevent soil erosion.
2. Increase beneficial soil microbes, microbial activity and nutrients.
3. Improve cation exchange capacity.
4. Reduces bulk density of soil, prevents soil compaction and erosion.
5. Suppression of soil-born plant diseases.
6. Increase water-holding capacity of soil.
7. Remove soil salinity and sodicity.
8. Maintain optimal pH value of soil.

Vermicompost is ideal organic manure for better growth and yield of many plants due to following reasons (Joshi *et al*., 2015):

1. Vermicompost has higher nutritional value than traditional composts.
2. This is due to increased rate of mineralization and degree of humification by the action of earthworms.
3. Vermicompost has high porosity, aeration, drainage, and water-holding capacity.
4. Presence of microbiota particularly fungi, bacteria and actinomycetes makes it suitable for plant growth. Nutrients such as nitrates, phosphates and exchangeable calcium and soluble potassium in plant-available forms are present in vermicompost.
5. Plant growth regulators and other plant growth influencing materials produced by microorganisms are also present in vermicompost.
6. Production of cytokinins and auxins was found in organic wastes that were processed by earthworms.
7. Earthworms release certain metabolites, such as vitamin B, vitamin D and similar substances into the soil.
8. In addition to increased N availability, P, K, Ca and Mg availability in the casts are found.

Vermicompost's role in the nutrition of agricultural fields has attracted attention of researchers worldwide only in recent decades. Waste management is considered as an integral part of a sustainable society, thereby necessitating diversion of biodegradable fractions of the societal waste from landfill into alternative management processes such as vermicomposting. Earthworms excreta (vermicast) is a nutritive organic fertilizer rich in humus, NPK, micronutrients, beneficial soil microbes; nitrogen-fixing, phosphate solubilizing bacteria, actinomycets and growth hormones auxins, gibberlins and cytokinins. Both vermicompost and its body liquid (vermiwash) are proven as both growth promoters and protectors for crop plants (Adhikary, 2012).

Vermicompost contains plant nutrients including N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and B. The high percentage of humic acids in vermicompost contributes to plant health, as it promotes the synthesis of phenolic compounds such as anthocyanins and flavonoids which may improve the plant quality and act as a deterrent to pests and diseases (Theusnissen *et al*., 2010).

Vermicompost is made up primarily of C, H and O and contains nutrients such as N, P, Ca, K, Mg, S and micronutrients that exhibit similar effects on plant growth and yield as inorganic fertilizers applied to soil. Similarly, vermicompost contains a high proportion of humic substances, which provide numerous sites for chemical reaction; microbial components known to enhance plant growth and disease suppression through the activities of bacteria (*Bacillus*), yeasts (*Sporobolomyces* and Cryptococcus) and fungi (*Trichoderma*), as well as chemical antagonists such as phenols and amino acids (Theunissen *et al*., 2010).

Earthworms and vermicompost can boost horticultural production without agrochemicals. It will provide several social, economic and environmental benefits to the society by way of producing 'chemical-free' safe, 'nutritive and health protective' (rich in minerals and antioxidants) foods (even against some forms of cancers) for the people; salvaging human wastes and replacing the dangerous 'agrochemicals' from the face of earth. The use of vermicompost in farms also 'sequester' huge amounts of atmospheric carbon (assimilated by green plants during photosynthesis) and bury them back into the soil improving the soil fertility, preventing erosion or compaction and also reducing greenhouse gas and mitigating global warming (Sinha *et al*., 2013).

Effect of vermicompost on agricultural crop performance

Yield. Studies on the production of important vegetable crops like tomato (*Lycopersicon esculentum*), eggplant (*Solanum melongena)* have yielded very good results (Adhikary, 2012). Similarly the overall productivity of potato was significantly higher on vermicompost applied about 6 tons/ha as compared to control (Adhikary, 2012). Vermicast produced higher garden pea green pod plants, higher green grain weight per plant, and higher green pod yield as compared to chemical fertilizer (Adhikary, 2012). The perusal of the data revealed that "Parthenium Vermicompost" applied at 5 t/ha enhanced the yield of eggplants (*Solanum melongena*) (Seethalakshmi, 2011). The use of vermicompost as a source of organic manure in supplementing chemical fertilizer is becoming popular among the farmers of the country. Vermicompost increase in crop yield probably because of higher nutrient uptake (Seethalakshmi, 2011).

