
Waste Management Using Vermicompost Derived Liquids in Sustainable Horticulture

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ABSTRACT

The technology of vermicomposting containing their leachates, teas and other extracts such as vermiwash as a result of earthworm action is widely applied for safe management of agricultural, industrial, domestic and hospital wastes. Remediation of polluted soils, improving crop productivity and inducing the resistance against biotic and abiotic stresses are other advantages of vermicompost derived liquids when used in agriculture. Contrary to the fact that chemical fertilizers are still widely used in agriculture, societies gradually become aware of the negative effects of these fertilizers on their health. Therefore, vermicompost derived liquids contain high amount of valuable plant nutrients which has the potential to be used as liquid fertilizer. This paper reviews the potential of vermicompost derived liquids as an efficient combination of nutrient source of vermicompost derived liquids contributing to plant growth and acting as a deterrent to biotic and abiotic stresses.

Keywords: Bio-fertilizer; Crop Production; Organic Waste Management; Sustainable Agriculture; Vermicompost Derived Liquids

1. Introduction

With increasing demand for crops, the need for fertilizers also increases dramatically. Although chemical fertilizers are still widespread in agriculture, people's awareness of their health effects is also increasing. The widespread use of chemical fertilizers in agriculture for improved crop production has been linked to increased health hazards to humans and livestock as well as causing severe environmental problems such as water and soil pollution, which are generally considered detrimental^[2,53]. On the other hand, soil fertility in the arable lands has reduced greatly due to excessive operation without the employment of suitable soil- management techniques. Several factors such as nutrient depletion, erosion, water scarcity, acidity, salinization, depletion of organic matter and poor drainage result in reducing soil productivity^[12]. At present, we see significant reductions in macro and micro- nutrients in many areas worldwide, which play a vital role in plant growth and development. Considering the risk of excessive use of chemical fertilizers, both for the plant and for the health of human, apart from the serious constraints that these fertilizers have on the environment, more attention is needed towards promoting the use of organic fertilizers to prevent environmental degradation while improving crop yields. One of the environmental friendly approaches of producing high quality derived organic fertilizer by which infertile soils could be improved is using the biostimulants such as vermicompost derived liquids which has brought the interest of preparing this review. In this review, vermicompost derived liquids have been introduced as convenient methods of application for crops growers, which, in addition to being less expensive and assist in minimizing the usage of chemical fertilizers, would efficiently improve crop production.

2. Vermicompost and its problem in agriculture

The interactions between earthworms and microorganisms accelerates the biological decomposition of organic wastes, which ultimately leads to the formation of vermicomposts including their leachates, teas and other extracts such as verminwash^[3]. High-quality vermicompost has a good physical texture and color, no smell, and minimum contaminants or pollutants^[21,22]. During the process of composting with earthworms, the important nutrients are transformed into

forms which are much more soluble and available to plants than those in the parent compounds^[25,18,43,55]. The final product of vermicomposting has high pH and electrical conductivity (EC), which enhances soil salinity. To reduce EC, vermicompost derived liquids such as vermicompost leachate, vermiwash and vermicompost tea have been developed^[31,40,43,10,11].

Vermicomposts including their leachates, teas, and other extracts are produced by the activity of earthworms from a wide range of organic wastes^[29,35,49,68].

3. Vermicompost derived liquids

3.1 Vermiwash and its Preparation method

After percolation of water through a column of worm actions, excretory products and mucus secretion of earthworm along with micronutrients from the soil organic molecules are collected leading to the production of liquid, called vermiwash (Fig 1). Properly collected vermiwash is a clear and transparent, pale yellow coloured fluid^[36,5]. Use of vermiwash extracted from vermicomposts of different combination of animal agro and kitchen wastes, is one of the effective liquid biofertilizer for growth and productivity of crops^[47]. This liquid partially comes from the body of earthworms and is rich in amino acids, vitamins, enzymes, macro and micro- nutrients like nitrogen, potassium, magnesium, zinc, iron, copper, and some plant growth regulators such as auxins and cytokinins. It also contains plenty of nitrogen-fixing and phosphate solubilising bacteria like Nitrosomonas, Nitrobacter and Actinomycetes. In addition to its high – quality in terms of nutrition, vermiwash has pest killing properties^[37]. Chattopadhyay (2015) described different preparation methods of vermiwash extraction which has been explained as follows^[14]:

