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Vermicompost and its Role in Plant Growth Promotion

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ABSTRACT

Intense use of agrochemicals, including inorganic fertilizers and pesticides, since "green revolution" of 1960s boosted crop productivity but at the expense of environment and health. This led to the exploration of alternatives to chemical fertilizers and pesticides among scientific communities. Several researches on potential of earthworms to degrade solid organic matter and analysis of worm cast have demonstrated the use of earthworm cast (vermicompost) in sustainable agriculture. Vermicompost is a nutritive organic fertilizer enriched with plant available forms of macro (Nitrogen, Phosphorus and Potassium) and micro (Iron, Copper, Zinc, etc.) nutrients, beneficial soil microbes; nitrogen-fixing and phosphate solubilizing bacteria, actinomycetes and plant growth regulators like auxins, cytokinins and gibberellins. In addition, composition of vermicompost show antagonistic ability against soil-borne pathogens thereby improving plant health. This article presents the importance and use of vermicompost in plant growth and protection and provides the insight on vermicomposting research in Nepal.

Key words: Vermicompost, Earthworm, Plant Growth Hormones, Soil Supplement, Vermisystems

INTRODUCTION

Vermicompost is finely divided peat-like material with low C:N ratio, high porosity, aeration, drainage, water holding capacity, microbial activity and is the end product of non-thermophilic biodegradation of organic materials by combined action of earthworms and associated microbes (Edwards and Burrows, 1988; Atiyeh *et al*., 2000a, 2000b; Arancon *et al*,. 2004). Earthworms act as mechanical blenders and by comminuting the organic substrate they alter its physical and chemical status thereby increasing the surface area favorable for microbial decomposition (Dominguez, 2004).
Earthworms after consuming soil and organic substances excrete tiny pellets or vermicast which is a nutritive organic fertilizer rich in humus, macronutrients (nitrogen, phosphorus and potassium), micronutrients, beneficial soil microflora, actinomycetes, and plant growth regulators (Adhikary, 2012). Earthworm gut plays a vital role in processing of soil and organic matters.(Drake and Horn, 2007) Activities of endosymbiotic microbes and gut enzymes (cellulase, protease, chitinase acid and phosphatase) of earthworm aid in transformation of ingested soil and organic matters into valuable product constituting essential nutrients and active components of microbial biomass (Zhang *et al*., 2000).

NUTRITIONAL QUALITY OF VERMICOMPOST

Important nutrients such as nitrogen, phosphorus, potassium, and calcium present in the feed material are converted through microbial action into available forms for plants (Kaushik and Garg, 2003). Vermicompost is abundant with macronutrients NKP (Nitrogen 2-3%, Potassium 1.85-2.25% and Phosphorus 1.55-2.25%) and micronutrients with beneficial microbes (Actinomycetes, *Azotobacter*, *Rhizobium*, *Nitrobacter* and Phosphate Solubilizing Bacteria, ranging from 10^2 - 10^6 per gm of vermicompost) and plant growth regulators (auxins, cytokinins and gibberlins) which are mandatory for plant growth (Edwards *et al*., 2004; Sinha *et al*., 2010). Quality of vermicomposts are in correlation with the type of feeding materials for vermicomposting and the earthworm species used. *Perionyx excavatus* (Perrier) was found to decompose waste resources generated from agricultural practices (crop residues, farm yard manure, and cattle dung) with the significant decrease in organic C content (21-29%), increase in total N (91-144%), available P (63-105%) and exchangeable K (45-90%) (Suthar, 2007). Use of *E. fetida* and post-harvest residues of wheat, millet and pulse as feeds for earthworms resulted in a significant increase in total N (97.3-155%), available P (67.5-123.5%), exchangeable K (38.3-112.9%), and exchangeable Ca (23.3-53.2%) and decrease in organic C content (20.4-29.0%) in the different vermibeds (Suthar, 2009). Humic acid present in worm casts provides binding sites for nutrients such as phosphorus, potassium, sulfur, iron, calcium; releases these elements when plant requires and stimulates plant growth even with small amount of humic acid in the vermicompost (Canellas *et al*., 2002; Zandonadi *et al.*, 2007**;** Adhikary, 2012**)**.

