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SHORT COMMUNICATION

Biotransformation of organic wastes through composting using *Trichoderma harzianum* and its effects on cucumber (*Cucumis sativus* L.) yield

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Abstract

Purpose Soil nutrient depletion and possible degradation have been highlighted as key reasons for lower crop yields in Nigeria. The present study was aimed to assess the effect of *Trichoderma harzianum* on the bioconversion of different solid organic wastes into compost and its application on cucumber.

Method The treatments were 3 levels of *T. harzianum* inoculum (0, 5 and 10 ml) and 4 types of solid organic wastes (maize-cob, groundnut-pods, sawdust and their mixture) and soil. A small portion of the solid wastes (40 g) was weighed into each incubation jar with 10 g of chopped Guinea grass (*Panicum maximum*) and 20 g each of poultry manure. The compost was thereafter incubated for 12 weeks.

Results Total N, P and K contents were significantly ($p < 0.05$) highest in the mixture of solid organic wastes (22800 mg/kg), corn cobs (2600 mg/kg) and groundnut pods (2300 mg/kg), respectively. The growth parameters (plant height, number of leaves, leaf length, leaf girth and stem girth) significantly increased with increasing *T. harzianum* concentration. The highest fruit weight (105.84 g/plant) of cucumber was obtained in compost inoculated with 10 ml/pot of *T. harzianum.* Compost made of corn-cobs, groundnut pods and the mixture of the solid wastes significantly promoted the growth parameters. The highest fruit weight (117.99 g/plant) was obtained in a pot treated with a mixture of solid wastes.

Conclusion The use of *T. harzianum* in biotransformation of organic wastes could be a better tool to improve soil conditions thus enhancing the productivity of cucumber.

Keywords Compost, Cucumber, Nutrients, Organic wastes, *Trichoderma harzianum*

Introduction

Nigeria's agricultural soils are under great strain to supply food and fiber for an ever-increasing population. The majority of Nigerian soils are deficient in soil organic carbon (SOC) and macro and micro nutrients. Furthermore, these soils are fragile and deteriorate with time as a result of over-exploitation for crop production and an uneven source and sink of carbon and plant nutrients (Ogumba 2018). Soil nutrient depletion and possible degradation have been highlighted as key reasons for lower crop yields and per

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capita food production in Sub-Saharan Africa (Henao and Baanante 2006). Thus, addressing soil degradation and increasing soil productivity will include making management decisions targeted at optimizing soil-water interactions for increased agricultural output through nutrient cycling and water conservation. In this regard, the utilization of adequate organic materials for soil fertility enhancement will have an impact on the soil's biochemical and microbiological properties. However, due to the scarcity of conventional organic materials such as animal manure (McGuire 2017b), the utilization of organic waste, sewage sludge, agricultural waste, and industrial solid waste as organic materials are increasing. Compost is the most cost-effective source of nitrogen among organic amendments. The widespread use of chemical fertilizer in vegetable production, as well as the negative side effects of chemical fertilizer, highlights the significance of organic amendment for sustainable agriculture (Sankar et al. 2017). Organic waste, such as manure, sewage sludge, and municipal compost, can be applied to soil to maintain soil organic matter, enhance soil quality, and supply nutrients required by plants (McGuire 2017a).

Compost is a combination of degraded organic waste that has been digested by microorganisms in a warm, moist, and aerobic environment, releasing nutrients in easily accessible forms for plant use. Fungi such as *Trichoderma* spp. are among these microbes (Parkash and Saikia 2015). They are compost fungal activators, which aid in the breakdown of organic waste.

Trichoderma harzianum, a filamentous fungus, has proven to be an effective biological control agent for a variety of soil-borne plant infections including *Pythium* spp., *Sclerotium rolfsii, Rhizoctonia solani, and Fusarium* spp. (Haque et al. 2012). *Trichoderma harzianum*, according to Haque et al. (2012), generated defensive responses and systemic resistance in addition to controlling plant diseases. Furthermore, different *Trichoderma* species aided in the growth and development of seedlings of vegetable and non-vegetable crops (Bal and Altintas 2008). The use of *Trichoderma* spp. boosted cucumber, bell pepper, and strawberry yields significantly, according to Haque et al. (2012). Efficient application of *Trichoderma*-enriched biofertilizer may boost output, minimize N fertilizer consumption, reduce soil-borne diseases, and improve soil health. The biofertilizer, which is also used as a soil conditioner, increases the population of beneficial microorganisms in the soil. It aids in the reduction of greenhouse gasses such as carbon dioxide and methane. *T. harzianum* boosts plant resistance to environmental stress and mineral uptake (Gupta et al. 2014). There is a rising demand to provide additives that improve soil fertility while being environmentally benign (Topliantz et al. 2005). Several researchers have focused on the impact of *Trichoderma* spp. on crop protection and bioconversion of solid organic wastes for soil amendments, but little study has been done on the influence of *Trichoderma* on compost bioconversion in South Eastern Nigeria as it affects cucumber production. The main objective of this study was to assess the effect of *T. harzianum* on the bioconversion of different solid organic wastes into compost and its application on cucumber.

