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Vermicompost production by earthworms and its role in sustainable agriculture

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Abstract
The aim of this study is to identify the role of vermicompost in soil properties, growth parameters, and crop yields as a sustainable ecosystem. Organic agriculture is an integrated system for managing agricultural production that enhances the sustainability of global food production and promotes soil health, ecosystem balance, and biodiversity. Worldwide, the use of organic fertilizers has become an alternative agricultural practice to maintain eco-friendly agricultural production with less environmental pollution. Vermicomposting is the process of converting biodegradable materials into nutrient-rich vermicompost using earthworms and is an essential practice for sustainable agriculture. Rich in hormones, enzymes, and growth-promoting microorganisms, vermicompost significantly enhances plant growth and disease resistance. The amount of organic waste produced annually worldwide is huge and is expected to increase from 1.3 billion tons to 2.2 billion tons by 2025. For this reason, vermicomposting has attracted attention as an environmentally friendly method of producing organic fertilizer. Vermicomposting influences microbial communities and nutrient availability while mitigating the effects of heavy metals, highlighting the need for a delicate nutrient balance. Vermicomposting has a positive effect on soil structure, reducing bulk density and increasing water retention, enhancing environmental sustainability.

Keywords: Clean agriculture, soil properties, organic fertilizers, plant growth, sustainable development

Introduction

1. Earthworms

Earthworms live and breed in wetlands, except in very dry desert areas. Some researchers believe that earthworms were wiped out in North America during the ice ages. With the end of the ice ages, earthworms recovered and diversified again. This diversity is due to two main factors: first, genetic mutations, and second, the influence of the environment surrounding the earthworms (Baker *et al*., 2011) [10]. Earthworms live below the soil surface and perform their major nutritional activity by devouring soil containing decomposed organic matter, algae, and fungi. After dusk and at night, earthworms come to the surface to continue their nutritional activity on leaves, plant debris, animal waste, and other organic matter, or to dispose of waste. They may also come to the soil surface to mate or to move from one soil to another (Cosín *et al*., 2010 and Wallis, 2014) [14, 36].

2. Earthworm food

Earthworms are omnivores, feeding on decomposed organic matter. Plant and animal food enters the mouth. The mouth is a very small opening in the first ring of the earthworm's body, above which there is a lip-like appendage. This appendage helps the earthworm to catch food. The earthworm also swallows soil along with the food. This helps in the digestive process and, in addition to extracting nutrients from the soil, increases the calcium concentration in the blood. Therefore, along the pharynx there are calcareous glands, which secrete calcium into the intestine to regulate the calcium concentration in the blood. Calcareous glands are not digestive glands, but act as ion regulators. They also regulate and stabilize the acidity of the body fluids (Singh, 2018) [32]. The pharynx is followed by a thin-walled vesicle, which is then followed by a muscular gizzard, which grinds up the food with the help of soil particles. The soil particles are swallowed by the worm along with the food. Digestion and absorption take place through the intestinal wall. The dorsal wall of the intestine has internal folds called typhlosols to increase the surface area for the absorption process. The intestine and dorsal blood vessels are surrounded by green matter-producing tissues in which sugar and fat-producing substances are synthesized. When the cells are filled with fat, they are released in the form of oil cells into the general cavity of the animal, which transport the fat to various body tissues and nourish them. There are foods and household waste that earthworms like, are suitable as a source of nutrition and do not cause them any harm. For example, cardboard and any kind of paper without ink or dyes are considered essential bedding for earthworms and are their main source of carbon. Also, dry green tree leaves, cucumber and potato peels, lettuce leaves, cabbage, apple peels, bananas, watermelon, pumpkin, carrots, eggplant, strawberries, egg shells and other vegetable and fruit peels, cereals such as oats, rice, corn, citrus fruits, onions, garlic, chili peppers, meat, oils and most kitchen waste except fatty foods. Dairy products can cause unpleasant odors, and earthworms can feed on cow, chicken, and horse waste (Baker *et al*., 2011; Bhat *et al*., 2018) [10, 12].

