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Effects of Vermicompost on Plant Growth and Soil Structure

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ABSRACT

Vermicompost is the name given to organic material in which virtually any organic waste is converted into a useful fertilizer and effective soil conditioner. Chemical substances that have been used intensively for many years have adversely affected soil fertility and microbial activity. Vermicompost products confer plant nutrient elements, various hormones, enzymes, humic substances and especially organic matter to the soil. Thus it improves the soil structure while preparing a suitable environment for plant growth as well. It is a material with high water holding capacity and cation exchange capacity. It also has a positive effect on the ventilation of the soil. It also helps plants to more efficiently utilize plant nutrients in the soil. The average organic matter content of our country's soils is quite low (2% or less). For all these reasons the use of vermicompost should be encouraged. The aim of this study is to give information about the properties of vermicomposts, and its effects on plant growth and soil structure and to provide a current literature source.

1. Introduction

In the last quarter-century, diversity and the materials utilized in agricultural production have spread into a wide ground. In addition to the yield, product quality has also become the target, in line with the needs of the market, the consumers and the industrialists, in the last quarter-century. Quality in plant production may be identified as the plant's desired properties' being at or close to the optimum level. In order to achieve these targeted characteristics, elements such as temperature, duration of the luminous exposure, humidity, nutritional requirements and climate should be met at the most appropriate level for each plant. If any of these factors cannot be met, plant development is negatively affected, and therefore product yield and quality are reduced. When environmental factors are appropriate, the plant must be fed correctly in order to achieve optimum quality in agricultural production.

With the use of inorganic fertilizers from the 1950s to the present day, the nutrients that plants need are quickly met (Schuman and Simpton, 1997). The use of highly fertile chemical fertilizers and medicines has brought along new discoveries with the understanding of the harm caused by long-term soil and human health (Bailer-Anderson and Anderson, 2000, Anonymous, 1997, Anonymous, 2001).

Even though the developments brought the organic agriculture to the agenda again, the increasing world population and the foresight that the nutritional needs will not be met, have allowed the generation of different perspectives. Livestock manure, used for agriculture for hundreds of years is insufficient in terms of the desired characteristics. As a result of these searches, a fertilizer with rich chemical content as vermicompost (worm fertilizer), which is a soil regulating material, have been discovered. Vermicompost is stated to be superior to other organic fertilizers (livestock manure, poultry manure, etc.) in many respects (Kiyasudeen et al., 2015). As the investigations deepened, vermicompost was found to contain many useful elements in addition to the plant nutrients such as vitamins, hormones, humic substances and antioxidants (Aracon et al., 2004).

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Vermicompost has positive effects on plant growth and soil structure. One of the attractive elements of vermicompost production is its positive effect on the environment. This is because the materials used as worm feed have a wide range of organisms that can rot in nature. Any material such as plant, animal, industrial and urban wastes can be transformed into beneficial fertilizers through the digestive system of worms (Edwards, 1995).

There are some special types of worms that are preferred in the production of vermicompost. In particular, Eisenia fetida and Lumbricus spp. species are the most preferred species (Simsek and Erşahin, 2007). In preferring these species, the predominant features are the facts such as high reproductive potential, rapid nutrient intake, broad adaptability ability, ability to produce vermicompost with higher organic matter content (Edwards and Bohlen, 1996). The material prepared as food for worms is first subjected to composting. The composted organic material is passed through the digestive tract of the worms and again mesophilic decomposition occurs. Thus, the organic material, which is subjected to further fragmentation, contains plant nutrients in its form in a shape that can be directly utilized by plants (Buchanan et al., 1988).

The purpose of this study is to create an understanding of the effects of vermicompost on plant development and soil structure in a comprehensive way. In a study conducted with a large literature review, we tried to provide a broad knowledge of the features and effects of vermicompost. This study also carries the character of being a current literature source.

2. The Characteristics of Vermicompost

Composting is done by earthworms in vermicomposting. There are some special species preferred for commercial production. The most important species are *Eisenia fetida*, *Eisenia andrei*, *Dendrobaena veneta*, *Lumbricus rubellus*, *Perionyx excavatus* and *Eudrilus eugeniae.*

Eisensia fetida is the most preferred worm species. One of the most important reasons for this is the higher reproductive potential. Worms in this species consume food faster than other worm species. This allows faster fertilizer production. Adaptation ability is much higher than other species. Vermicompost products obtained with this worm species have higher organic matter content. (Domínguez, ve Edwards, 2011).