In the first method which is based on the heat stress application, Well-grown adult earthworms *Eisenia foetida* are separated from casting materials by placing the worms in a plastic tub for some time. Then the earthworms are removed carefully from the casting materials and transferred to a glass beaker containing 500 ml of warm (40 °C) distilled water and stirred for 5–6 min. Around 30 g of worms are taken. They are then removed immediately and added to another pre-sterilized plastic container filled with water at room temperature. Here the worms are rinsed thoroughly to collect the remaining excretory and secretory products adhering to the body of the worms. The earthworms are then released back to the stock culture container. The light yellow straw-coloured contents of the glass beaker and plastic beaker are mixed and the solution is stored in sterilized dark colour glass bottle at 4 C to be used for the experimental purpose. In the second method which is based the cold stress application, around 30 g of total weight of well-grown matured worms (*E. foetida*) of approximately equal length are applied cold stress by keeping them in chilled conditions, in ice cubes in beaker at -5 °C for 3–4 min. The earthworms were then transferred to a 500-ml glass beaker containing cold distilled water and kept for 7–8 min with occasional stirring. The worms are transferred to a sterilized beaker containing distilled water at room temperature and rinsed for around 2–3 min and then released to the stock culture container. The light yellow-coloured exudates from the petridish, glass beaker and plastic beaker are all mixed together and the vermiwash is stored in dark-coloured sterilized glass bottle at 4 °C for experimental purpose.

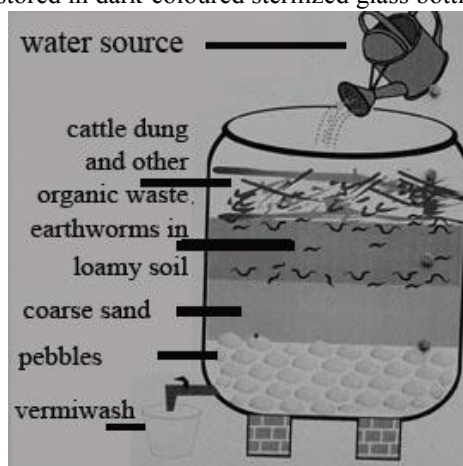


Figure 1; The above diagram shows the vermiwash preparation steps schematically.

3.2 Vermicompost leachate and its preparation method

Most of the animal wastes cannot be used directly without any treatment and their disposal may cause environmental contamination problems especially in large amount. Processing by earthworms converts these wastes to a safe and nutritious source of fertilizer for plant growth^[37]. Vermicompost leachate is a kind of bio-fertilizer that is a liquid nutrient gathered after transition of water through a pile of vermicompost^[33,47,54,56,55,10,57].

The method of vermicompost leachate preparation has been described by Ayyobi *et al.* (2014)^[10] and Shirani Bidabadi *et al.* (2016)^[57]. The cattle manure-based vermicompost is processed by Earthworms (*Eisenia fetida*) at a rate of 25 g earthworms per 1 kg of cattle manure and vermicomposted for 2 months. A cotton bag containing the prepared vermicompost is placed in a container of water equipped with a simple pump system (Fig 2) to flood the tank water. Vermicompost is then flushed with water and leachate brewed and then collected in the system reservoir. This excess water that leaches out is commonly known as vermicompost leachate or worm bed leachate. Reviewing of research studies shows that vermicomposting leachate contains high amount of plant nutrients that may act as liquid fertilizer for improving plant growth^[29,10,57]. The chemical properties of the vermicompost leachate depends on the chemical composition of the substrates used in the vermicomposting process. Shirani Bidabadi *et al.* (2017) analyzed the chemical properties of vermicompost leachate obtained from cattle manure (Table 1)^[58]. Plant height, fresh and dry shoot weight of *Stevia rebaudiana* was significantly affected by the use of vermicomposting leachate^[57].