Materials and methods

Experimental materials

The soil used for the experiment was obtained from the Farm Operations Unit of the University of Nigeria, Nsukka (UNN). The soil was collected at a depth of 0-15 cm, air dried and passed through a 2 mm sieve. The solid organic wastes such as sawdust was obtained from saw-mill industry at Opi Junction, Nsukka, maize-cobs (*Zea mays*) sourced from farmers at Edem-Ani, groundnut pods (*Arachis hypogaea*) obtained from Orba Market, poultry manure collected from a poultry farm at Opi and Guinea grass (*Panicum maximum*) collected around the greenhouse area of Department of Soil Science, UNN.These amendments were air dried and crushed into sizable shapes.

Trichoderma harzianum inoculum was sourced from the Biotechnology laboratory of the Federal University of Agriculture, Abeokuta, Nigeria.

Soil preparation and analysis

The experimental soil was air dried, passed through 2 mm sieve and analyzed routinely. Particle size distribution was determined by the hydrometer method (Bouyoucos 1962) as modified by Gee and Bauder (1979). The soil pH was determined in water using a soil solution ratio of 1:2:5 with the aid of a glass electrode pH meter, as described by McLean (1982). Soil moisture and water holding capacity was determined using the method described by Michael (1978). Total Nitrogen was determined by the macro Kjeldahl digestion method (Bremner and Mulvaney 1982). The available phosphorus was determined by the Bray II method (Bray and Kurtz 1945) as described by Olsen and Sommers (1982).

Experimental treatments and design

The incubation study was a 3 x 5 factorial experiment arranged in completely randomized design with three replicates. The treatments consisted of three (3) levels of *Trichoderma harzianum* inoculums (0, 5 and 10 ml) and four (4) types of Solid organic wastes (Maize cob, groundnut shell, saw dust and mixture of all the solid organic wastes) and soil (control). A small portion of the solid wastes (40 g each) was weighed into each incubation jar with 10 g of chopped Guinea grass (*Panicum maximum*) and 20 g each of poultry manure. The materials were mixed together, thoroughly moistened to 70% moisture holding capacity and inoculated with *Trichoderma harzianum* at 0, 5 and 10 ml respectively, per incubation jar to make the compost. The compost was thereafter incubated for 12 weeks.

Greenhouse study

After the maturity of the compost (12 weeks), it was air-dried, analyzed for N, P and K content and stored for application to Cucumber. The soil culture experiment was also a 3 x 5 factorial, arranged in completely randomized design with three replications. The treatment was five (5) compost types (corn cob-based and groundnut pod-based, sawdust-based, topsoil-based and mixture of all solid organic wastes-based composts) applied at 20 t ha^{-1}. Treatments were thoroughly mixed with the 5 kg each of soil in polythene bags. The soil was moistened with water to 70% moisture holding capacity and allowed to equilibrate for 2 weeks before planting. The test crop (cucumber) was thereafter planted in the pots and watered as and when due. Data were collected at 2 weeks interval on number of leaves per plant, plant height and fruit weight per plant. After 8 weeks of planting, soil samples were collected from each polythene bag to determine the effects of the compost on the N, P and K release in the soil.

Data analysis

The data collected were subjected to Analysis of Variance (ANOVA) using SAS software 9.2 version (SAS 2012) to determine treatment effect while the means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability

Results and Discussion

Table 1 shows the physical and chemical properties of the experimental soil used.

The textural class of the soil used for the experiment is loamy sand with a slightly acidic pH (5.8).

Total nitrogen (0.08%), exchangeable acidity (0.8 cmol kg^{-1}), organic carbon (1.0%), exchangeable Na^+ (0.04 cmol kg^{-1}), K^+ (0.07 cmol kg^{-1}), Ca^{2+} (3.6 cmol kg^{-1}), Mg^{2+} (1.4 cmol kg^{-1}) and cation exchange capacity (5.91 cmol kg^{-1}) were relatively low.

