Indian Journal of Agriculture and Allied Sciences
A Refereed Research Journal

ISSN 2395-1109
Volume: 1, No.: 4, Year: 2015

Received: 25.10.2015, Accepted: 21.11.2015

VERMICOMPOST AS A SOIL AMENDMENT

Y.V. Singh*, P.K. Sharma, R.A. Meena, S. K. Shahi[1], Manish Kumar Singh, S.N. Singh[2], Shobhit Singh[3] and Mukesh Kumar[4]

**Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005 (U.P.), E-mail: yvsingh59@rediffmail.co.in, [1]Department of Soil Science and Agricultural Chemistry, U.P. College Varanasi–221 002 (U.P.), [2]Krishi Vighyan Kendra, Institute of Agricultural Sciences, Banaras Hindu University RGSC, Barkccha, Mirzapur -231 001(U.P.), [3]Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005 (U.P.) and [4]Department of Soil Science and Agricultural Chemistry, R.B.S. College, Bichpuri, Agra -283105 (U.P.), Corresponding Author: Y.V. Singh*

Abstract: *The utility of epigeic earthworm for successful degradation of organic wastes is well documented for different industries such as paper and pulp. Compared to thermal composting, vermicomposting with earthworm often produces a product with a lower mass, lower processing time, and humus content; phytotoxicity is less likely; more N is released; fertilizer value is usually greater; and additional product (earthworms) which can have other uses is produced. Therefore, vermicomposting seems to be more appropriate and an efficient technology to convert industrial waste to a valuable community resources at low input basis. However, the composting efficiency and biology of only a few epigeic earthworm species has been studied, for example, Eisenia foetida. Compost is an excellent product; being homogenous and retaining most of the original nutrients and reduced levels of organic contaminants with respect to the starting material. It can be applied to soil to increase soil organic matter content and content of nutrients, which can be released upon decomposition, improve soil structure, and increase cation exchange capacity. Composting has been updated to process organic wastes of different origin, such as sewage sludge, animal manure, and agro-industrial wastes. However, composting is a time-consuming process taking at least 6 months and requiring frequent mixing with possible losses of nutrients, that is,* NH_3*. Additionally, earthworms reduce numbers of pathogens and the same effect is obtained in traditional composting by the increase in temperature. Vermicomposting has been successfully used for composting different types of wastes, such as municipal and industrial sludges. Though optimal moisture and the best proportions of organic waste are required for an efficient vermicomposting*
Key words: *Vermicompost, nutrients, soil structure, earthworm and animal manure etc.*

Introduction: Vermicomposting as a principle originates from the fact that earthworms in the process of feeding fragment the substrate thereby increasing its surface area for further microbial colonization. During this process, the important plant nutrients such as nitrogen, potassium, phosphorus, and calcium present in the feed material are converted through microbial action into forms that are much more soluble and available to the plants than those in the parent substrate [1]. Earthworms are voracious feeders on organic waste and while utilizing only a small portion for their body synthesis they excrete a large part of these consumed waste material in a half digested form. Since the intestine of earthworms harbor wide ranges of microorganisms, enzymes, hormones, etc., these half digested substrates decompose rapidly and are transformed into a form of vermicompost within a short time. Earthworm prepares organic manures, through their characteristic functions of breaking up organic matter and combines it with soil particles. The final product is a stabilized, well humidified, organic fertilizer, with adhesive effects for the soil and stimulator for plant growth and most suitable for agricultural application and favorable environmentally. Biochemical changes in the degradation of organic matter are carried out through enzymatic digestion, enrichment by nitrogen excrement, and transport of organic and inorganic materials. About 5–10% of ingested material is absorbed into the tissue for their growth and metabolic activity and rest is excreted as vermicast [2]. The vermicast is mixed with mucus secretion of the gut wall, and of the microbes and transformed into vermicompost. The decomposition process continues even after the release of the cast by the establishment of microorganisms. The studies on the effect of vermicomposting on some components of organic waste showed that vermicompost enhances degree of polymerization of humic substances along with a decrease of ammonium N and an increase of nitric N. Vermicompost is a peat-like material with high porosity, aeration, drainage, water holding capacity, and microbial activity and has large particular surface area that provides many micro sites for microbial activity and for the strong retention of nutrients. The plant growth regulators and other plant growth influencing materials, that is, auxins, cytokinins, humic substances, etc., produced by microorganisms have been reported from vermicompost.

