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Review Article

Vermicompost as Organic Amendment: Effects on Some Soil Physical, Biological Properties and Crops Performance on Acidic Soil: A Review

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Abstract

One of the most precious natural resources is soil, which provides ecological functions necessary for life's survival and sustenance. Therefore, preserving and enhancing soil health is crucial for agricultural and ecological sustainability. However, careless application of mineral fertilizer lowers fertility and organic matter and has negative impacts on the environment, ground water quality, and soil health, whereas the use of organic amendments is essential for enhancing soil health. In order to improve the physical, biological, and crop productivity of acidic soil, this review emphasizes the potential of vermicompost as a soil conditioner. Thus, adding organic amendments to soil is a management tactic that can boost microbial populations, activity, and variety, enhances soil fertility and improve soil structure. Vermicompost (VC) is one type of organic amendment that is created when earthworms and soil microorganisms interact. The end product has a high degree of maturity, high porosity, aeration, drainage, water storage capacity, and microbial activity. As a result, applying this amendment encourages biological activity, which raises the soils' potential for production both directly through increased nutrient availability and indirectly through improved physical characteristics. Similarly, the addition of vermicompost (VC) to soil raised its pH levels, phosphorus, potassium, calcium, magnesium, and total organic carbon; it also enhanced the soil's cation exchange capacity, microbial biomass carbon, micronutrient content, and nitrogen content, all of which increased crop yield. In addition to raising crop yield and improving soil quality and nutrient availability, vermicompost also strengthens crop resistance to pests and diseases. By adding essential nutrients, humic acids, growth-regulating hormones, and enzymes to the soil, it acts as an organic fertilizer that improves plant nutrition, photosynthesis, and overall crop quality.

Keywords

Organic Amendment, Soil, Vermicompost, Nutrient

1. Introduction

Since soil is the original source of the nutrients we utilize to develop crops, it is an essential component of successful agriculture. Human nutrition, ecosystem services, and good plant development all depend on healthy soils [38]. However, prolonged use of mineral fertilizers without organic conditioners degrades the physicochemical properties of soil in

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particular and pollutes the environment. Although mineral fertilizer makes nutrients easily accessible for plant growth, it has no effect on the physical, chemical, or biological conditions of the soil. On the other hand, organic matter inputs in the form of organic amendments not only provide nutrients but also enhance soil aggregation and promote microbial activity and diversity [8]. Furthermore, according to Albiach *et al.* [4], organic fertilizers not only supply nutrients and organic matter but also greatly boost soil microbial activity, biodiversity, and population size. They also affect soil structure, nutrient turnover, and a variety of other physicochemical properties. VC, a form of organic matter found in organic fertilizer, is produced naturally when organic materials are broken down by microorganisms and earthworms. It has elements that the plants can easily absorb, such as calcium, phosphorus, potassium, magnesium, and nitrate. VC is an excellent soil conditioner or amendment due to its high porosity, microbial activity, drainage, aeration, and water-holding capacity [33]. The microbial biomass in the soil is increased by the many enzymes included in VC, which also improve the activities of microbial organisms [14]. Applying VC improves the soil's microbial population, water retention, humic substances, mineralization, and nutrient release in addition to adding plant nutrients (both macro and micro) and growth regulators. In addition, VC increases soil aeration, decreases soil erosion and evaporation-induced water loss, speeds up the humification process, promotes microbial activity, deodorizes offensive odors, and lowers soil pollutants [31]. This review offers a comprehensive perspective on how VC, as organic amendment, affects certain biological and physical characteristics.

