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Maximizing mushroom residues benefits to produce vermicompost for *Fusarium Oxysporium* resistance in maize

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Abstract

Background Since the ecosystem is the first link in the food chain for all living things, including humans, animals, and plants, restoring it has become a global priority in recent years, particularly in agricultural soils by expanding the trend of fertilization and biological control instead of relying more on the use of chemical pesticides. Therefore, this study aims to maximize and enhance the advantages of mushroom residues (MR) to make vermicompost that can resist *Fusarium Oxysporium* (FO) in maize. This study was conducted in three stages: compost preparation, composting, and planting.

Results The mixing process of vermicompost with the soil was improved by the lowest CV. The highest productivity was achieved by using a plastic rotary drum composter which had a patching size of 60 kg at a speed of 15 rpm for 8 min. In addition, the production of vermicompost from (MR) was improved by adding the aqueous extraction of licorice residue (LR), where helped to increase the vermicompost's pH and the amount of dissolved Cu and Zn. The wilt illness disease caused by FO in maize crop was decreased by adding the mixture of vermicompost (MR and LR) to the soil infested with Fusarium, as compared to the control.

Conclusions The combination of 25% vermicompost (MR + LR) and 75% agri-soil proved to be the most effective treatment for wilt disease control, with a disease severity score of 1.90. It was discovered that treated maize roots produced more peroxidase and polyphenol oxidase activity compared to the control.

Keywords Vermicompost, Mushroom residues, Licorice residues, Mixing, Maize seed, *Fusarium Oxysporium*

Background

Recent years have seen a rise in the importance of ecosystem restoration, especially in agricultural soils by relying less on chemical pesticides and promoting fertilization and biological control. Additionally, the overall trend is to use as much agricultural waste as possible, including mushroom breeding waste, to produce bio-organic fertilizers such as vermicompost (Paymaneh et al. 2023). According to Yang et al. (2017), vermicomposting is a crucial and useful stage in the recycling of biowaste. Vermicompost provides a bigger supply of nutrients and requires less time to prepare. Vermicompost is a fertilizer rich in nutrients that is environmentally beneficial owing to the concentration of vital nutrients for plants in it. Vermicompost is accelerating the transformation of organic residues into fertilizer with the aid of earthworms and microorganisms (Raza et al. 2023). Vermicompost generated by housefly larvae raised the organic C content of the soil to 42%. In addition, vermicompost enhances the enzymatic activity of the soil to 68% for dehydrogenase, 56% for phosphatases and 107% for urease. Continuously

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applying vermicompost to the soil increased soil carbon and microbial biomass, accelerated soil mineralization, and elevated C-, N-, and P-related enzymatic activities (Zhang et al. 2020). Reduced putrescible wastes can be achieved through biotreatment using housefly larvae (Zhang et al. 2012; Zheng and Zhou 2013; Čičková et al. 2015; Negi et al. 2020; Cheng et al. 2021; Guo et al. 2021; Miranda et al. 2021).

Vermicompost can only be produced through the two processes of grinding and mixing. The feeds are further ground down in size so that earthworms may easily devour them. Contrarily, the mixing procedure ensures that meals have a consistent texture and quality before being placed in the beds (Atienza et al. 2021; Amer et al. 2022). Conventional vermicomposting takes 45 to 60 days to produce a fully mature crop compared to rotary drum composting which takes from 25 to 30 days. So, the duration of vermicomposting can be reduced to 15–20 days by using drum composting (Kauser and Khwairakpam 2022). Vermicomposting was used to amend soil to improve its physical and biological properties, as well as to increase the amount of organic matter and soil fertility. Globally, vermicomposting is being utilized more in sustainable agriculture as a biofertilizer that is safe for the environment and suited for the soil. It is well recognized that vermicomposting can affect plant diseases brought on by soil-borne pathogens; vermicomposting's level of stabilization has a beneficial impact on the prevention of disease (Millner et al. 2004; Noble and Coventry 2005; Reham et al. 2017).

Mushrooms are a vital component in the human diet to prevent and treat various diseases. In the upcoming years, mushrooms are expected to meet the growing demand for their nutritional content and active ingredients (Barbosa et al. 2020). Remains from mushrooms are typically considered as agricultural trash and disposed of in landfills, incinerators, or open fires, strewn on the ground, or composted with animal manure without being properly utilized. Since inappropriate disposal could result in environmental problems such soil contamination, air pollution, and water pollution, this has presented a considerable barrier (Collela et al. 2019).

Meng et al. (2018) improved soil nutrient profiles supporting tomato seedlings and yield by using both separate and combination applications of composted biogas slurry and wasted mushroom substrates. Spent mushroom substrates have previously been widely accepted for crop fertilization. Similar to (Collela et al. 2019), they used mushroom substrates obtained from *Agaricus bisporus* in tomato production increased by 20% Compared to untreated tomato.

Moreover, *Glycyrrhiza glabra* "licorice". is an herbaceous perennial belonging to Leguminosae family. Erk sous is the common traditional arabic name and one of the preferred beverages in Egypt. The licorice root has been utilized for thousands of years due to its therapeutic properties. It is still popular in the Arab Area and in many parts of Europe (Falet et al. 2019; Tabrizi et al. 2021). Pistachio nut shells that have been zinc chloride-impregnated and licorice remnants together were used by Moradi et al. (2020) as a possible biosorbent to take the place of mercury in aquatic solutions.