Characteristics of Vermicompost: The nutrient status of vermicompost produced with different organic wastes is: organic carbon 9.15–17.98%, total nitrogen 0.5–1.5%, available phosphorus 0.1–0.3%, available potassium 0.15, calcium and magnesium 22.7–70 mg per 100 g, copper 2–9.3 ppm, Zinc 5.7–11.5 ppm, and available sulfur 128–548 ppm [3]. The vermicasts have been reported with a higher Base Exchange capacity and are rich in total organic matter, phosphorus, potassium, and calcium with reduced electrical conductivity, large increase in oxidation potential and significant reductions in water-soluble chemicals which constitute possible, environmental contaminants. The chemical analysis of casts shows 2 times the available magnesium, 5 times the available nitrogen, 7 times the available phosphorus, and 11 times the available potassium compared to the surrounding soil. The vermicompost is considered an excellent product since it is homogeneous, has reduced level of contaminants, and tends to hold more nutrients over a longer period without impacting the environment.

Application of Vermicompost in Plant Growth: Being rich in macro- and micronutrients, vermicompost has been found ideal organic manure enhancing biomass production of a number of crops [4]. The importance of vermicompost in agriculture, horticulture, waste management, and soil conservation has been reviewed by many workers. Stated that the earthworms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. The beneficial effect of earthworms on plant growth may be due to several reasons apart from the presence of macronutrients and micronutrients in vermicasts and in their secretions in considerable quantities. It is believed that earthworms produce certain metabolites, vitamins, and similar substances into the soil which may be the B or D group vitamins. Fresh casts often contain high ammonium levels, but rapid nitrification results in stable levels of both nitrogen forms due to organic matter protection in dry casts. Nutrients in casts are initially physically protected, but this is reduced as the aggregate structure weakens over time. In addition to increased N availability, C, P, K, Ca, and Mg availability in the casts is also greater than in the starting feed material [5]. Earthworm cast amendment has been shown to increase plant dry weight demonstrated the importance of the synchronization between nutrient release and plant uptake and showed that slower release fertilizers can increase plant yield and reduce nutrient leaching. Soil quality is affected by soil aggregates and these aggregates often determine the retention and movement of water, diffusion of gasses, growth and development of roots in the soil.

Metals and Agrochemicals Accumulation from Soil by Earthworms: Earthworms ingest large amount of soil and are therefore exposed to heavy metals through their intestine as well as through the skin, therefore concentrating heavy metals from the soil in their body [6]. Earthworms may serve as bio indicators of soil contaminated with pesticides, that is, polychlorinated biphenyls, polycyclic hydrocarbons. Lead, cadmium, zinc, and copper are accumulated and under some environmental conditions, bio concentrated in earthworms. It is presumed that in many cases zinc is the critical toxic metal for these organisms. Mortality and fecundity of earthworms as bio indicating organisms may serve as reliable, but ultimate and time consuming, indices of environmental pollution. Suppression of labile aluminum in acidic soils by the use of vermicompost extract was observed by chelation combined with pH-induced precipitation [7]. The same authors in 1992 also reported that in solutions above pH 6.0, a 98% reduction of total aluminum was obtained due to chelation. This will bring down the risk of entry of these pollutants into plant system and then into sequential food chain. When worms are used for this purpose, they should be prevented from entering into food chain as they are found to concentrate very high levels of these toxins in their tissue [8].