SOURCES OF VERMICOMPOST

The ability of some earthworms to consume a wide range of organic residues has been fully established. Vermicomposting has been shown to be successful for processing sewage sludge (Domínguez, *et al*., 2000; Gupta and Garg, 2008; Ludibeth *et al*., 2012), cotton waste from hospitals (Pramanik and Chung, 2010; Mathur *et al*., 2006), fresh water weeds (Najar and Khan, 2013), institutional and agro-residues (Garg *et al*., 2006; Suthar 2009) and animal manures (Chan and Griffiths, 1988; Garg *et al*., 2005). Eco-friendly conversion of these organic remains via earthworms provides a best alternative to manage solid wastes and generate valuable organic fertilizers.

POTENTIAL SPECIES OF EARTHWORM FOR VERMICULTURE

Eisenia fetida (Savigny 1826), *Dendrodrilus rubidus* (Savigny 1826), *Dendrobaena veneta* (Rosa 1886), *Lumbricus rubellus* (Hoffmeister 1843), *Drawida nepalensis* (Michaelsen 1907), *Eudrilus eugeniae* (Kinberg 1867), *Perionyx excavatus* (Perrier 1872), *Polypheretima elongata* (Perrier 1872) are the species of earthworms found in the world that show potential for vermicomposting while, most vermiculture operations in Southeast Asia use *Eisenia fetida* (Savigny 1826) and *Eisenia andrei* (Bouché 1972) because these species being epigeic (Bouché 1977) display characteristics like high rates of processing of organic wastes, high reproductive rates and tolerant to wide range of environmental factors (Dominguez, 2004; Gunadi, 2011).

ROLES OF VERMICOMPOST IN PLANT GROWTH AND DEVELOPMENT

Vermicompost accelerates plant growth directly by supplying nutrients and indirectly by enhancing the communities of plant friendly microbes by suppressing soil borne diseases (Canellas *et al*., 2002; Zandonadi *et al.*, 2007; Lazcano and Dominguez, 2011).

1. Source of plant nutrients:

From earlier findings it is evident that vermicompost provides all necessary nutrients in plant available forms and also enhances uptake of nutrients by plants. Significant accumulation of N, P, K, Ca and Mg in root and shoot system with the application of humic acids derived from vermicompost was correlated to uptake of nutrients by plants (Baldotto *et al*., 2009). Moreover, integrated application of vermicompost and inorganic fertilizer showed increased nutrient content in plant body. Vermicompost enriched with P_2O_5 demonstrated its superiority over other treatments for yield and uptake of major nutrients like N, P, K, Ca and Mg (Kumari and Ushakumari, 2002).

2. Greater diversity of beneficial microbes:

Earthworm enhances microbial diversity and enzymatic activities of ingested microbes through gut associated processes (Drake and Horn, 2007). As a result, vermicompost consisted of greater pool of soil friendly bacteria, fungi and actinomycetes (Brown, 1995; Chaoui *et al*., 2003). Digestive enzymes (lipases, chitinases, and cellulases) are secreted into the intestine of earthworms by worm and ingested microorganisms which function in decompostition of ingested organic wastes (Urbasek and Pizl, 1991).

Earthworm gut provides home for anaerobic nitrogen-fixing bacteria and excrete them along with nutrients in its cast (Singleton *et al*., 2003). Changes in biochemical properties of cow manure during processing by earthworms (*Eisenia andrei* (Bouché) and the effects on seedling growth of lettuce and tomato established the effect of earthworms to enhance the activity of microbes responsible for nitrogen mineralization and increase the rates of conversion of ammonium-nitrogen into plant available forms (Atiyeh *et al*., 2000c).
Phosphorus is usually considered as limiting element for plants as it is present in insoluble forms in greater amount in the soil but plant can uptake only phosphate in a soluble ionic form (Pi) (Goldstein, 1986). Enrichment of vermicompost with phosphate solubilizing bacteria like *Pseudomonas striata* aids in conversion of phosphorus in plant available form when phosphorus containing substances are added in the organic feed (Kumar and Singh, 2001). (Kaushik *et al*., 2008) demonstrated that enrichment of vermicomposts (prepared from cow dung spiked solid textile mill sludge) with nitrogen fixing and phosphate solubilizing bacteria resulted in greater phosphorus content (20.8 ± 0.20 g kg^{-1}) in *Pseudomonas maltophila* inoculated cow dung vermicompost as compared to cow dung plus sludge vermicompost (0.45 g kg^{-1}) after 75th day of inoculation. Fungi capable of degrading cellulose can be part of the diet of earthworms and get excreted along with worm cast. When, earthworms ingest cellulolytic fungi along with the organic feed, cellulolytic activity in their gut is attributed to those fungi and the cellulase enzymes of earthworms gut. In presence of earthworms (*Eisenia fetida*) rate of cellulose decomposition was significantly increased (0.43 and 0.26% cellulose loss day^{-1}, with