The temperature range of the production environment is important for the vital activities of worms. The main reason for this is that they have open circulation. For this reason, body temperatures vary with ambient temperature. At around 7-8 ^{o}C, although they can survive, their ability to operate is very limited, and below 0 ^{o}C deaths can be seen. While varying between species, the optimum ambient temperature should be between 15-25 ^{o}C so that vital activities can be at the upper level (Rostami et al., 2009a).

2.1. Physical Characteristics of Vermicompost

Some special worm species are fed with animal and vegetable wastes, and the process of converting this organic material into a valuable fertilizer through their body is called "vermicomposting". The last product formed is given the name of "bio-humus" or "vermicompost" (Karaçal and Tüfenkçi, 2010). Vermicompost has a granular structure. However, it is dark, odourless and homogeneous (Doube and Brown, 1998). This material, both easier to dissolve and slow to release, is a nutrient source that plants can use for a long time (Buchanan et al., 1988).

Another feature that makes vermicompost important is its mass density. As the mass density effects plant growth positively, it also has positive effects on porosity, aeration and moisture content in the soil. The low or high mass concentration causes adverse effects on these contents. Aerobite microorganisms are damaged if there is insufficient air in the soil. At the same time, the roots have difficulty in meeting their energy needs due to oxygen deficiency. This leads to adverse effects on plant development. (Kiyasudeen et al., 2015).

In a quality vermicompost product, the porosity should account for 70-80% of the total volume and the rate of aeration in the pores should be between 20-30% and 55-75%. These criteria have been determined considering optimum plant development (Atiyeh et al., 2001). At the end of vermicompost production, the moisture content is around 50-90%, with changes (Dominguez and Edwards, 2011).

2.2. Chemical Characteristics of Vermicompost

Vermicompost has more positive effects than compost materials produced by thermophilic methods and using synthetic fertilizers (Kiyasudeen et al., 2015). Furthermore, vermicompost, which is a result of further fragmentation, has plant nutrients in the form that plants can directly benefit (Buchanan et al., 1988).

The most important factor affecting the content of vermicompost products is the nature and structure of the substrate material used. In terms of chemical composition, the product quality of the vermicompost is determined by such factors as the quality of the product, the mineralization of the organic matter, the increase of microbial viability, the breakdown of carbohydrates and the high humic acid fractions (Elvira et al., 1995). Vermicompost products contain numerous nutrients (N, P, K, Mg, Ca, etc.), vitamins, growth hormones, humic substances, enzymes and antioxidants in their constituents as they are obtained by the breakdown of the organic wastes of plants and animals (Aracon et al., 2004).

The chemical composition of vermicompost products can vary greatly. The causes of this situation include the type of subtrate material used (waste from different animals, urban wastes, vegetable wastes, etc.), disintegration due to ambient temperature, moisture status during production and type of worm used in production.

For example, the pH value of sheep manure is 8.6 and the mean value of livestock manure is 6.0-6.7. In sewage, which is another waste material used for vermicompost production, the pH value is about 7.2. The animal waste that is commonly used in the production of vermicompost is livestock manure. Studies have shown that the pH value changes between 5.8-8.65 with the analysis of samples from different vermicompost materials (Barlas et al., 2018; Jouquet et al., 2011; Mehrizi et al., 2015; Jabeen ve Ahmad, 2016; Göçmez, 2013).

The problem of salinity, which causes significant loss of plant growth, it is not usually encountered in vermicompost products. The main reason for this is that after it passes through the digestive system of the worms, due to certain biological and chemical effects, are at a level where the salt is not a problem in the product even if the salt content of the used substrate material is high (Edwards and Aracon, 2004; Lim et al., 2015). It was observed that the EC values of vermicompost materials are in the range of 0.89-3.44 dS/m, while the EC values caused salinity stress on plants begin with 4 dS/m (Banik et al., 2007; Namlı et al., 2014; Mehrizi et al., 2015; Barlas et al., 2018).

In Vermicompost materials, generally, the total C and N concentrations are higher than other compost products. The C: N ratio of the organic material used in the production of vermicompost should be around 20-22. If this ratio is higher than these values, the stability of the organic material used is low due to the organic carbon, and this data shows that this material is not a very suitable choice.