2. Overview of Vermicomposting and Vermicompost

Vermicomposting is the process by which earthworms and other microorganisms break down and stabilize organic waste biologically. It has great qualities, is easy to prepare, and doesn't hurt plants. In comparison to the composts produced by conventional composting techniques, earthworms speed up the mineralization rate and transform manures into castings with a higher nutritional content and level of humification. While the microbes produce a humified environment that transforms the oxidized instable organic matter into more stable forms [25], earthworms contribute significantly to the decomposition process by breaking down and conditioning the substrates, increasing the surface area available for microbial development, and altering biological activity [13]. Earthworms perform a variety of functions during the conversion of organic residues, including aeration, chemical degradation, crushing, grinding, and biological stimulation [37]. Decomposition of organic substrates is accelerated by the cooperative efforts of earthworms and microorganisms. After passing through physical, chemical, and microbiological changes, earthworms produce VC, an organic amendment that is rich in nutrients and microbiologically active, as castings of the biomass they have consumed. In order to hold and retain plant nutrients, it is a mixture of earthworm casts, partially decomposed bedding materials, seeds or cocoons, humic substances, and related microorganisms that are stabilized to small particles of a peat-like material with high porosity, more water-holding capacity, low C:N ratio, and a very large surface area [13]. Auxins, gibberellins, and cytokinins are among the active substances and essential nutrients found in VC that support plant growth. Additionally, it is environmentally friendly and non-toxic to plants. These materials support plant growth in addition to offering advantageous qualities like permeability, aeration, drainage, water-holding capacity, and microbial activity [36]. For a satisfactory qualitative and quantitative yield, it can be applied either by itself or in conjunction with other organic and inorganic fertilizers [19].

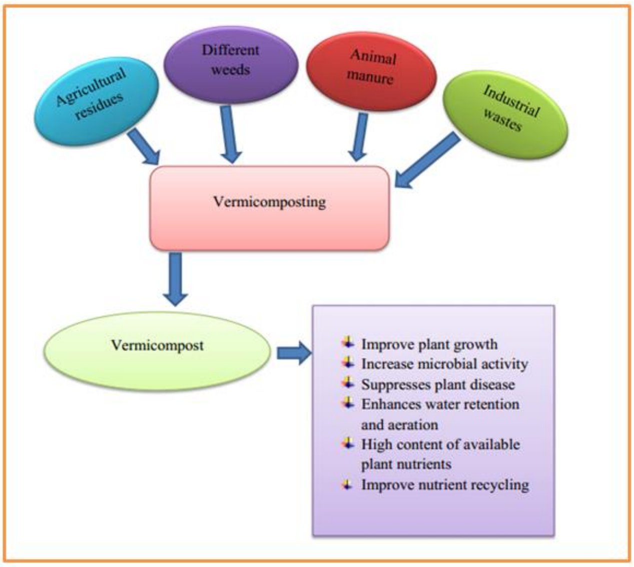

Figure 1. *The process of vermicomposting of different types of organic wastes.*

3. Effects of Vermicompost on Soil Physical Properties

3.1. Soil Bulk Density

Bulk density (BD) is used as an indicator of soil compaction. One well-known technique for maintaining soil organic matter, repairing degraded soil, and giving plants nutrition is the use of organic resources like crop wastes, compost, and vermicompost. By increasing aggregate stability, overall porosity, air and water permeability, and a corresponding decrease in BD and penetration resistance, VC application improves the physical characteristics of soil. In a similar vein, VC treatments considerably lower the bulk density of the soil, which lowers compaction levels and improves the stability of soil aggregates. [12]

Showed that under various irrigation regimes ($100\%_{+}$f, $50\%_{+}$f, and $25\%_{+}$f), VC treatment had a favorable impact on bulk densities; greater dosages of VC treatment were associated with lowering soil bulk density values. According to Azarmi et al. [7], the current VC treatments resulted in a drop in mean BD values from 1.28 g cm^{-3} to 1.20 g cm^{-3}. The BD of the soil decreased as VC rates increased. Because compost increased the soil's porosity, the BD significantly decreased. According to Gopinath et al. [16], the application of VC also led to a decrease in bulk density. [10] It was stated that adding organic compost to soil would similarly lower BD. Similarly, according to Aksakal et al. [3] the highest mean total porosity and the lowest mean BD were found when the most VC was added.