and without earthworms, respectively) (Aira *et al.*, 2006). However, the direct contribution of *E. fetida* to cellulose degradation was not pronounced, although its presence augmented microbial biomass and enzymatic activity (cellulase and b-glucosidase) that can be associated to fungi (Aira et al. 2006).

Earthworms along with beneficial microbes show greater enzymatic activity for processing of organic substrates. In addition, the number of microbes is also increased in the vermicompost as compared to compost. Comparative assessment of enzyme activities and microbial population in vermicompost and normal compost resulted in maximum enzymatic (cellulase, amylase, invertase, urease and protease) activity in vermicompost than compost (Haritha Devi *et al.*, 2009). Additionally, most of the enzymes showed positive correlation with change in number and types of bacteria, fungi and actinomycetes during vermicomposting with maximum number of $126x10^6$, $28x10^4$, $93x10^5$ CFU gm^{-1} of sample, respectively. Vermicompost is reported to contain microbial produced plant growth promoting hormones like auxins, gibberellins and cytokinins (Tomati *et al.*,1988). Growth promoting activity of vermicompost was assessed in *Zea mays* (Nagavallemma *et al*. 2004). The marked differences in plumule length of maize seedling soaked in vermicompost water (18.6 cm) and normal water (16.6 cm) for 48 hours was correlated with the plant growth promoting hormonal activity in vermicompost.

3. Vermicompost as soil supplement:

Vermicompost not only adds beneficial microbes and nutrients in the soil but also modulates soil's physio-chemical properties which stimulate better growth and development of crops. It is observed that supplement of vermicompost at the rate of 20 t ha^{-1} to an agricultural soil in two consecutive years significantly ameliorated soil porosity and aggregated stability (Ferreras *et al*., 2006). The effects of vermicompost on soil physio-chemical properties evaluated in tomato (*Lycopersicum esculentum* var. Super Beta) field (Azarmi *et al*., 2008) showed that application of vermicompost at rate of 15 t ha^{-1} significantly ($P < 0.05$) increased contents of soil total organic carbon and nutrients, decreased soil pH, improved bulk density, total porosity and electrical conductivity in soil as compared to the control plots (without vermicompost). Effect of vermicompost on soil properties, soil losses and soil restoration showed positive result with decrease in soil loss (31.2% compared with unamended soil) and increase in soil quality (Tejada *et al*., 2009).

4. Plant growth, yield and fruit quality:

Vermicompost can induce plant growth and increase yield when supplemented to the soil. Substitution of vermicompost prepared from different sources into soilless nutritive medium Metro-mix 360 in different ratios resulted in increased germination, flowering and growth of *Petunia* (Arancon *et al*., 2008). (Joshi and Vig, 2010) had studied the effect of vermicompost on growth, yield and quality of tomato (*Lycopersicum esculentum L*). They demonstrated growth, yield and quality parameters that increased significantly in tomatoes grown in soil amended with vermicompost as compared to soil without fortified with vermicompost.

Supplement of vermicompost in soil is dose dependent for better yield of plant and soil properties. Increase in total yield of tomato was found when using vermicompost dosage to cow manure of 500g/m^2 that can be attributed to the improvement of soil quality with application of vermicompost (Alidadi *et al*., 2014). (Gutiérrez-Miceli *et al*., 2007) demonstrated that yields of tomatoes were significantly greater when vermicompost:soil ratio was 1:1, 1:2 or 1:3, 100 days after transplanting.