On the other hand, Asasian et al. (2012) noted that agricultural residues with soft structures, such as licorice residues, rice husks, and bagasse, cannot be converted into adsorbents with good enough properties despite having relatively large amounts of carbon. Furthermore, Ruangjanda et al. (2022) discussed how cassava pulp, eggshells, Azolla biomass, and fruit peels affected the spent mushroom substrate's ability to degrade because using just spent mushroom substrate may not be appropriate for vermicomposting. Patra et al. (2022) showed a comparison to compost produced without the use of earthworms, vermicompost prepared from mushroom spent waste, water hyacinth (Eichhornia crassipes), eaf litter (Tectona grandis), and cauliflower waste showed excellent nutritional and microbiological qualities. Furthermore, Hřebečková et al. (2020) discussed that vermicomposting from spent mushroom substrate showed less electrical conductivity and raised the bacterial/fungal ratio as well as total P.

One more popular cereal grain worldwide is maize or corn. It is the primary food crop in many nations throughout the world, outpacing wheat and rice in regard of area, yield, and productivity (Walder et al. 2017; Lanubile et al. 2017). It is quite frequently referred to as the "Queen of Cereals" since it offers the highest potential for genetic yield. and nutritional value (Maschietto et al. 2017). The rainy season is when maize is mostly grown, and it is used as a primary source of food, fuel, fodder, and industrial raw materials. (Sharma and Rayamajhi 2022). In Egypt, one of the important crops in the rural economy and livelihood is maize (Salama 2019). Egypt produces 7.50 million Tons on 1.46 million ha. Egypt imported 7.88 million Tons worth $1.88 billion in 2020 as domestic maize production is insufficient to meet the demand (FAOSTAT 2022). On the other hand, Fandohan et al. (2003) noted that fungi are the second-leading cause of maize degradation and loss in the field after pests and the fungus could harm farmers' maize by 50 to 80 percent. One more significant fungal pathogen affecting crops is *Fusarium* (fusarium ear rot), which produces disease complexes in maize (Orsi et al. 2000; Walder et al. 2017). These fungi obstruct the plant's water-conducting vessels, and when the infection advances into the leaves and stems, it inhibits the flow of water, resulting in yellowing and foliage wilting, and then it can reduce maize grain yield and quality. Moreover, it causes a significant economic loss, as well as mycotoxin-contaminated grains that pose a concern to human health (Lanubile et al. 2017; Maschietto et al. 2017).

In this concern, synthetic fungicides are traditionally applied to treat this disease. However, because fungicides were used carelessly, the toxicity accumulated, which lead to a change in the ecological balance of the soil by killing off the useful microorganisms. In the current study, the importance of implementing biological approaches (restoring the ecosystem) as an alternative form of disease control has been highlighted by increased awareness of the risks associated with fungicides. Thus, the goal of this investigation is to maximize the benefits of mushroom residues to produce vermicompost that can resist *Fusarium Oxysporium* in maize.

Methods

Experiment materials

Agricultural residues and soil

- Mushroom residues (MR)

The MR was collected from BIOTECH farm at Ismailia Desert Road, Ismailia governorate, Egypt. It was contained from breeding soil and deformed mushrooms.

- Licorice residues (LR)

The LR was collected from Licorice drink manufacturers production and results of aqueous extract of licorice roots.

- Soil

The clayey soil was obtained from the Unit of Identification of Microorganisms, Plant Pathology Research Institute (A.R.C.), Giza, Egypt.

Chemical properties of the mushroom residues (MR), licorice residues (LR), and clayey soil are displayed in Table 1.

Maize seeds

The seeds of maize 324 (*Zea mays L.*) white hybrids three-way cross (TWC 324) were obtained from the Field Crop Research Institute, ARC, Giza, Egypt. In order to disinfect the seeds, they were immersed in a 5% sodium hypochlorite solution for 3 min.

Plastic rotary drum composter (PRDC)

The reactor unit was manufactured according to the common model (Kauser and Khwairakpam 2022). The length, diameter, and thickness of the drum are 0.93 m, 0.58 m, and 0.005 m, respectively. The drum can hold between 100 and 150 kg of wet waste and about 50 to 75 kg of the final product. With the aid of center axes in two side bases, the drum is supported by a metal stand and rotates mechanically. In order to properly mix, agitate, and aerate the ingredients during rotation, a 50 mm angle is set inside the drum. It was fixed in the middle of the two bases with two horizontal rotation axes and based on side holders that hold the drum. A hand is attached to one of them that allows the barrel to be rotated by hand. The barrel is open in a part of the side space that allows filling when it is up and empties when turned downwards and the hole is closed when turning vermicompost or mixing fertilizer with the soil. Inside the cylinder, there are holes in the opposite direction of the opening fill to drain the surplus water, good ventilation, and worms' exit after decomposition.

Experiment description

This experiment was carried out at three steps as shown in Fig. 1. The first step was done at Ali farm, Elqnayat, Elsharkia Governorate, Egypt, while the second step was conducted in Agricultural Engineering Research Institute (AEnRI), ARC, Giza, Egypt during summer 2021. In addition, the 3rd step was executed during season 2022 at the Unit of Microorganisms Identification, Plant Pathology Research Institute, ARC, Giza, Egypt.

Table 1 The chemical properties of agricultural residues and soil

Agricultural residues	pH	Ec	N	K	P	Fe	Mn	Zn	Cu
MR	6.60	8.94	1.88	0.68	0.06	0.24	0.004185	0.00238	0.001235
LR	9.90	0.83	4.20	0.20	0.035	1.075	11.40	23.60	25.00
Sterilized clay soil	7.88	2.96	0.000333	0.0360	0.00055	0.000671	0.000652	0.000468	0.000774

