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Review

Vermiculture bio-technology: An effective tool for economic and environmental sustainability

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Vermicompost production and use is an ‘environment friendly, protective and restorative’ process as it diverts waste from ending up in landfills and also reduces emission of greenhouse gases (GHG) due to very small amount of energy used in its production process. Application of vermicompost in farm soil acts as soil conditioner and help to improve its physical, biological and chemical properties. Vermicompost production is also an ‘economically productive’ process as it ‘reduces wastes’ at source and consequently saves landfills space. Construction of engineered landfills incurs 20 to 25 million US dollars upfront before the first load of waste is dumped. Over the past five years, the cost of landfill disposal of waste increased from $29 to $65 per ton of waste in Australia. However, landfills have to be monitored for at least 30 years for emissions of GHG and toxic gases and leachate (Waste Juice) which also incur cost. During 2002 to 2003, waste management services within Australia costed $2458.2 million. Even in developing nations where there are no true landfills, dumping of wastes cost alot on government. This paper elaborates on the importance of this technology to environmental sustainability and economic empowerment.

Key words: Vermicompost, earthworm, nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg).

INTRODUCTION

Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways (Gandhi et al., 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10 to 32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby resulting earthworm castings (worm manure) rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes. In short, earthworms, through a type of biological alchemy, are capable of transforming garbage into ‘gold’ (Vermi, 2001; Tara, 2003).

Earthworms consume various organic wastes and reduce the volume by 40 to 60%. Each earthworm weighs about 0.5 to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day. These worm castings have been analyzed for chemical and biological properties. The moisture content of castings ranges between 32 to 66% and the pH is around 7.0. The worm castings contain higher percentage (nearly twofold) of both macro and micronutrients than the garden compost. From earlier studies it is also evident that vermicompost provides all nutrients in readily available form and also enhances uptake of nutrients by plants. Sreenivas et al. (2000) studied the integrated effect of application of fertilizer and vermicompost on soil available nitrogen (N) and uptake by ridge gourd (*Luffa acutangula*) at Rajendranagar, Andhra Pradesh, India. The available nitrogen in soil increased significantly with increase level of vermicompost and highest nitrogen uptake was obtained at 50% of the recommended fertilizer. Similarly, the uptake of nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) by rice (*Oryza sativa)* plant was highest when fertilizer was applied in combination with vermicompost (Jadhav et al., 1997). The new economic theory of development today is ‘Environmental-Economics’ which advocates for judicious balance between ‘economy and ecology’ in all developmental programs including agricultural development and amalgamation of ‘economic development’ programs with ‘ecological conservation’ strategies to usher in the era of sustainable development. The new economic philosophy of development also stresses mankind to switch over from the ‘fossil fuel (petroleum products) based economy’ to ‘renewable resource based and waste recycling based economy’. We have to understand that every natural resource, commodity, goods and services that we use from the environment has an environmental cost’ (the hidden cost of environmental damage and repair while the raw material is procured from the earthly resources) other than its ‘economic cost’ (the cost of processing, manufacturing and trading) and only after adding the two costs, we arrive at the true cost of the product. There may be ‘social cost’ as well in the form of impaired human health and quality of life. We only pay for the cost of food grown in farms and its processing and transport. We never pay for the damage done to the environment due to production and use of chemical fertilizers and pesticides. Conventional economists are not bothered to deduct the cost of environmental damage (e.g. degradation of farmland and soil) and the cost of environmental repair and restoration (e.g. soil regeneration and management of degraded lands) from the GNP of nations. But the environmental-economists do (Tobey et al., 1996). The cost of production of vermicompost is simply insignificant as compared to chemical fertilizers.

Vermicompost is produced from a ‘cheap raw material’ (community wastes including farm wastes) which is in plenty all over the world and is growing in quantity with the growing human population while the chemical fertilizers are obtained from ‘petroleum products’ which are not only very ‘costly raw materials’ but also a ‘vanishing resource’ on earth. Vermicompost can be produced ‘on farms’ by all farmers, but the chemical fertilizers has to be produced in ‘factories’ at a high economic and environmental cost so vermicompost can be afforded by all farmers. The worms itself after producing the vermicompost can be sold to fishery, poultry, dairy and pharmaceutical industries for economic benefits.

