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INFLUENCE OF HOME AND MUNICIPAL-SORTED SOLID WASTES ON THE GROWTH PERFORMANCES OF TWO TOMATO VARIETIES (*Solanum lycopersicon* MILL) IN ABEOKUTA, NIGERIA.

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ABSTRACT

Field experiment was conducted at the Directorate of University Farms, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria during the early and late cropping seasons, 2019. Treatments were: composted municipal solid waste (CMSW); composted home sorted waste (CHSW); pyrolyzed municipal solid waste (PMSW) and pyrolyzed home sorted waste (PHSW) all applied at the rate of 10 t ha^{-1}, set up in a 5 × 2 factorial arranged in randomized complete block design in three replicates. Roma VF and Ibadan-local tomato varieties were test crops. Data were collected on plant height (PH), stem girth (SG), number of leaves (NL), number of flowers (NF), total number of fruits (TNFr) and cumulative fruit yield (CFY). Data were subjected to Analysis of Variance and means were separated using Duncan's Multiple Range Test (DMRT) at $p<0.05$. Treatments had significant effects on growth performance of tomatoes. Incorporation of PHSW enhanced PH, SG, NF and NFr in both planting seasons while CHSW enhanced only NL in both planting seasons. Plots amended with PHSW enhanced CFY at early (1019 t ha^{-1}) and late (269 t ha^{-1}) seasons compared to other amendments. However, Roma VF performed better at early season while Ibadan local responded well at the late season probably due to their adaptability and physiological factors during growing period. It is concluded that composted and pyrolyzed home sorted wastes improved growth performance in organic tomato production while planting of Roma VF at early season and Ibadan local at late season are therefore recommended for optimal production of tomato.

Keywords: Composted waste, Home sorted waste, Ibadan local, Municipal solid waste, Pyrolyzed waste, Roma VF.

INTRODUCTION

Municipal solid waste (MSW) is the materials generated from the result of human daily activities resulting from places such as households, public area and city streets, shops, offices and hospitals (Medina, 2000). The rate at which solid waste is generated in the society is increasing with an increase in population, technological development and change in lifestyle (Abdulahi, 2009).Waste management according to (UN, 1997) refers to all the activities and actions required to manage waste from its inception to its final disposal. The management includes collection, transport, treatment and disposal of waste together with monitoring and regulation. Waste management reduces adverse effects of waste on health, the environment or aesthetics.

Home waste is one of the important components of municipal waste. Home wastes include food waste, paper, glass, metals, plastics, textile, plants such as vegetables and fruits peel and so on (Mohammad *et al*., 2021). Home wastes, generated from several sources with variable human activities, and from different socio-economic areas all over the world, are heterogeneous in nature having variables and source dependent physical characteristics. The organic portion of municipal solid waste can be processed into organic fertilizer either through compost or pyrolysis. In poor fertile soil, organic fertilizer improves organic matter content and then provides essential macro and micro nutrients for plant growth (Sanchez-Moneru *et al*., 2004; Tejada *et al*., 2009).

Tomato is the edible fruit of the plant belonging to the family Solanaceae which originated from Central and South America. Tomato is considered the most widely grown vegetable crop in the world because of its economic impact on growers and its nutritional quality by way of its richness in vitamins A and C and minerals (Villareal, 1980). Increased productivity is attained only when tomato is grown adopting improved varieties and agro techniques. Low and declining soil fertility is one of the major constraints to profitable tomato cultivation and has been worsened by continuous cultivation without adequate soil fertility enhancement measures (Kimani *et al.,* 2003). Adequate organic fertilizer application is required by tomato for growth and yield at the same time sustaining productivity. Objective of this study was to determine the effects of composted and pyrolyzed organic wastes on the performance of two varieties of tomato (*Solanum lycopersicon* Mill.).

MATERIALS AND METHODS

The study was carried out at the Research Farm, Directorate of University Farms (DUFARMS), Federal University of Agriculture, Abeokuta in the year 2019. Two cropping seasons: main cropping (early season: April-August) with treatment application and residual (late season: August-December) without any further treatments application were involved.