3.2. Soil Aggregation

Maintaining long-term agricultural productivity and evaluating the physical health of the soil depend heavily on aggregate stability [15]. Gas diffusion, water transfer, root penetration, and seedling emergence may all be aided by increased soil aggregate stability. Granular and crumb-type aggregate formation and stability are mostly facilitated by organic matter. The addition of organic matter to the soil improves aggregate stability and greatly increases macro-aggregate fractionation. In addition to providing nutrients, Carpenter-Boggs et al. [9] found that organic matter inputs through organic amendments enhance soil aggregation and promote microbial diversity and activity. According to Aksakal et al. [3], applying VC enhanced the wet aggregate stability of agricultural soil and raised the proportion of water-stable aggregates. Likewise, Zhu *et al.*, [43] observed that VC may well improve the proportion of water-stable aggregates and mean weight diameter. Waste organic additions increased the percentage of water-stable aggregates and improved the structural stability of copper mine soils [5]. In addition to providing nutrients, organic matter inputs through organic amendments enhance soil aggregation and promote microbial variety and activity [9]. Enhancement of soil aggregation promotes root development and seedling emergence through its effects on temperature, aeration, mechanical impedance, and soil water content. Applying VC as a soil amendment improves soil aggregation and structure by increasing nutrient content, cation exchange capacity, and soil organic matter, all of which boost soil fertility [39]. The maintenance of soil structure is very useful for root development and nutrient availability to the plants. The addition of mucus secreted by earthworms and their gut microbes improves the soil's aggregate stability [20]. VC has been realized to be useful for enhancing soil structure, aggregation, and moisture-holding ability as well as cation-exchange capacity and, ultimately, crop yields [40]. Ekrem *et al.*, [3] reported that application of VC had improved the percentage of macro-aggregates significantly from 25.4 to 31.2 percent. He suggested that the effectiveness of VC on aggregate stability improved with the increases in application doses. When means were compared, the highest aggregate stability values were obtained from the maximum dose (4%) of vermicompost. When compared to the control, VC application greatly improved the wet aggregate stability of all soils in all aggregate size fractions, with the exception of those that were less than 0.42, 0.42–0.84, and 6.4–12.7 mm in size [12]. As application doses were raised, VC impact on aggregate size grew as well. The proportion of water stable soil aggregates was significantly higher in plots amended with VC from household solid waste, horse and rabbit manure, and chicken manure at the rate of 20 Mg ha^{-1}. Aggregate stability, mean weight diameter and structural stability index of the soils were significantly influenced by VC treatments [11]. Frequent organic fertilization increases soil organic carbon, which in turn increases soil aggregate stability. Therefore, carbon inputs from VC, roots, and root exudates under various soil treatments alter the amount of organic carbon in the soil, which in turn affects the aggregate structure. By increasing the carbon concentrations to 45 g kg^{-1} of the initial levels, VC as a soil amendment could help to improve the structural stability of the soil particularly that of the macro aggregates [16]. VC seems to enhance polysaccharides, which are important cementing agents in soils that improve drainage, aeration, aggregate stability, and water retention. Furthermore, [11] showed that VC treatments had a substantial impact on the soils' aggregate stability, mean weight diameter, and structural stability index. In particular, when treated with 5% VC at a high irrigation level ($100\%_{+}$f), the mean weight diameter, aggregate stability, and structural stability index were higher than those of the vermicompost-free control. Following the application of soil amendments, improved aggregate stability and mean weight diameter are signs of improved soil physical characteristics that would support certain soil microorganisms and other chemical processes essential for the best possible plant growth. By maintaining adequate aeration through a well-balanced pore distribution that contains water and air, well-aggregated soil often offers the best conditions for plant growth.

3.3. Total Porosity

Since soil porosity affects many soil processes, understanding its properties is increasingly being utilized to describe soil structure. Water transfer is one of the soil's key roles, and it has a direct impact on the environment and plant productivity. According to Lin et al. [26], meso-pores (0.06–0.5 mm) and macro-pores (>0.5 mm) accounted for approximately 89% of the total water flux. Applying organic waste to the soil is a management technique that can increase soil structure, total porosity, and fertility by lowering losses of soil organic matter. Similarly, the addition of organic matter from amendments enhanced the distribution of pore sizes, increased pore size, and maintained pore space, which facilitates the movement of gasses and water via roots and is directly linked to plant growth. [28]. VC has been identified as one of the most efficient organic additions for enhancing soil aggregation, structure, and porosity. As reported by Parthasarathi et al. [34], soils treated with 100% old press mud and dried and chopped sugarcane waste VC had a significantly higher porosity. According to Marinari et al. [28], VC treatments raised the number of round pores in the soil, increasing its overall porosity. In the same way, Pushpa et al. [35] found that adding organic manure expanded the soil's pore space. It was lowest (22.5158%) in the control plot and highest (37.16%) in the plot with VC 12.5 t ha^{-1}, increased porosity in VC treated soil is most likely the result of soil particle aggregation caused by the VC microorganisms, which create polysaccharides that cement soil particles together, and perhaps by fungal mycelia as well.