VERMICULTURE

The production of degradable organic waste and its safe disposal is currently becoming a global problem. The rejuvenation of degraded soils by protecting topsoil and sustainability of productive soils is a major concern at the international level. Provision of a sustainable environment in the soil by amending with good quality organic soil enhances the water holding capacity and nutrient supplying capacity of soil with the increase of resistance in plants against pests and diseases. By reducing the time of humification process and by evolving the methods to minimize the loss of nutrients during decomposition, the fantasy becomes fact. Earthworms can serve as tools to facilitate these functions. They serve as “nature’s plowman” and form nature’s gift to produce good humus, which is the most precious material to fulfill the nutritional needs of crops. The utilization of vermicompost results in several benefits to farmers, industries, environment and overall national economy. The production of vermicompost and its uses are ‘environmental friendly, protective and restorative’ as it diverts wastes from ending up in landfills and also reduces emission of greenhouse gases (GHG) due to very small amount of energy used in its production process. Application of vermicompost to crop field soil’s physical, biological and chemical properties.

Vermicompost production is also an ‘economically productive’ process as it ‘reduces wastes’ and consequently saves landfills space. Construction of engineered landfills incurs 20 to 25 million US dollars upfront before the first load of waste is dumped. Over the past five years the cost of landfill disposal of waste has increased from \$29 to \$65 per ton of waste in Australia. Landfills have to be monitored for at least 30 years for emissions of GHG and toxic gases and leachate (Waste Juice) which also incur cost. During 2002-2003, waste management services within Australia costed \$2458.2 million. Even in developing nations where there are no true landfills, dumping of wastes incurs high cost on government. Earthworms converts a product of ‘negative’ economic and environmental value that is, ‘waste’ into a product of ‘highly positive’ economic and environmental values that is,‘highly nutritive organic fertilizer’ (brown gold) which improve soil fertility and enhance farm productivity to produce ‘safe food’ (green gold) in farms. Vermiculture can maintain the global ‘human sustainability cycle’-that is, producing food in farms back from food and farm wastes.

Vermicomposting is a self-promoted, self-regulated, self-improved and self-enhanced, low or no-energy requiring zero-waste technology, easy to construct, operate and maintain. It excels all other waste conversion technologies by the fact that it can utilize waste organics that otherwise cannot be utilized by others. It excels all other biological or mechanical technologies for production of ‘bio-fertilizer’ because it achieves ‘greater utilization’ than the rate of ‘destruction’ achieved by other technologies and the process becomes faster with time as the army of degrader worms and the decomposer microbes multiply in millions in short time (Sinha et al., 2008). Earthworms involve about 100-1000 times higher ‘value addition’ in any medium (composting wastes or soil) wherever it is present (Appellof et al., 2003). Some of the advantages of vermi-cultural technology are next presented.

Lower cost of food production

A matter of considerable economic and environmental significance is that the 'cost of food production'. The use of vermiculture could be significantly low by more than 60 to 70% as compared to chemical fertilizers and the food produced will be a 'safe chemical-free food' for the society. It is a 'win-win' situation for both producers (farmers) and the consumers. The cost of production of vermicompost is less as compared to chemical fertilizers. The former is produced from 'human waste'-a raw material which is plenty all over the world and the latter is obtained from 'petroleum products' which is a vanishing resource on earth. Vermicompost can be produced 'on-farm' at low-cost by simple devices, while the chemical fertilizers are high-tech and high-cost products manufactured in factories (Munroe, 2007). Vermicompost also helps the crops to attain maturity and reproduce faster, it shortens the 'harvesting time' (Sinha et al., 2008). It further cuts the cost of production and also adds to the economy of farmers as farmers can grow more crops every year in the same field.

Reduced usage of chemical pesticides and cut cost

Widespread use of chemical pesticides became an important requirement for the growth of high-yielding varieties of crops which was more susceptible to pests and diseases. Continued application of chemical pesticides induced 'biological resistance' in crop pests and diseases and consequently much higher doses are required to eradicate them. There has been considerable evidence in recent years regarding the ability of vermicompost to protect plants against various pests and diseases either by suppressing or repelling them or by 'inducing biological resistance' in plants to fight them or by killing them through pesticidal action. Pesticide spray was significantly reduced where earthworms and vermicompost were used in agriculture (Suhane, 2007). Studies also indicate that use of vermicompost help in disease control by almost 75% which significantly cut down the cost of food production.

Reduced usage of water for irrigation and cut cost

Vermicompost is able to retain more soil moisture thus reduces the demand of water for irrigation by nearly 30 to 40%, (Suhane, 2007).