Table 2 shows some selected chemical properties of composted solid organic wastes (CSOW). The results indicate that the mixtures of all the organic wastes had the highest amount of nitrogen followed by groundnut pod, corn cob, soil and sawdust in that order. According to Landon (1991), the level of nitrogen in the mixture of all the organic wastes was relatively high. The highest level of nitrogen in the mixture of organic waste could be as a result of the different types of organic waste added (Brady and Weils 2004). Corn cobs had the highest amount of phosphorus while sawdust had the least. Potassium was highest in the groundnut pod while the mixture of wastes was the least. The highest level of potassium recorded is in line with Nirmala and Vasavi (2018), who reported an increase in the level of potassium of the media with the use of groundnut shell compost. Addo et al. (2022) had also reported an increase in N, P and K in the compost produced from municipal solid organic wastes.

Table 1 Physical and chemical properties of the experimental soil

Parameter	Value
pH (H_2O)	5.8
Organic carbon (%)	1.0
Total nitrogen (%)	0.08
Available Phosphorus (mg kg^{-1})	15.86
Na^+ (cmol kg^{-1})	0.04
K^+ (cmol kg^{-1})	0.07
Ca^{2+} (cmol kg^{-1})	3.6
Mg^{2+} (cmol kg^{-1})	1.4
Exchangeable acidity (cmol kg^{-1})	0.8
CEC (cmol kg^{-1})	5.91
Clay (%)	10
Silt (%)	6
Fine sand (%)	43
Coarse sand (%)	41
Textural class	Loamy sand

Table 2 Selected chemical properties of composted solid organic wastes

Composted solid organic wastes	Total N (mg kg^{-1})	Total P (mg kg^{-1})	Total K (mg kg^{-1})
Mixture of wastes	22800^a	1300^c	1200^e
Groundnut pods	16800^b	1400^b	2300^a
Corn cobs	12600^c	2600^a	2200^b
Soil	11200^d	1000^d	1900^c
Saw dust	10700^e	900^e	1400^d

Means with similar alphabets are not significantly different according to Duncan's multiple.
Range Test at $P < 0.05$

Table 3 shows the effect of the composted solid organic wastes (CSOW) and *T. harzianum* on plant height of cucumber at 4, 8, 10 and 12 weeks after planting. The composted solid wastes applied had a significant ($p < 0.05$) effect the plant height throughout the period of observation. The application of the mixture of all solid wastes-based compost recorded the highest value of plant height at 4 and 8 WAP while groundnut pod and corn cob-based compost produced the tallest plants at 10 and 12 WAP, respectively, although these were not significantly different from the mixture of wastes-based compost. Soil-based and sawdust-based compost had the least value of the plant heights at 10 and 12 WAP, respectively. The results are in line with Eifediyi and Remison (2010) who observed a strong influence by a combined manure on growth parameters of cucumber.

Trichoderma harzianum inoculum also had significant effect on the plant height throughout the period of observation. *Trichoderma harzianum* inoculation at 10 ml increased generally the plant height of cucumber above the control (0 ml). However, inoculation at 5 ml was significantly different from that of 10 ml in its effect on the plant height of cucumber only at 4 WAP. The composted organic waste gave the cucumber plant enough nutrients for rapid growth and development as reported by Eifediyi and Remison (2010).

Table 3 Effect of the composted solid organic wastes and *T. harzianum* inoculum on plant height (cm) of cucumber

Composted solid organic wastes	**4 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Corn cobs	12.67^{bc}	59.88^{a}	53.70^{b}	63.37^{a}
Groundnut pods	16.94^{ab}	50.71^{a}	73.20^{a}	61.56^{a}
Sawdust	10.50^{c}	51.33^{a}	45.10^{bc}	29.33^{b}
Soil	13.44^{bc}	27.55^{b}	34.58^{c}	52.08^{a}
Mixture	18.05^{a}	64.22^{a}	58.32^{ab}	58.33^{a}
T. harzianum inoculation				
0 ml	9.33^{c}	34.07^{c}	38.11^{b}	36.68^{b}
5 ml	13.73^{b}	48.96^{b}	57.52^{a}	59.49^{a}
10 ml	19.90^{a}	69.20^{a}	63.32^{a}	62.85^{a}

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at $P < 0.05$
WAP: Week after planting

The effect of CSOW and *T. harzianum* on the number of leaves at 4, 8, 10 and 12 weeks after planting is presented in Table 4. Generally, the mixture of all solid wastes-based compost recorded the highest mean values in number of leaves except at 8WAP where corn cob-based compost recorded the highest, although this was not significantly different from that of the mixture of wastes. The least number of leaves was obtained with sawdust-based compost at 4 WAP and soil-based compost at 8 WAP. All the other compost types were not significantly different in their effects on number of leaves.