Waste collection and sorting

Home wastes were collected from designated homes where organic materials had been sorted at household level by collecting the organic waste in separate containers. Municipal solid wastes were collected from Johnson landfill site along Baptist boys' high school, Saje Abeokuta, and sorted to remove non-degradable materials. Both home sorted wastes and municipal solid organic wastes were then composted or pyrolyzed separately.

Compost and biochar production

The Indian indore hot heap method was adopted for composting (Albert, 1945). The two sets of organic wastes (home and municipal-sorted waste) were composted separately. The two sets of waste materials were also pyrolyzed to produce biochar using pyrolyzer. The biochar production was by ignition method. Waste materials were placed in Top-lit Updraft Kiln (Nsamba, *et al.*, 2015) and ignited for 10 minutes residence time at 450 ^{o}C. Biochars formed were homogenized and milled to fine texture. Chemical analyses were carried out on compost and biochar using standard method.

Chemical analysis of compost and biochar

For compost samples: the nutrients (organic carbon, nitrogen and phosphorus) were determined using AOAC (1990) standard methods. Calcium and magnesium concentrations were determined by EDTA titration (Anderson and Ingram, 1998) while sodium and potassium concentrations were determined by flame photometer.

For pyrolyzed (biochar) sample: Biochar pH was measured using 1:2 (soil: water) ratio after shaking for 30 minute in deionized water. Total organic carbon was determined by Van Bemmelene factor i.e 0.58. Total nitrogen content in the biochar was determined by Kjedahl's method (Bremner, 1996). Phosphorous was determined by the ammonium molybdate method using a spectrophotometer. Calcium and Magnesium concentrations were determined by EDTA (Ethylene diamine tetra acetic acid) titration (Anderson and Ingram, 1998), while sodium and potassium concentrations were determined by flame photometer.

Land preparation and plot layout

Experimental site was cleared, ploughed and harrowed. Experimental land size was 806 m^2. Plots measuring 4 x 4 m (16 m^2) were demarcated with 1 m intra and inter row spacing.

Experimental design and treatments

Experiment was 5 x 2 factorial arranged in randomized complete block design (RCBD) with 3 replications. Treatments were: Composted municipal solid waste, composted home-sorted waste, pyrolyzed municipal solid waste, pyrolyzed home-sorted waste; all at 10 t ha^{-1} and the Control (CTR) (no amendment). Tomatoes (Roma VF and Ibadan local) were used as test crop.

Planting (nursery and transplanting)

Tomato seeds were established in the nursery by broadcasting in trays filled with soil and watered for 4 weeks before transplanting. Seedling transplanting was done manually two weeks after treatments incorporation at 10 t ha^{-1} into the plots. Two seedlings were transplanted per stand at a spacing of 75 x 50 cm, planted at a depth of 5 cm; and thinned to one where both survived at one week after transplanting.

Treatment application

Treatments (Composted municipal solid waste, composted home-sorted waste, pyrolyzed municipal solid waste, pyrolyzed home-sorted waste), all at 10 t ha^{-1} were incorporated by uniformly spread on the surface of each plot and worked into the soil using a shovel.

Cultural practices

Weeding was done manually at three weeks interval using cutlass and hoe. Two cropping seasons: main cropping (early season: April-August) with treatment application and residual (late season: August-December) without any further treatments application were involved.

Soil sampling and analysis

Prior to treatment application, initial soil samples was obtained by collecting samples

(0 - 20 cm depth) randomly at 8 different points with the aid of soil auger on the experimental site for determination of initial soil properties. Soil samples were air-dried, grounded, passed through 2.0 mm sieve for general analysis while a sub sampled was ground to past through 0.5 mm sieve for total N and soil organic matter determination. After harvest, soil samples were obtained by collecting samples (0 - 20 cm depth) from each experimental plot for analysis.