Plant Growth Trials Using Vermicomposts: Various animal, agricultural, and industrial wastes were vermicomposted, including pig, poultry, and cattle manure, potato, brewery, paper, and mushroom wastes. Plant trials were carried out on ornamental shrubs, vegetables, and bedding plants, using a commercial plant growth medium as a control [9]. Because most of the castings tended to be alkaline (pH > 7), it was necessary to dilute with peat for some trials. Early plant growth was reported to be better with vermicompost than in the commercial growing medium, and seeds germinated faster for most plant species grown in vermicompost. After transplanting into pots, the ornamentals grew better in vermicompost/peat mixtures than in the commercial growth medium. Also, several of the flowering plants flowered much earlier. Vermicompost mixed with peat or other materials makes superb plant growth media and that there could be significant commercial potential. Edwards and Burrows also noted that the paper waste vermicompost was one of the best feed stocks in terms of consistency of product. Confirmed that the trend in trials for plants grown in container media was that the optimum responses normally occurred when worm castings constituted 10–20% of the volume of the mix. They believed that the substantial growth effects that were observed were more than simply a function of the mineral nutrient content of the castings. They considered that the effects might also be related to enhanced micronutrient availability, the presence of plant growth regulators, or the activity of beneficial microorganisms in the castings. However, that does not deny the fact that vermicomposts do contain nutrients in forms that are most readily taken up by the plants such as nitrates, exchangeable phosphorus, and soluble potassium, calcium, and magnesium [10]. That vermicomposts tend to differ from composts in that they normally have higher nitrogen levels with more of that nitrogen in the nitrate rather than the ammonium form. This enhanced germination rates greatly, comparable to the germination obtained in a commercial medium that already contained a starter nutrient fertilizer in its formulation. The researchers also made a key observation that vermicomposts still boosted growth rates even when additional fertilizers were applied. That is, their effects must be due to more than just nutrient values. Earthworm castings as a propagation and growing substrate for ornamental plant production and found a promotion of root development and a reduction in fertilizer use in plants grown in substrates containing castings [11]. While the researchers have demonstrated that the addition of vermicomposts to growing media normally produces beneficial effects on plant growth, the reasons why the effects happen are still not yet fully understood. The earthworms certainly fragment the organic waste substrates stimulate enhanced microbial activity and increase rates of mineralization, rapidly converting the wastes into humus-like substances. A decrease in the carbon from fulvic acids and an increase in the percentage of the carbon from humic acids are seen in the vermicomposting process [12].

Disease and Pest Suppression: The beneficial effects of worm casts on plant growth can be put down largely to increased microbial populations that produce plant growth hormones. Those hormones are believed to be adsorbed on to the humates produced during the vermicomposting process. Beneficial effects were not simply confined to plant growth. They were apparent on the incidence of plant diseases and pest attacks from plant parasitic nematodes, insects, and mites [13]. The pathogen suppression was almost eliminated if the vermicomposts were sterilized prior to use. Low applications of vermicomposts have also been found to affect the populations of plant parasitic nematodes. Vermicomposts from paper waste, food waste, and cattle manure, applied at 2–8 tons per acre to soils planted with tomatoes, peppers, strawberries, or grapes, gave a consistent and significant suppression of plant parasitic nematodes. The incorporation of small proportions of vermicompost was found to reduce arthropod pests (aphids, mealy bugs, spider mites) on tomatoes, peppers, and cabbage and the extent of crop damage caused by them. Effect of vermicomposts on the growth and infection of tomato seedlings by Phytophthora nicotianae. While vermicomposts produced from animal manure significantly reduced the infections in the seedlings, vermicomposts from sewage sludge offered no protection [14].

Potential for Transmission of Pathogens: Earthworms feeding on sludge may be potential vectors of a wide range of parasitic and pathogenic organisms [15]. It has been determined that passage of organic material through the gut of an earthworm can reduce numbers of some microorganisms and increase numbers of others. Spores and cysts of some parasites pass unharmed through the gut of earthworms while some pathogens are reduced [16]. Feeding on a growing medium inoculated with Salmonella eneritidus, reduced populations of this enteric pathogen by 42 times, compared to controls, after 28 days with the greatest rate of reduction of pathogen in the first 4 days. That two species of Enterobacteriaceae, Serratia marcessens and Escherichia coli, which inoculated in soil were killed when ingested by the earthworm Lumbricus terrestris [17].