Trichoderma harzianum inoculation at 10 ml generally increased the number of cucumber leaves above the control (0 ml). The leaf length of cucumber was also significantly highest in pot treated with the mixture of all the solid organic wastes across the period of observation (Table 5). Sawdust-based compost recorded the least leaf length while the other compost types were not significantly different in their effects on leaf length. *Trichoderma harzianum* inoculum also had a significant effect on the leaf length across the periods of observation (Table 5). *Trichoderma harzianum* inoculation at 10 ml generally increased the leaf length of cucumber above the control (0 ml). There was, however, no significant difference between 5 and 10 ml applications except at 4 WAP. Islam et al. (2014) has also reported the significant influence of *Trichoderma* compost on the growth characteristics of vegetables as observed in this study.

Table 4 Effect of the composted solid organic wastes and *T. harzianum* inoculum on number of leaves of cucumber

Composted solid organic wastes	4 WAP	8 WAP	10 WAP	12 WAP
Corn cobs	6.33[abc]	9.44[a]	5.33[a]	3.55[a]
Groundnut pods	6.77[ab]	7.11[ab]	6.22[a]	3.55[a]
Sawdust	5.66[c]	7.33[ab]	5.33[a]	3.33[a]
Soil	5.88[bc]	5.11[b]	5.00[a]	4.00[a]
Mixture	7.00[a]	8.00[a]	6.00[a]	3.77[a]
T. harzianum inoculation				
0 ml	5.13[b]	6.13[b]	4.86[b]	2.87[b]
5 ml	6.60[a]	7.27[b]	5.60[ab]	3.93[a]
10 ml	7.27[a]	8.80[a]	6.26[a]	4.13[a]

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at P < 0.05

WAP: Week after planting

Table 5 Effect of the composted solid organic wastes and *T. harzianum* inoculum on leaf length (cm) of cucumber

Composted solid organic wastes	4 WAP	8 WAP	10 WAP	12 WAP
Corn cobs	11.22[b]	14.16[b]	13.57[a]	14.73[a]
Groundnut pods	11.50[b]	11.56[bc]	15.57[a]	12.87[ab]
Sawdust	8.13[c]	13.44[b]	13.02[a]	10.43[b]
Soil	9.53[c]	10.08[c]	13.11[a]	13.74[a]
Mixture	15.38[a]	16.73[a]	15.51[a]	15.26[a]
T. harzianum inoculation				
0 ml	7.05[c]	10.13[b]	10.38[b]	10.14[b]
5 ml	11.25[b]	14.07[a]	16.75[a]	15.19[a]
10 ml	15.15[a]	15.40[a]	15.34[a]	14.90[a]

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at P < 0.05

WAP: Week after planting

Table 6 shows the effect of the composted solid organic wastes and *T. harzianum* inoculum on leaf girth of cucumber at 4, 8, 10 and 12 WAP. The results showed that the application of composted solid organic wastes had a significant ($p<0.05$) effect on the leaf girth of cucumber throughout the period of observation. The leaf girth of cucumber was highest across the period of observation when the mixture of all solid wastes was applied. The least leaf girth was recorded with the application of sawdust based-compost at 4 and 12 WAP while 8 and 10 WAP recorded the least leaf girth with the application of soil–based compost. *Trichoderma harzianum* inoculum also had significant effect on the leaf girth across the periods of observation (Table 6). *Trichoderma harzianum* inoculation at 10 ml generally increased the leaf girth of cucumber above the control (0 ml). The response to inoculation followed a similar pattern with that of leaf length. The effect of composted solid organic wastes (CSOW) and *T. harzianum* inoculum on stem girth at 4, 8, 10 and 12 WAP is presented in Table 7. The CSOW had a significant effect on stem girth at 4 and

8 WAP only. Mixtures of solid organic wastes recorded the highest stem girth while sawdust-based compost gave the least at 4 and 8 WAP.

