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Soil properties and performance of celosia (*Celosia Argentea*) as affected by compost made with *Trichoderma asperellum*

Adenike Fisayo Komolafe [a,*], Christianah Olubunmi Kayode [a], Dorcas Tinuke Ezekiel-Adewoyin [b], Olufemi Emmanuel AyanfeOluwa [a], David Ogundeji Ogunleti [c], Aderemi Isaiah Makinde [a]

[a] Department of Agriculture, Federal College of Agriculture, Ibadan, Nigeria
[b] Department of Soil Science and Land Management, Federal University of Technology, Minna, Nigeria
[c] Department of Horticulture and Landscape, Federal College of Agriculture, Ibadan, Nigeria

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Author(s)

A.F. Komolafe *
C.O. Kayode
D.T. Ezekiel-Adewoyin
O.E. AyanfeOluwa
D.O. Ogunleti
A.I. Makinde

* Corresponding author

Abstract

This study evaluated the effect of two plant materials (*Panicum maximum* and *Tridax procumbens*) composted with cow dung, with or without *Trichoderma asperellum* inoculation on soil properties and yield of celosia in 2014 and 2015. The treatments were tridax-based compost without *Trichoderma* (TBC), tridax-based compost with *Trichoderma* (TTBC), panicum-based compost without *Trichoderma* (PBC), panicum-based compost with *Trichoderma* (TPBC) and control (no compost). All compost were applied at 240 kgN/ha. The design was RCBD with three replicates and data analyzed using ANOVA at $\alpha_{0.05.}$ Results showed that compost enhanced growth, nutrient uptake and yield of celosia. In 2014, highest fresh weight (57.09 t/ha) was obtained from plant treated with TPBC, which compared favourably with TTBC TTBC (57.00 t/ha) but significantly higher than TBC (43.85 t/ha) and PBC (47.32 t/ha) while control gave the least significant value (20 t/ha). A similar trend was obtained in 2015. This infers that plants that received inoculated compost gave better yield compared to uninoculated compost. Post-cropping soil chemical analysis revealed that compost improved soil N, P, K and organic C. This shows that *Trichoderma* inoculated compost could be better than the uninoculated compost for celosia production in an Alfisol.

Keywords: Accelerated compost, Celosia, Soil chemical properties, *Trichoderma asperellum*.

Introduction

Maintenance of soil fertility under continuous cropping has only been made possible through the use of fertilizer (Das and Mandal, 2015). Mineral, unlike organic fertilizers with their quick-release formula gave rescue treatment to plant that is malnourished and this has greatly increased crop yields (Omolayo and Ayodele, 2009). However, unconscious excessive application of this fertilizer can make the quick-releasing salts to build up fast through its mobility status in soil, it can cause soil acidity, run off or leaching of soil nutrients and land degradation (Plaster, 2014). These identified negative effects on soil environment have renewed research interest in organic fertilizers.

Compost is a form of organic fertilizer produced from organic wastes, including municipal and agricultural wastes, urban wastes, sewage, activated sludge, household wastes, sawdust, etc. Organic materials decompose naturally by the activities of microorganisms from the environment. These natural (conventional) composting procedures take a longer period before it matures. It takes three to eight months

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depending on the nature of the organic substrates (recalcitrant or labile) involved and methodology in use (Adejuyigbe et al., 2006). The recalcitrant organic substrate like lignin, cellulose and hemi-cellulose degraded partially and transformed to organic matter at lower rate; however, research has found out some cultured microorganisms like *Trichoderma* spp which can be introduced into compost pile in order to hasten the decomposition rate of these recalcitrant organic substrates. Hence, the cultured microbes serve as compost accelerator which offers the possibilities for reducing the maturity period of compost from the conventionally known method time to three weeks (Badar et al., 2014). The technology has the potential to increase the level of production of compost thereby making it available to farmers (AyanfeOluwa, 2019).