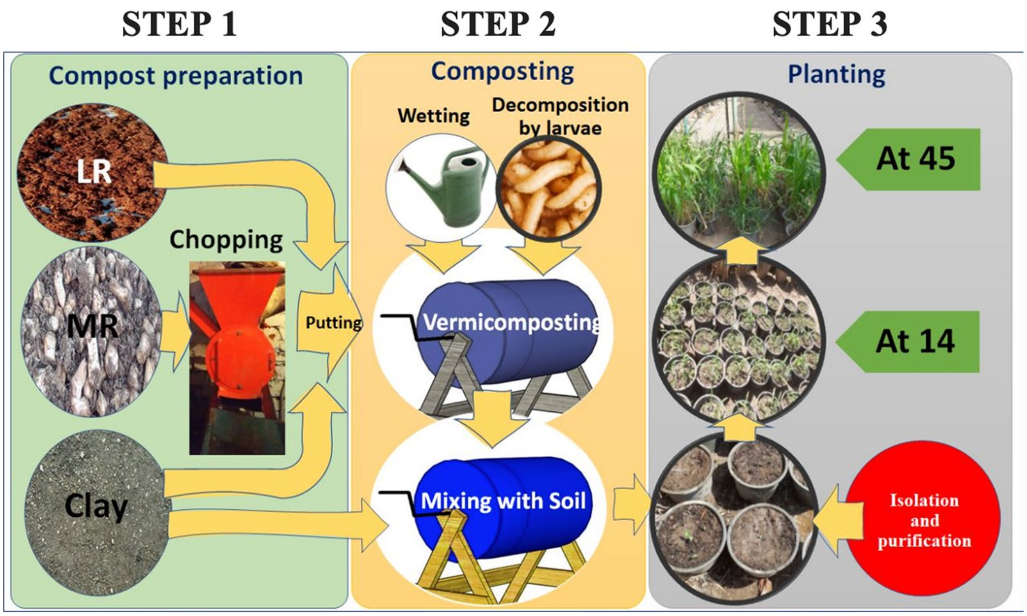

Fig. 1 Steps of experimental study

Step 1 (Compost preparation)

The chopping of MR was conducted by a hammermill (screen-less) with long track conditions, at 700 kg/h of a feeding rate with drum speed of 3000 rpm, and 48 h of sun drying at 27 °C (Amer et al. 2022). To prepare licorice residue, a 50 gm of licorice root was soaked in 500 ml water (water extract) at room temperature with sporadic shaking for 48 h. Mixture was filtered by cheese cloth to get the residues of cold-water extract that from above the filter (Falet et al. 2019).

Step 2 (Composting)

The residues were placed in layers even in the middle of PRDC before allowing the larvae to appear, stir the compost twice a week for ventilation to reduce the temperature, distributing moisture, non-decomposing materials and larvae, and preventing the increase of larvae in limited areas.

Two types of vermicompost were prepared for use in the experimental to compare these vermicompost for *Fusarium* resistance in Maize; the first type was vermicompost produced from MR only and second type produces from 75% of MR and 25% of LR.

All treatments were placed in PRDC with keeping it open at temperature (30 ± 5.00 °C) under normal conditions. Samples are sprayed with water almost twice a week. In addition, the average of moisture content of all tratments was regularly measured within the study period and maintained 70% using (Vakdon, B09CPTS52W), and then organic mixtures were biodegraded by housefly larvae. Due to their higher fecundity and quicker developing time than black soldier fly larvae, house fly (*Musca domestica* L.) larvae were chosen for waste biotransformation (Čičková et al. 2015).

All of these substrates were subjected to 20 days of biodegradation. Organic combination was exposed to natural fly oviposition, which triggered the biodegradation process inside the containers. The containers were covered with a net, and larvae were collected ten hours following natural oviposition. Then, after 25 days are free from larvae, they are left to dry and prepare for use.

In order to optimize these parameters (six vermicompost types), soil mixture tests were carried out in preparation for the application of vermicompost in agriculture (Table 2). These parameters were done in a five operational mixing times (4, 6, and 8 min), three batching sizes (50, 60 and 75 kg) and manual mixing to choose as control treatment to choose the best treatment for soil preparation for cultivation.

Step 3 (Planting)

- Isolation and identification of F. oxysporum wilt

Samples of Maize (*Zea mays* L.) plants with the usual wilt disease signs were gathered from six different governorates, i.e., El-Behaira, El-Qalyobia, El-Sharkia, Kafr-El Sheikh, El-Garbia and El-Giza. Samples were transferred at the Unit of Identification

Table 2 All treatments used in the experiments

Treatments	Soil infested	Soil clay (%)	Vermicompost (%)		
			MR, (%)	LR (%)	Clay, %
CU10	No	100	NPK		
CI10	Yes	100	NPK		
TM70	Yes	100	NPK + Topsin-M (70%)		
V1M1L0	Yes	0	100		
		0	50	–	50
V1M7L2	Yes	0	100		
		0	37.5	12.5	50
V7M1L0	Yes	25	75		
		25	37.5	–	37.5
V7M7L2	Yes	25	75		
		25	28.125	9.375	37.5
V5M1L0	Yes	50	50		
		50	25	–	25
V5M7L2	Yes	50	50		
		50	18.75	6.25	25
V2M1L0	Yes	75	25		
		75	12.5	–	12.5
V2M7L2	Yes	75	25		
		75	9.375	3.125	12.5

of Microorganisms using ice box. Isolation and identification methods according (Abou-Zeid et al. 2018).

- Pathogenicity test

Ten isolates of *F. oxysporium* (FO) were subjected to pathogenicity tests at the Unit of Identification of Microorganisms under greenhouse conditions. A susceptible maize cultivar was used for the pathogenicity test of the FO isolates that were obtained.

- Inoculum preparation

The most aggressive isolate from the evaluated isolates was chosen and employed in the current investigation. For FO, sterilized clayey soil with a different vermicompost treatment (5% formalin) was placed in plastic pots (30 cm in diameter) (Abou-Zeid et al. 2002). The soil was watered and left for a week to ensure that the pathogenic fungi were evenly distributed throughout the soil. In the control treatment, the same volume of sterilized, non-inoculated sorghum grains was added to the soil.