Macro and micro nutrient concentrations in the vermicompost material also show significant differences. When the average values are examined; total nitrogen ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$) 0.71-3.39%, soluble phosphorus (P_2O_5) 0.33-2.6%, soluble potassium (K_2O) 1.14-3.65%, Ca^{2+} 3.51-22.8 ppm, Mg^{2+} 0.61-6.64 ppm, Fe^{2+} 7.9-11.5 ppm, Cu^{2+} 0.89-98.3 ppm, and Mn^{2+} 275-304.3 ranges were found (Banik et al., 2007; Zhu et al., 2017; Singh ve Singh, 2017; Namlı et al., 2014; Mehrizi et al., 2015; Barlas et al., 2018).

It is possible to observe different values in the same substrate matelyal products in the same production area as it affects compost values which are derived from animal, plant and city wastes. Differences can be observed even in samples taken from different layers of the production pool. This is thought to be due to differences in temperature, humidity, microbial density and the composition of the substrate material in that area. It is seen that the substrate material used in vermicompost production affects pH, EC, organic carbon values and also changes the hemicellulose, cellulose and lignin ratios. Moreover, according to the results of the vermicomposting process, it is stated that while the carbohydrate concentration of the organic material decreases, the total soluble carbon and humic matter ratios increase (Nada et al., 2012).

2.3. Biological Characteristics of Vermicompost

Composting and vermicomposting techniques are the two best-known processes for providing the biological balance of organic wastes. In the composting process, the microorganisms break down the organic matter under controlled conditions, while the joint activities of soil worms and microorganisms in the vermicompost provide biooxidation of the resulting organic matter. Another point that makes vermicompost special is the degradation is mesophilic. This is the main reason why vermicompost products increase microbial activity and diversity (Fracchia et al., 2006). The effects of Vermicompost products on soil structure and microbial activity are determined by molecular techniques and specific enzyme activities (Garcia et al., 1993, Benitez et al., 1999, Benitez et al., 2005; Fracchia et al., 2006). Vermicompost products are superior to other organic fertilizers in terms of microbial activities of bacteria, actinomycetes and fungi (Huang et al., 2013, Emperor and Kumar, 2015). Initially, the organic matter with a low population of bacteria, fungi and actinomycetes is enriched in microbial activity activities after application of vermicomposting (Esakkiammal et al., 2015). A material with a low C:N ratio makes it an ideal environment for increasing the microbial population. Because the basic nutrient source that microorganisms need for their reproduction is nitrogen (Ndegwa and Thompson, 2000; Kumar and Shweta, 2011).

The compounds contain carbon are vital for microbial communities. While many bacterial populations are fed with easily available C compounds, the fungi prefer the more complex C compounds. However, fungi prefer more complex carbon compounds (Meidute et al., 2008). Vermicompost products also contribute to C mineralization. The integrated use of various organic fertilizers contributes 16-20% more to the increase of microbial activity because of the diverse requirements of different communities (González et al., 2010).

Although the short-term effects of the Vermicompost have been observed, they are not always detectable. However, long-term and regular applications increase microbial biomass and diversity in the soil (Dinesh et al., 2010).

It is known that the vermicompost product has a higher dehydrogenase enzyme and some other enzymes than the substrate and other compost products used as the starting material. However, the factor that increases the dehydrogenase enzyme activity is not the vermicompost dose applied but the NH4-N, NO3-N, and orthophosphate compounds that the vermicompost product has (Parthasarathi et al., 2016; Aracon et al., 2006).

The use of dense inorganic fertilizers to increase yield reduces soil fertility and reduces sustainable agricultural potential. In case of using Vermicompost with inorganic fertilizers, soil productivity can be increased thanks to organic carbon, active hormones and some enzymes provided to the soil. In addition, it also has a positive effect on the uptake of inorganic fertilizers by plants (Anwar et al., 2007). This issue has been discussed in more detail in the section on the effects of compost on soil structure and plant growth.

The starting material also affects biological properties. The use of livestock manure as a substrate in the production of vermicompost allows a product with higher microbial population compared to municipal waste (Pramanik et al., 2007).