Celosia (*Celosia argentea)* is one of the most highly acceptable leaf vegetable grown in southern Nigeria. It is rich in iron, protein, energy, vitamin A and vitamin C (Grubben and Denton, 2004). However, the yield and composition is strongly influenced by environmental factors, age of plant at harvest, soil fertility and fertilizer type (Ojeniyi et al., 2009). The objective of this research is therefore to evaluate the effects of compost prepared with *Trichoderma asperellum* inoculation on growth and yield of celosia.

Materials and Methods

Composting and field trial were conducted at the experimental site of the Federal College of Agriculture, Ibadan in the year 2014 and 2015, longitude 7° 33'N and latitude 3° 56°E at elevation of 183 m above sea level. The average annual rainfall recorded for the location for a period of sixteen years was 1289.2 mm (Junge et al., 2010) while the range of annual temperature was 21.3 to 31.2°C. It was noted that the rainfall amount in 2014 was higher than in 2015 (Figure 1). The soil which is sandy loam belongs to Typic Kanhaplustalf and locally classified as Iwo series (Nwachokor and Uzu, 2008). Iwo series is a gravelly soil derived from coarse grained, granite and gneiss which is classifield in the order of Alfisol (Harpstead, 1974).

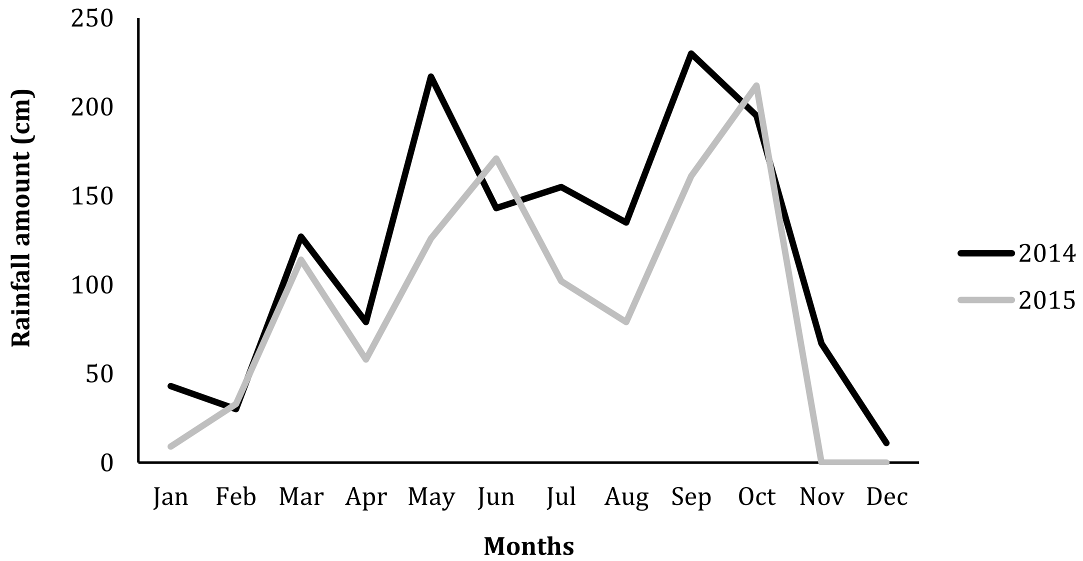

Figure 1. Rainfall data for the years of cropping in the experimental location (Source: NASA-Power)