- Greenhouse experiment

Five seeds of maize per pot were sowed after being sterilized. For each particular treatment, three replicates were employed. At 14 and 45 days after the initial vaccination, the experiment came to the end.

On a scale of 1 to 5, the root rot severity brought on by the isolates on corn seedlings was rated as follows: 1 = germination and healthy seedling with no visible root colonization; 2 = germination and lesions on 1 to 19% of the root; 3 = germination and lesions on 20 to 74% of the root; 4 = germination and lesions on 75% or more of the root; and 5 = no germination and complete colonization of seed.

Measurements and calculations

Coefficient of variation (CV)

Coefficient of variation (CV) was used as a mixing performance indicator. Also, standard deviation (SD) was calculated as an amount of variation in sample population. The CV under 5% is considered good, and between 5 and 10% is considered unimproved, as reported by Golub et al. (2019).

$$CV,\% = \frac{SD}{\overline{X}} \times 100$$

where SD: standard deviation; $\overline{X}$: average of samples population.

Standard deviation is an amount of variation in sample population, defined as equation:

$$SD = \sqrt{\frac{\sum x^2 - \frac{\left(\sum x^i\right)^2}{n}}{n-1}}$$

Vermicompost physical and chemical properties

The analysis was done in (AEnRI) and Soil, Water and Environmental Institute Lab, ARC.

Enzymes activity in maize roots

Root samples were promptly homogenized with liquid nitrogen at 14 and 45 days after inoculation with the various ingredients (Ojha and Chatterjee 2012). At 4 °C, 2 ml of 0.1 M sodium phosphate buffer (pH 7.00) was used to extract one gramme of the powdered material. At 4 °C and 4000 rpm, the homogenate was centrifuged for 20 min. The peroxidase activity (min^{-1} g^{-1}) was determined according to Hartee (1955). The polyphenol oxidase was calculated following the methodology of Mayer et al. (1965), when ß-1, 3-glucanase activity was measured as described by Miller (1959).

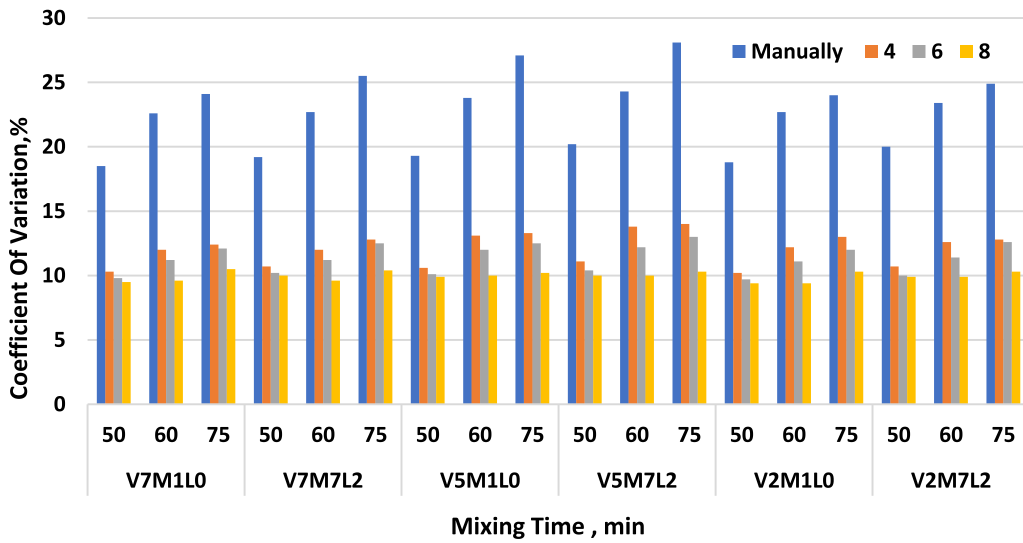

Fig. 2 Effect of mixing time on coefficient of variation

Table 3 Physical and chemical properties of the vermicompost

Physical and chemical properties	MR	LR	V1M1L0	V2M7L2
pH	6.60	9.90	6.88	8.00
Ec	8.94	0.83	4.30	5.20
N	1.88	4.20	2.40	2.80
K	0.68	0.20	0.87	0.60
P	0.06	0.035	0.50	0.23
Fe	0.24	1.075	0.94	1.78
Mn	0.004185	11.40	16.40	15.06
Zn	0.00238	23.60	10.66	11.90
Cu	0.001235	25.00	13.60	47.00
Bulk density (g)	0.3889	0.4396	0.5620	0.5466
Repose angle	58.34°	54.23°	36.66°	34.31°
Friction factor	41°	40°	24°	22°

Table 4 Pathogenicity test of F. oxysporum on Maize under greenhouse conditions

Isolates	Governorate	Localities	Disease severity
1	Sharkia	Hehia	2.70
2	Behaira	Etay-El Baroud	3.80
3	Kafr-El Sheikh	Kleen	4.30
4	Kafr-El Sheikh	Sakha	5.00
5	Sharkia	Menia-Elamh	1.90
6	Garbia	Tanta	3.30
7	Qualubia	Miet-Kinana	4.20
8	Qualubia	Toukh	4.50
9	Giza	Bdrasheen	2.80
10	Giza	Giza	3.00
Control			0.00
L.S.D at 5%			0.795

Statistical analysis
According to the methodology provided by Sneddecor and Cochran (1980), statistical analysis was performed using the F-test for significance at p 0.05 and computing least significant difference (LSD) test, values to distinguish means in distinct statistical groups.