3. Benefits of earthworms

Earthworms have several benefits, but the most important benefit is the production of high-quality organic fertilizer, called vermifertilizer or vermicompost, which contains the nutrients required for plant growth. It also increases the yield of crops that are safe in terms of health and the environment, free of chemical pollutants, and have a natural taste. According to a study, earthworms can increase soil aeration by digging tunnels, and increase soil fertility and the availability of fast acting elements in the soil through several activities that earthworms perform (Adhikary, 2012) [2]. Earthworms bring organic waste into their tunnels and release the nutrients in a form that is easily absorbed by plants with the help of microorganisms**.** The soil that passes through the earthworm's stomach with the food and then emerges from the stomach contains a higher percentage of important nutrients that are easily absorbed by plants, such as nitrogen, phosphorus, potassium, calcium, and trace elements. As these earthworms die and decompose, they add organic matter and fast acting nutrients to the soil. The digestive system of earthworms, through which the soil passes, contains acids that serve to neutralize the soil's acidity and also stimulate beneficial microorganisms such as bacteria. The numbers of earthworms increase on the sides of earthworm tunnels and passageways because the mucus surrounding the earthworms is an important nutrient for bacteria, in addition to the nutrients that the earthworms provide to them as they enter the tunnels and create the right conditions for these microorganisms. The increase in earthworm numbers is associated with a sharp reduction in the numbers of pathogens and nematodes due to some secretions secreted by these earthworms (Bhat *et al*., 2015 and Usmani *et al*., 2017) [35].

4. Worm compost organic worm compost

The term vermicompost is a Latin word that consists of two parts. The first part is Virmi, which means earthworms. The second part is Compost, which means fertilizer. Thus, the word vermicompost is vermifertilizer produced by earthworms that eat organic waste such as household and garden waste, kitchen waste, leaves, and waste paper, secrete and excrete enzymes in their digestive system (Ngo *et al*., 2012) [28]. Wormcompost is also the least polluting type of fertilizer, including the types of organisms that cause plant diseases, and is rich in plant nutrients, and the components of vermicompost are soluble in water, making it easier for plants to absorb and benefit from them. Worm fertilizer can be fed directly to plants or placed at the bottom of seeds (Wallis, 2014 and Hanc and Dreslova, 2016) [36, 20]. Earthworms break down organic matter into a homogenous humus-like material. It is a complex mixture of worm waste and microorganisms that has a low C/N ratio and contains more of many nutrients such as nitrogen, phosphorus, potassium and calcium than conventional compost. Earthworms have the ability to consume many types of organic wastes such as livestock waste, agricultural waste, sewage sludge and other industrial and agricultural wastes. Vermicompost also plays a role in sustainable agriculture by promoting the use of environmentally friendly fertilizers and reducing inorganic fertilizers. Vermicompost accelerates biological processes by 2-5 times compared to conventional compost (Bhat *et al*., 2018) [12].

In the concept of organic agriculture technology, vermicompost is a microbiologically active organic fertilizer resulting from the interaction of earthworms and microorganisms, and organic agriculture can be defined as an environmentally friendly agricultural production management system that improves soil fertility, maintains soil biological activity, species biodiversity, ecological balance of the environment, and enhances and ensures the health of the agroecosystem In the world, 72,213 000 hectares of agricultural land (1.5% of the total area) are cultivated with organic agriculture (Arancon and Solarte, 2019) [5]. Compared to conventional composting, which requires mesophilic, hot and cold stages, vermicomposting involves only a mesophilic stage and consists of two stages, the active stage and the mature stage, which involve earthworm activity (Ayeni, 2012) [8]. Active stage In the active stage, earthworms rather than microorganisms are mainly involved in the decomposition process. The decomposition process consists of various changes in its physical state and microbial composition. At this stage, the gut-associated process (GAP) is a process that includes all the changes that occur in the decaying organic matter and microorganisms during its passage through the earthworm gut. Earthworms act directly on the decay of organic matter throughout the digestive tract-related process by ingestion, digestion, assimilation of organic matter and microorganisms in the gut, and trimming effects**.**