Improvement of growth and higher yield

Studies indicate that smaller amount of vermicompost in fact promote better growth performance of crops. Subler et al. (1998) reported that in all growth trials the best growth responses were exhibited when the vermicompost constituted a relatively small proportion (10 to 20%) of the total volume of the container medium. Valani (2009), found that 200 g of vermicompost applied in pot soils performed better growth in wheat crop than those with 400 and 500 g of vermicompost. Singh (2009), found that in the farm plots where vermicompost was applied in the 2nd, 3rd and 4th successive years, the growth and yield of wheat crop increased gradually over the years at the same rate of application of vermicompost that is, at 20 Q/ha. In the 4th successive year the yield was 38.8 Q/ha which was very close to the yield (40.1 Q/ha) where vermicompost was applied at 25 Q/ha. Use of vermicompost in farm soil eventually leads to increase in the number of earthworm population in the farmland over a period of time as the baby worms grow out from their cocoons. It infers that slowly over the years, as the worms build up the soil's physical, chemical and biological properties, the use of vermicompost can slowly be reduced. The yield per hectare may also increase further as the soil's natural fertility is restored and strengthened. Webster (2005) found that single application of vermicompost increased yield of 'cherries' for three consecutive years after. Yield was much higher when the vermicompost was covered by 'mulch'. At the first harvest, trees with 5 and 20 mm vermicompost plus mulch yielded cherries of the value of AU $ 63.92 and AU $ 70.42 respectively. After three harvests, yield per tree were AU $ 110.73 and AU $ 142.21 respectively for the 5 and 20 mm vermicompost with mulch. The trees yielded cherries of AU $ 36.46 per tree with 20 mm vermicompost in the first harvest and after three harvest AU $ 40.48 per tree. Webster (2005) also studied the agronomic impact of compost in vineyards and found that the treated vines produced 23% more grapes due to 18% increase in bunch numbers. The additional yield in grapes was worth additional AU $ 3,400/ha.

As a commercial commodity

Vermiculture is a growing industry not only for managing waste and land very economically but also for promoting 'sustainable agriculture' by enhancing crop productivity both in quantity and quality at significantly low economic cost than the costly agrochemicals (Bogdanov et al., 1996). Earthworms not only converts 'waste' into 'wealth' it itself becomes a valuable asset as worm biomass. Large-scale production of vermicompost has the potential to replace chemical fertilizers, protein rich 'earthworms' can be a good business opportunity with awareness growing about the use of these products in agriculture and other allied industries (George, 2004). Municipal solid waste (MSW) is growing in huge quantities in every country with growing population and there will be no dearth of raw materials for production of vermicompost. Vermiculture has also enhanced the livelihood standard of poor's in India and have generated self-employment opportunities for the unemployed. In several Indian villages, Non Governmental Organization's (NGO) are freely distributing cement tanks and 1000 worms to encourage rural people to collect waste from villages and farmers, vermicompost them and sell both worms and vermicompost to the farmers (Hati et al., 2001). People are earning from Rupees 5 to 6 lakhs (Approx. AU $ 15-20 thousands) every year from sale of both worms and their vermicompost to the farmers. It is estimated that one ton of earthworm biomass on an average contain one million worms approximately. One million worms doubling after every two months can become 64 million worms at the end of a year. Approximately each adult worm (particularly *Eisenia fetida*) consume waste organics equivalent to its own body weight everyday, 64 million worms (weighing 64 tons) can consume 64 tons of waste everyday and can produce 30-32 tons of vermicompost per day at 40 to 50% conversion rate, (Visvanthan et al., 2009). In any vermiculture practice, earthworms biomass comes as a valuable by-product and they are good source of nutritive 'worm meal'. They are rich in proteins (65%) with 70-80% high quality essential amino acids 'lysine' and 'methionine' and are used as feed material in 'fishery', 'dairy' and 'poultry' industry. Also the by- product of vermicultural practices are used in the manufacture of pharmaceuticals and in the making of 'antibiotics' from the ceolomic fluid as it has anti-pathogenic properties.