Soil pH was obtained 1:1 (Soil: Water) ratio using pH glass electrode meter (Thomas, 1996). Organic carbon was determined by Walkley-Black procedure using dichromate as oxidizing agent (Nelson and Sommers, 1996), Total nitrogen was determined by Khedhal method of Bremner (1996), Available phosphorous was also extracted with Bray1solution and colorimetrically determined using the vanado-molybdate method (Okalebo *et al.,* 2002). Exchangeable bases were extracted with ammonium Acetate (1N NH_4OAc) buffered at pH 7. Sodium and Potassium in the extract was determined by flame photometer while Calcium and Magnesium was determined using AAS. Particle size analysis was determined by the hydrometer method (Okalebo *et al.,* 2002) using sodium hexa metaphosphate as dispersing agent. The proportion of sand, clay and silt was used to determine the textural class of the soil using USDA textural triangle.

Data collection

Five (5) plants were randomly selected at the middle row of each plot for collection of agronomic data at two (2) weeks interval. Data were collected on: plant height, stem girth, number of leaves and number of flowers according to Ogundare *et al.* (2015). Cumulative total fruit yield harvested was taken per plot using mettler weighing balance and their yield was expressed in t ha^{-1} (Isah *et al.,* 2014).

Statistical analysis

All data collected were subjected to Analysis of Variance (ANOVA) using Genstat discovery, 12th Edition. Means were separated using Duncan's Multiple Range Test (DMRT) at 5 % level of probability.

RESULTS

The soil was near with a pH of 6.8. Organic carbon (7.50 g kg^{-1}) and total nitrogen (0.26 g kg^{-1}) were very low. The exchangeable potassium (0.33 cmol kg^{-1}) and exchangeable sodium of 0.47 cmol kg^{1} were moderate (Table 1). Available phosphorus (Bray 1 P) was however adequate (24.14 mg kg^{-1}) while exchangeable magnesium (0.37 cmol kg^{-1}) and exchangeable calcium were low (0.40 cmol kg^{-1}). The soil was sandy loam in texture with 764 g kg^{-1} sand, 13 g kg^{-1} clay and 223 g kg^{-1} silt particles (Table 1).

At 4 WAT, there was no significant difference among the amendments at both early and late seasons (Table 2). At both planting seasons, treatment applied showed significant effects on plant height of tomato at 6, 8, 10, 12, 14 and 16 WAT while all the amendments significantly increased plant height above the control at 10, 12, 14 and 16 WAT. At early season, pyrolyzed home sorted waste (PHSW) enhanced plant height than all other amendments. However, composted home sorted waste (CHSW) and composted municipal solid waste (CMSW) treated plant had comparable plant height with PHSW followed by pyrolyzed municipal solid waste (PMSW) and the least with the control plot at 6 and 8 WAT. There was a varietal difference in the height of tomato in the early season at 10, 12, 14 and 16 WAT with Roma VF having taller plant than Ibadan local (Table 2).

At late season, all the amendments significantly increased height of tomato above the control at 6 WAT. Significantly tallest plant was observed with the plot treated with PHSW while CHSW, CMSW and PMSW were not significantly different from one another. At 8 WAT, plots that received CHSW, PMSW and PHSW enhanced height of tomato while CMSW had comparable height with the control plot. However, Ibadan local produced taller plant compared with Roma VF at 6, 10 and 12 WAT (Table 2).

There was significant difference in stem girth due to amendments incorporation at both planting seasons while all the amendments significantly increased stem girth above the control (Table 3). At early season, widest stem was observed with pyrolyzed home sorted waste (PHSW) at 6 WAT (4.7 cm), 8 WAT (6.3 cm) and 10 WAT (7.1 cm).