Compost evaluated in this study was prepared from two plant materials; *Tridax procumbens* and *Panicum maximum* with cow dung which was composted with or without *Trichoderma asperellum* inclusion to give a total number of four compost which were tridax-based compost without *Trichoderma* (TBC), tridax-based compost with *Trichoderma* (TTBC), panicum-based compost without *Trichoderma* (PBC) and panicum-based compost with *Trichoderma* (TPBC). The plants were chopped into smaller particles of below 5 cm using cutlass while Indore hot heap method of composting was adopted. The dimension of each compost pile was 2 m x 3 m with 1.5 m height; its walls were lined with black polythene sheet and the plant material was layered with cow dung in a 3:1 ratio. Pure cultured plate of *Trichoderma asperellum* which was sourced from International Institute of Tropical Agriculture, Ibadan was multiplied with potato dextrose agar in the laboratory, following the procedure of Heritage et al. (1996). The rate of *Trichoderma* application was 0.05% of the total weight of the substrates (about 500 g compost activator per 1000 kg substrate). The compost heaps were monitored till maturity; turning was done fortnightly and pH and ambient temperature observed weekly. At maturity, the different compost were evacuated from the heap, air dried, shredded, bagged and stored under shade. The different compost were sampled for analysis to determine the nutrient composition. The nutrient composition of compost (Table 1) revealed that *Trichoderma* inoculated compost irrespective of composting material had higher concentration of nutrients than uninoculated ones. The TTBC contained 15.3 g/kg N, 27.6 g/kg P and 3.50 g/kg K, TPBC contained 14.3 g/kg N, 11.7 g/kg P and 3.00 g/kg K, PBC contained 13.3 g/kg N, 14.5 g/kg P and 5.20 g/kg K while TBC contained 13.2 g/kg N, 21.6 g/kg P and 3.3 g/kg K.

Table 1. Nutrient Composition of Composts used in the study

Compost	N, g/kg	P, g/kg	K, g/kg
Tridax based compost with *Trichoderma* (TTBC)	15.3	27.6	3.50
Panicum based compost with *Trichoderma* (TPBC)	14.3	11.7	3.00
Panicum based compost without *Trichoderma* (PBC)	13.3	14.4	5.20
Tridax based compost without *Trichoderma* (TBC)	13.2	21.6	3.30

The land preparation was carried out by ploughing and harrowing after which pre-cropping soil samples were collected at 0-15 cm depth and the composite sample was air dried and sieved with 2 mm diameter mesh for routine analysis. The chemical properties of the soil (Table 2) revealed that the soils were slightly acidic with pH of 6.7 and 6.1, respectively for both years. The total nitrogen (0.9 and 0.8 g/kg) and organic carbon content (8.5 and 8.3 g/kg), respectively were low. The available P (14 and 13 mg/kg) were medium while exchangeable K (0.2 cmol/kg) were also low (FMARD, 2012). The treatments imposed on celosia were five; tridax-based compost with *Trichoderma asperellum* (TTBC), panicum-based compost with *Trichoderma asperellum* (TPBC), Panicum-based compost without *Trichoderma asperellum* (PBC), Tridax-based compost without *Trichoderma asperellum* (TBC) and control (no compost application). All compost treatments were applied at the rate of 240 kg N/ha. The experiments were laid out in a randomized complete block design with three replications. The dimension of each plot was 1 m x 1.5 m (1.5 m^2) with 0.5 m space between plots and 1 m space between blocks. The compost were spread on the plots and worked into the soil at two weeks before sowing. The seeds of *Celosia argentea* were sown by drilling method at 25 cm interval between the rows. Weeding was done manually by uprooting. Data collection commenced at four weeks after sowing (4 WAS). Six (6) plants were randomly selected and tagged per plot for assessment of growth performance (plant height, leave count and stem girth). At 6 WAS, three plants were uprooted per plot, washed and oven dried at 65°C till constant weight to determine the dry matter. It was thereafter milled to determine the nutrient concentration, and nutrient uptake was calculated. Harvesting was done by uprooting at 5, 6, 7 and 8 WAS. Fresh yield obtained from each plot was weighed and recorded separately after which cumulative yield per plot was calculated. Post-cropping soil samples were collected per plot at 0-15 cm and processed for routine analysis. Particle size analysis was carried out according to Gee and Or (2002), pH by pH meter (Thomas, 1996) and organic carbon by Walkley-Black procedure (Nelson and Sommers, 1996). Available P was determined"according to the procedure of Murphy and Riley (1962) and total exchangeable acidity by titrimetry method. Exchangeable bases (Ca^{2+}, K^+, Mg^{2+} and Na^+) were extracted by 1N neutral ammonium acetate, K^+ and Na^+ read by flame photometry and Ca^{2+} and Mg^{2+} read by Atomic absorption spectrophotometry. Effective cation exchange capacity was obtained using summation method. Data collected were analysed using analysis of variance and means separated by Duncan multiple range test (DMRT) at $\alpha_{0.05}$.