Organic waste is softened by saliva in the earthworm's mouth. The organic compounds are then softened and neutralized by calcium (which is excreted from the lining of the esophagus) and sent to the gizzard for further action in the esophageal region of the earthworm's body. Finally, the organic compounds are finely ground in the muscular gizzard into small particles. In the stomach, the organic compounds are digested by proteolytic enzymes. Various enzymes involved in the breakdown of pulped organic matter components, such as proteases, lipases, cellulases, and chitinases, are secreted in the gut, and the digested material is absorbed by the intestinal epithelium. The earthworm excretes undigested food material from the feces. During the passage through the gut, some bacteria become active, while others remain intact and are absorbed in the intestinal tract, thus changing the microbial community [Guo *et al*, 2019] [19]. These changes include the addition of sugars and other substances, changes in microbial diversity and activity, and inherent processes of homogenization, digestion, assimilation, and production of mucus and excretory substances such as urea and ammonia, which constitute a pool of nutrients that microorganisms can easily attack. The first example is due to gut-associated processes (GAPs). These processes include all the changes that decaying organic matter and microorganisms undergo during their passage through the earthworm gut. In the earthworm gut, toxic metals are immobilized by enzymatic activity, suggesting that telotechnology is an efficient process for removing heavy metals from industrial organic waste (Hernández, 2014) [21].

Maturation-like stages After the completion of the gut-associated processes, the resulting feces undergoes fecal-associated processes (CAPs), which are more closely linked to the aging process, the action of the microflora and microbiota present in the substrate, and physical changes in the excreted material. After passing through the earthworm gut, microorganisms, mainly fungal and protozoan spores and some resistant bacteria, are available for colonization of the newly formed earthworm feces. These newly deposited manures are generally rich in ammonium nitrogen and relatively digested organic matter, providing a suitable substrate for microbial growth. During the maturation process, more microorganisms than earthworms become involved, and the vermicompost reaches an optimum in terms of biological properties that promote plant growth and suppress plant diseases (Díez *et al*, 2008) [16].

Traditional vermicomposting methods 1. Windrow Vermicomposting by windrow can be done in a variety of ways. Here we will describe the three most common methods. 2. Static pile windrow (batch) Static pile windrow is a pile of mixed bedding and feed (or bedding with feed layered on top), inoculated with earthworms, and left to process until completion. These piles are usually elongated in the windrow style, but can also be square, rectangular, or any other shape. However, they should not exceed one meter in height (before settling). They require maintenance and care to provide a good environment for the earthworms. That is why the choice of bedding type is very important. Windrows do not need to be rotated, but they do need watering and covering (Arancon *et al*, 2007) [6].

Top-fed windrow (continuous flow) Top-fed windrows are set up as a continuous flow operation. This means that the bedding is laid first, then inoculated with earthworms, and then repeatedly covered with a thin (less than 10 cm) layer of feed. Earthworms tend to consume feed at the litter interface and then drop their waste near the bottom of the windrow. Over time, a layered windrow is created with finished product at the bottom, partially consumed litter in the middle, and fresher feed on top. A new layer of litter must be added periodically to replace the litter material that is gradually consumed by the earthworms. Harvesting is typically done by first removing the top 10–20 cm, usually with a front-end loader or tractor equipped with a bucket. This is the system used at a 77-acre operation run by America Resources Recovery in Northern California, which processes 300 tons of paper waste per day (Djidonou, *et al*, 2018). The advantages of top-feeding are primarily that the operator has greater control over the earthworms' environment. Because feed is added periodically, the operator can simultaneously easily assess conditions and adjust feeding rate, pH, moisture content, etc. as needed. This highly efficient. Wedge (Continuous Flow) A vermicompost wedge, i.e. an initial stock of bedding worms, is placed within an enclosure-type structure (with three sides) no more than 3 feet or 1 meter high. The sides of the enclosure can be concrete, wood, or even bales of hay or straw. Fresh material is added periodically through the open side using a bucket loader. The worms follow the fresh feed stock over time, leaving the processed material behind. When the material reaches the open end of the enclosure, the finished material is harvested by removing the back of the enclosure and scooping the material with the loader. The fourth side is then placed in place and the direction is reserved. With this system, the worms do not need to be separated from the vermicompost and the process can continue indefinitely. In the coldest months, a layer of insulating hay or straw can be placed over the active part of the wedge. The width of the enclosure is arbitrary, the only constraint being that the interior of the pile can be accessed for monitoring and corrective measures such as adjusting moisture content and pH levels. Ideally, the enclosure should be about 6 feet wide with foot space between. The ideal length depends on the material being processed, the earthworm population, and other factors that affect processing time (Atoo, *et al*, 2021) [7].