There is sufficient scientific evidence that humic acid fraction in vermicompost can trigger plant growth and increase yield. Growth of tomato and cucumber seedlings in terms of plant heights, leaf areas, shoot and root dry weights was observed with increasing concentrations of humic acids (shows hormone like activity) derived from vermicompost and the plant growth increased by treatments of the plants with 50–500 mg/kg humic acids (Atiyeh *et al*., 2002). (Arancon *et al*., 2003; Arancon *et al*., 2006) observed the growth of greenhouse plants (peppers, tomatoes, strawberries and marigolds) with the substitution of humates by 250-1000 mg/kg. The structural analysis revealed the presence of exchangeable auxin groups in the macrostructure of the humic acid fraction of vermicompost which aid in the root growth and development of maize (*Zea mays*) seedlings with increase in H^+-ATPase activity (Canellas *et al*., 2002). Vermicompost not only increase growth and yield but also improve nutritional quality of some vegetables (Gutiérrez-Miceli *et al*., 2007), strawberries (Singh *et al*., 2008), lettuce (Coria-Cayupan et al., 2009) and Chinese cabbage (Wang *et al*., 2010).

Vermicompost fertilizers also increases the essential oil content of aromatic plants (Argüello *et al*., 2006). Moreover, integrated use of vermicompost and NPK fertilizer showed positive effect on essential oil content in *Foeniculum vulgare* (Valiki *et al*., 2015). Application of 15 t/ha of vermicompost had the highest oil content (57.1%) in *F. vulgare* over control with no fertilizer (24.8%).

5. Suppression of plant diseases:

Vermicompost provides biological control of plant diseases (bacterial and fungal); yet, data on plant disease inhibition mediated by this organic use is scarce (Rivera and Wright, 2009). Presence of bacterial and fungal load in vermicompost has been confirmed (Anastasi *et al*., 2005). Suppressive effect of vermicompost on some root infecting pathogens i.e., *Phytophthora nicotianae* var. nicotianae, *Fusarium oxysporum* f. sp. lycopersici of cabbage and tomato has been identified (Szczech *et al*. 1993). Vermicompost application is dose-dependent, the highest level of root rot (a complex disease of *Coleus forskohlii under* involving *Fusarium chlamydosporum* and *Ralstonia solanacearum*) disease suppression (percent wilt incidence and percent disease incidence; 73 % and 82 %, respectively), was found when using vermicompost at the concentration of 5t h^{-1}(Singh *et al*., 2012). Also, vermicompost has proven to be the best option in management of tomato bacterial spot disease caused by *Xanthomonas campestris* (Reddy *et al*., 2012).

Control of fungal plant pathogen *Rhizoctonia* spp. and *Sclerotium* spp using vermicompost is equally important (Ersahin *et al*., 2009; Rivera *et al*., 2013). Vermicompost is enriched with beneficial bacteria and fungi (*Proteobacteria, Bacteroidetes, Verrucomicrobia, Actinmycetes, Aspergillus, Trichoderma* and *Firmicutes*) which shows antagonistic effect against various plant pathogens like *Fusarium* species and protect plant health

(Szczech, 1999; Yasir *et al*., 2009; Gopalakrishnan *et al*., 2011; Usha *et al*., 2012). Severity of infections of *Phytopthora* spp. in plants was reduced with the application of vermicompost and vermicompost extract (Szczech and Smolinska, 2001; Zaller, 2006). Use of aqueous extract of vermicompost in control of powdery mildew (*Erysiphe cichoracearum*) of pea was correlated with the induction of phenolic acids and antifungal activity (Singh *et al*., 2003). Moreover, worm cast also enhances the performance of plant growth promoting rhizobacteria against fungal pathogens. Performance of *Pseudomonas syringae* (PUR46) was enhanced in the presence of 25% (v/v) vermicompost and reduced the mortality percent of collar rot of chickpea caused by *Sclerotium rolfsii* by 76% (Sahni *et al*., 2008). Biological management of common scab of potato through *Pseudomonas* spp. has also confirmed the enhancement of performance of beneficial bacteria in the presence of vermicompost (Singhai *et al*., 2011).