Effect of Worm Castings on Crop Yields: There is little scientific literature on the subject of the usefulness of vermicompost on plant growth. During the passage through the gut of the earthworm, ingested material is mixed and has its physical, chemical, and biotic components altered, but very little material is actually digested by the worm, and the structure and composition of the casts is dependent on the composition of the food source [18]. Organic materials differ greatly in their nutrient content; processing by the earthworm can change the form of these compounds but has very little effect on the total amounts contained [19]. The physical structure of the casts also depends on the source material; however, the final product usually comprises finely mixed and relatively stable aggregates with good structure, porosity, and moisture-holding capacity. The composition of casts from earthworms feeding on sewage sludge can be expected to have a different composition to those produced by earthworms feeding on un amended soils. Casts produced from soil have increased nitrate and exchangeable calcium, magnesium, potassium, and phosphorus than the original soil. Other chemical and physical changes in earthworm casts compared to parent soil [20]. The nutrient contents of several organic wastes before and after being worked by earthworm: all had increased nitrate, soluble P and exchangeable potassium, calcium, and magnesium when worm-worked. They found that emergence and growth of range of seedlings in pots was frequently enhanced in these worm-worked compared to un worked media. Fresh earthworm casts may contain high salt soluble concentrations, especially of Na+, sufficient to damage plants [21]. That leaching cast with water reduced these salts to tolerable levels while still retaining most of the plant beneficial nutrients. The porosities, salinities, nutrient contents, pH values, and trace elements of several vermicomposts and potting mixes. Vermicomposts varied widely in total nutrient content: most had negligible amounts of soluble N-nitrates but had ample amounts of P and some had high concentrations of Zn and Cu. Few reports deal with field trials involving the application of vermicompost. Significant increases in the colonization of soil by microbes (including N-fixers, Actinomycetes, spore formers, and Mycorrhizae) occurred in the experimental plots compared to the control plots without added vermicompost. Higher levels of total N in the experimental plot where vermicompost was added was attributed to higher counts of N-fixing microbes [22]. The growth of maize on a loamy soil in Pakistan was enhanced by the addition of casts of Metaphire posthuma and that their effect was greater than was obtained with the addition of farmyard manure. In India, the growth of an ornamental shrub, Vinca rosea and rice, Oryza sativa, in soils with or without the casts of Pheretima alexandri. Those V. rosea plants in casts grew better and produced flowers and fruits earlier than plants in soil alone. Rice is growing for 4 months in pots with highest concentrations of added casts grew best, the whole plant lengths (means) being 81.5 cm in soil mixed with casts compared to 62.8 cm in soil alone [23].

Detrimental Effects of Earthworms: Despite the many documented and putative beneficial effects of earthworms on soil structure, nutrient dynamics, and plant growth, some aspects of earthworm activities are considered undesirable [24]. Detrimental activities include removing and burying of surface residues, which would otherwise protect soil surfaces from erosion; producing fresh casts that increase erosion and surface sealing; increasing compaction of surface soils; depositing castings on the surface of lawns and golf greens, where they are a nuisance; dispersing weed seeds in gardens and agricultural fields; transmitting plant or animal pathogens; riddling irrigation ditches, making them less able to carry water; increasing losses of soil nitrogen through leaching and denitrification; and increasing loss of soil carbon through enhanced microbial respiration [25]. It is the net result of positive and negative effects of earthworms that determines whether they have detrimental impacts on ecosystems [26]. Obviously, an effect such as mixing of organic and mineral soil horizons may be considered beneficial in one setting (e.g., urban gardens) and detrimental in another (e.g., native forests). The undesirable impacts of exotic species are central to assessing the risks associated with their introduction and spread [27].

Interpretation of Findings: Some microbial and enzyme activities are occurring within the gut of the earthworm that (1) enhances the breakdown of cellulose material, and (2) conveys some property, or properties, to the breakdown product (casting) that are generally beneficial to plant growth [28]. The research team at Ohio State University has demonstrated that it is not just because of the relatively high levels of nutrients and micronutrients within castings [29]. The explanation may be more deeply linked to the richer microbial calories conveyed through the castings, or could be due to the relatively high humification, and specifically the levels of humic acid associated with the castings [30]. In general, researches have shown that blending vermicomposts with traditional growth media has shown positive effects on plant growth, particularly on root growth but also on shoot and leaf growth and fruit and flower production as well. Some experiments have shown that the application of vermicompost produces poorer growth than that produced in the controls [31]. The scientific evidence is less strong with regards to vermicompost having any positive effects on seed germination. Some researchers have found it may inhibit germination slightly, though once germinated the plants can then pick up and forge ahead in the vermicompost [32]. Effects on plants have been seen with as little as 5–10% of vermicompost added to the growing media. An addition of around 20–40% vermicompost is considered to provide the optimum blend [33]. Then there appears to be a turnaround for concentrations above 40% with the higher rates impacting negatively on plant growth [34].