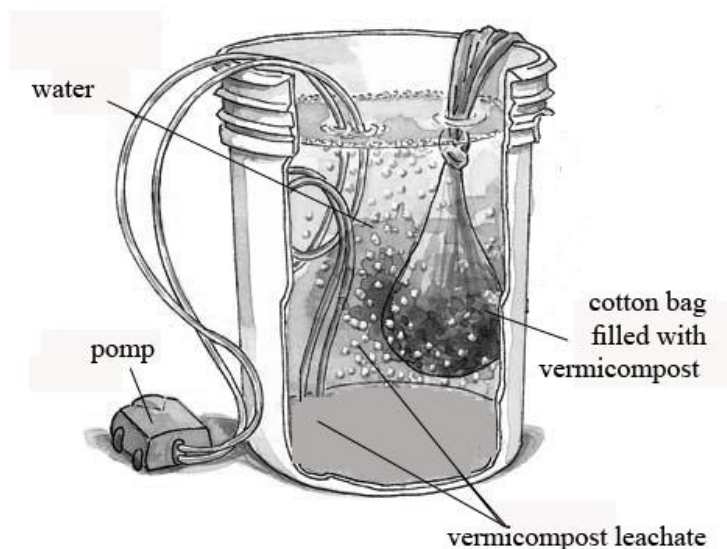


Figure 2; A simple way to collect leachate from vermicompost.

| | |
|--|------|
| pH | 7.56 |
| Electrical conductivity(ds m ⁻¹) | 5.42 |
| N (%) | 1.3 |
| P ₂ O ₅ (%) | 0.7 |
| K ₂ O (%) | 0.9 |
| Cu (%) | 0.05 |
| Zn (%) | 0.09 |
| Mn (%) | 0.18 |

These values are subjected to variations depending on the cattle feeding

Table 1. characteristic of vermicompost leachate obtained from cattle manure analysed by Shirani Bidabadi et al. (2017)^[58]

3.3 Vermicompost tea and its preparation method

Vermicompost tea is the water extracts of solid vermicomposts from which microorganisms, soluble nutrients and plant-beneficial substances are converted into a liquid form. Vermicompost tea contains stirring and aeration during extraction to increase aerobic microbes in the aqueous solution (Fig 3). The aerated tea solution can be supplied with additives that can enhance the microbial activity. Molasses, humic acids, kelp, rock powders, fish emulsions, and a variety of other ingredients have been used as additives^[19,24]. Vermicompost tea can be used in a wide range of horticultural and agricultural systems to elicit plant growth and pest and disease management responses through a variety of mechanisms. It can be applied directly to plant foliage. It is also used as a soil drench and has been shown to be effective in relatively small quantities^[24]. Carballo *et al.* (2008) designed a reactor, which allows teas to be produced under aerated and non-aerated conditions under different temperatures. This reactor could also be adopted for vermicompost tea production (Fig 3)^[13]. Pant *et al.* (2009) asserted that The chemical properties and mineral nutrient content of vermicompost tea differed significantly with extraction method, but the microbial population and activity were not dependent on extraction methods^[50].

4. Application of vermicompost derived liquids in crop plants

Several authors have shown the positive role of vermicompost derived liquids on the improvement of growth and phytochemical content in plants^[26,50,62,27,30,65,8,47,11,7,4,16,9,44,57,42,58]. The positive effect of soil drenching with vermicompost leachate on the growth of greenhouse-grown ‘Williams’ bananas was also demonstrated^[6]. Vermicompost teas are now being produced and used in large-scale agriculture, viticulture, orchards, horticulture, nurseries, turf greens, commercial landscaping, and home gardens. Rates, frequency, and modes of its application depend the cropping system, pest and disease pressures, and existing conditions^[37].

