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A REVIEW

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Vermicompost - A boon to crop production

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ABSTRACT

Vermicomposting is a process in which earthworms are used to convert organic materials into humus-like material known as vermicompost. A number of researchers throughout the world have found that the nutrient profile in vermicompost is generally higher than traditional compost. In fact, vermicompost can enhance soil fertility physically, chemically and biologically. Physically, vermicompost-treated soil has better aeration, porosity, bulk density and water retention. Chemical properties such as pH, electrical conductivity and organic matter content are also improved for better crop yield. It contains plant nutrient like N, P, K, Ca, Mg, Fe, Mn and Zn which has a positive effect on the plant growth, yield, soil fertility and soil microbes. Environmental as well as health problems have raised the alarm on the effects of usage of chemical fertilizer and consuming of heavily chemically fertilized crops. Vermicomposting has been getting attention due to its environmental friendly approach.. This review paper discusses in detail the effects of vermicompost on soil fertility physically, chemically and biologically.

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INTRODUCTION

The long term use of inorganic fertilizers without organic supplements damages the soil physical, chemical and biological properties and cause environmental pollution (Aebiach *et al.*, 2000). Heavy use of agrochemicals since the "green revolution" of the 1960s boosted food productivity at the cost of environment and society. It killed the beneficial soil organisms and destroyed their natural fertility, impaired the power of 'biological resistance' in crops making them more susceptible to pests and diseases. Chemically grown foods have adversely affected human health. Environmental friendly approach of producing high quality organic fertilizer is one of the major concerns of researchers lately Organic manures act not only as a source of nutrients and organic matter, but also increase size, biodiversity and activity of the microbial population in soil, influence structure, nutrients turnover and many other related physical, chemical and biological parameters of the soil (Aebiach *et al.*, 2000). Vermicomposting technology is globally becoming a popular solid waste management technique (Abbasi *et al.*, 2009; Thamaraj *et al.*, 2011; Manyuchi *et al.*, 2012 and Manyuchi *et al.*, 2013). Vermicomposting is the bioconversion of organic waste into a bio-fertilizer due to earthworms' activity (Abbasi *et al.*, 2009; Shweta, 2011; Thamaraj *et al.*, 2011; Manyuchi *et al.*, 2012 and Manyuchi *et al.*, 2013). The earthworms feed on the organic waste and the earthworms' gut acts as a bioreactor whereby the vermicasts are produced (Ansari and Sukhraj, 2010). By the time the organic waste is excreted by the earthworms as vermicasts, it will be rich in nitrogen (N), phosphorus (P) and potassium (K) as well as trace elements depending on the feedstock type used (Thamaraj *et al.*, 2011; Manyuchi *et al.*, 2012; Muthukumaravel *et al.*, 2008; Palsania *et al.*, 2008 and Gurav and Pathade, 2011). This environmental friendly approach and the rising demand of the naturally derived fertilizer have brought the interest of preparing this review.

Vermicomposting :

Vermicomposting is a decomposition process involving the joint action of earthworms and micro-organisms.Vermicomposting, that involves the composting of organic wastes through earthworm activity, has proven to be successful in processing sewage sludge and solids from wastewater (Neuhauser *et al.*, 1988 and Dominguez *et al.*, 2000), materials from breweries (Butt, 1993), paper waste (Butt 1993, and Elvira *et al.*, 1995), urban residues, food and animal wastes (Edwards *et al.*, 1985; Allevi *et al.*, 1987; Edwards, 1988; Elvira *et al.*, 1996 and Dominguez and Edwards, 1997), as well as horticultural residues from processed potatoes, dead plants and the mushroom industry (Edwards, 1988). It is a mesophilic process that utilizes micro-organisms and earthworms that are active at 10° C to 32° C (not ambient temperature but temperature within the pile of moist organic material). The process is fast as the material passes through the earthworm gut, a significant but not fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators and fortified with pest repellence attributes as well. In short, earthworms through a type of biological alchemy are capable of transforming garbage into "gold" (Crescent, 2003 and Vermi, 2011).