5. Vermicompost production

Mahitha *et al*. (2016) [25] confirmed that recycling cotton plant waste residues can produce good quality vermicompost with high nutritional value. The presence and accumulation of cotton plant waste residues creates problems in the soil and leads to the spread of pests and diseases. These wastes can be recycled and converted into fast decomposing vermicompost that contains elements necessary for plants, which greatly benefits the soil and plants and meets the nutritional needs of crops.

The best way to obtain high quality organic vermicompost from kitchen waste or farm waste in a short time is to use a very simple system that can be installed in your kitchen or restaurant or in various residential areas. In general, earthworms eat any organic matter and convert it into organic fertilizer that is beneficial for plants (Amouei *et al*., 2017) [3].

An experiment was conducted to produce organic vermicompost using two types of earthworms (Eisenia fetida and Eudrilus euginae) in a container with certain amounts of banana waste, cow dung, and shredded paper to find out which one can produce vermicompost with better specifications more efficiently. The required properties were measured at different periods (15, 30, and 45 days). The results showed that there were differences in pH, EC, and elemental concentrations during these periods, and finally pH (7.10-7.50), EC (3.59-3.64 dS m-1), total nitrogen (2.15-2.78%), total phosphorus (10.56%), total potassium (4.19%), total calcium (2.96%), total organic carbon (32.46%), and C/N ratio (11-14) were obtained. The results also showed that vermicompost with better specifications was obtained and is suitable for clean agricultural production. The performance of the nematode Eisenia fetida was shown to be better than that of the nematode Eudrilus euginae (Devi and Khwairakpam, 2020) [15].

This study aimed to make vermicompost from wastes of different sources: seaweed T1, sugarcane waste T2, coconut seeds T3, and vegetable and fruit waste T4. All these sources were measured for nutrient concentration, reaction rate, C/N ratio, cellulose/lignin ratio, and cellulose/nitrogen before the vermicomposting process. Then, appropriate containers were prepared, earthworms were added, and appropriate humidity and ventilation ratios were maintained. The results showed that after 50 days, all these sources were transformed into vermicompost and the C/N ratios were reduced to (T1: 23.9, T2: 41.82, T3: 48.23, T4: 69.81) and (11.03, 19.12, 27.13, 28.05), respectively. There was also a decrease in C/P ratio, decrease in cellulose/lignin ratio, decrease in cellulose/nitrogen ratio, decrease in pH, and increase in total NPK concentration of all sources after conversion to vermicompost (Biruntha *et al*., 2020) [13].

6. Factors affecting vermicompost production

1. The occurrence of unpleasant odors. This can be caused by:
    a. Excess food in the worm bin.
    b. Poor ventilation.
    c. High humidity.
    d. Food tends to be acidic. This can be caused by an excess of citrus fruits and their peels, an excess of meat and fat, leftover cooked food and dairy products, etc.
2. The presence of insects such as flies and mosquitoes. In that case, the food waste needs to be tightly covered or buried.
3. The waste of cows, sheep and chickens is not fully decomposed.
4. Earthworms are active in a moderate temperature range of 15-25°C, so when the temperature drops in winter, the earthworms are affected and their activity decreases and they may die.
5. Mineral fertilizers have different effects on earthworms. Fertilizers that increase acidity are lethal to earthworms, whereas herbicides have no direct effect but are effective by killing weeds that are a food source for earthworms (Baker *et al*., 2011) [10].