6. **Protection against arthropod and nematode pests:**

The ability of vermicompost to protect plants against arthropod and nematode pests by suppressing, killing, repelling or by inducing biological resistance in plants to fight against them have been demonstrated. Significant decrease in arthropods (aphids, buds, mealy bug, spider mite) number and following reduction in plant damage, in tomato, pepper and cabbage trials was observed with 20% and 40% vermicompost supplementations (Edwards and Arancon, 2004). Other successful experimental trials against arthropods have been performed by many researchers (Yardim *et al*., 2006; Arancon *et al*., 2007; Edwards *et al*., 2010a, 2010b).

Application of vermicompost also regulates the diversity of nematode communities in the soil (Arancon *et al*., 2003). Soils from all of the vermicompost treated plots contained smaller populations of plant parasitic nematodes and increment in population of fungivorous and bacteriovorous nematodes as compared to soil from inorganic fertilizer treated plots. Also, vermicompost has been proven effective against infestation of nematode i.e. *Meloidogyne incognita* (Pandey and Kalra, 2010; Nath *et al*., 2011).

VERMICOMPOSTING RESEARCHES IN NEPAL

Although, Nepal is an agricultural country, only few researches regarding vermicomposting have been conducted so far. Assessment of fruit and vegetable waste at wholesale markets in Nepal for vermicomposting showed greater potential for vermicomposting (in terms of nutrient content) from leafy vegetables waste, composite waste, leguminous vegetable waste and fruit waste, however, root vegetables waste contained significantly lower N,P,K values (Devkota *et al*, 2014).

Feeding materials for earthworms show pronounced effect in growth, reproduction and quality of vermicompost. Effect of feeding materials (cow dung, cabbage, banana stem, grasses and mixture of all in equal ratio) on yield and quality of vermicompost and multiplication of *Eisenia fetida* was conducted in sub-tropical environment of Nepal (Tripathi *et al*, 2015). The result showed total N, P, K content significantly higher in cow dung vermicompost (2.1%, 1.7%, 1.9%) followed by mixture, cabbage, grasses and banana stem vermicomposts. Moreover, multiplication of worms was shown to be highest in cow dung (3854 worms) followed by mixture, banana stem, grasses and cabbage. In another study, elephant vermicompost showed significantly higher phosphorus and potassium content (2.8475% and 3.7425%) as compared to rhino dung, garbage and litter vermicomposts (Dhimal *et al.*, 2013). Solid wastes generated from Kathmandu Valley (Ayurveda industry, sugar mill, wood mill, kitchen and vegetable and fruit market) was vermicomposted using *Eisenia foetida* and resulted significantly higher N,P,K content and organic matter in Ayurveda industry waste (woddy and non-boiled waste and boiled and non-woody wastes) but rapid multiplication of worms was found in sugarcane bagasse (sugar mill) (Pant *et al.*, 2008). Utilization of different types of feeding material (Sericulture waste, leaves of *Populus deltoides* and whole plant of *Eupatorium adenophorum*) for production of earthworm (*Eisenia fetida*) biomass through vermiculture was conducted (Patrabansh, 2002). Maximum no. of cocoon and earthworm biomass was obtained in sericulture wastes (239±14 and 252.29%) and minimum in *E. adenophorum* plants (8±2.9 and 42.37%). However, feeding materials along with inoculation of beneficial microbes also shows significant difference in earthworm population and NPK content in the final vermicompost. Using *Eisenia foetida*, sawdust + *Rhizobium* sp. showed best for earthworm multiplication, *Ageratina adenophora* + *Trichoderma* + *Rhizobium* showed highest potassium content, *Lantana camara* + *Trichoderma* + *Rhizobium* sp. showed highest phosphorus content and *Lantana camara* + *Rhizobium* sp. showed highest nitrogen content (Baral *et al*., 2012).

Evaluation of different vermisystems (bed, cement ring and bin systems) for recycling of fruit and vegetable wastes in Bharatpur area of Chitwan was conducted (Shrestha *et al.*, 2014). The bin system was found superior in terms of production of superior quality (nitrogen content significantly higher i.e., 2.5%) and quantity (11.44kg/100kg of waste) of vermicompost along with significantly higher earthworm density (5485 earthworms/m^3), however, phosphorus (1.9%) and potassium (1.8%) content was found to be significantly higher in cement ring system.