Earthworms :

Various earthworms have been used for vermicomposting and these include *Megascolex Mauritii, Eisenia Fetida, Eudrilus Eugeniae, Perionnyx Excavatus, Lampito Mauritii, Eisenia Andrei, Lampito Rubellus and Drawida Willis* (Thamaraj *et al.*, 2011; Manyuchi *et al.*, 2012; Ndegwa *et al.*, 2000; Singh and Suthar, 2012; Manyuchi *et al.*, 2013). However, *Eisenia Fetida* has been noted as the earthworm of choice for vermicomposting and is adaptable to changing conditions and has lower chances of compromising on the vermicompost process (Thamaraj *et al.*, 2011; Manyuchi *et al.*, 2012; Ansari and Sukhraj, 2010; Ndegwa *et al.*, 2000; Singh and Suthar, 2012 and Manyuchi *et al.*, 2013). The change in earthworms weight, length, reproduction rate and population density have also been used to measure the progress of vermicomposting (Kumari *et al*., 2011; Lim *et al.*, 2011; Lim *et al.*, 2012 and Narkhede *et al.*, 2011).

Influence of environmental factors on survival and growth of earthworms :

Earthworms exhibit fairly complex responses to changes in temperature. Neuhauser *et al.* (1988) studied the potential of several species of earthworms to grow in sewage sludge and they concluded that all these species have optimum temperatures for growth ranging between 15 and 25° C.

There is a relationship between the moisture content in organic wastes and the growth rate of earthworms. In vermicomposting systems, the optimum range of moisture contents has been reported to be between 50 to 90 per cent.(Dominguez *et al.*, 2000).

Earthworms are relatively tolerant to pH, but when given a choice in the pH gradient, they move towards the more acid material, with a pH preference of 5.0. Earthworms avoid acid soils of pH less than 4.5 and prolonged exposure to such soils could have lethal effects (Edwards and Bohlen, 1996).

Earthworms have no specialized respiratory organs, and oxygen diffuses in through the body wall and carbon dioxide diffuses out. However, earthworms are very sensitive to anaerobic conditions and their respiration rates are depressed in low oxygen concentrations, around 55 to 65 per cent (e.g., at oxygen levels of 0.25 its normal partial pressure (Edwards and Bohlen, 1996) and feeding activity might be reduced under these sub-optimal conditions.

Earthworms are very sensitive to ammonia and cannot survive in organic wastes containing high levels of this cation (e.g., fresh poultry litter). They also die in organic wastes with large amounts of inorganic salts (%) (Dominguez *et al*., 2000).

When environmental conditions are maintained at adequate ranges, a maximum yield of 10 dry unit weights of earthworm biomass can be expected from an initial 100 units (dry weight) of substrate, independent of nitrogen concentration, when a minimum of about 1 per cent or more N is initially present (Hartenstein, 1983 and Edwards, 1988).

Benefits of vermicomposting :

Vermicompost, like conventional compost, provides many benefits to agricultural soil, including increased ability to retain moisture, better nutrient-holding capacity, better soil structure, and higher levels of microbial activity. A search of the literature, however, indicates that vermicompost may be superior to conventional aerobic compost in a number of areas. These include the following.

Availability of nutrients :