7. Vermicompost and its effects on soil

Wormcompost is an excellent soil conditioner and a key factor in making it the best organic fertilizer, which is more environmentally friendly than mineral fertilizers**.**

Earthworms and their waste (vermicompost) are a green revolution to replace destructive pesticides such as chemical fertilizers and pesticides that have brought more harm than good to both farmers and farmland. Earthworms secrete organic fertilizers rich in humus, NPK, trace elements, soil organisms such as nitrogen-fixing and phosphate-decomposing bacteria, enzymes, and growth hormones, thus restoring and improving soil fertility and significantly increasing crop productivity (Hanc and Dreslova, 2016) [20].

A field experiment was conducted to investigate the impact of integrated nutrient management on soil health. The experimental treatments consisted of a combination of organic fertilizers, with farmyard manure, chicken manure, vermicompost and inorganic fertilizer as the main treatments. For mineral fertilizers, the full fertilizer recommendation and 50% of the fertilizer recommendation were used. The addition of organic fertilizers and vermicompost had a positive impact on tuber yield and nutrient absorption (Lim *et al*.,2015) [24] on the use of vermicompost in organic agriculture and its impact on soil and economy pointed out that the fertilizer produced by earthworms improves the physical, chemical, fertility and biological properties of soil, leading to improved soil porosity, aeration and water retention, improved pH and electrical conductivity, as well as increasing the availability of elements required for plants, organic matter and beneficial microbial activity in the soil.

Piya *et al*. (2018) [30], in their study on the importance of vermicompost, stated that it improves soil physical properties such as increasing soil water retention and reducing apparent density. It also improves soil chemical properties such as providing the right degree of interaction and reducing salinity. It is an excellent source of trace elements such as iron, manganese, copper and zinc, and therefore contains both macro- and micronutrients. Most importantly, as a result of the activity of microorganisms in the soil, elements are released from vermicompost in amounts that fit the needs of the plants. This study aimed to investigate the possibility of replacing mineral fertilizers with vermicompost. The treatments consisted of vermicompost with organic fertilizers and livestock manure at the fertilizer levels recommended for the pea plant Cajanus cajan (10%, 50% and 100%). The results show that the use of mineral fertilizers at 10% and 50% in vermicompost increased organic carbon in cultivated soils and also (humic and fulvic acids). The addition of vermicompost also increased the soil's water-holding capacity, reduced the apparent density (6.10-13.0%), and improved the soil's chemical and physical properties. This study proved that vermicompost can be used to achieve sustainable agricultural growth (Das *et al.,* 2019). Vermicompost is used as an organic fertilizer to increase the concentration of nutrients, growth regulators, and enzymes in the soil, thus increasing productivity, improving the soil's physical and chemical properties, and creating a safe ecosystem for food production. The use of vermicompost also increases the amount of organic matter in the soil and increases the cation exchange capacity, which not only allows for the production of crops with a desirable taste, but also eliminates or reduces the use of mineral fertilizers and pesticides that have harmful effects on public health and environmental pollution (Mohammed *et al*., 2019) [26].

8. Vermicompost and its effects on plants

1. Vermicompost and its effects on vegetable crops (horticultural crops)

Wormcompost is an ideal organic fertilizer that promotes the growth and production of many horticultural crops, increasing crop yields and protecting crops from harmful pests as well as reducing environmental pollution. Application of vermicompost increases seed germination, stem height, leaf number, leaf area, dry leaf weight, root length, root number, total yield, number of fruits per plant, chlorophyll content, juice pH, TSS, nutrients, carbohydrate %, protein %, and improves fruit and seed quality (Joshi *et al*., 2015) [23].