Table 1. *Influence of applying vermicompost on soil porosity.*

Vermicompost (t ha^{-1})	Porosity (%)	Source
0	35.33	
5	37.66	[6]
10	38.66	
15	40.33	

3.4. Soil Structure

The primary determinants of a land's agronomic potential are its physical characteristics, such as its structure. The root penetrability, potential rooting volume, nutrient uptake and mobility, soil aeration, and water availability will all be significantly impacted by these characteristics. One significant method of enhancing soil structure is the introduction of organic amendments. By improving soil structure and increasing aggregate formation, adding organic matter to the soil improves its aeration and water-holding ability. In a similar vein, organic additions influence soil structure and numerous other physicochemical characteristics in addition to providing organic matter and nutrients [4]. Among organic additions, VC improves soil structure and plant growth. Vermicompost products provide the soil with humic compounds, enzymes, different hormones, plant nutrients, and most importantly, organic matter. Consequently, it enhances the soil's structure and creates an atmosphere that is conducive to plant growth. Furthermore, because VC increases soil fertility, productivity, and structural stability, it has a greater impact on soil quality than other organic waste-based soil supplements.

4. Influence of Vermicompost on Soil Biological Properties

4.1. Microorganism Community Improvement

Microbial community describes the number of different species of microbes present and their distribution in the soil. Soil microbes are the living components of the soil's organic matter and react sensitively to both positive and ecological activities, such as nutrient cycling, decomposition, and the inhibition of harmful and pathogenic species [13]. The diversity of plants, animals, and microbes that are found in the soil has a big impact on the health of the soil. Care of soil organic matter is vital for the long-term productivity of soil ecosystem. However, overuse of chemical fertilizers over time has led to the degradation of soil quality indices such nutrient content, soil microbial biomass, and communities, which in turn impacts crop productivity, health, and soil sustainability. On the other hand, applying organic amendments is a management technique to increase the biological qualities of soil by halting the gradual loss of organic matter. Among organic fertilizer, use VC significantly promotes greater microbial biomass and variety in the soil. The soil treated with vermicompost was better for microbial development and reproduction. Similarly, VC is abundant in a wide variety of microbial communities, especially fungus, bacteria, and actinomycetes. It also contains elements that influence growth, such as plant growth regulators, that are created by microorganisms [6]. Additionally, applying VC as an organic fertilizer creates a friendly habitat for the microbial community, which includes a population of bacteria, fungus, archaea, nematodes, earthworms, and microarthropods. This increases the respiration and enzymatic activity of the soil. VC improves soil microorganisms because of its high specific surface area, robust aggregation structure, efficient ion exchange, and adsorption capability. Additionally, it contains a wealth of beneficial bacteria and nutrients that enhance the physicochemical characteristics of soil and promote plant growth [41]. For example, microbes are protected by the enormous specific surface area of soil aggregates. Additionally, the VC pH is nearly neutral, making it ideal for microbial reproduction and having a beneficial impact on the microbes. According to Ferreras et al. [14], adding VC to soil is regarded as a good management practice in any agricultural production system because it promotes soil microbial growth and has a large particulate surface area that offers numerous microsites for microbial activity and strong nutrient retention, which leads to the mineralization of plant nutrients and improved soil fertility and quality. Furthermore, vermicompost is rich in a wide variety of microbial communities, especially fungi, bacteria, and actinomycetes, according to Atiyeh et al. [6], in addition to which it contains plant growth regulators and other growth influencing materials produced by microorganisms. Additionally, VC can increase the activity and proliferation of mycorrhizal fungi and rhizobacteria that promote plant growth, which can enhance nutrient uptake and plant resistance to environmental stresses. A study by Mondal et al. [29] found that adding vermicompost to soil improved tomato plant growth and raised the quantity of beneficial rhizosphere microorganisms, such as nitrogen-fixing and phosphate-solubilizing bacteria. Generally, application of vermicompost enhances the functional diversity of soil microbial populations. Also, applying VC increased the activity of enzymes linked to the nitrogen and carbon cycles, indicating an improvement in the functional diversity of soil microbial populations.