Results
Mixing vermicomposting with soil
The results revealed that the mixing time and batching size were important factors effect on CV of the mixing process. With respect to the effect of mixing time on CV, Fig. 2 represents the CV under three mixing times and three batching sizes. The results showed that by increasing the mixing time from 4 to 8 min, the CV of the mixing process decreased in all types of vermicomposting mixing by 25%, 50%, and 75% of soil at batching sizes of 50, 60, and 75 kg, respectively. This contrasts with manual mixing when the CV rose throughout all mixing processes.

Vermicompost physical and chemical properties
Table 3 shows the changes that occur to the physical and chemical properties of produced vermicompost from different agricultural residues. It was noted that the produced vermicompost from MR and LR was recorded an increase in the pH level from 6.60 to 8.00 compared to the pH of the produced vermicompost from MR. On the other hand, electrical conductivity

Table 5 Disease severity in infested maize crop under vermicompost

Treatment code	Disease severity
CU10	0.00
CI 10	5.00
TM70	1.50
SC10	3.20
V1M1L0	4.80
V1M7L2	4.30
V7M1L0	4.50
V7M7L2	4.00
V5M1L0	4.10
V5M7L2	3.80
V2M1L0	3.50
V2M7L2	1.90
L.S.D at 5%	0.607

(Ec) in vermicompost resulting from (MR and LR) was increased from 4.30 to 5.20 as compared to the vermicompost resulting from MR. From another side, the nutritional characteristics (N, P, Cu) contents increased in the both type of vermicompost MR and (MR and LR) compared to the used agricultural residues.

Pathogenicity test

Data in Table 4 pertain to wilt disease brought on by FO. The isolate No. 4 from (Sakha) was discovered to be noticeably more aggressive than the other isolates and to have the greatest illness severity (5). The strain No. 5 (Menia-Elamh), which had the lowest disease severity (1.90) in the infection and was the least virulent, allowed the fungus to enter the grains more easily.

Green houses experiment

Disease severity

Information in Table 5 showed that treated maize with different vermicompost reduced the wilt disease's disease severity caused by *F. oxysporum* compared to control (untreated). Fungicide Topsin-M (70%) TM70 and V2M7L2 were the most effective substances in controlling wilt disease that recording 1.50 and 1.90 of disease severity, respectively. In the meantime, wilt disease severity was reduced by all evaluated bioagents. On the other hand, V1M1L0 and V7M1L0 were the lowest effective treatments in controlling wilt disease which recorded 4.80 and 4.50 of disease severity, respectively. These results were in agreement with Millner et al. (2004); Noble and Coventry (2005); Reham et al. (2017).

Enzymes activity

Data in Table 6 revealed that treated maize roots resulted an increase in peroxidase and polyphenol oxidase activity compared with (uninfestedand infected) control treatments at both measuring times. In general, the activities of peroxides and polyphenol oxidase enzyme at 14 days post-treatment were higher than those at 45 days post-treatment. The highest increased peroxidase activity was recorded (1.336 and 1.101) at 14 days and (1.259 and 1.067) at 45 days, respectively, and polyphenol oxidase activity were recorded (1.15 and 1.01) at 14 days and (0.971 and 0.971) at 45 days,

Table 6 Enzymes activity of infested maize roots as treated by the different vermicompost

Treatment code	Enzyme peroxidase activity		Enzyme polyphenol oxidase activity		Enzyme gluconase activity	
	14 days	45 days	14 days	45 days	14 days	45 days
CU10	0.12	0.03	0.10	0.03	0.01	0.287
CI 10	0.44	0.41	0.452	0.221	0.03	0.291
TM70	0. 50	0.121	0.515	0.461	0.132	0.449
SC10	0.801	0.721	0.854	0.769	0.096	0.389
V1M1L0	0.507	0.442	0.583	0.511	0.069	0.202
V1M7L2	0.53	0.412	0.658	0.576	0.072	0.46
V7M1L0	0.646	0.537	0.69	0.621	0.082	0.227
V7M7L2	0.691	0.431	0.776	0.6	0.085	0.5
V5M1L0	0.792	0.664	0.862	0.782	0.099	0.346
V5M7L2	0.801	0.711	0.912	0.832	0.111	0.59
V2M1L0	1.15	0.971	1.01	0.971	0.125	0.563
V2M7L2	1.336	1.259	1.101	1.067	0.165	0.825
L.S.D at 5%	0.151	0.071	0.184	0.131	0.071	0.151

respectively, with V2M7L2 and V2M1L0 in infested maize plants with *F. oxysporium* and treated compared with other treatments at 14 and 45 days, respectively. In contrast to other treatments, TM70 showed the lowest peroxidase activity on both measuring times. On the other hand, all treatments increased the activity of β-1,3-glucanase after 45 days in roots infested with *F. oxysporium* more than those after 14 days of infection. The maximum increased in β-1,3-glucanase activity was recorded (0.165 and 0.125) at 14 days and (0.825and 0.563) at 45 days in inoculated roots with *F. oxysporium* and treated roots with V2M7L2 and V2M1L0 at both measuring times compared with other treatments.

Discussion

Mixing vermicomposting with soil

The results indicated that the CV decreased by increasing mixing time and the same trend at all batching sizes under the conditions and variables of the experiments. This may be due to the increasing the movement of the components for a long time, which in turn caused charging of the components through electrostatic charges, which in turn led to an increase in fine-grained on the surface of the large-grained. These results were in agreement with Alkoaik et al. (2018). The results showed that the best values for CV were at a mixing time of 8 min and a patching size of 60 kg, due to its higher productivity compared to 50 kg. So that, this treatment was chosen to mixing vermicompost with soil under third stage of experiments.