Vermicompost is an excellent soil additive made up of digested compost. Worm castings are much higher in nutrients and microbial life and therefore, are considered as a higher value product. The chemical composition of vermicasting is given in Table 1. Worm castings contain upto 5 times the plant available nutrients found in average potting soil mixes. Chemical analysis of the castings was conducted (Ruz-Jerez *et al*., 1992 and Parkin and Berry, 1994) and found that it contains 5 times the available nitrogen, 7 times the available potash and 1.5 times more calcium than that found in 15 cm of good top soil. Atiyeh *et al*. (2000) found that vermicompost tended to be higher in nitrates, which is the more plant-available form of nitrogen. Similarly, work at NSAC by Hammermeister *et al*. (2004) indicated that "Vermicomposted manure has high N availability on a weight basis". In addition, the nutrient life is upto 6 times more in comparison to the other types of potting mixes. It is reported that phosphorous while passage through gut of worms is converted to the plant available form (Reinecke *et al*., 1992). Phosphorus is usually considered as a limiting element for plant growth. Therefore, any process that significantly increases phosphorus availability through plants and organic matter will be very important for agriculture. The average potting soil mixes that is found in the market are usually sterile and do not have a microbial population. The combination of nutrients and microbial organisms are essential for growing healthy and productive plants. Vermicompost not only adds microbial organisms and nutrients that have long lasting residual effects, it also modulates structure to the existing soil, in-creases water retention capacity. Vermicompost may also have significant effects on the soil physical properties. It was observed that addition of vermicompost @ 20 t ha^{-1} to an agricultural soil in two consecutive years significantly improved soil porosity and aggregate stability (Ferreras *et al*., 2006). The number of large, elongated soil macro pores in-creased significantly after a single application of a dose of vermicompost equivalent to 200 kg ha^{-1} of nitrogen to a cornfield (Marinari *et al*., 2000). Similarly, a significant decrease in soil bulk density and a significant increase in soil pH and total organic carbon after application of vermicompost in two consecutive growing seasons, at a rate equivalent to 60 kg ha^{-1} of N. Together these changes in soil proper-ties improve the availability of air and water, thus encouraging seedling emergence and root growth (Gopinath *et al*., 2008). Vermicompost contains an average of 1.5 per cent - 2.2 per cent N, 1.8 per cent - 2.2 per cent P and 1.0 per cent - 1.5 per cent K. The organic carbon is ranging from 9.15 to 17.98 and contains micronutrients like sodium (Na), calcium (Ca), zinc (Zn), sulphur (S), magnesium (Mg) and iron (Fe). Hammermeister *et al*. (2004) showed that the supply rate of several nutrients, including P, K, S and Mg, were increased by vermicomposting.

In a report (Nagavallemma *et al*., 2004) it is observed that the worm castings contain higher percentage (nearly two fold) of both macro and micronutrients than the garden compost Earthworms consume various organic wastes and reduce the volume by 40 per cent - 60 per cent. Each earthworm weighs about 0.5 to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50 per cent of the waste it consumes in a day. The moisture content of castings ranges between 32 per cent to 66 per cent and the pH is around 7.0.

From various studies it is also, evident that vermicompost provides all nutrients in readily available form and enhances uptake of nutrients by plants. Soil available nitrogen increased significantly with increasing levels of vermicompost and highest nitrogen uptake was obtained at 50 per cent of the recommended fertilizer rate plus 10 t ha^{-1} vermicompost. Similarly, the uptake of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by rice (*Oryza sativa* L.) plant was highest when fertilizer was applied in combination with vermicompost (Jadhav *et al.*, 1997). The production of potato (*Solanum tuberosum*) by application of vermicompost in a reclaimed sodic soil in India was studied and observed that with good potato growth the sodicity (ESP) of the soil was also reduced from initial 96.74 kg/ha to 73.68 kg/ha in just about 12 weeks. The average available nitrogen (N) content of the soil increased from initial 336.00 kg/ha to 829.33 kg/ha (Ansari, 2008). Vermicompost contains enzymes like amylase, lipase, cellulase and chitinase, which can break down the organic matter in the soil to release the nutrients and make it available to the plant roots (Chaoui *et al.*, 2003).

Availability of beneficial micro-organisms :

The literature has less information on this subject than on nutrient availability, yet it is widely believed that vermicompost greatly exceeds conventional compost with respect to levels of beneficial microbial activity. Much of the work on this subject has been done at Ohio State University, led by Dr. Clive Edwards (Subler *et al.*, 1998). In an interview (Edwards, 1999), he stated that vermicompost may be as much as 1000 times as microbially active as conventional compost, although that figure is not always achieved. Moreover, he went on to say that " ...these are microbes which are much better at transforming nutrients into forms readily taken up by plants than you find in compost – because we're talking about thermophillic microbes in compost – so that the microbial spectrum is quite different and also much more beneficial in a vermicompost. I mean, I will stick by what I have said a number of times that a vermicompost is much, much preferable to a compost if you're going in for a plant-growth medium."

Enhances plant growth :

This is the area in which the most interesting and exciting results have been obtained. Many researchers have found that vermicompost stimulates further plant growth even when the plants are already receiving optimal nutrition. Atiyeh *et al.* (2002) conducted an extensive review of the literature with regard to this phenomenon. The authors stated that: "These investigations have demonstrated consistently that vermicomposted organic wastes have beneficial effects on plant growth independent of nutritional transformations and availability. Whether they are used as soil additives or as components of horticultural soil less media, vermicomposts have consistently improved seed germination, enhanced seedling growth and development, and increased plant productivity much more than would be possible from the mere conversion of mineral nutrients into more plant-available forms." Moreover, the authors go on to state a finding that others have also reported (e.g., Arancon, 2004), that maximum benefit from vermicompost is obtained when it constitutes between 10 and 40 per cent of the growing medium. It appears that levels of vermicompost higher than 40 per cent do not increase benefit and may even result in decreased growth or yield.