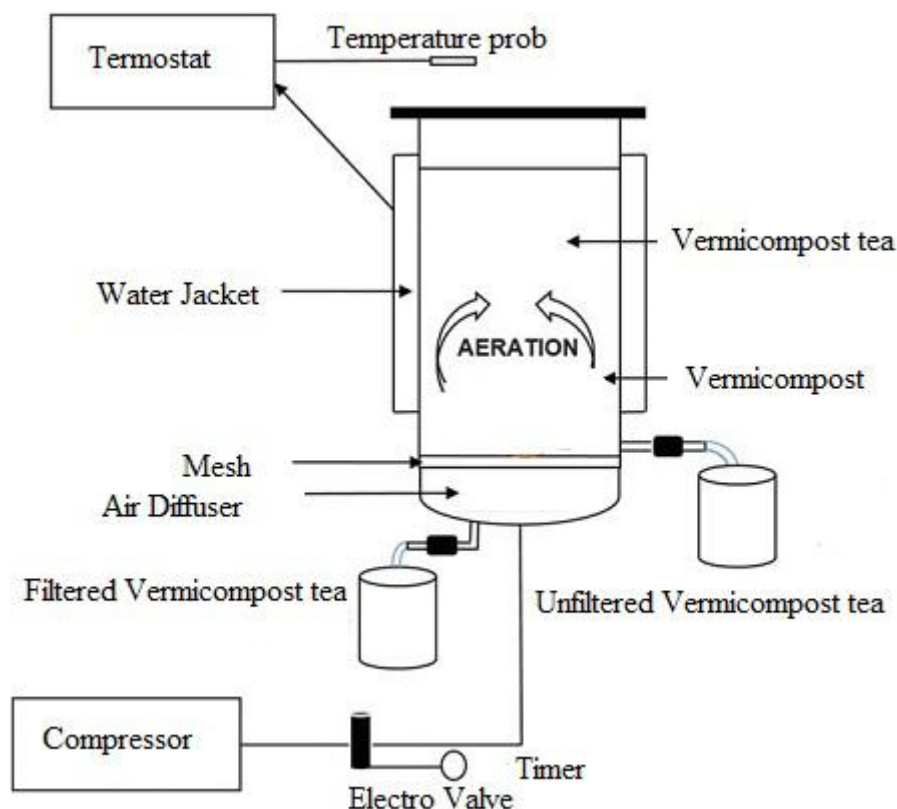


Figure 3; A reactor designed by Carballo *et al.* (2008) which can be adopted for producing vermicompost tea.

Some reports suggest the presence of plant growth regulators such as auxins, gibberellins, cytokinins in vermicomposts and their liquid derivatives like vermicompost tea that are formed by the addition of microorganisms^[39,28,66]. Growth and

development of plants may be dramatically affected by such vermicompost derived liquids, because of the presence of these substances. Vermicompost tea enhances soil microbiological activity. The active components in vermicompost tea include microorganisms, water-soluble fulvic acids (building blocks for humic acids) and particulate humates, plant-growth hormones produced by microorganisms, and materials that improve the availability of micronutrients. Soluble nutrients present in vermicompost tea nourish plants directly as well as feed existing soil microorganisms. Like vermicompost, it increases soil biological activity and provides beneficial organic compounds. Unlike vermicompost, it can be applied directly to plant foliage as well as to the soil. Direct foliar application of vermicompost tea provides nutrients that may be utilized directly by the plant while also introducing a diverse array of microorganisms that colonize leaf surfaces^[37]. Improved plant growth and productivity obtained with vermicompost derived liquids via hydroponic system and foliar application opens new prospects for organic crop production. Reviewing the results confirms that there is a large variation in vermicompost derived liquid effects depending on the plant genotype. Therefore, within a given crop certain genotype or varieties may be more suitable for organic or combined inorganic-organic cropping systems, than others as Shirani Bidabadi *et al.* (2016) reported that replacing inorganic fertilizer with vermicompost leachate or developing an equilibrated fertilization strategy that combines the proper ratios of vermicompost leachate and inorganic fertilizer (3:1) could be justified in stevia cultivation systems^[57].