Table 2. Physical and chemical properties of pre-cropping soil

Parameters		Soil Value
Particle size distribution	Silt (g/kg)	116
	Clay (g/kg)	84
	Sand (g/kg)	800
	Textural class	Sandy loam
pH (H_2O)		6.7
Organic carbon (g/kg)		8.5
Av. P (mg/kg)		14
Total N (g/kg)		0.9
Exchangeable bases	Ca^{2+} (cmol/kg)	4.8
	Na^+ (cmol/kg)	0.4
	K^+ (cmol/kg)	0.2
	Mg^{2+} (cmol/kg)	0.8
Ex. acidity (H^+)		0.1
ECEC (cmol/kg)		6.3

Results

The effect of compost treatments on growth parameters of celosia in both years is presented in Figure 2. In the first year, TPBC had the tallest plants at 4 and 8 WAS (49.46 and 68.55 cm) though not significantly different ($p>0.05$) from other treatments, except control at 4 WAS and that of TTBC at 8 WAS. In the second year, TTBC gave the tallest plant (49.89 cm) at 4 WAS, which was not significantly different from TPBC (49.86 cm) and PBC (49.37 cm) though higher than TBC (31.38 cm), while control (26.17 cm) had the shortest plant. At 8 WAS, there was no significant difference in the height of plants obtained from all compost applied, though TPBC (62.85 cm) was the highest, while control (35.29 cm) had the shortest plant. The highest leave count (30 and 20) was obtained from TPBC at 8 WAS, though, not significantly different from other treated plants but the control (12 and 10) in the first and second year, respectively. The widest stem girth (1.86 and 4.47 cm) was obtained from TTBC at 4 and 8 WAS at first year though were not significantly different from others except PBC (1.47 and 3.13 cm), while the control (1.02 and 3.13 cm) had the thinnest stem girth at 4 and 8 WAS, respectively. In the second year, plants that received TPBC (2.05 and 3.59 cm) had the widest stem girth which was comparable to TTBC (1.94 and 3.37 cm) while the uninoculated compost (PBC and TBC) had less stem girth and control (1.00 and 2.40 cm) recorded the lowest values of stem girth at 4 and 8 WAS, respectively.