Trichoderma harzianum inoculum had significant effect on the stem girth across the periods of observation. The response of stem girth followed a similar pattern with that of leaf girth.

Table 6 Effect of the composted solid organic wastes and *T. harzianum* inoculum on leaf girth (cm) of cucumber

Composted solid organic wastes	4 WAP	8 WAP	10 WAP	12 WAP
Corn cobs	8.91^{a}	10.20^{ab}	10.14^{ab}	10.71^{a}
Groundnut pods	9.11^{a}	9.22^{bc}	11.45^{a}	10.72^{a}
Sawdust	6.43^{b}	9.13^{abc}	8.73^{b}	8.34^{b}
Soil	7.13^{b}	7.89^{c}	8.61^{b}	9.90^{ab}
Mixture	10.01^{a}	11.68^{a}	10.82^{a}	10.72^{a}
T. harzianum inoculation				
0 ml	5.91^{c}	7.57^{b}	7.82^{b}	8.13^{b}
5 ml	8.56^{b}	9.97^{a}	10.84^{a}	11.24^{a}
10 ml	10.49^{a}	11.33^{a}	11.20^{a}	11.87^{a}

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at $P < 0.05$

WAP: Week after planting

Table 7 Effect of the composted solid organic wastes and *T. harzianum* on stem girth of cucumber

Composted solid organic wastes	**4 WAP**	**8 WAP**	**10 WAP**	**12 WAP**
Corn cobs	1.91^{bc}	2.45^{ab}	2.44^{a}	2.56^{a}
Groundnut pods	2.07^{ab}	2.29^{bc}	2.86^{a}	2.4^{a}
Sawdust	1.71^{c}	2.11^{c}	2.44^{a}	2.17^{a}
Soil	1.97^{a}	2.18^{bc}	2.94^{a}	2.17^{a}
Mixture	2.25^{a}	2.67^{a}	2.45^{a}	2.43^{a}
T. harzianum inoculation				
0 ml	1.49^{c}	1.95^{c}	2.02^{b}	2.09^{b}
5 ml	2.03^{b}	2.39^{b}	2.94^{a}	2.46^{a}
10 ml	2.44^{a}	2.69^{a}	2.71^{ab}	2.51^{a}

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at $P < 0.05$

WAP: Week after planting

Table 8 shows the effect of the CSOW and *T. harzianum* inoculum on fruit weight of cucumber at 10 WAP. Mixture of SOW recorded the highest fruit weight of cucumber while sawdust-based compost gave the least. However, corn cob, groundnut pod and soil-based composts were not significantly different in their effects on cucumber fruit weight. This result might be due to the fact that mixtures of SOW contributed greatly to improve the soil chemical properties resulting in the improved yield response of cucumber compared with others.

Pellejero et al. (2015) had earlier reported the effectiveness of mixtures of solid organic wastes in improvement of soil chemical properties. Inoculation with *T. harzianum* at 10 ml resulted in the highest fruit weight of cucumber followed by 5 ml while the control (0 ml) gave the least. However, 5 ml inoculation of *T. harzianum* was not significantly different from the control in its effect on cucumber fruit weight. This result is in agreement with Islam et al. (2014) who found *Trichoderma harzianum* to be the most effective activator in composting among other fungi. The capability of the solid organic wastes to increase inorganic nitrogen, nutrient supply and meet subsequent plant demand in soil have been reported by many (Iglesias-Jimenez and Alvarez 1993; Mylavarapu and Zinati 2009).

Table 8 Effect of the composted solid organic wastes and *T. harzianum* on fruit weight of cucumber at 10WAP

Composted solid organic wastes	Fruit weight (g/plant)
Corn cobs	37.67[b]
Groundnut pods	38.04[b]
Sawdust	22.54[b]
Soil	54.29[ab]
Mixture	117.99 [a]
T. harzianum inoculation	
0 ml	12.73[b]
5 ml	43.75[b]
10 ml	105.84[a]

Means with similar alphabets are not significantly different according to Duncan's multiple Range Test at $P < 0.05$

Conclusion

Cucumber grown in optimal weather and soil conditions requires both water and nutrient availability. This study confirmed that the application of mixed solid organic wastes increased the accumulation of N, P and K more than the application of a single solid organic waste. The mixture of solid organic wastes treated with 10 ml of *T. harzianum* was the best management system for increasing soil fertility and cucumber yield.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

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