Atiyeh *et al.* (2000) further speculate that the growth responses observed may be due to hormone-like activity associated with the high levels of humic acids and humates in vermicomposts: "…there seems a strong possibility that …plant growth regulators which are relatively transient may become adsorbed on to humates and act in conjunction with them to influence plant growth". This important concept, that vermicompost includes plant-growth regulators which increase growth and yield, has been cited and is being further investigated by several researchers (Canellas *et al.*, 2002).

Suppresses diseases :

There has been considerable anecdotal evidence in recent years regarding the ability of vermicompost to protect plants against various diseases. The theory behind this claim is that the high levels of beneficial micro-organisms in vermicompost protect plants by out-competing pathogens for available resources (starving them, so to speak), while also blocking their access to plant roots by occupying all the available sites. This analysis is based on the concept of the "soil foodweb", a soil-ecology-based approach pioneered by Dr. Elaine Ingham of Corvallis, Oregon (*http://www.soilfoodweb.com*). Work on this attribute of vermicompost is still in its infancy, but research by both Dr. Ingham's labs and the Ohio State Soil Ecology Laboratory are very promising. With regard to the latter institution, Edwards and Arancon (2004) report that "…we have researched the effects of relatively small applications of commercially-produced vermicomposts, on attacks by Pythium on cucumbers, Rhizoctonia on radishes in the greenhouse, and by Verticillium on strawberries and Phomopsis and Sphaerotheca fulginae on grapes in the field. In all of these experiments, the vermicompost applications suppressed the incidence of the disease significantly." The authors go on to say that the pathogen suppression disappeared when the vermicompost was sterilized, indicating that the mechanism involved was microbial antagonism. Arancon (2004) indicates that OSU's Soil Ecology Laboratory will be conducting significant research in this area over the next few years.

Repulses the pests :

Work in this area is very new and results to date have been inconsistent. Never the less, there seems to be strong evidence that worm castings sometimes repel hard-bodied pests (Biocycle, 2001; Arancon, 2004 and Edwards and Arancon, 2004). Why this repellency works sometimes and not others remains to be determined. One theory is put forward by George Hahn, a vermicompost producer in California, who claims that his product repels many different insect pests. He feels that this is due to the production by the worms of the enzyme chitinase, which breaks down the chitin in the insects' exoskeleton. Arancon (2004) believes that the potential exists, but that the factors are complicated and are a function of the entire soil foodweb, rather than one particular substance such as chitinase. In recent research, Edwards and Arancon (2004) report statistically significant decreases in arthropod (aphid, mealy bug, spider mite) populations and subsequent reductions in plant damage, in tomato, pepper and cabbage trials with 20 per cent and 40 per cent vermicompost additions to Metro Mix 360 (the control). They also found statistically significant suppression of plant-parasitic nematodes in field trials with peppers, tomatoes, strawberries, and grapes. Much more research is required, however, before vermicompost can be considered as an alternative to pesticides or alternative, non-toxic methods of pest control.

Reduces the use of fertilizer :

Over successive years of application, vermicompost build-up the soils natural fertility improving its total physical (porous), chemical (rich in nutrients) and biological (beneficial soil microbes) properties. It also regenerates a rich population of worms in the farm soil from the cocoons which further help improve soil fertility and subsequently lesser amount of vermicompost is required to maintain a good yield and productivity (Bhawalkar, 1995; Chaoui *et al.*, 2003 and Sinha *et al.*, 2009). On the contrary, with the continued application of chemical fertilizers over the years the natural fertility of soil is destroyed and it becomes addict. Subsequently greater amount of chemicals are required to maintain the same yield and productivity of previous years. There is also significant loss of chemical fertilizer from the farm soil due to oxidation in sunlight. Study reveal that upon application of 100 kg urea (N) in farm soil, 40-50 kg gets oxidised and escapes as ammonia (NH_3) into the air, about 20-25 kg leaches underground polluting the groundwater, while only 20-25 kg is available to plants.(Suhane, 2007).