Vermicompost physical and chemical properties

Increasing pH level of the produced vermicompost from mushrooms compared to the pH in natural mushroom resides. It appeared conceivable that these outcomes are caused by the microbial breakdown of organic acids, as well as the production and buildup of ammonia (NH_3) (Negi and Suthar 2018). These results were in consistent with Ruangjanda et al. (2022; Patra et al. 2022). The decreases of pH were observed in vermicompost produced from MR and LR compared to agricultural resides which were caused by the balance in pH of mushrooms and licorice. These results were in agreement with Yavari et al. (2009). Decreasing (Ec) in vermicompost resulting from MR and (MR and LR), these alterations could be due to how housefly larvae and microorganisms use and absorb soluble salts (Mahaly et al. 2018; Raza et al. 2022). These results were in agreement with Ruangjanda et al. (2022; Patra et al. 2022; Hřebečková et al. 2020). From another side, the nutritional characteristics (N, P, Cu) contents increased in the both type of vermicompost MR and (MR and LR) because of the existence of larvae that modified the biological activity, produced nitrogenous excreta, enzymes beside mineralized phosphorus and copper and breakdown of organic matter, reduced volume (Gong et al. 2019). These results were in consistent with Yavari et al. (2009); Ruangjanda et al. (2022); Patra et al. (2022); Raza et al. (2022). On the contrary, there has been a decrease in (K) and might be caused by the leachate produced during the degradative processes (Zziwa et al. 2021). These results were in agreement with Ruangjanda et al. (2022).

Enzymes activity

These findings were in line with those reported by Zhang et al., (2011), who stated that licorice pulp application boosted plant height, leaf area, shoot dry weight, flavonoid content, and N, P, and K uptake. In addition, at the highest degree of licorice pulp application (20% v/v), all evaluated traits. On the other hand, plants require copper, a micronutrient, to grow and develop. It was a part of numerous enzymes, including ascorbic acid oxidase, polyphenol oxidase, and cytochrome oxidase (Wang et al. 2013). Moreover, the addition of copper sulfate to all planting techniques significantly reduced the incidence of root rot disease and enhanced yield quantity and quality. Furthermore, copper sulfate inhibited the growth, sporulation, and/or sclerotia of most root rot fungi in vitro. *FO*, Rhizoctonia solani, and Sclerotium rolfsii were the most successful (Zhang et al. 2011).

Conclusions

The mixing process of vermicompost with the soil was improved by the lowest CV. The highest productivity was achieved by using a plastic rotary drum composter (PRDC) which had a patching size of 60 kg at a speed of 15 rpm for 8 min. As a result, the third step of the tests' treatment of mixing vermicompost with soil was chosen. When agri-residues were turned into vermicompost using LR and MR, the amount of dissolved Cu and Zn increased significantly, and the vermicompost's pH also rose as a result of these effects. In comparison with controls, the wilt illness generated by a mixture of vermicompost (MR and LR) and soil infested with the more aggressive FO was less severe. (untreated). The most effective treatments for wilt disease, with a disease severity of 1.90, were 25% vermicompost (MR + LR) and 75% agri-soil revealed that, on both days, treated maize roots had higher peroxidase and polyphenol oxidase activity than control treatments.

Abbreviations

FER	Fusarium Ear Rot
MR	Mushroom Residues
LR	Licorice Residues
CV	Coefficient of Variation

FO Fusarium Oxysporium
PPO Polyphenol oxidase activity
PO Peroxidase activity

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Author contributions
M. A. A. and E. A. E. A. conceived the presented idea and wrote the manuscript with support from H. T. and G.S. All authors contributed to sample preparation. E. A. E. A. and M. A. A. conceived the presented idea, developed the theory, performed the computations and carried out the experiments. H. T. analyzed all treatment-related soil diseases. G.S. conceived and planned the experiments. All authors provided critical feedback and helped shape the research, analysis, and manuscript. Also, all authors discussed the results and contributed to the final manuscript. All authors read and approved the final manuscript.