3. The Effects of Vermicompost

3.1. Effects of Vermicompost on plant growth

The fact that vermicompost is an effective plant nutrition product was first noticed at the beginning of 1970's (Fosgate and Babb, 1972). The positive effects of vermicompost products are seen on a large plant population. It is stated that the vermicompost encourages the development of the plant in vegetable plants such as tomatoes (Atiyeh et al., 1999, 2000a, 2000b, 2001, Gutierrez-Miceli et al., 2007), pepper (Aracon et al., 2004a, Aracon et al., 2005), garlic (Argüello et al., 2006), eggplant (Gajalakshmi and Abbasi, 2004), strawberry (Aracon et al., 2004b), sweet corn (Lazcano et al., 2011) and green beans (Karmegam et al., 1999). Vermicompost products have also been shown to be effective in the production and yield of certain medical aromatic plants (Anwar et al., 2005), cereals such as sorghum and rice (Bhattacharjee, 2001, Reddy and Ohkura, 2004, Sunil et al., 2005), fruits such as bananas and melons (Cabanas-Echevarria et al., 2005, Acevedo and Pire, 2004), and ornamental plants such as geranium (Chand et al., 2007), marigold (Atiyeh et al., 2002) and petunia (Aracon et al., 2008). Forest species such as acacia, eucalyptus and pine trees (Lazcano et al., 2010a, 2010b) also have positive effects with vermicompost application. In the Indian oranges, 10 kg of vermicompost per tree provides about 40-61% increase in total crop yield and positive effects on crop quantity, fruit weight and product quality (Makode et al., 2015). Vermicompost applications (5 and 10 tons/ha) are also reported to increase the growth and yield of the strawberry plant (Arancon et al., 2004). In addition, vermicompost results in an increase in the rate of 37% for the leaf area of the plant, 37% for the root biomass of the plant, 40% for the flowering rate and 35% for the marketable fruit (Arancon et al., 2004).

Vermicompost application is reported to increase the total dry matter ratio in the rate of 24% for tomato plants (Azarmi et al., 2008), 65.26% for chickpea plants (Shrimal and Khan, 2017) and 12.5% for in onion nuts (Kenea and Gedama, 2018). Again, this substance is indicated to be affecting the nitrogen uptake (Tomati et al., 1990) and leaf area enhancement (Jeyabal and Kuppuswamy, 2001). The main reason why vermicompost products affect the intake of plant nutrients is the rich humic substances that they have in their structure. Humic substances exhibit a buffering property over a wide pH range. These materials form bonds with cations quickly, thanks to the negative charges of the humic acids present in their structures. Thus, they are easily caught by plant roots (Yılmaz, 2007). Thanks to these properties, they have an important influence on the retention of nutrients and the removal of these elements from plant roots.

Depending on the application of increasing vermicompost (0, 500, 1000 kg/da) and phosphorus (0, 50, 75 and 100 ppm) (TSP) in the corn plant, the chlorophyll content of the plant appears to increase vegetative growth and product yield (Amyanpoori et al. , 2015). In addition, it is indicated that the plant could not use the phosphorus in the same amount when it was applied without vermicompost when compared to the phosphorus applied with vermicompost (Amyanpoori et al., 2015). Zinc-enriched vermicompost has been reported to have increased the yield in a ratio of 100-113% in plants treated with vermicompost compared to the untreated plants in studies on the effect of vermicompost on the geranium plants' grass and oil yield (Chand et al., 2007).

As a result of the decomposition of the organic substrate in the vermicompost production process, various organic acids such as malonic, fumaric, succinic acids and soluble humic molecules (Atiyeh et al., 2001) are released. The released organic acids help to dissolve the nutrients of the useless plant nutrients and convert them into a viable form. Inorganic phosphorus (triple superphosphate) applied at different doses indicates that co-administration with vermicompost enhances the growth, yield and intake of some basic plant nutrients (NPK) and increases the plant height by about 50% (Muhammad et al., 2016). Application of inorganic nitrogen, phosphorus and potassium fertilizers with vermicompost has a positive effect on yield and quality criteria in sweet pepper plant grown in regions with high altitude and also reduces the maturing period. (Bahuguna et al., 2016). Phosphorus-enriched vermicompost is reported to have beneficial effects on yield of groundnut plant (Das et al., 2015).

Plants also have basic amino acids like humans and animals. Apart from certain amino acids that they have in their structures, there are also amino acids that they cannot produce and that they have to get from outside in the ready form. When amino acids are given together with vermicompost, it is indicated that it increases the growth rate, the amount of basic oil production, and the quality of the oil produced in daisy flower (Hadi et al., 2011).