Reduces the water requirement for irrigation :

Vermicompost has very high porosity, aeration,

Table 1 : Chemical composition of vermicasting (Kumar, 1994)

Parameter	Value
Organic carbon (%)	9.15 to 17.88
Total nitrogen (%)	0.5 to 0.90
Available phosphorus'(%)	0.1 to 0.26
Available potassium (%)	10.15 to 0.56
Available sodium (%)	0.05 to 0.30
Ca and Mg (MEQ/IOO g)	22.67 to 47.6
Copper (ppm)	2.0 to 9.5
Iron (ppm)	5.7 to 9.3
Zinc (ppm)	5.7 to 11.50
Available sulphur (ppm)	128.0 to 548.0

* Worms fed on different types of organic wastes

drainage and water holding capacity than the conventional compost (Nighawan and Kanwar, 1952) and hence, the use of vermicompost reduces the requirement of water for irrigation by about 30 per cent - 40 per cent. On the contrary, use of chemical fertilizers require high amount of water for irrigation.

Increases the yield :

Banana plants grow well when vermicompost was applied (Barve, 1992) with having a mean bunch weight of 15 kg / plant, more fingers/branch and more reducing sugars. Vermicompost at a rate of 250.000 worms / ha resulted in a significantly reduced harvesting time in "Rajapuri" banana (Athani *et al.*, 1999). Venkatesh *et al.* (1997) revealed that *in situ* vermiculture and use of vermicompost with graded levels of chemical fertilizers of vermicompost alone increased the yield of grapes (*V. vinifera*) significantly more than the control, which had also been reported earlier (Gunjal and Nikam, 1992). Application of vermicompost at 2.5 t/ha was reported to significantly increase the yield, sweetness and reduce the harvesting period when compared to the control, where as application in combination with *Neem* cake gave significantly higher and better yield than control and higher yield, improved quality of custard apple (*Annono squamosa*) (Patnaik,1992) by soil application of vermicompost. The application of vermicompost increased the growth and yield of peppers (*Piper nigrum*) significantly, including increased leaf area, plant shoot biomass and marketable fruit weights (Norman *et al.*, 2005). Sanwal *et al*. (2007) observed that tomato (*Solanum lycopersicum*) and okra (*Hibiscus esculcnta*) were also reported with high growth and yield parameters when vermicompost was applied (Premsekhar and Rajashree, 2009). (Prabha *et al.*, 2007) showed that growth parameters (root length, shoot length, number leaves) of vegetables like *Hibiscus esculenta* and *Solanum melongena* and medicinal plants like (*Adhatoda vasica* and *Solanum trilobatum* showed higher values in vermicompost applied after 90 days, the germination percentage was also higher in vegetable peanuts to which vermicompost was applied. The application of vermicompost provided better yield than other organic manures and the control in marigold (*Calendula officinalis*) as reported by (Singh *et al.*, 2007). A laboratory experiment conducted using *Octolasion tyrtacum* on maize, barley and wheat showed better growth parameters of shoot and root(Bisht *et al.*, 2006). Yield of (*Alliam cepa*) increased significantly when 100 and 50 per cent nitrogen was applied through vermicompost produced by *E.eugeniae* using decomposed leaf powder along with 50 kg/ha, phosphorus potassium + 50 kg/ha, k in separate plots (Rao *et al.*, 2010) . The rate of application of earthworms for *in situ* vermiculture along with the species employed and application of vermicompost, which have shown growth and yield attributes (increase in height, mean bunch weight, leaves, fruits, nutrients) for horticultural crops suggest the significance of vermicompost in the field of agriculture and food production, which is of prime importance for a developing country like India.

Conclusion :

Earthworms activity influences the rate of soil organic matter. Improvements in the consistency of soil texture with a concomitant increase in porosity, infiltration and soil – water retention are other characteristics of worm worked soils (Munnoli, 2007). The most effective uses of earthworms are organic waste management and supplement of readily available plant nutrients and vermicompost demands the credit as it maintains as well as improves soil health. Thus an application of vermicompost not only enrich the nutrient status of soil but also elevates the physical condition of it. Therefore it is said that vermicomposting and vermiculture are environmentally beneficial processes that have great potential and provides the best answer for ecological agriculture, as components of sustainable agriculture.

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