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References

Abou-Zied NM, El-Garhy AM, Abd El-Aal AM, Afifi AE (2002) Effect of biological and chemical control of chocolate spot disease in faba bean. In: root rot/ wilt disease in faba bean, lentil and chickpea and chocolate spot disease in faba bean. International Center for Agricultural Research in Dry Areas. ICARDA / NVRSRP. Cairo. Egypt, pp 57–61
Abou-Zeid NM, Mahmoud NA, Abbas MS, Soliman Ash, Eid HT (2018) Induction of systemic resistance against Tomato wilt disease under greenhouse conditions in Egypt. Biosci Res 15(4):4559–4570
Alkoaik FN, Abdel-Ghany AM, Rashwan MA, Fulleros RB, Ibrahim MN (2018) Energy analysis of a rotary drum bioreactor for composting tomato plant residues. Energies 11:449. https://doi.org/10.3390/en11020449
Amer MA, Ali EAE, Dawood VM (2022) Modified and improved performance of local hammermill for mushroom residues chopping. Bull Natl Res Centre 46:228. https://doi.org/10.1186/s42269-022-00920-y
Asasian N, Kaghazchi T, Soleimani M (2012) Elimination of mercury by adsorption onto activated carbon prepared from the biomass material. J Ind Eng Chem 18(1):283–289. https://doi.org/10.1016/j.jiec.2011.11.040
Atienza AH, Erinco IK, Martinez MB, Visande VJ (2021) Dual grinding and mixing machine for vermicompost and worm biomass production. In: IOP conference series: earth and environmental science 765: 012067. https://doi.org/10.1088/1755-1315/765/1/012067
Barbosa JR, Freitas MM, Martins LH, Junior RN (2020) Polysaccharides of mushroom *Pleurotus* spp.: new extraction techniques, biological activities and development of new technologies. Carbohydr Polym 229:115550. https://doi.org/10.1016/j.carbpol.2019.115550
Cheng Z, Yu L, Li H, Xu X, Yang Z (2021) Use of housefly (*Musca domestica* L.) larvae to bioconversion food waste for animal nutrition and organic fertilizer. Environ Sci Pollut Res 28(35):48921–48928. https://doi.org/10.1007/s11356-021-14118-8
Čičková H, Newton GL, Lacy RC, Kozánek M (2015) The use of fly larvae for organic waste treatment. Waste Manage 35:68–80. https://doi.org/10.1016/j.wasman.2014.09.026
Collela CF, Costa LMAS, Moraes TSJ, Zied DC, Rinker DL, Dias ES (2019) Potential utilization of spent agaricus bisporus mushroom substrate for seedling production and organic fertilizer in tomato cultivation. Ciencia e Agrotecnol. **43**, 017119. https://doi.org/10.1590/1413-7054201943017119
Falet JP, Elkrief A, Green L (2019) Hypertensive emergency induced by licorice tea. CMAJ 191(21):E581–E583. https://doi.org/10.1503/cmaj.180550
Fandohan P, Hell K, Marasas WFO, Wingfield MJ (2003) Infection of maize by Fusarium species and contamination with fumonisin in africa. Afr J Biotech 2(12):570–579. https://doi.org/10.5897/AJB2003.000-1110
FAOSTAT (2022) Food and agriculture organization, statistical division. Available online: http://www.fao.org/faostat/en/#data/QC. Accessed on 24 June 2022
Golub G, Myhailovych Y, Achkevych O, Chuba V (2019) Optimization of angular velocity of drum mixers. Eastern-Eur J Enterprise Technol 3(7):64–72. https://doi.org/10.15587/1729-4061.2019.166944
Gong XQ, Li SY, Carson MA, Chang SX, Wu Q, Wang L, An ZF, Sun XY (2019) Spent mushroom substrate and cattle manure amendments enhance the transformation of garden waste into vermicomposts using the earthworm Eisenia fetida. J Environ Manag 248:109263. https://doi.org/10.1016/j.jenvman.2019.109263
Guo H, Jiang C, Zhang Z, Lu W, Wang H (2021) Material flow analysis and life cycle assessment of food waste bioconversion by black soldier fly larvae (*Hermetia illucens* L.). Sci Total Environ 750:141656. https://doi.org/10.1016/j.scitotenv.2020.141656
Hartee EF (1955) Modern methods of plant analysis (1st edn), 106–116
Hřebečková T, Wiesnerová L, Hanč A (2020) Changes in layers of laboratory vermicomposting using spent mushroom substrate of *Agaricus subrufescens* P. J Environ Manag. https://doi.org/10.1016/j.jenvman.2020.111340
Kauser H, Khwairakpam M (2022) Organic waste management by two-stage composting process to decrease the time required for vermicomposting. Environ Technol Innov 25:102193. https://doi.org/10.1016/j.eti.2021.102193
Lanubile A, Maschietto V, Borrelli VM, Stagnati L, Logrieco AF, Marocco A (2017) Molecular basis of resistance to Fusarium Ear rot in maize. Front Plant Sci 8:1774. https://doi.org/10.3389/fpls.2017.01774
Mahaly M, Senthilkumar AK, Arumugam S, Kaliyaperumal C, Karupannan N (2018) Vermicomposting of distillery sludge waste with tea leaf residues. Sustain Environ Res 28:223–227. https://doi.org/10.1016/j.serj.2018.02.002
Maschietto V, Colombi C, Pirona R, Pea G, Strozzi F, Marocco A, Rossini L, Lanubile A (2017) QTL mapping and candidate genes for resistance to Fusarium ear rot and fumonisin contamination in maize. BMC Plant Biol 17:20. https://doi.org/10.1186/s12870-017-0970-1
Mayer AM, Harel E, Shaul RB (1965) Assay of catechol oxidase as critical comparison methods. Phytochemistry 5:783–789. https://doi.org/10.1016/S0031-9422(00)83660-2
Meng X, Dai J, Zhang Y, Wang X, Zhu W, Yuan X, Yuan H, Cui Z (2018) Composted biogas residue and spent mushroom substrate as a growth medium for tomato and pepper seedlings. J Environ Manage 216:62–69. https://doi.org/10.1016/J.JENVMAN.2017.09.056
Miller GL (1959) Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal Chem 31:426–428. https://doi.org/10.1021/ac60147a030
Millner PD, Ringer CE, Maas JL (2004) Suppression of strawberry root disease with animal manure composts. Compost Sci Utiliz 12:298–307. https://doi.org/10.1080/1065657X.2004.10702198
Miranda CD, Crippen TL, Cammack JA, Tomberlin JK (2021) Black soldier fly, *Hermetia illucens* (L.) (Diptera: Stratiomyidae), and house fly, Musca domestica L. (Diptera: Muscidae), larvae reduce livestock manure and possibly Associated Nutrients: an assessment at two scales. Environ Pollut 282:116976. https://doi.org/10.1016/j.envpol.2021.116976