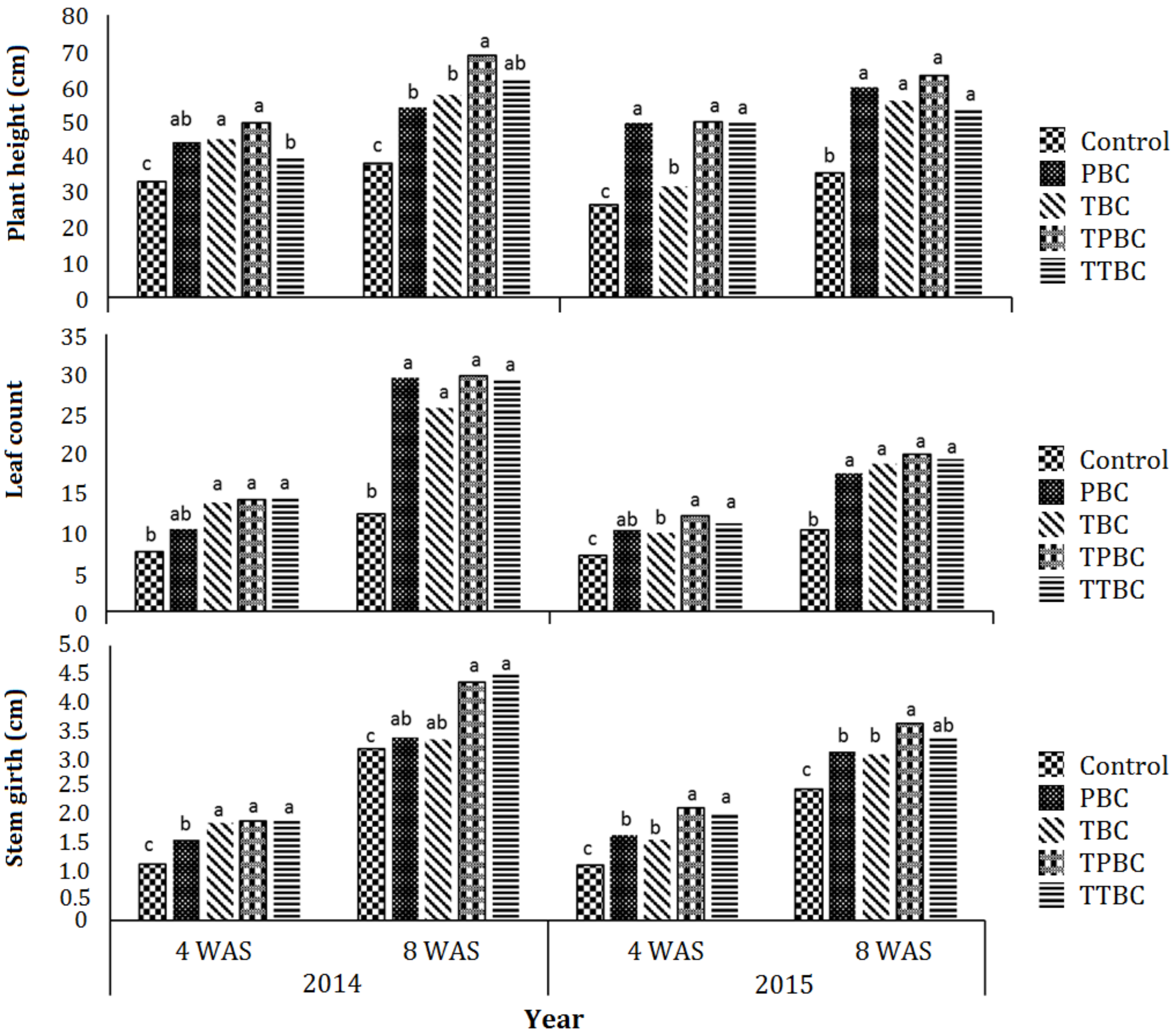

Figure 2. Effect of compost treatments on growth parameter of celosia

Legend: PBC: Panicum-based compost without Trichoderma, TBC: Tridax-based compost without Trichoderma, TPBC: Panicum-based compost with Trichoderma, TTBC: Tridax-based compost with Trichoderma

The result of nutrients uptake by celosia is presented in Table 3. Plant treated with TPBC had the highest N uptake (6.10 g/plant) which differed not significantly from TTBC (6.02 g/plant) but higher than PBC (5.50 g/plant), TBC (4.07 g/plant) and control (2.43 g/plant) in the first year. In the second year, plant treated with TBC had the highest N uptake (6.65 g/plant) which differed not significantly from TPBC (6.36 g/plant), TTBC (6.01 g/plant) and PBC (6.42 g/plant) but higher than control (2.28 g/plant). The difference in the P uptake across the treatments were not significant in the first year; however, in the second year, plant treated with TPBC had the highest P uptake (0.69 g/plant) which was similar to PBC (0.64 g/plant), TTBC (0.61 g/plant) but significantly higher than TBC (0.52 g/plant) and control (0.43 g /plant). The differences in K uptake among the treatments differed significantly in both years In the first year, plant treated with TPBC had the highest K uptake (7.67 g/plant) which was similar to TTBC (7.63 g/plant) and TBC (6.7 g/plant) but significantly higher than PBC (6.53 g/plant) and control (5.47 g/plant). In the second year, plant treated with TTBC had the highest K uptake (6.39 g/plant) which was similar to other treated plants but the control (3.46 g/plant).