Table 1: Properties of the soil used for the field experiment

Soil properties		Unit	Values
Soil pH (H_2O)			6.8
Organic Carbon		(g kg^{-1})	7.50
Total Nitrogen		(g kg^{-1})	0.26
Available Phosphorus		(mg kg^{-1})	24.14
Exchangeable Cation:	Ca	(cmol kg^{-1})	0.40
	Mg	(cmol kg^{-1})	0.37
	K	(cmol kg^{-1})	0.33
	Na	(cmol kg^{-1})	0.47
Particle size:	Sand	(g kg^{-1})	764
	Clay	(g kg^{-1})	13
	Silt	(g kg^{-1})	223
Textural class		Sandy loam	

Table 2: Effects of composted and pyrolyzed sorted wastes on plant height at early and late seasons

	Plant height (cm)													
	Early Season							Late Season						
Varieties (V)	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	14 WAT	16 WAT	4 WAT	6 WAT	8 WAT	10 WAT	12 WAT	14 WAT	16 WAT
Roma VF	6.7a	11.7a	23.1a	41.7a	68.5a	72.1a	76.4a	5.4a	7.6b	17.9a	23.0b	35.1b	44.7a	48.6a
Ibadan local	6.5a	11.1a	22.3a	38.5b	60.0b	63.5b	67.0b	5.2a	8.7a	16.2a	27.2a	41.6a	40.3a	43.9a
Amendment (A)														
CTR	6.5a	9.03c	14.3c	22.6b	43.2b	45.8b	49.4b	5.1a	5.9c	9.1b	11.7b	20.3b	23.3b	26.1b
CMSW	6.6a	11.6ab	24.3ab	44.8a	67.2a	71.7a	76.9a	5.4a	8.1b	15.9ab	23.7a	39.7a	46.7a	50.1a
CHSW	6.7a	12.0ab	25.7ab	46.5a	72.8a	77.0a	80.3a	5.3a	8.4b	20.5a	29.6a	41.4a	44.8a	48.2a
PMSW	6.5a	11.2b	21.1b	37.9a	63.9a	67.0a	70.5a	5.2a	8.3b	19.2a	27.3a	43.3a	47.5a	52.7a
PHSW	6.7a	13.3a	27.9a	48.4a	74.3a	77.4a	81.4a	5.4a	10.1a	20.6a	33.3a	47.0a	50.2a	54.0a
V×A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean value with same letters along the column are not significantly different by DMRT ($p < 0.05$)
Note: Composted municipal solid waste, Composted home sorted waste, Pyrolyzed municipal solid waste, Pyrolyzed home sorted waste, WAT- Weeks After Transplanting, NS – Not Significant

Table 3: Effects of composted and pyrolyzed sorted wastes on stem girth at early and late seasons

	Stem girth (cm)													
	Early Season							Late Season						
Varieties (V)	**4 WAT**	**6 WAT**	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**	**4 WAT**	**6 WAT**	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**
Roma VF	2.4a	4.3a	5.5a	6.4a	7.1a	7.8a	8.5a	2.1a	2.5a	3.6a	3.9b	4.8b	5.8a	6.5a
Ibadan local	2.2a	4.2a	5.0a	6.1a	6.8b	7.7a	8.3a	2.1a	2.5a	3.2a	4.4a	5.1a	5.6a	6.3a
Amendment (A)														
CTR	1.8b	3.3c	4.1c	5.0c	5.6b	6.4b	6.8b	1.9b	1.9b	2.5c	3.4b	3.6b	4.4b	4.8c
CMSW	2.4a	4.6ab	5.3ab	6.2b	7.1a	7.8a	8.6a	2.1a	2.7a	3.3b	4.2a	5.0a	5.8a	6.6b
CHSW	2.5a	4.6ab	5.5ab	6.3b	7.2a	7.9a	8.6a	2.2a	2.7a	3.6ab	4.3a	5.1a	5.9a	6.6b
PMSW	2.4a	4.0b	5.3b	6.3b	7.2a	8.1a	8.9a	2.2a	2.6a	3.6ab	4.3a	5.2a	6.1a	6.8b
PHSW	2.4a	4.7a	6.3a	7.1a	7.5a	8.4a	9.3a	2.2a	2.7a	4.1a	4.9a	5.5a	6.4a	7.3a
A×V	S	S	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	NS	NS