In the sunflower plant grown under the salinity stress of the vermicompost and organic biogas slurry, the application has shown positive results on nitrogen metabolism and plant growth (Jabeen and Ahmad, 2016). It is also stated that the activity of N assimilation enzymes is also increased and that the addition of organic biogas slurry of vermicompost contributes to decrease salinity stress in plants (Jabeen and Ahmad, 2016).

3.2. Effects of Vermicompost on Soil Fertility

Vermicompost applications enrich the soil with micro and macro nutrients, vitamins, enzymes and hormones and contribute to plant development by regulating the physico-chemical properties (Makulec, 2002) (Sinha et al., 2009, Hazra, 2016). Vermicompost products contain essential nutrients in the form that plants can take directly (Pathma and Sakthivel, 2012, Lim et al., 2012). The main reason for this is that after thermolithic composting, the vermicompost passes through the mesolithic composting process which leads to further dissolution. Vermicompost (Erdal et al., 2000, Sönmez et al., 2013), which turns into a certain material, which is rich in humic acids, contributes to the increase of plant biomass and the root development (Delibacak and Ongun, 2016).

The plant nutrients found in the soil can be held in the soil by various factors, or they can form compounds with opposite ions. Vermicompost is expressed not only in plant growth but also in regulating soil pH and increasing electrical conductivity without causing salinity problems (Argüello et al., 2006). Vermicompost application improves the water-air balance in the soil and increases the macro-porous rate from 50 micron meters to 500 micron meters (Marinari et al., 2000). The surface area of the vermicompost increases the micro-porous area, allowing more nutrients to be retained (Shi-wei and Fu-zhen, 1991, Ali et al., 2015). It has been reported that more inorganic N, P, K fertilizers aplied to the soil together with vermicompost are received by the plants (Thirinavukkarasu and Vinoth, 2013). It has also been reported that vermicompost application has a more positive effect on plant growth and soil structure compared to fertilizers of thermolithic compost and inorganic N, P, K (Jouquet et al., 2011) in degraded tropical soils due to various reasons.

Vermicompost products have antibiotic properties due to the biochemical hormones they contain (Edwards and Bohlen, 1996). It has been reported that vermicompost applied with soil humic substances increases the concentration of plant growth hormones (Edwards and Aracon, 2004) and positively affected soil structure (Singh et al., 2008).

Today, heavy metals, which are commonly accumulated in soil and groundwater resources, are an important environmental problem posing a threat to the life of all living beings on earth (Okcu et al., 2009). Vermicompost has been reported to reduce the concentration of heavy metals in the applied soil (Dominguez, 2004). Studies on the handling of lead (Pb2 +) and cadmium (Cd2 +) heavy metals with livestock manure and vermicompost produced from them indicate that the livestock manure retention rate of these metals ranged from 39.57% to 99.22%, while that of with vermicompost was in the range of 69.43% to 99.88% et al., 2017). It is also stated that soil worms can accumulate metal in their bodies, and the effect of heavy metals in the soil can be reduced by earthworms (Taciroğlu et al., 2016).

One of the important factors affecting fertility in the soil is the presence of organic matter in the soil and microbial activities. Vermicompost products, with high organic matter content, enrich soil structure. It contains highly organic carbon and useful plant nutrients (Edwards and Bohlen, 1996, Parthasarathi et al., 2007). Vermicompost applications have been reported to increase microbial biomass concentration and phosphatase enzyme activity in soil (Şahin et al., 2016).

Vermicomposting is the most efficient way to protect natural resources, both environmentally and economically. It is estimated that the annual amount of organic waste in the world is about 1.3 billion tons, which is expected to reach 2.2 billion tons per year by 2025 (Singh and Singh, 2017). In a study conducted in Uganda and Kampala, composts prepared from livestock manure and nutrient waste were used for vermicompost production and it was stated that vermicomposting is an effective way of getting rid of organic wastes (Lalander et al., 2015).

4. Results

Vermicompost is a form of production where vegetable and animal products are transformed into a useful material. In agricultural areas, vermicompost application improves the physical, chemical and biological properties of the soil, as well as organic matter in the soil. Rich in nutrients, hormones, vitamins, enzymes and humic substances, this substance has a potential that can help improve the degradation of agricultural soils. Vermicompost, when used in production areas, provides many benefits directly and

indirectly to plant growth and product quality. The carried out studies confirms this. Increasing the production and use of vermicompost should be encouraged. Thus, an important step will be taken to increase the rate of organic matter and productivity in agricultural soils.

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