Table 3. Effects of compost treatments on the nutrient uptake (g/plant) by celosia

Treatments	2014			2015		
	N- uptake	P- uptake	K- uptake	N-uptake	P- uptake	K-uptake
Control	2.43c	0.51	5.47c	2.28b	0.43b	3.46c
PBC	5.50ab	0.47	6.53b	6.42a	0.64ab	5.21b
TBC	4.07b	0.47	6.7ab	6.65a	0.52b	5.88b
TPBC	6.10a	0.47	7.67a	6.36a	0.69a	6.07a
TTBC	6.02a	0.43	7.63a	6.01a	0.61ab	6.39a

Means with same letter (s) in a column are not significantly different at 5% by DMRT
Legend: PBC: Panicum-based compost without *Trichoderma* , TBC: Tridax-based compost without *Trichoderma,* TPBC: Panicum-based compost with *Trichoderma*, TTBC: Tridax-based compost with *Trichoderma*

The result of celosia fresh yield is shown in Figure 3. In the first year the difference in the yield obtained from plants treated with both TTBC and TPBC (57.09 and 57.00 t/ha, respectively) differed not significantly but were significantly higher than TBC and PBC (43.85 and 47.32 t/ha, respectively). The control resulted in the lowest significant yield (28.34 t/ha). In the second year, TPBC resulted into the highest yield (48.72 t/ha) which differed not significantly from TTBC (47.45 t/ha) but significantly higher than other treated plants, while the control produced the lowest yield (20.03 t/ha).

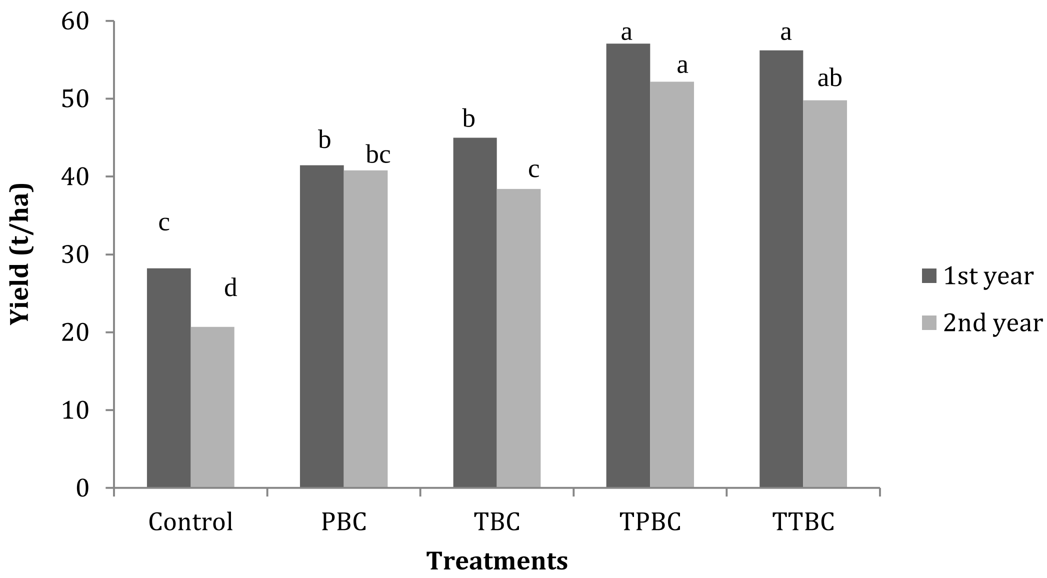

Figure 3. Effect of compost treatments on fresh yield of celosia
Legend: PBC: Panicum-based compost without *Trichoderma*, TBC: Tridax-based compost without *Trichoderma*, TPBC: Panicum-based compost with *Trichoderma*, TTBC: Tridax-based compost with *Trichoderma*