An experiment was conducted to examine the effect of organic vermicompost addition on the productivity of spinach and turnip. The treatments were 4, 5, and 6 tonnes/hour of vermicompost. The results showed that the soil quality improved significantly overall in the panel treated with 6 tonnes/hour of vermicompost. Total productivity of vegetable crops during a two-year experimental period was significantly higher in plots treated with 6 tons of vermicompost (Ansari, 2008) [4]. An experiment was conducted to determine the effect of vermicompost on growth, productivity and quality. Growth and productivity of tomato fruits were compared with different doses of vermicompost (0, 5, 10 and 15 tons). Results showed that the addition of 15 tons of vermicompost increased growth and yield compared to the control treatment. The addition of 15 tons of vermicompost increased the juice and dry matter content of tomato fruits by 24% and 30%, respectively. Also, the K, P, Fe and Zn contents of the vegetative parts of the plants increased by 55, 73, 32 and 36% compared to the treatment without vermicompost (Azarmi *et al*., 2008) [9]. A study was conducted to explore the potential of vermicompost in enhancing growth and productivity of potato tubers. Statistical analysis of the data revealed that the number of tubers, yield per plant and total potato yield were significantly increased by using vermicompost levels compared to the control treatment (Narayan *et al*., 2014) [27].

A study conducted on tomato plants aimed to determine the effect of vermicompost on tomato growth and productivity. Vermicompost was produced by earthworms. Vermicompost was added at the rate of 1 kg, 3 kg, and 4 kg. Results showed that vermicompost showed a significant effect on plant height, number of leaves per plant, number of branches, root length, number of fruits per plant, and harvest index (Gopinathan and Prakash, 2014) [18].

An experiment was conducted to determine the effect of vermicompost and vermicompost tea on strawberry growth and productivity. Results showed that vermicompost tea recorded the highest values in green mass and yield (337 and 359 g per plant) and improved the quality of strawberries. Meanwhile, the use of vermicompost had a positive effect compared to the control treatment (Abul-Soud *et al*., 2015 [1].

A study was conducted to determine the effect of vermicompost, organic fertilizer (decomposed animal waste), and inorganic fertilizer on potato tuber yield and the content of major and micronutrients in the tubers. The experimental treatments consisted of (75% and 100% NPK), (12.5 and 25 tons/hour vermicompost), (12.5 and 25 tons/hour animal waste) in addition to a comparison treatment. Results showed that tuber yield was increased when 25 tons/hour vermicompost was used compared to 100% of the recommended amount of fertilizer. The interaction treatment of 25 tons/hour vermicompost + 100% of the recommended amount of fertilizer was superior in terms of NPK and trace element concentrations in the tubers than the interaction treatment of 25 tons/hour animal organic fertilizer + 100% of the recommended amount of fertilizer. Vermicompost treatment was superior to other treatments in all the traits measured, both in interaction and individually (Shambhavi and Sharma, 2008) [31].

In a study investigating the effect of vermicompost on potato vegetative growth and yield, NPK absorption by potato tubers, and the effect of vermicompost at four levels (0, 4.5, 9 and 12 tonnes/ha), the 150 kg/ha treatment was shown to be superior in the traits of plant height, dry weight of vegetative groups, number of main stems, leaf area, wet and dry weight of tubers, total tuber weight, total number of tubers, tuber diameter, percentage of nitrogen, phosphorus and potassium in tubers. The results also showed that the addition of vermicompost at the rate of 12 tonnes/ha improved all the above traits except plant height as compared to the control treatment. Moreover, the interaction between different nitrogen levels and the addition of vermicompost significantly improved plant growth parameters, yield, and NPK content of tubers compared to treatments with nitrogen or vermicompost alone (Yourtchi *et al*., 2013) [37].

Field experiments were conducted to study the effects of organic vermicompost, which led to increased yield, increased tuber number, plant height, increased leaf area, and increased dry weight of vegetative groups (Narayan *et al*., 2014) [27]. A study was conducted to investigate the effects of vermicompost and vermicompost tea on potato growth, tuber yield, and characteristics. The treatments were (vermicompost 300, 580, 860 g/plant) and (vermicompost tea 5, 10, 15 ml/plant) and salinity stress (NaCl levels 15, 20, 25 mmol cm^{-1}). The addition of vermicompost and vermicompost tea reduced the effect of salinity stress on potato growth factors and tuber characteristics. The addition of vermicompost 580 g/plant and 15 ml/plant increased plant height and stem diameter. Plants treated with vermicompost (860 g/plant), vermicompost tea (15 ml/plant) and salinity stress (15 mmol cm^{-1}) had higher pH values and reduced electrical conductivity values in potato tubers. The study concluded that the presence of vermicompost and vermicompost tea reduced the impact of salinity and improved potato growth and productivity (Pérez *et al*., 2017) [29].