Growth. Worms and vermicompost promoted excellent growth in the vegetable crop with more flowers and fruits development (Adhikary, 2012). Vermicompost can have dramatic effects upon the germination, growth, flowering, fruiting and yields of crops (Mistry, 2015). Vermicompost stimulated growth of tomato transplants, with up to a 2.2-fold increase occurring in shoot biomass. Differences in growth were attributed mainly to differences in nutrient content of the potting mixtures, but some changes in physical and biological properties of the substrate could also be responsible (Tringovska, Dintcheva, 2012). The perusal of the data revealed that "Parthenium Vermicompost" applied at 5 t/ha enhanced the growth of eggplants (*Solanum melongena*) (Seethalakshmi, 2011). Application of vermicompost increased seed germination, stem height, number of leaves, leaf area, leaf dry weight, root length, root number, total yield, number of fruits/plant (Joshi *et al*., 2015).

Nutrient content. Vermicast produced higher percentage of protein content and carbohydrates in garden pea as compared to chemical fertilizer (Adhikary, 2012). The perusal of the data revealed that "Parthenium Vermicompost" applied at 5 t/ha enhanced the food quality of eggplants (*Solanum melongena*) (Seethalakshmi, 2011). Application of vermicompost increased chlorophyll content, pH of juice, total soluble solids of juice, micro and macronutrients, carbohydrate (%) and protein (%) content and improved the quality of the fruits and seeds. Studies suggested that treatments of humic acids, plant growth promoting bacteria and vermicomposts could be used for a sustainable agriculture discouraging the use of chemical fertilizers (Joshi *et al*., 2015).

Plant protection. The most significant observation was drastically less incidence of diseases in worm and vermicompost applied plant (Adhikary, 2012). Accordingly, vermicompost also protects plants against various pests and diseases either by suppressing or repelling them or by inducing biological resistance in plants (Sinha *et al*., 2013). Disease resistance is a plus Cornell University lab trials have shown promise for applying the solid vermicompost and its non-aerated extract as a control for *Pythium aphanidermatum*, a disease common to many vegetable crops. "Garlic doesn't tend to have *Pythium* problems," points out Fraser (Dunn, 2011). "So I was looking for how well the compost would support plant growth. We saw a definite impact on leaf growth and weight gain." "The healthier and more vigorous the plants are with the microbiology in their root zone, the more the plants are able to thwart attacks from destructive crop pathogens and insect pests," he elaborates Recent Ohio State University studies also concluded that crops fed with vermicompost are also more resistant to blight, bacterial wilt, parasitic nematode attacks and powdery mildew than those on synthetic fertilizers (Dunn, 2011).

Human health. Organically grown fruits and vegetables especially on 'earthworms and vermicompost' have been found to be highly nutritious, rich in 'proteins, minerals and vitamins' and 'antioxidants' than their chemically grown counterparts and can be highly beneficial for human health. They have elevated antioxidants levels in about 85% of the cases studied. They have been found to be protective against several forms of 'cancers' and against 'cardiovascular diseases' (Sinha, 2012).

Conclusions

Vermicompost produced by the activity of earthworms is rich in macro and micronutrients, vitamins, growth hormones, enzymes such as proteases, amylases, lipase, cellulose and chitinase and immobilized microflora. Vermicompost is optimal organic manure for better growth and yield of many plants. It can increase the production of crops and prevent them from harmful pests without polluting the environment. Application of vermicompost increased growth, improved plants nutrient content, and improved the quality of the fruits and seeds.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author contributions

MO – contributed to the preparation, creation and/or presentation of the manuscript.

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