Vermicompost alone or integrated use of vermicompost and mineral fertilizers shows plant growth promotional effect and yield. The application of vermicompost at 6.25mt/ha in the study area resulted in increment of height, diameter and yield of cauliflower by 15.62%, 37.58% and 38.95%, respectively over farmyard manure (Aryal *et al.*, 2013). Furthermore, vermicompost produced highest vitamin C content in cabbage (*Brassica Oleraceae* L. var. Capitata) (80mg) as compared to chemical fertilizers (56mg) (Kafle *et al.*, 2011). Vermicompost sole (100%) and integration of vermicompost (50%) and urea (50%) showed superiority in vegetative growth and fruit weight (V100:91.14gm and V50+U50:82.96gm) of sweet pepper cv. California Wonder as compared with NPK chemicals (74.26gm) (Ghimire *et al*., 2013). Moreover, recommended dose of NPK (750gm:375gm:750gm)+50Kg vermicompost and 3/4 recommended dose of NPK+68.75kg vermicompost were effective for improvement of leaf nutrient status of walnut (*Juglans regia* L.) (Bhattarai and Tomar, 2009).

The integrated use of vermicompost and farmyard manure shows effect on growth and yield of plants. Head weight (2.56kg/plant) and marketable yield (20.07kg/plot) were found higher in the cabbage field where combination of farmyard manure and vermicompost was applied (Bhattarai *et al*, 2011). Moreover, plant growth (height: 16.27cm and no. of leaves: 11.3cm) and root yield (59.66gm) of carrot (*Daucus carota*) were found best in combination of vermicompost and farmyard manure (Bhattarai and Maharjan, 2013). However, integrated use of vermicompost, farmyard manure and recommended dose of NPK chemicals also shows plant growth promotional effect. Maximum plant height and number of leaves per plant along with fruit yield of 25.74mt/ha were observed in tomato (*Lycopersicon lycopersicum* (L.)) plant with treatment of 16.66mt/ha farmyard manure+8.33mt/ha vermicompost+NPK (100:80:60kg/ha) (KC and Bhattarai, 2011).

The use of vermicompost along with inoculation of rhizospheric organisms shows beneficiary response on growth of plants. Application of *Azotobacter chroococcum* + *Piriformospora indica* + vermicompost showed significant increase in growth parameters (shoot length, root length, fresh shoot and root weight, dry shoot and root weight and panicle number) of rice plant (Prajapati *et al.*, 2008). Moreover, integrated use of vermicompost, bacterial and mineral fertilizers also shows significant effect in yield of plants. Combined application of vermicompost, *Rhizobium* and mineral fertilizer had positive effect in yield of vegetable green soybean (Bajracharya *et al.*, 2007).

Vermicompost provides biological control of plant and soil pathogens. Among 38 Actinomycetes isolated from saw dust and husk containing vermicompost samples, four (VAH1, VAH3, VAH8 and VAS9) of them belonged to *Streptomyces* genus and were active against at least one of the tested phytopathogenic fungi i.e., *Fusarium oxysporum, F. moniliforme, F. proliferatum, F. eridiforme, Sclerotium rolfsii, Stemphylium botryosum, Candida albicans, Aspergillus spp.* and *Exoserohilum turticum* (Baniya and Vaidya, 2011).

CONCLUSION

Vermicompost has been shown to have several positive impacts on soil, plant growth and health. In addition, it is considered as a promising alternative to harmful chemical fertilizers and pesticides in crop production. It is becoming popular as a major component of organic agriculture to produce healthier foods and better option for management of organic solid wastes. Exploration of potential species of earthworms in vermiculture technology along with soil friendly microbes, use of different high nutrient organic substances, efficient vermiculture system, dose specific use of vermicompost, integrated use of vermicompost with other inorganic fertilizers and research on earthworm-microbe interactions provide bright future of vermicompost use in organic farming systems. To sum up, this article opens the scope for further researches regarding vermicompost in sustainable agriculture and provides the potential of vermicomposting in Nepal.

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