1.2 Vermicompost and its effects on field crops

The experiment was conducted for the evaluation of the performance of Maize plant to Vermicompost, Vermi-tea and Chemical Fertilizer**.** Vermicompost used as a fertilizer and soil conditioner responsible for the improvement of the physical properties of soil and supply vital plant nutrients. Though single nutrient source may supply the respective required nutrients for plant but integrated use of all sources is required for balanced plant nutrition. Both earthworms and its vermicast and body liquid (vermiwash) are scientifically proving as both „growth promoters and protectors‟ for crop plants. With the objective to combat the nutrients deficiency. In field four different fertilizers [F1: Control (No fertilizer application); F2: Solid vermicompost @ 5 ton/ha; F3: vermi-tea 6 %; F4 : Chemical fertilizers (N and P) @120-100 kg/ha were applied in maize hybrid M30E71. The plants were harvested 60 days after sowing and the evaluation was done on the basis of various morphological (root length,shoot length, root fresh weight, shoot fresh weight, root dry weight, shoot dry weight, number of leaf, leaf length, stem girth) and physiological parameters (relative water contents (RWC), chlorophyll contents The obtained results indicated that vermi-fertilizers significantly increased all of the above said parameters of maize as compared to control but foliar application of 6% vermi-tea treatment showed maximum morphological and physiological performance of maize.(Tripathi and Pal,2024w) [34].

A field experiment was designed to determine the effects of compost tea on the quality parameters of sweet corn produced without the use of mineral fertilizers **.**

The fertilizer treatments in this study were 500kg ha-1 NPK fertilizer (Control), 1 kg compost per 10 L water compost tea, 1 kg compost per 20 L water compost tea and 1 kg compost per 30 L water compost tea, arranged in Randomized Complete Block Design, replicated thrice. Findings: The results indicated that the treatments had significant ($P \leq 0.05$) effects on the physical, chemical and sensory characteristics of the sweet corn evaluated. The mineral (NPK) fertilizer treatment gave highest mean total soluble sugar content (33.13 mg g^{-1}), followed by 1 kg compost per 10 L water compost tea (33.10 mg g^{-1}), then 1 kg compost per 20 L water compost tea (31.72 mg g^{-1}) and 1 kg compost per 30 L water compost tea gave the lowest total soluble sugar content (29.88 mg g^{-1}). Yet, the effects of 1 kg compost per 10 L water compost tea treatment and mineral (NPK) fertilizer treatment were the same ($p > 0.05$). Research limitations: There were no limitations to the report. Originality/Value: This study illustrated the possibility of utilizing 1 kg compost per 10 L water compost tea concentration to produce a good yield and quality of sweet corn without mineral fertilizers (Bako and Aminu,2024) [11].

The experiment included 54 experimental units resulted from the combination between two levels of Mycorrhizal biofertilizer (*Glomas mosseae*), three levels of verimcompost (0, 10, 20 tha^{-1}) and three levels of irrigation water (1.2, 3 and 5 dsm^{-1}) to evaluate the effect of these three factors on growth and grain Yield of mungbean and the availability of NPK. Results showed significant mcreased in plant height, shoot dry weight and grain Yield due to the addation of mycorrhizal biofertilizer that gave the value (26.19 cm, 4.65gm $plant^{-1}$ and 2.74 Mg ha^{-1} resipectvely.

addation of 20 tha^{-1} vermicompost gave (27.45cm, 5.31 gm $plant^{-1}$ and 3 tha^{-1} resipectvely while the availability of soil nutrients (NPK) were 48.82, 12.22 and 180.20 $mgkg^{-1}$ due to mycorrhizal biofertilizer addation. of 20 tha^{-1} vermicompost gave NPK availability 51.92, 13.76 and 197.40 $mgkg^{-1}$, the irrigated water of 1.2dsm^{-1} gave 50.91, 31.01 and 205.70 $mgkg^{-1}$ of NPK resipectvely.The mycorrhiza treatment gave salanity accumulation of 76.90% while vermicompost and 1.2 dsm^{-1} of irrigation water gave 46.80% and 58.90% resipectvely (Jabbar *et al*, 2020) [22].