Mean value with same letters along the column are not significantly different by DMRT ($p < 0.05$)
Note: Composted municipal solid waste, Composted home sorted waste, Pyrolyzed municipal solid waste, Pyrolyzed home sorted waste, WAT Weeks After Transplanting, NS – Not Significant, S-Significant

All the amendments were not statistically different from one another at 4, 12, 14 and 16 WAT. At late season, PHSW also stimulated widest stem at 8 WAT (4.1 cm) and 16 WAT (7.3 cm) while all other amendments were not statistically different from one another at 4, 6, 10, 12, and 14 WAT. Similarly, there was a varietal difference in the girth of tomato in the early season at 12 WAT with Roma VF having wider girth compared with Ibadan local while in the late season at 10 and 12 WAT, Ibadan local produced wider girth than Roma VF (Table 3).

There was significant difference in the number of leaves due to amendments incorporation at both early and late seasons (Table 4). However, all the amendments significantly increased the number of leaves above the control. At early season, CHSW produce the highest number of leaves at 4 WAT (4.3) while CHSW and PHSW resulted in highest number of leaves at 6 WAT (8.2 and 7.8) respectively. Moreover, highest number of leaves was also observed with PHSW at 8 WAT (12.0) and 10 WAT (26.5) while CMSW, CHSW and PMSW were not significantly different from one another. Also, CHSW, PMSW and PHSW increased the number of leaves more than CMSW at 12, 14 and 16 WAT. At late season, CHSW stimulated the highest number of leaves at 4 WAT (4.7) and12 WAT (47.7). Home waste (CHSW and PHSW) increased the number of leaves more than municipal waste (CMSW and PMSW) at 6 WAT, while similar trend was observed at 8 and 10 WAT. Varietal response was significant in both seasons with Ibadan local having higher number of leaves compared with Roma VF (Table 4).

There was significant difference between pyrolyzed and composted wastes at 8 and 10 WAT in early season and 8 WAT in late season with PHSW having significant highest number of flower compared with other amendments (Table 5).

Table 4: Effects of composted and pyrolyzed sorted wastes on number of leaves at early and late seasons

	Number of leaves													
	Early Season							Late Season						
Varieties (V)	**4 WAT**	**6 WAT**	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**	**4 WAT**	**6 WAT**	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**
Roma VF	3.7b	6.1b	9.5b	14.3b	33.9b	40.6b	46.5b	4.0b	5.8b	8.1b	12.3b	29.7b	36.2b	41.9b
Ibadan local	4.0a	7.6a	11.0a	28.9a	52.8a	58.9a	64.0a	4.5a	6.7a	9.5a	23.5a	46.9a	52.9a	57.9a
Amendment (A)														
CTR	3.5b	5.2b	8.0b	13.0b	19.7b	24.3b	28.8b	4.0b	5.0b	6.5b	11.0b	17.2b	21.7b	25.7b
CMSW	3.8ab	6.7ab	10.5ab	21.5ab	42.2ab	47.5ab	52.2ab	4.2ab	6.2ab	9.0a	17.8ab	36.0ab	41.0ab	45.7ab
CHSW	4.3a	8.2a	12.0a	26.5a	53.8a	61.8a	68.7a	4.7a	7.2a	10.3a	22.0a	47.7a	55.5a	62.5a
PMSW	3.7ab	6.3ab	10.3ab	22.0ab	49.8a	57.5a	63.5a	4.2ab	6.2ab	8.7ab	18.7ab	45.5ab	51.2a	56.2a
PHSW	3.8ab	7.8a	10.3ab	24.8ab	51.3a	57.5a	63.2a	4.2ab	6.7a	9.2a	20.2a	45.2ab	53.3a	59.7a
A×V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Note: Composted municipal solid waste, Composted home sorted waste, Pyrolyzed municipal solid waste, Pyrolyzed home sorted waste, WAT- Weeks After Transplanting, NS – Not Significant, S-Significant