The result of post-cropping soil chemical properties is shown in Table 4. In the first year, soil treated with TTBC had significantly higher organic carbon content (16.1 g/kg) which differed not significantly from other compost treatments but was significantly higher than the control (6.2 g/kg). The available P was significantly higher in soil treated with TPBC (37 mg/kg), though similar to other compost treatments except the control (10 mg/kg). The result of total N, Na^{+}, K^{+} and Ca^{2+} followed the same trend with soil treated with

TPBC having the highest significant value (1.6 g/kg, 0.8 cmol/kg, 0.5 cmol/kg and 5.3 cmol/kg, respectively), though, they were not significantly different from other compost treatments but were significantly higher than the control (0.6 g/kg, 0.2 cmol/kg, 0.2 cmol/kg and 2.1 cmol/kg, respectively). Soils treated with Trichoderma inoculated compost; TTBC and TPBC had significantly higher values of Mg^{2+} (2.3 and 2.4 cmol/kg) and ECEC (8.0 and 9.1 cmol/kg), respectively than those that received uninoculated compost; TBC and PBC (Mg^{2+}; 1.1 and 1.0 cmol/kg, ECEC; 6.7 and 6.4 cmol/kg), respectively. Control plot had the least significant values of Mg^{2+} (0.4 cmol/kg) and ECEC (2.0 cmol/kg). In the second year, soil treated with TTBC had the highest levels of organic carbon (15.4 g/kg) and available P (21 mg/kg) with no significant differences among other compost treatments applied but control had significant lower values (organic carbon; 7.5 g/kg and P; 11 mg/kg). The differences among the treatments differed not significantly with respect to Ca^{2+}, Na^+, H^+ and K^+. The highest significant value of Mg^{2+} (5.27 c/mol/kg) was obtained from soil treated with TPBC, though, was not significantly different from TTBC (4.11 cmol/kg) and PBC (4.03 cmol/kg) but was significantly higher than TBC (2.67 cmol/kg). Control had the least significant value (1.37 cmol/kg). The TPBC treated soil had the highest significant ECEC (7.44 cmol/kg) while the control plot gave the lowest significant value (3.01 cmol/kg).

Table 4. Effects of compost treatments on chemical properties of soil before and after cropping

Treatments	pH	Org. C (g/kg)	Avail. P (mg/kg)	Total N (g/kg)	Exchangeable bases (cmol/kg) Na^+	K^+	Ca^{2+}	Mg^{2+}	H^+ (cmol/kg)	ECEC (cmol/kg)
					2014					
					Pre-cropping soil properties					
	6.7	8.5	14	0.9	0.4	0.2	4.8	0.8	0.1	6.3
					Post-cropping soil properties					
Control	6.4	6.2b	10b	0.6b	0.2b	0.2b	2.1b	0.4c	0.1	2.0c
PBC	6.4	15.4a	31a	1.6a	0.6a	0.4a	4.3a	1.0b	0.1	6.4b
TBC	6.3	14.7a	32a	1.5a	0.7a	0.4a	4.4a	1.1b	0.1	6.7b
TPBC	6.3	15.9a	37a	1.6a	0.8a	0.5a	5.3a	2.4a	0.1	9.1a
TTBC	6.5	16.1a	35a	1.6a	0.7a	0.4a	4.5a	2.3a	0.1	8.0a
	ns								ns	
					2015					
					Pre-cropping soil properties					
	6.1	8.3	13	0.8	0.4	0.2	2.5	0.6	0.1	3.8
					Post-cropping soil properties					
Controls	6.6a	7.5b	11c	0.6c	0.3	0.3	1.1	1.4c	0.1	3.0c
PBC	6.5a	14.6a	17b	1.5a	0.2	0.3	1.1	4.0ab	0.1	5.8b
TBC	6.3b	12.3a	18b	1.2b	0.3	0.3	1.4	2.7b	0.1	4.7b
TPBC	7.0a	13.2a	19ab	1.7a	0.2	0.3	1.6	5.3a	0.1	7.4a
TTBC	6.5a	15.4a	21a	1.6a	0.2	0.3	1.2	4.1ab	0.1	5.9b
					ns	ns	ns		ns	