4.2. Microbial Abundance

It is well recognized that soil fertility and quality are determined by processes like nutrient cycles, organic matter synthesis, and organic matter breakdown, all of which are mostly attributed to microorganisms. Thus improving the functionality of microorganisms in agricultural systems is a crucial ecological tactic for achieving production sustainability. Applying organic fertilizers is therefore advised since it promotes microbial activity and growth, which results in a more chemically and physically suitable soil environment for plant growth. Incorporation of VC to the soil significantly promotes biological richness of soil. Because VC contains plant growth hormones including gibberellic acid, cytokinins, and auxins, as well as enzymes like amylase, lipase, cellulase, and chitinase. Additionally, it has defense mechanisms and antibacterial compounds that shield worms from the contagious effects of microbes [22]. VC also contains a lot of microorganisms (bacteria, fungi, and actinomycetes) that create enzymes (dehydrogenase, urease) and phytohormones (indole 3acetic acid, gibberellic acid, and kinetin) that help plants grow.

According to Tejada et al. [41], VC enhanced respiration and soil microbial biomass by 69% and 59.1%, respectively, in comparison to VC untreated soil. In comparison to the VC untreated plot, the treatment of VC also considerably increased the activities of dehydrogenase, urease, β-glucosidase, phosphatase, and aryl sulfatase in the soil. These enzyme activities were more enhanced with increasing rate of vermicompost application [40]. Because VC has vast particle surface areas, it retains nutrients well and offers a multitude of microsites for microbial activity. Likewise, higher levels of growth-promoting chemicals, vitamins, and enzymes in vermicompost led to an increase in the microbial population. The addition of azospirillum also increased the production of root biomass, which in turn led to a higher production of root exudates, which in turn increased the population of beneficial bacteria, fungi, and actinomycetes in the rhizosphere region. [39] Stated that the type and rate of organic matter put to the soil affected the stimulation of the dehydrogenase enzyme's activity in the soils amended with organic matter. In this regard, when compared to the control soil, the soil dehydrogenase activity rose 80.8% and 76.6%, respectively, in soils treated with cow dung and green forage vermicompost. In a similar vein, Ferreras et al. [14] observed that adding various VC to soil increased enzymatic activity. Soil enzymes can be thought of as early indicators of biological changes since they function as biological catalysts of particular reactions that are dependent on a number of variables, including crop type, amendment type, and inhibitor presence or absence. VC has an impact on soil enzymatic activities because it may contain extracellular and intracellular enzymes and may also increase soil microbial activity.

4.3. Modification of Microbial Habitats

The decomposition of organic matter and preservation of soil health depend on soil microorganisms. The soil environment is made up of microbes, which then take part in the biological processes of the soil and act as a conduit for the materials that plants and soil exchange. VC is rich source of micro and macro-nutrients, and microbial enzymes. In the same manner, applying VC improves soil biodiversity by encouraging the growth of beneficial microbes, which in turn promotes plant growth both directly through the production of hormones and enzymes that regulate plant growth and indirectly through the control of nematodes, plant pathogens, and other pests, improving plant health and reducing yield loss. VC high particle surface area also creates a number of microsites for bacteria, solid nutrient preservation, and soil fungus activity. Therefore, the majority of plant macro and micronutrient are readily available [42]. Moreover, the advantages of employing substrates based on VC in agriculture include increased crop yields, accelerated growth, and the creation of a favorable environment for beneficial microorganisms [32].