Table 5: Effects of composted and pyrolyzed sorted wastes on number of tomato flower at early and late seasons

	Number of tomato flower									
	Early Season					Late Season				
Varieties (V)	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**	**8 WAT**	**10 WAT**	**12 WAT**	**14 WAT**	**16 WAT**
Roma VF	3.1a	7.7a	14.7a	18.2a	13.4a	2.7a	6.1a	11.9a	14.9a	12.3a
Ibadan local	1.9a	4.3b	7.3b	10.0a	9.5a	2.3a	4.5a	5.9a	7.9a	8.9a
Amendment (A)										
CTR	0.0b	1.8b	5.0a	6.0a	5.5a	0.8b	2.7a	3.3a	4.8a	5.5a
CMSW	1.8ab	4.8ab	10.7a	12.7a	11.3a	2.2ab	4.0a	8.3a	10.3a	10.3a
CHSW	2.7ab	7.8a	14.0a	22.3a	15.8a	2.5ab	5.8a	8.5a	10.3a	10.7a
PMSW	2.3ab	5.7ab	14.8a	17.2a	13.7a	2.7ab	5.0a	10.5a	12.7a	11.3a
PHSW	5.2a	9.8a	11.7a	12.3a	10.8a	4.2a	9.0a	14.0a	18.7a	14.8a
A×V	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Mean value with same letters along the column are not significantly different by DMRT ($p < 0.05$)
Note: Composted municipal solid waste, Composted home sorted waste, Pyrolyzed municipal solid waste, Pyrolyzed home sorted waste, WAT- Weeks After Transplanting, NS – Not Significant

while the least was observed with control. At 10 WAT, home waste (CHSW and PHSW) increased the number of flower more than municipal waste (CMSW and PMSW) in early season planting. However, there were no significant differences among the amendments at 12, 14 and 16 WAT in both planting seasons. Varietal response was significant in early season with Roma VF having higher number of flower compared with Ibadan local at 10 and 12 WAT (Table 5).

Plants treated with PHSW had significantly higher total number of tomato fruits at early (50.50) season than all other amendments (Table 6). However, PMSW (38.00), CHSW (34.00) and CMSW (29.67) treated plants had comparable total number of tomato fruits with PHSW and the control (13.00) which had the lowest total number of tomato fruits. Similar trend was also observed at late season. However, varietal response was significant at both planting seasons with Roma VF having produced more total number of tomato fruits than Ibadan local at early season while Ibadan local produced higher total number of tomato fruits than Roma VF at late season (Table 6).

Plants that received PHSW had significantly higher yield (1019.0 t ha^{-1}) than all other amendments. However, PMSW (554.5 t ha^{-1}) and CHSW (752.5 t ha^{-1}) treated plants had comparable yield with PHSW followed by CMSW (386.0 t ha^{-1}) and the control (128.0 t ha^{-1}) which had the lowest yield at early season (Table 7).

The highest yield in the late season was produced by plants treated with PHSW (269.0 t ha^{-1}) and CHSW (239.5 t ha^{-1}) and least in the control (95.5 t ha^{-1}). However, yield from plant treated with CMSW and PMSW were not significantly different (Table 7).

Table 6: Effects of composted and pyrolyzed sorted wastes on total number of tomato fruits at early and late seasons

	Total number of tomato fruits	
Varieties (V)	**Early Season**	**Late Season**
Roma VF	43.5a	17.6b
Ibadan local	22.6b	35.4a
Amendment s (A)		
Control	13.00b	10.67b
Composted municipal solid waste	29.67ab	24.00ab
Composted home sorted waste	34.00ab	26.67ab
Pyrolyzed municipal solid waste	38.00ab	30.17ab
Pyrolyzed home sorted waste	50.50a	41.00a

Mean value with same letters along the column are not significantly different by DMRT ($p < 0.05$)

Table 7: Mean effect of composted and pyrolyzed sorted wastes on cumulative fruit yield of tomato at early and late seasons