5. The role of vermicompost derived liquids on plant nutrition management

Vermicomposts can significantly influence the growth and productivity of plants due to their micro and macro elements, vitamins, enzymes and hormones^[42,59,51]. Unlike chemical fertilizers, the amount of nutrients provided by vermicompost derived liquids may vary notably depending on the original feedstock, processing time and maturity of the vermicompost^[57,58,10,11]. Masondo *et al.* (2016) suggested application of vermicompost leachate to plants lacking nitrogen as a suitable management method for improving yield under nitrogen deficiency stress^[44]. Arthur *et al.* (2012) asserted that vermicompost leachate could serve as a potential substitute for P and K deficiency^[8]. Vermicomposts contain nutrients such as nitrates, exchangeable phosphorus, soluble potassium, calcium, and magnesium in plant available forms and have large particular surface area that provides many microsites for microbial activity and for the strong retention of nutrients. During vermicomposting the heavy metals also form complex, aggregates with humic acids and other polymerized organic fractions resulting in lower availability of heavy metals to the plant, which are otherwise phytotoxic. Therefore, soil amended with vermicompost produced better quality fruits and vegetables with less content of heavy metals or nitrate, than soil fertilized with mineral fertilizers^[48,63,38,17,51].

6. Role of vermicompost bacteria in biomedical waste management

Biomedical wastes are infectious and have to be disinfected before being disposed into the environment. Thus, using safe, cheap and easy methods to refine these wastes must be given more attention. Biomedical wastes also contain an array of pathogenic microorganisms^[32,51]. Because the earthworm's body acts as a biofilter, vermicomposting plays a vital role for safe management of biomedical wastes and its bioconversion into valuable composts free from enteric bacterial populations. Vermicomposting does not involve a thermophilic phase, which might increase the risk of using this technology for management of infectious wastes, but surprisingly vermicomposting resulted in a noticeable reduction in the pathogen indicators such as fecal coliform and Salmonella in the biomedical wastes^[20,59,51]. Reports reveal that vermicomposting converts the infected biomedical waste containing various pathogens to a harmless waste^[67]. Reduction in the pathogen population during the process of vermicomposting might be due to the digestive enzymes and mechanical grinding by earthworms^[46,24]. Earthworm's diet including microorganisms and earthworms ability to selectively digest them caused a reduction or removal of the enteric bacterial populations at the end of vermicomposting period^[24,25]. Depending on the earthworm species, vermicomposting has been known to reduce the level of different pathogens such as Salmonella, Escherichia coli and human viruses in different types of waste^[1].

7. The role of vermicompost derived liquids in reducing the destructive effects of biotic and abiotic stresses on crop plants

Vermicompost derived liquids acts as a suitable soil amendment product to improve overall soil fertility and, more

importantly, growth of plants, even under temperature and water stress conditions^[16]. Excessive and consistent applications of chemical pesticides in conventional agriculture induced a resistance to pathogens and pests which results in more need for pesticide use^[52]. Vermicompost application has a great potential to reduce the use of chemical pesticides and fertilizers; hence, significantly to cut down on the costs of food production. According to the mechanisms proposed for compost reported by Lazcano and Dominguez (2011) anti-disease properties of vermicompost derived liquids may be attributed to either direct suppression of pathogens or to the induction of systemic resistance in the plants^[40]. There is still a big gap in methodology for the production and uses of vermicompost derived liquids such as vermicompost teas in terms of optimal dilution and application rates with respect to targeted plant pest or pathogen^[23]. Overall research on applications of liquefied vermicompost products, to control plant diseases management has shown that suppression effect is due to a biological nature rather than chemical, similar to that of compost products. Thus, the enhanced suppression ability of the vermicompost derived liquids on plant pathogens could be attributed to its microflora, as its suppressive property disappeared after autoclaving^[60,61,64]. Vermicompost leachate may have also an important role in alleviating the salinity-induced damage to the chloroplasts by reducing chlorophyllase activity^[15]. The results of the research conducted by Shirani Bidabadi *et al.* (2017) strongly proved that foliar application of vermicompost leachate improved growth parameters and physiological factors, enabling vermicompost leachate-treated pomegranate seedlings to perform better^[58]. Therefore, they suggested application of vermicompost leachate under salt-stress conditions. Vermicompost leachate is extensively being popular among farmers as it is effective in enhancing the quality of crops for both hydroponic systems and foliar sprays.