The Experiment included 54 experimental units resulted from the combination between two levels of Mycorrhizal biofertilizer (*Glomas mosseae*), three levels of vermicompost (0, 10, 20 tha^{-1}) and three levels of irrigation water (1.2, 3 and 5 dsm^{-1}) to evaluate the effect of these three factors on the availability of NPK, growth and grain Yield of Millet.

Results showed significant increase in the available concentrtions NPK in soil due to mycorrhiza addition that gave the value 46.10, 12.00 and 192.93 mgk^{-1} resipectvely. Addation of 20 tha^{-1} vermicompost gave NPK available concentration 50.19, 12.14 and 207.50 mgk^{-1} respctively, while irrigation with 1.2 dsm^{-1} water gave NPK available concentration of 46.17, 12.52 and 197.67 mgk^{-1}.

The electrical conductivity was 4.91dsm^{-1}, 4.54 dsm^{-1} and 3.82 dsm-1 with the treatments mycorrhiza, 20 tha^{-1} vermicompost and 1.2 dsm^{-1} water respectively.

Results showed significant increase in plant height, leat area and shoot dry weight due to the addition of mycorrihzal biofertilizer that gave 39.40cm, 218.0 cm^2 $plant^{-1}$ and 5.28 tha^{-1} respectively while these value were 41.86cm, 250.80cm^2 $plant^{-1}$ and 5.66 tha^{-1} due to addition of 20 tha^{-1} vermicompost but the irrigation with water of 1.2 dsm^{-1} gave 40.70cm, 227.30 cm^2 $plant^{-1}$ and 6.36 tha^{-1} respectively(Jabbar *et al*,2020) [22].

The nutrient type and amount contributed from vermicompost varies depending on the source material, earthworm type used, agro-ecology and farmers' management. These call for crop, soil and site specific study. This study, therefore, aimed at determining the optimal vermicompost application rate/s for wheat and maize production; and the role of vermicompost on soil fertility improvements. Field experiments in three agro-climatic zones (highland, midland and lowlands) were established on wheat and maize crops following a randomized complete block design. The treatments were vermicompost (2.5, 5.0, 7.5 and 10 t ha^{-1}), conventional compost (10 t ha^{-1}), and recommended rates of Nitrogen and Phosphorus (NP = 100 kg DAP and 50 kg Urea) fertilizers. Our results revealed that the studied soil chemical properties, primarily, organic carbon (OC %), N (%) and available P (mg kg^{-1}) increased with increasing vermicompost rate. The 10 t ha^{-1} vermicompost treated plots had 157-210%, 64-81% and 100-242% higher soil total nitrogen content as compared to the control, 10 t ha^{-1} conventional compost and NP fertilizer treatments, respectively. Application of 10 t ha^{-1} vermicompost also resulted in a 1.5-fold and 43-63% grain yield increment of both tested crops compared to the control and NP treated plots, respectively. However, the highest net benefit was obtained from 5 t ha^{-1} vermicompost for maize (86% increase) and 10 t ha^{-1} of vermicompost for wheat (152% increase compared to the control). In conclusion, vermicompost at 5 t ha^{-1} for maize and 10 t ha^{-1} for wheat can be recommended to sustainably manage farm productivity (Teka *et al*,2024) [33].

Conclusions

1. Vermicompost plays an important role in improving soil fertility, biological, physical and chemical properties and enhancing plant growth and yield standards**.**

2. Vermicompost plays a role in reducing the use of mineral fertilizers, reducing soil pollution and following a sustainable agricultural system.

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