Amendments	Fruit yield (t ha^{-1})	
	Early season	Late season
Control	128.0c	95.5b
Composted municipal solid waste	386.0b	154.5ab
Composted home sorted waste	752.5ab	239.5a
Pyrolyzed municipal solid waste	554.5ab	214.0ab
Pyrolyzed home sorted waste	1019.0a	269.0a

Mean value with same letters along the column are not significantly different by DMRT ($p < 0.05$)

Post-harvest soil chemical properties of the study site at both planting seasons

Soil chemical properties at the end of the field trial in both planting seasons (Table 8) indicated that the pH of the soils ranged from neutral to moderately alkaline. At early season, there were no significant differences in the K, Ca and Na of the soil across all the treatments. The pH of the soil ranged from neutral to mildly alkaline. The concentration of phosphorus was highest in the plot amended with PHSW (29.53 mg kg^{-1}) compared to the other treatments.The highest OC (10.80 g kg^{-1}) and TN (2.28 g kg^{-1}) were observed with PMSW and PHSW respectively and the least in control plot. Plots amended with PHSW (0.84 cmol kg^{-1}) and PMSW (0.88 cmol kg^{-1}) had the highest Mg compared with CHSW (0.40 cmol kg^{-1}) and CMSW (0.40 cmol kg^{-1}), while the least was observed in control (0.37 cmol kg^{-1}). However, the pH of the soil at late season ranged from neutral to mildly alkaline. Pyrolyzed waste materials increased the soil pH more than composted waste materials which was not significantly higher than the control. All the amendments significantly increased OC, Mg and Na above the control while there was no significant difference between the amendments whether pyrolyzed or composted in OC, Mg and Na. Plots treated with CHSW resulted in the highest TN (2.84 g kg^{-1}) while PMSW (1.92 g kg^{-1}), PHSW (1.95 g kg^{-1}) and CMSW (1.98 g kg^{-1}) were not statistically different from one another, with least in control. However, all the amendments increased P and K with the exception of PHSW which was not statistically different from the control (Table 8).

Table 8:Post-harvest soil chemical properties

Treatments	Early Season								Late Season							
	pH	OC	T N	P	K	Ca	Mg	Na	pH	OC	TN	P	K	Ca	Mg	Na
		(g kg^{-1})		(mgkg^{-1})		(cmol kg^{-1})				(g kg^{-1})		(m gkg^{-1})		(cmol kg^{-1})		
CTR	6.80b	7.84d	1.08d	24.33d	0.40a	0.39a	0.37c	0.58a	6.72b	5.44b	1.08c	19.39b	0.27b	0.28a	0.31b	0.24b
CMSW	7.51a	8.42c	1.99c	27.45b	0.40a	0.40a	0.40b	0.59a	6.84b	5.99a	1.98b	21.21a	0.40a	0.30a	0.35a	0.34a
CHSW	7.49a	8.85c	2.11b	26.59c	0.40a	0.40a	0.40b	0.59a	6.82b	6.20a	2.84a	21.13a	0.40a	0.33a	0.33a	0.39a
PHSW	7.52a	9.33b	2.28a	29.53a	0.40a	0.41a	0.84a	0.59a	7.22a	6.22a	1.95b	20.60ab	0.38ab	0.32a	0.34a	0.36a
PMSW	7.50a	10.80a	1.95c	27.48b	0.41a	0.40a	0.88a	0.62a	7.42a	6.28a	1.92b	21.47a	0.43a	0.31a	0.35a	0.34a

Mean value with same letters along the column are not significantly different by DMRT ($p<0.05$).
Note: CTR- Control; **CHSW**- Composted home sorted waste; **CMSW**- Composted municipal solid waste. **PHSW**- Pyrolyzed home sorted waste; **PMSW**-Pyrolyzed municipal solid waste, Nitrogen (N), Phosphorus (P), Potassium (K),Calcium (Ca),Magnesium (Mg)