Means with same letter (s) in a column are not significantly different at 5% by DMRT

Legend: PBC: Panicum-based compost without *Trichoderma,* TBC: Tridax-based compost without *Trichoderma,* TPBC: Panicum-based compost with *Trichoderma,* TTBC: Tridax-based compost with *Trichoderma*

Discussion

There was consistent increase in growth parameters across the compost applied to the celosia in both years. However, the value obtained in the first year was higher than that of the second year. This was because there was an unusual dry spell at the middle of the rainy season of that year (Figure 1) and this fell into the period when the crop was at its log phase. This agrees with the report of (Adejuyigbe et al., 2006) that climate played a crucial role on the performance of fertilizer. The compost treatments improving the growth parameters of celosia suggest that the compost mineralized for the plant use. Thus, tridax and panicum-based compost could be suitable soil amendments for spinach growth. This is in agreement with the report of (Sanni and Adesina, 2012) compost enhanced the growth of celosia.

The nutrient uptake of celosia was improved by compost application irrespective of inoculation, this is in line with the findings of Kayode et al. (2018) where organic amendments enhanced uptake of N, P, K, Ca and Mg by plants. However, compost inoculated with *T. asperellum* performing better than the uninoculated ones implies that *T. asperellum* aided the mineralization of nutrients in line with the report of Baldi et al. (2010) and Mbouobda et al. (2014). This is in agreement with the reports that rapid composting methods improved compost quality and efficiency (Rasapoor et al., 2009; Jusoh et al., 2013). The efficiency of *T.*

asperellum isolate on compost nutrient availability to onion plants has also been confirmed by Ortega-García et al. (2015).

The yield of celosia recorded revealed that the plant that received inoculated compost responded better compared to uninoculated compost, regardless of composting materials. This confirms that the presence of *Trichoderma* has a great influence in hastening the release of nutrients to plant, hence, improved the yield; which validated the findings of Jusoh et al. (2013) that rapid compost improved the yield of crops than conventional ones). The compost applied improved the soil nutrient status after cropping in comparison with the control. This is in concordance with the findings of Hossain et al. (2017) that compost improved the post-cropping chemical properties. This confirmed the gradual nutrient release nature of compost as reported by Tejada and Gonzalez (2007). Of note is the improvement of organic carbon, phosphorus and ECEC. The sharp increase in soil organic carbon confirmed the potential of compost to sequestrate carbon and this confirmed the recommendation of composting as a method for greenhouse gas emission reduction (UNFCCC/CCNUCC, 2007).

Conclusion

The result of this work revealed that the growth, nutrient uptake and fresh yield of celosia were higher in celosia plants treated with Trichoderma inoculated compost relative to uninoculated ones while both the inoculated and uninoculated compost improved the postcropping soil chemical properties. Therefore, the use of Trichoderma asperellum as compost additive could be recommended to farmers in order to hasten the readiness of compost as well as improving the yield of crop and soil chemical properties. However, it is recommended that further studies be carried out using different organic substrates as composting materials with Trichoderma asperellum inoculation as additive.

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