Conclusions: Vermicomposting technology involves harnessing earthworms as versatile natural bioreactors, which play a vital role in decomposition of organic matter, maintaining soil fertility, and bringing out efficient nutrient recycling and enhanced plants' growth. A variety of organic solid wastes, domestic, animal, agro-industrial, human wastes, etc. can be vermicomposted. The value of vermicompost is further enhanced as it has simultaneously other benefits: excess worms can be used in medicines and as protein rich animal feed provided they are not growing on polluted wastes and can be used as an antisoil pollutant. Earthworm can be used as bio indicators for the monitoring of ecosystem state and changes. Various workers identified the earthworms for evaluating the effect of soil contamination with heavy metals and pesticides, agricultural practices, and acid rain, etc. There are numerous studies about the heavy metal influence on the growth, reproduction, and mortality of earthworms. Earthworms increase the water infiltrations rate of the soil and observed a mean rate of 150 mm h 1 per 100 g m 2 of earthworms; however the anecic species shows maximum infiltration (282 mm h 1 per g m 2). Heavy metals are perhaps of greatest concern, and it may be possible to exploit some aspect of earthworm behavior for their removal. Processing by the earthworms may alter the solubility or stability of some heavy metals or perhaps, enhance other physical, chemical, or microbial means of removal. Accumulation of pesticide may be less of a problem as these chemicals and their metabolites often have known rates and products of decay. Earthworms may be used in combination with conventional composting techniques to reduce pathogens, although the temperatures involved are incompatible for earthworm survival. Vermicomposting of municipal wastes may be particularly suitable option for production of useable products. Composition and consistency of these products would largely depend on the composition of the initial waste materials and of any materials with which they are combined. As for sludge treatment, there would be a requirement to constantly monitor nutrients, contaminants and to prevent pathogen regrowth, in both the raw materials and the final products.

References

1. Alter, D. and Mitchell, A. (1992). Use of vermicompost extract as an aluminum inhibitor in aqueous solution. *Commun Soil Sci Plant Anal*, 23:231–240.
2. Bruzewitz, G. (1959). Studies on the influence of earthworms on numbers of species and role of micro-organisms in soils. *Arch Mikrobiol*, 33:52–82.
3. Buchanan, M.A., Russell, G. and Block, S.D. (1988). Chemical characterization and nitrogen mineralization, potential of vermicompost derived from differing organic wastes. In: Edwards CA, Neuhauzer EF (eds) Earthworms in waste and environmental management. SPB Academic Publishing, The Hague, pp 231–239.
4. Cantanazoro, C.J., Williams, K.A. and Sauve, R.J. (1998). Slow release versus water soluble fertilization affects nutrient leaching and growth of potted chrysanthemum. *J Plant Nutr*. 21:1025–1036.
5. Cegarra, J., Famandez, F.M., Tercero, A. and Roig, A. (1992). Effects of vermicomposting of some components of organic wastes. Preliminary

results. Mitteilungen-aus-dem-hamburgischen zoologischen-museum-und-Institute 89:159–167.