Moradi P, Hayati S, Ghahrizadeh T (2020). Modeling and optimization of lead and cobalt biosorption from water with Rafsanjan pistachio shell, using experiment based models of ANN and GP, and the grey wolf. Chemometrics Intell Lab Syst 202:104041. https://doi.org/10.1016/j.chemolab.2020.104041
Negi R, Suthar S (2018) Degradation of paper mill wastewater sludge and cow dung by brown-rot fungi Oligoporus placenta and earthworm (Eisenia fetida) during vermicomposting. J Clean Prod 201:842–852. https://doi.org/10.1016/j.jclepro.2018.08.068
Negi S, Mandpe A, Hussain A, Kumar S (2020) Collegial effect of maggots larvae and garbage enzyme in rapid composting of food waste with wheat straw or biomass waste. J Clean Prod 258:120854. https://doi.org/10.1016/j.jclepro.2020.120854
Noble R, Coventry E (2005) Suppression of soil-borne plant diseases with composts: a review. Biocontrol Sci Technol 15:3–20. https://doi.org/10.1080/09583150400015904
Ojha S, Chatterjee CN (2012) Induction of resistance in tomato plants against Fusarium oxysporum f. sp. lycopersici mediated through salicylic acid and Trichoderma harzianum. J Plant Protect Res 52(2):220–225. https://doi.org/10.2478/v10045-012-0034-3
Orsi RB, Corrêa B, Possi CR, Schammass EA, Nogueira JR, Dias SMC, Malozzi MAB (2000) Mycoflora and occurrence of fumonisins in freshly harvested and stored hybrid maize. J Stored Prod Res 36(1):75–87. https://doi.org/10.1016/S0022-474X(99)00029-6
Patra RK, Behera D, Mohapatra KK, Sethi D, Mandal M, Patra AK, Ravindran B (2022) Juxtaposing the quality of compost and vermicompost produced from organic wastes amended with cow dung. Environ Res 214-114119. https://doi.org/10.1016/j.envres.2022.114119
Paymaneh Z, Sarcheshmehpour M, Mohammadi H, Hesni MA (2023) Vermicompost and/or compost and arbuscular mycorrhizal fungi are conducive to improving the growth of pistachio seedlings to drought stress. App Soil Ecol 182-104717. https://doi.org/10.1016/j.apsoil.2022.104717
Raza ST, Wu J, Rene ER, Ali Z, Chen Z (2022) Reuse of agricultural wastes, manure, and biochar as an organic amendment: a review on its implications for vermicomposting technology. J Clean Prod 360-132200. https://doi.org/10.1016/j.jclepro.2022.132200
Raza ST, Zhu B, Yao Z, Wu J, Chen Z, Ali Z, Tang JL (2023) Impacts of vermicompost application on crop yield, ammonia volatilization and greenhouse gases emission on upland in Southwest China. Sci Total Environ 860-160479. https://doi.org/10.1016/j.scitotenv.2022.160479
Reham R, El-Demerdash P, Entsar EA, El-Said HM, Atia MM (2017) Management Fusarium ear rot of Maize and its relation to damping-off. Zagazig J Agric Res 44 (6A). https://doi.org/10.21608/ZJAR.2017.51231
Ruangjanda S, Iwai CB, Greff B, Chang SW, Ravindran B (2022) Valorization of spent mushroom substrate in combination with agro-residues to improve the nutrient and phytohormone contents of vermicompost. Environ Res 214-113771. https://doi.org/10.1016/j.envres.2022.113771
Salama HSA (2019) Yield and nutritive value of maize (*Zea mays* L.) forage as affected by plant density, sowing date and age at harvest. Ital J Agron 14:114–122. https://doi.org/10.4081/ija.2019.1383
Sharma N, Rayamajhi M (2022) Different aspects of weed management in maize (*Zea mays* L.): a brief review. Adv Agric 2022-7960175. https://doi.org/10.1155/2022/7960175
Sneddecor GW, Cochran WG (1980) Statistical methods. Oxford & J.BH Pubishing com, 6th edition, p 251
Tabrizi L, Lakzaei M, Motesharezadeh B (2021) The yield potential and growth responses of licorice (*Glycyrrhiza glabra* L.) to mycorrhization under Pb and Cd stress. Int J Phytoremediat 23(3):316–327. https://doi.org/10.1080/15226514.2020.1813076
Walder F, Schlaeppi K, Wittwer R, Held AY, Vogelgsang S, van der Heijden MGA (2017) Community profiling of fusarium in combination with other plant-associated fungi in different crop species using SMRT sequencing. Front Plant Sci 8:2019. https://doi.org/10.3389/fpls.2017.02019
Wang Z, He N, Wang Y, Zhang J (2013) Effects of copper on organisms: a review. Adv Mater Res 726–731:340–343. https://doi.org/10.4028/www.scientific.net/AMR.726-731.340
Yang F, Li G, Zang B, Zhang Z (2017) The maturity and CH_4, N_2O, NH_3 emissions from vermicomposting with agricultural waste. Compost Sci Util 25(4). https://doi.org/10.1080/1065657X.2017.1329037
Yavari S, Eshghi S, Tafazoli E, Karimian N (2009) Mineral elements uptake and growth of strawberry as influenced by organic substrates. J Plant Nutr 32:1498–1512. https://doi.org/10.1080/01904160903092697
Zhang G, Zhang L, Wei M, Liu Z, Fan Q, Shen Q, Xu G (2011) Effect of arbuscular mycorrhizal fungi, organic fertilizer and soil sterilization on maize growth. Acta Ecol Sin 31(4):192–196. https://doi.org/10.1016/j.chnaes.2011.04.005
Zhang Z, Wang H, Zhu J, Suneethi S, Zheng J (2012) Swine manure vermicomposting via housefly larvae (Musca domestica): the dynamics of biochemical and microbial features. Biores Technol 118:563–571. https://doi.org/10.1016/j.biortech.2012.05.048
Zhang Z, Wang X, Wang H, Huang E, Sheng J, Zhou L, Jin W (2020) Housefly larvae (Musca domestica) vermicompost on soil biochemical features for a chrysanthemum (Chrysanthemum morifolium) farm. Commun Soil Sci Plant Anal 51(10):1315–1330. https://doi.org/10.1080/00103624.2020.1763389
Zheng C, Zhou L (2013) Antibacterial potency of housefly larvae extract from sewage sludge through bioconversion. J Environ Sci 25(9):1897–1905. https://doi.org/10.1016/S1001-0742(12)60256-3
Zziwa A, Jjagwe J, Kizito S, Kabenge I, Komakech AJ, Kayondo H (2021) Nutrient recovery from pineapple waste through controlled batch and continuous vermicomposting systems. J Environ Manag 279:111784. https://doi.org/10.1016/j.jenvman.2020.111784

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