5. Effects of Vermicompost on Crop Productivity

Crop yield is essential to the world's food supply and provides millions of people with their main source of sustenance and income. However, there are serious worries about the sustainability of the crop productivity and the risks to environment associated with the traditional use of chemical fertilizers and pesticides in cultivation and pest control. It has been widely documented that using synthetic fertilizers to boost agricultural yields degrades soil quality by increasing salt and acidity. Therefore, crop field nutrient management is a critical component of agricultural success. Additionally, one of the most important ways to increase yield is by adequate fertilization, but when inorganic fertilizers are applied carelessly without organic additives, the environment is contaminated and the physical, chemical, and biological qualities of the soil are harmed. Using fertilizers sparingly is one way to preserve soil fertility for sustainable agricultural production, which is linked to increased yield and decreased fertilizer pollution. Therefore, applying organic fertilizer results in a decrease in exchangeable aluminum and bulk density and an increase in electrical conductivity, total soil nitrogen, microbial organic carbon, total soil organic carbon, available, exchangeable, and soil pH. Improving soil fertility also improves crop performance [30]. Applying VC has been shown to improve crop quality and yield across a variety of crops. VC can be utilized as a soil conditioner due to its high content of organic matter, micronutrients, and important plant macronutrients [18]. Additionally, using VC as an organic fertilizer promotes the growth, development, flowering, and fruit production of a wide range of plant species. These beneficial effects on plant growth could be caused by a number of things, including the availability of nutrients like nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, and iron; better air and water availability; the presence of substances that regulate plant growth; and the prevention or reduction of plant diseases. Similarly, [24] showed that vermicompost promotes plant growth both directly by providing nutrients and indirectly by improving the populations of bacteria that are beneficial to plants and preventing soil-borne illnesses. [23] found that applying VC increased mung bean germination (93%) in comparison to using bio digested slurry (84%). Additionally, using VC greatly increased the mung bean's growth and production. According to Hagh et al. [17], VC provides a natural solution enhanced with essential nutrients, humic acids, hormones that regulate plant growth and enzymes that have a favorable impact on photosynthesis, plant nutrition, and the nutrient content of different plant sections. According to Kale et al. [21], using VC increased the rates of nutrient uptake in cereal and ornamental plants while also increasing the symbiotic microbial interaction. The application of VC improved the physical conditions of the soil, supporting better aeration to plant roots, water drainage, facilitation of cations nitrogen, phosphorus, and potassium exchange, sustained availability of nutrients, and consequently the uptake by the plants leading to better growth, which is why beans have grown, yielded, and been of higher quality. [27]. When compared to VC untreated soil, the application of VC had a considerably positive impact on plant growth, yield, and elemental content. In this sense, compared to an untreated plot, the addition of VC at a rate of 15 t ha^{-1} greatly enhanced plant growth and yield. The electrical conductivity of fruit juice and the percentage of fruit dry matter rose by 30 and 24%, respectively, at a vermicompost rate of 15 t ha^{-1} [2]. According to Adiloğlu et al. [1], the lettuce plant's crop output, fresh weight, diameter, number of leaves, and leaf size and width all increase with increasing VC application dosages.

6. Conclusion

In light of the thorough literature review applying organic fertilizers in agricultural soil offers numerous potential benefits. Among organic fertilizer use of vermicompost as organic fertilizer have great benefit for sustainable agriculture productivity. It is simple, feasible, and economically viable and environmentally beneficial method for both remediating and reducing a wide range of environmental pollutants, including organic contaminants. Vermicompost as organic soil amendment under different soil characteristics improved soil physical, properties by reduced soil bulk density and increased the field capacity, available water capacity, saturated hydraulic conductivity, total porosity and aggregate stability of the soils. VC has been demonstrated to have significant amounts of micronutrients, phosphorus, potassium, and total and accessible nitrogen. The intake of these nutrients has a beneficial impact on plant development, nutrition, photosynthesis, and leaf chlorophyll content. VC increased the population and availability of growth regulators, enzymes, and microorganisms. It can also raise soil organic carbon when used consistently and appropriately under control. Similar to this, the use of VC improves the physical state of soils, which supports better aeration to plant roots, water drainage, the facilitation of cations nitrogen, phosphorous, and potassium exchange, and the sustained availability of nutrients, all of which improve plant uptake and growth. Use of VC for agricultural soil is the most cost-effective and environmentally beneficial method for both remediation and mitigation of a wide range of environmental pollutants, including organic contaminants. Furthermore, carrying out a cost-benefit analysis would offer insightful information on the economic viability and possible profitability of VC utilization in grain crop production and improvement of soil properties. The results of this literature study conclude by highlighting the potential of VC and its derivative products for improving soil qualities and producing grain crops in a sustainable manner. By examining and filling in the highlighted research gaps, stakeholders can make well-informed decisions about implementing and improving vermicompost application strategies in agricultural systems.

Abbreviations

BD	Bulk Desity
VC	Vermicompost

Conflicts of Interest

The authors declare no conflicts of interest.

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