VERMICULTURE AND CHEMICAL FERTILIZER

Chemical agriculture triggered by widespread use of agro-chemicals in the wake of 'green revolution' of the 1960s came as a 'mixed-blessing' rather a 'curse in disguise' for mankind. It dramatically increased the 'quantity' of the food produced but severely affected its 'nutritional quality' and also the 'soil fertility' over the years. The soil has become addict and increasingly greater amount of chemical fertilizers are needed every year to maintain the soil fertility and food productivity at the same levels. The early response to chemical fertilizers is 'levelling off' after a 3% annual increase within the period of 1950 to 1984. There is evidence that a plateau has been reached in global efforts to increase further the yield per hectare through agro-chemicals. Increased use of agro-chemicals has virtually resulted into 'biological droughts' (severe decline in beneficial soil microbes and earthworms which help to renew the natural fertility of soil) in soils in the regions of green revolution in world where heavy use of agro-chemicals were made. High use of agro-chemicals also demands high use of water for irrigation which causes severe stress on ground and surface water. Widespread use of chemical pesticides became a necessity for the growth of high-yielding varieties of crops which are highly 'susceptible to pests and diseases'. Continued application of chemical pesticides induced 'biological resistance' in crop pests and diseases. Studies indicate that there is significant amount of 'residual pesticides' contaminating our food stuff long after they are taken away from farms for human consumption. Vegetable samples were contaminated 100% with Hexachlorocyclohexane (HCH) and 50% with dichlorodiphenyltrichloroethane (DDT) (Rao, 1993). The Society for Research and Initiative for Sustainable Technologies and Institutions (SRISTI), Ahmedabad, India, analysed the residual pesticide in soil of croplands of Gujarat. They found that 41 out of 70 samples contained insecticidal residues of Phosphamidon, Methyl parathion, Malathion, Chlorpyriphos and three different pyrethroids. Rao (1993) also found residues of pest in chemically grown food, UNEP/GEMS (1992), the farmers today are caught in a 'vicious circle' of higher use of agrochemicals to boost crop productivity at the cost of declining soil fertility. This is also adversely affecting their economy as the cost of agrochemicals has been rising all over the world. Rao (1993) also reported residues of pesticides in meat, fish, eggs, butter, milk including in mother's milk and human fat. The contamination was 100% with HCH, 69% with DDT and 43% with aldrin. In human fat DDT residue ranged from 1.8 ppm in Lucknow to 22.4 ppm in Ahmedabad; HCH ranged from 1.6 ppm in Bombay to 7 ppm in Bangalore. Adverse effects of agro-chemicals on the agricultural ecosystem (soil, flora, fauna and water bodies in farms) and also on the health of farmers using them and the society consuming the chemically grown food have now started to become more evident all over the world. According to United Nation Environment Program (UNEP) and the World Health Organization (WHO) nearly 3 million people suffer from 'acute pesticide poisoning' and some 10 to 20 thousand people die every year from it in the developing countries, (UNEP, 1992). US scientists predict that up to 20,000 Americans may die of cancer, each year, due to this low levels of 'residual pesticides'.

ENVIRONMENTAL AND ECONOMIC BENEFITS OF VERMICULTURE

Sustainable agriculture is a process of learning new and innovative methods developed by both farmers and the farm scientist and also learning from the traditional knowledge and practices of the farmers and implementing what were good in them and also relevant in present times. Vermiculture was practiced by traditional and ancient farmers with enormous economic benefits for them and their farmlands. There is need to revive this 'traditional concept' through modern scientific knowledge-a 'Vermiculture Revolution'. Sir Charles Darwin called the earthworms as 'farmer's friends'. There is great wisdom in this statement of the great visionary scientist who advocated to use the earthworms, the 'nature's gift' in farm production. It is necessary to adopt and implement food and agriculture production system which must ensure:

(i) High productivity and stability of yield over the years.

(ii) Productivity with minimum use of water and even sustain dryness or heavy rainfall.
(iii) Preservation of crop diversity (biotopes).
(iv) Preservation of soil, water and air quality in the farm ecosystem.
(v) Preservation of benevolent organisms (predators) flora and fauna in the farm ecosystem.
(vi) Preservation of groundwater table.
(vii) Preservation of good health for all.
(viii) Reduction of water and energy use.

Sustained vermiculture practices and use of vermicompost in farm soil over the years would meet several of the above requirements for a truly sustainable agriculture. Vermicompost rich in microbial diversity and plant available nutrients; improve the moisture holding capacity of soil reduces water for irrigation. It also improves physical, biological and chemical properties of soil; soil porosity and softness. There are also ample opportunities in the reduction of uses of energy and GHG emissions in vermicompost production locally at farms by the farmers themselves, (Singh, 1993).

CONCLUSION

Planning global organic farming and sustainable agriculture can truly bring in 'economic prosperity' for the farmers, 'ecological security' for the farms and 'food security' for the people. This will require embarking on a 'Second Green Revolution' and this time through 'Vermiculture Revolution' by the earthworms. This practice will ensure economic viability and environmental sustainability.

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