6. Chan, P.L.S. and Griffiths, D.A. (1988). The vermicomposting of pre-treated pig manure. *Biol Wastes* 24:57–69.
7. Chaoui, H., Edwards, C.A., Brickner, A., Lee, S.S. and Arancon, N.Q. (2002). Suppression of the plant diseases, Pythium (damping-off) Rehizoctonia (root rot), and Verticillium (wilt) by vermicomposts. Proceedings of Brighton Crop Protection Conference-Pest and Diseases. vol II, 8B- 3:711–716.
8. Cortet, J., Gomot., De, Vauflery, A., Poinsot Balaguer, N., Texier, G.L., Ch, C.D. (1999). The use of soil fauna in monitoring pollutants effects. *Eur J Soil Bid* 35:115–134.
9. Murrray, London and Day, G.M. (1950). Influence of earthworms on soil micro-organisms. *Soil Sci,* 69:175–184.
10. Decaens, T., Rangel, A.F., Asakawa, N. and Thomas, R.J. (1999). Carbon and nitrogen dynamics in ageing earthworm cast in grassland of the eastern plains of Colombia. *Biol Fertil Soils*, 30:20–50.
11. Edwards, C.A. (1981). Earthworms, soil fertility and plant growth. In: Applehof M. Workshop on the role of earthworms in the stabilization of organic residues. vol 1, Proceedings. Beech Leaf, Kalamazoo, MI pp 61–85.
12. Edwards, C.A. and Arancon, N.Q. (2004). Interactions among organic matter, earthworms and microorganisms in promoting plant growth. Functions and management of organic matter. In: Magdoff F, Weil R (eds) Agro-ecosystems, vol 11. CRC, Boca Raton, pp 327–376.
13. Martinez, S.D. and Gomez Zambrano, J. (1995). The use of earthworm composts in commercial production of chrysanthemums. Acta Agronomica Universidad Nacional de Colombia, 45:79–84.
14. McInerney, M. and Bolger, T. (2000). Temperature wetting cycles and soil texture effects on carbon and nitrogen dynamics in stabilized earthworm casts. *Soil Biol Biochem*, 32:335–349.
15. Mitchell, A. and Alter, D. (1993). Suppression of labile aluminum in acidic soils by the use of vermicompost extract. *Commun Soil Sci Plant Anal*, 24:1171–1181.
16. Morgan, J.E. and Morgan, A.J. (1999). The accumulation of metals (Cd, Cu, Pb, Zn and Ca) by two ecologically contrasting earthworm species (Lumbricus rubellus and Aporrectodea caliginosa): implications for eco-toxicological testing. *Appl Soil Ecol*, 13:9–12.
17. Muscolo A, Bavolo F, Gionfriddo F, Nardi S (1999) Earthworm humic matter produces auxins-like effect on Daucus Carota cell growth and nitrate metabolism. *Soil Biol Biochem*, 31:1303–1311.
18. Ndegwa, P.M. and Thompson, S.A. (2001). Integrating composting and vermicomposting in the treatment of bio-conversion of bio-solids. *Bioresour Technol*, 76:107–111.
19. Orozco, F.H., Cegarra, J., Trujillo, L.M. and Roig, A. (1996). Vermicomposting of coffee pulp using the earthworm Eisenia fetida: effects on C and N contents of the availability of nutrients. *Biol Fertil Soils*, 22:162–166.
20. Paoletti, M.G., Faveretto, M.R., Stinner, B.R., Purrington, F.F. and Batter, J.E. (1991). Invertebrates as bioindicators of soil use. *Agric Ecosyst Environ,* 34:341–362.
21. Riggle, D. and Holmes, H. (1994). New horizons for commercial vermiculture. *Biocycle*, 35:58–62.
22. Saint-Denis, M., Narbonne, J.F., Arnaud, C., Thybaud, E. and Ribera, D. (1999). Biochemical responses of the earthworm Eisenia fetida, andrei exposed to contaminated artificial soil: effects of benzo (a) pyrene. *Soil Biol Biochem*, 315:1827–1846.
23. Satchell, J.E. (1983). Earthworm microbiology. In: Satchell JE (ed) Earthworm ecology: from Darwin to vermiculture. Chapman and Hall, London, pp 351–365.
24. Sharma, S., Pradhan, K., Satya, S. and Vasudevan, P. (2005). Potentiality of earthworms for waste management. *J Am Sci*, 1:4–16.
25. Singh, A. and Sharma, S, (2002). Composting of a crop residue through treatment with microorganisms and subsequent vermicomposting. *Bioresour Technol*, 85:107–111.
26. Spurgeon, D.J. and Hopkin, S.P. (1999). Comparisons of metal accumulation and excretion kinetics in earthworms (Eisenia fetida) exposed to contaminated field and laboratory soils. *Appl Soil Ecol*, 11:227–243.
27. Spurgeon, D.J. and Hopkin, S.P. (2000). The development of genetically inherited resistance to zinc in laboratory-selected generation of the earthworm Eisenia fetida. *Environ Pollut*, 109:193–201.
28. Subler, S., Edwards, C.A. and Metzger, J. (1998). Comparing vermicomposts and composts. *Biocycle*, 39:63–66.
29. Suthar, S. (2006). Potential utilization of guargum industrial waste in vermicompost production. *Bioresour Technol*, 97:2474–2477
30. Suthar, S. (2007). Vermicomposting potential of Perionyx sansibaricus (perrier) in different waste materials. *Bioresour Technol*, 98:1231–1237.
31. Szczech, M. and Smolinska, U. (2001). Comparison of suppressiveness of vermicomposts produced from animal manures and sewage sludge against phytophthora nicotianae Breda de Haan var. Nicotinae. *J. Phytopathol*, 149:77–82
32. Tomati, U., Galli, E., Grapelli., A. and Hard, J.S. (1994). Plant metabolism as influenced by

earthworm casts. Mitteilungen aus dem Hamburgischem Zoologischen Museum and Institute, 89:179–185

33. Tyagi, R.D. and Couillard, D. (1991). An innovative biological process for heavy metals removal from municipal sludge. In: Martin AM (ed) Biological degradation of wastes. Elsevier Science Publishers, London, pp 307–321.
34. Zhang, H. and Schrader, S. (1993). Earthworm effects on selected physical and chemical properties of soil aggregates. *Biol Fertil Soils*, 15:229–234.