DISCUSSION

Pre-treatment experimental soil indicates the poor fertility status of the soil which might be due to continuous use of the land for cropping over the years. Most Nigerian soils are deficient in the primary major essential nutrients required by plants (Aduayi *et al.,* 2002), while Omisore and Abayomi (2016) reported that the sustainable method of improving nutrient deficient soils is by fertilizer application. Highest values of growth parameters of tomato obtained from waste materials than control plot could be attributed to availability of essential nutrients required for plant growth in the organic waste materials than control. However, the tallest plant, widest stem, highest flower and fruit observed with pyrolyzed waste; most especially PHSW could be attributed to positive effect of biochar in supplying essential nutrients for vegetative growth. She *et al.* (2018) reported that there was an increase in tomato vegetative growth parameters at higher doses of biochar incorporation. Furthermore, the highest number of leaves observed with CHSW could be due to the formation of more humic substances which resulted from the degradation of more recalcitrant organic substrates over time by the microorganisms; humic substances are prominent in accelerating root respiration, formation and growth (Serra–Wittling *et al.,* 1996; Adejumo *et al.,* 2010). Baris *et al.* (2009) observed that the effect of humic substances on wheat plant under salinity condition could result in increased efficiency of the plant rooting system, which in turn improves the upper growth of plants such as shoots, leaves, flowers and fruit yield. However, tomato growth responded to home sorted waste compared to municipal solid waste and this corroborate with the findings of Akhter *et al.* (2015), who reported that the responses of plant growth depend upon the organic material used for amendments. Highest yield of tomato was observed with incorporation of pyrolyzed home sorted waste. This could be attributed to the improved growth characteristics such as height, girth, number of flowers as well as number of fruits from the pyrolyzed amendments as this contains some amount of nutrients, which could have been taken up by the plants for an enhanced biomass partitioning. Jeffery *et al.* (2017) reported that application of biochar (pyrolyzed organic materials) to soils boost crop yield and productivity. Bruun *et al.* (2010) also reported that application of pyrolyzed based organic waste improved the yield of tomato. All the plant growth parameters observed in the early planting season were significantly higher than the late season planted tomato. This was due to the fact that nutrients being released have been used up during the early season. Varieties differ in their growth and yield depending mainly on the physiological process which is controlled by both genetic make-up and the environment. Roma VF performed better in the early season while Ibadan local responded well in the late season. This might be due to genetic variability, adaptability, morphological features as well as physiological factors during the crop growth period.

Post-harvest soil chemical properties (OC, TN, P, Mg and Na) were significantly improved by pyrolyzed wastes compared to composted waste at early season. The highest increase in OC and TN could be due to decomposition which might have occurred when pyrolyzed waste material is added to soil. The higher OC content would provide better living condition for soil microbes and these can partly improve the effect of biochar on soil structure (Luo *et al.*, 2016). However, biochar has been reported to improve total soil N status in several previous tropical studies (Mensah and Frimpong, 2018; Agegnehu *et al.*, 2016) and the results may depend strongly on soil type (Zhu, 2015). Biochar can enhance P sorption of the soil and help to extend the supply of mineralized P (hong and Lu, 2018). The observed increase in exchangeable cations (Mg and Na) in pyrolyzed amendment soil might be attributed to the ash content of the pyrolyzed material. The ash content of biochar helps for the immediate release of occluded mineral nutrients like Ca Mg and K for crop use (Scheuner *et al.*, 2004; Niemeyer *et al.*, 2005). It is concluded that tomato plants treated with pyrolyzed home sorted waste (PHSW) grew taller in comparison with other treatments applied both in main cropping (early season) and residual (late season). Soil chemical properties were significantly improved by pyrolyzed wastes (PHSW and PMSW) at early season compared to other treatments. However, composted home sorted wastes (CHSW) and pyrolyzed municipal solid wastes (PMSW) had greater residual effects. Different performances of these varieties may be attributed to genetic variability, adaptability, morphological features as well as physiological factors during the crop growth period. Roma VF is therefore recommended for higher yield at early season and Ibadan local at late season.

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