8. The potential of vermicompost derived liquids as foliar fertilizer

The most important advantage of vermicompost derived liquids when used to leaves as a foliar fertilizer is its homogeneity compared with when added as fertilizer to the soil. Soils with different texture show different rates of leaching. High leaching intensity of soils causes the efficiency of fertilizer applied to the soil surface to be decreased as the nutrient will be leached out easily and plant nutrients are lost due to this leaching problem as it is leached out before they are taken up by plants. Therefore, foliar application of vermicompost derived liquids results in preventing leaching problem due to soil properties^[45]. Another potential for vermicomposting leachate is that it can be used as a growth promoter during early stage of plant growth when the roots have not yet well developed^[54]. Singh *et al.* (2010) confirmed that leachates derived from vermicomposting process could potentially apply to strawberry as foliar fertilization^[62]. Ali *et al.* (2014) reported that foliar application of vermicompost leachate caused a remarkable influence on growth and yield of tomato plants^[4]. Shirani Bidabadi *et al.* (2017) reported that, foliar spray of vermicompost leachate induced salt tolerance by reducing the accumulation of Na⁺ in the pomegranate seedlings^[58].

9. The potential of vermicompost derived liquids in hydroponic systems

Shirani Bidabadi *et al.* (2016) reported an efficient management of using vermicompost derived liquids as a nutrient supplement in stevia culture via a suitable hydroponic system. Hoagland's hydroponic solutions were used in their study in hydroponic culture for *Stevia rebaudiana*^[57]. Higher photosynthetic efficiency and enhanced activities of superoxide dismutase (SOD), (peroxidase) POX and (catalase) CAT were observed compared with control. Hence they indicated the potential use of vermicomposting leachate as nutrient solution.

10. Vermicompost derived liquids in the market

Vermicomposts including their leachates, teas and other extracts such as vermiwash are marketed for a broad range of purposes, including gardening, landscaping, agriculture, forestry, and horticulture and pollution management. They can be produced from organic wastes, such as food and wastes, have an enormous economic potential for increasing crop yields and suppressing attacks by pests and diseases. In light of the researches conducted in this regard, it is clear that vermicompost derived liquids organizes a promising alternative to inorganic fertilizers in boosting plant growth. However, further research into the exact mechanisms and circumstances that stimulate plant growth by this organic material is necessary in order to maintain consumer confidence in this type of fertilizer. For the high-value end markets, the vermicompost products must be very uniform and consistent in quality and nutrient content. What's clear is that markets for vermicompost derived liquids is expanding. Market-development advances for vermicompost derived

liquids continue to increase considerably as their benefits become known better. Reviewing of the research projects are showing that the benefits of vermicompost derived liquids go far beyond the usual provision of organic matter and plant nutrients, to providing plant growth stimulants and other plant- and soil-improving properties especially under both biotic and abiotic stress conditions^[50,30,8,47,11,7,16,9,44,57,41,58].

11. Conclusion

There has been little work carried out to characterize the impacts of vermicompost derived liquids on soils and crops, therefore, there is a huge need to optimize the production and use of vermicompost derived liquids to improve crop quality. The research conducted on vermicompost derived liquids applications, for plant protection purposes proved them to be effective in suppression of pathogens and pest attacks. Capability of vermicompost derived liquids to enhance soil biodiversity by promoting the beneficial microorganisms results in improving plant health and minimizing the yield loss. Therefore, vermicompost derived liquids could be used to promote sustainable agriculture and also for the safe management of agricultural, industrial, domestic and hospital wastes which may otherwise pose serious threat to life and the environment.

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